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BOOK REVIEW

Should the Historical Star-System in Chemical Education Be Replaced?

Eric Scerri (2016) A Tale of Seven Scientists and a New Philosophy of Science. Oxford University Press, New York, NY. ISBN: 9780190232993, 228 + xxxiv Pages, Price: $29.95 (Hardback).

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In this short work, Eric Scerri seems to recommend that anyone seeking to understand the periodic properties of the elements should concentrate on the work of *obscure* scientists rather than on the famous investigators now featured in introductory chemistry courses. He tells about seven individuals, currently nearly unknown, who provided results later incorporated into developments generally considered to have been major breakthroughs but which advances are usually attributed to scientists other than those discussed here.

These anti-heroic stories suggest what the author calls "a new philosophy of science" which he has found useful "to unify the various intellectual strands" (p. xxiv) in his own life. The basis of this approach is: "science proceeds by almost imperceptible small steps in an evolutionary fashion, not so much through the genius and brilliance of individual scientists but more by a process of trial and error, chance and sheer stumbling around. Above all, science is a collective enterprise, but not consciously so" (pp. 4–5). Scerri concedes that, in the past, others have also advocated evolutionary and communitarian understandings of scientific progress but asserts and that he arrived at his system independently, without studying earlier authors.

The first two of the seven scientists covered here dealt with large questions. British physicist John Nicholson (1881–1955) was interested in the spectra of astronomical nebulae and also in the weights of chemical elements and the internal structure of atoms. He postulated that the elements with which we are familiar were produced from several "proto-elements" which no longer exist on Earth but which persist in distant nebulae. Using theories based on such ideas (most of which were quite contrary to then-established and also later understandings—that is, those notions were *wrong*) he was able to compute quite accurate atomic weights for most of the then-known elements and to rationalize complex line-spectra of

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the Orion Nebula and of the solar corona. Nicholson also correctly predicted frequencies of a number of spectral lines that had not been observed before his publications but were found shortly thereafter. He also came to the conclusion that the angular momentum of electrons within atoms must be quantized. Although earlier versions of Niels Bohr's theory of the electronic structure of atoms did not include this feature, quantization of electronic angular momentum became quite prominent in Bohr's later revisions—and Bohr fully credited Nicholson with having discovered that quantization.

Dutch lawyer Anton Van den Broek (1870–1925) developed a serious spectator's interest in atomic physics. He followed up an incidental suggestion of Mendeleev and designed a three-dimensional periodic table. He also closely studied Geiger and Marsden's reports of how alpha-particles were scattered by various elements. Shortly after Rutherford published his conclusion that atoms had positively-charged nuclei (without specifying the magnitude of nuclear charge), Van den Broek, based on numerical analysis of experimental results of others, suggested (in *Nature*, no less) that the charge of each atomic nucleus was equal to the index-number of that element in the periodic table. Henry Moseley later stated that his justly-famous experiments (which established the correctness of this suggestion) were carried out "with the express purpose of testing Van den Broek's hypothesis."

Introductory chemistry courses frequently consider how electrons distribute themselves among energy levels and energy sublevels in the lowest-energy states of individual atoms of each of the elements[1]—as if such information was important in determining periodic properties. The remaining five of the scientists covered in this book made important contributions in this context. German electrochemist Richard Abegg (1869–1910) was important in the development of the electronic understanding of the combining capacities of atoms. English chemist Charles Bury (1890–1968) clarified the relationship between the electronic structure of atoms of the elements and their placement in the periodic table. British chemist, John D. Main Smith[2] showed how atomic electron-shells are structured, with two electrons more tightly held than the rest.[3] English physicist Edmund Clifton Stoner (1899–1968) developed more-adequate models of sublevel structure and of collective-electron ferromagnetism. French engineer, Charles Janet (1849–1932)[4]—among other contributions—developed the left-step periodic table.

In the past, chemists have often made important contributions to philosophy. Charles Sanders Peirce (1839–1914), generally recognized as one of the most significant of North-American philosophers, identified himself as a chemist throughout his career. Hilary Putnam documented that Peirce's important contributions to the logic of relations were widely known among European logicians in the late nineteenth century, at a time when Gottlob Frege's related work (published 4 years earlier than Peirce's) remained largely unknown.[5] Frege's logical work became widely known only after Bertrand Russell revived it in connection with his advocacy of logic-centered philosophies such as those now called "positivism" and "analytical philosophy." Michael Polanyi (1891–1976), Hungarian-born British physical chemist and philosopher, argued that positivism supplies a false account of knowing, which

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[1] Such as might conceivably be found in highly dilute vapors of monatomic gases, if such did exist.

[2] Dates for John Main Smith do not seem to be available.

[3] Main Smith "discovered the s-electrons".

[4] Janet worked sequentially in geology, entomology, biology, and chemistry, each for about 10 years, and achieved notable—but not outstanding—success in each of those areas.

[5] Peirce's linear notation was used in the important logical works of that era, whereas no one else ever used Frege's three-dimensional notational system.

if taken seriously undermines our highest achievements as human beings. Polanyi vigorously advocated the view that science was a community enterprise, dependent on shared "interpretive frameworks."

German-born British philosopher, Heinz Post, Eric Scerri's Ph.D. mentor, was much impressed by how, in 1962 and later, the work of Thomas Kuhn (1922–1976) on scientific revolutions brought about shifts in general philosophical understanding of scientific development.[6] Kuhn was certainly aware of Polanyi's work and on some occasions indicated that he was influenced by it. Many authors have pointed out strong similarities between Kuhn's "paradigms" and the awkwardly-named "interpretive frameworks" described by Polanyi. Though both Polanyi and Kuhn recognized similarities in their approaches, each pointed out their fundamental difference in general outlook from the other. Kuhn was generally understood as denying that science leads to truth, thereby generating accusations of relativism. Kuhn denied those accusations, but formally rather than persuasively. Post distanced himself from Kuhn, stating: "Contrary to Kuhn, I believe that scientific theory converges towards a unique truth." Throughout this book, Eric Scerri downplays the scientific importance of truth and falsity, while also inserting what amount to formal denials of relativism.

Scerri does recognize that the general philosophical approach that dominated North-American academic philosophy for decades has now run into problems. Toward the end of the present work (p. 212) he asks: "Why, one might ask, has analytical philosophy of science not withered away yet?" Perhaps, an anti-analytical objection Marjorie Grene raised against philosopher Arthur Fine might be applicable both to Kuhn's work and also to Scerri's more-recent effort. Grene claimed that Fine held that realism must be justified by an argument more rigorous and exact than the methods by which scientific conclusions are reached. That is, the notion of truth which some (perhaps many) analytically-trained philosophers have internalized is "a God's-eye view"—an account of reality which would be adequate for any and every conceivable purpose. This hypothetical notion of truth might well be coherent with logic-focused philosophy but it is not consistent with contemporary (post-Peirce) scientific realisms, such as Rom Harré's "policy realism."

A striking characteristic of contemporary philosophy of science[7] seems to be that those who vigorously defend certain explanatory levels as fundamental then tend to display little or no interest regarding what can validly be inferred concerning those levels. Jaegwon Kim, for instance, vigorously argues that physical processes can all be understood in term of functioning of submicroscopic entities, but makes no explicit use of submicroscopic reasoning in his own work. Similarly, in this book, Eric Scerri argues that scientific research is much like biological evolution, but refers to the obsolete[8] quasi-biological concept "missing link" as if it were in current use in discussions in evolutionary science, and gives short shrift to conclusions of recent biological researchers, barely mentioning the powerful notion of punctuated equilibrium. (It is widely agreed that pattern is important, even though how it should be explained is debated.) Current studies of the evolution of microorganisms (where rapid generation-turnover facilitates study of evolution, see van Boxtel, C. et al. "Taking chances and making mistakes") demonstrate that the course of evolution is partially determined by regularities of several sorts, but is additionally determined by contingent circumstances of many types. Factors involved in

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[6] Post was especially interested in how major scientific changes often preserve significant pieces of earlier approaches ("the correspondence principle").

[7] Remarkably, neither philosophers nor scientists show much interest in "philosophy of science."

[8] Prominent in the 1908 controversy regarding the Piltdown man.

the origin of novelties are important—but characteristics which influence the "spread of novelties through populations" are often of even more significance. Such considerations seem to be pertinent to why, although Michael Polanyi's approach still has strong supporters, Thomas Kuhn's work achieved (and retains) much wider acceptance.

The result typified by the Polanyi/Kuhn contrast can also be seen in non-philosophical chemistry. In 1954, John O. Edwards correlated rates of nucleophilic chemical reactions in terms of two parameters (basicity to protons and polarizability), characteristic of each reactant nucleophile. In 1961 and 1962, Edwards published results of collaborative research with Ralph Pearson. Starting in 1963, Pearson published many papers, reviews, and chapters all vigorously promoting his theory of hard and soft acids and bases (HSAB). This generalized the approach Edwards had used on nucleophiles to wider subject-areas and re-packaged it using concise and easily-remembered terms. "The Edwards equation" is still used by some few organic chemists, but HSAB theory generated much more widespread and lasting interest than Edwards' work had ever received. Analogous to the cases of microorganism evolution and philosophical theory-acceptance, contingent details of how scientific innovations are presented and promoted have profound influence on how or whether those innovations spread and persist. Pearson's developments of Edwards' approach—relatively superficial though they may have been—were in fact highly important.

It is surely the case that scientific progress occurs by an evolutionary process and that science is mainly communitarian rather than principally individualistic. As mentioned above, chemist-philosophers Charles Peirce in the nineteenth century and Michael Polanyi in the mid-twentieth century made closely similar points. Those conclusions are new only in as much as they differ from the customary presuppositions of many analytical philosophers.

Postmodern literary critic, John Barth recommended that, to appreciate any historical period, students of literature should read *mediocre* writers rather than great ones. This seems to be similar to Scerri's counsel to pay more attention to now-obscure scientists. Barth wrote *The Sot Weed Factor* (in part, at least) to illustrate his advice. That 1960 novel runs tediously on for more than 740 often rather-turgid pages. Chemical educators surely will want to include aspects of the interesting stories that are told in this book in their courses, but they should think long and hard before they abandon linking major conceptual shifts to specific historical figures. At least since ~ 700 B.C. when Hesiod composed his *Theogany*, tales about outstanding individuals and their (however mythical) achievements have been both memorable and inspiring in ways that more historically-accurate accounts usually are not.

This book contains a selection of interesting background-stories for one of the main themes of introductory chemistry courses, and also provides some first-hand testimony about how analytically-trained philosophers can belatedly discover aspects of reality inconsistent with their own earlier presuppositions without taking notice of the earlier work of others on those aspects.

Compliance with Ethical Standards

Conflict of Interest The author of this review asserts that no conflicts of interest exist regarding this review or its contents.