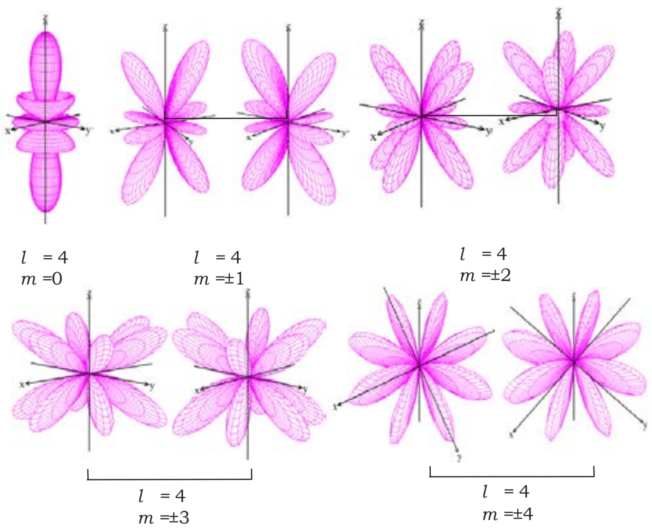
Visualizing non-famous orbitals

By simply converting the angular wave equations in table 1 to Winplot code as described by Chung (2013), one can visualize many types of less familiar atomic orbital representation. As example, representation of orbital for $l = 4$ is presented in figure 1.



CONCLUSIONS

A large set of less familiar atomic orbitals has been successfully generated by students using simple Winplot software. Applying Winplot makes students project to visualize orbital become simple and possible. Then, this powerful software is highly recommended to be used in teaching atomic structure in schools or universities.

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BIBLIOGRAPHY

Atkins, P. W., Paula, J. D., *Physical Chemistry*, 9th ed., W. H. Freeman: Madison Evenue, NY, 2010, p. 374 –377.

Budde, M., Niedderer, H., Scott, P., Leach, J., 'Electronium': a quantum atomic teaching model, *Physics Education*, **37**, [3], 197–203 , 2002.

Chung, W. C., Three-Dimensional Atomic Orbital Plots in the Classroom Using Winplot, *Journal of Chemical Education*, **90**, [8], 1090-1092, 2013.

Cooper, R., Casanova, J., Two-Dimensional Atomic and Molecular Orbital Displays using Mathematica, *Journal of Chemical Education*, **68**, [6], 487–488, 1991.

Ellison, sp^3d^n Hybrid Orbitals and Molecular Geometry, *Journal of Chemical Education*, **81**, [10], 1534, 2004.

Finley, F.N.; Stewart, J.; Yarroch, W.L., Teachers' perceptions of important and difficult science content, *Science Education*, **66**, [4], 531-538, 1982.

Indonesian Curriculum Standard for Secondary Education, Content Standard of Chemistry for Secondary School, General Board of Elementary and Secondary Education, Jakarta, Indonesia, 2013.

McQuarrie, D. A., Quantum Chemistry, *University Science Books*, Sausalito, CA, 1983, p. 398 – 407.

Mortimer, R. G., *Physical Chemistry*, 3rd ed., Elsevier Academic Press: Burlington, MA, 2008, p. 853 - 855.

Niaz, M.; Aguilera, D.; Maza, A.; Leindo, G., Arguments, contradictions, resistances, and conceptual change in students' understanding of atomic structure, *Science Education*, **86**, [4], 505-525, 2002.

Park, E.J., Light, G., Indentifying atomic structure as a threshold concept: students mental models and troublesomeness, *International Journal of Science Education*, **31**, [2], 233-258, 2009.

Parris, R., Winplot Home Page, http://math.exeter.edu/rparris/winplot.html (accessed Jun 2016).

Shechter, E., Matlab Home Page, http://www.mathworks.com/matlabcentral/ileexchange/44604-plot-hydrogen-atom-molecular-orbital (accessed Jun 2016).

Saputra, A., Canaval, L.R., Sunyono, Fadiawati, N., Diawati, C., Setyorini, M., Kadaritna, N., Kadaryanto, B., Visualizing Three-Dimensional Hybrid Atomic Orbitals Using Winplot: An Application for Student Self– Instruction, *Journal of Chemical Education*, **92**, [9], 1557-1558, 2015.

Stewart, B., Hylton, D. J., Ravi, N., Using Maple to Visualize Atomic Orbitals, *Proceedings of The National Conference On Undergraduate Research (NCUR), University of Wisconsin La Crosse*, 11-13 Apr 2013, University of Wisconsin, 2013, p. 303-308.

Taber, K.S., The atom in the chemistry curriculum: fundamental concept, teaching model or epistemological obstacle?, *Foundations of Chemistry*, **5**, [1], 43–84, 2003.

Tsaparlis, G., Atomic orbitals, molecular orbitals, and related concepts: conceptual difficulties among chemistry students, *Research in Science Education*, **27**, [2], 271-287, 1997.

Tsaparlis, G., Papaphotis, G., *Quantum-chemical concepts: are they suitable for secondary students?, Chemistry Education:* Research And Practice In Europe, 3, [2], 129–144, 2002.

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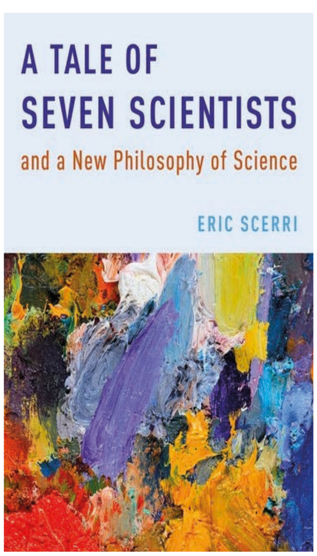
Books review

Eric R Scerri. A TALE OF SEVEN SCIENTISTS AND A NEW PHILOSOPHY OF SCIENCE. Published by Oxford University Press, 2016. ISBN: 9780190232993



This is an intriguing book that provides an extensive source of information about seven little-known chemists and their contribution the development of chemical ideas. It also pictures the nature of scientific development in ways that challenge our more usual views. The author perceives the progress of science to be much more an 'evolution to fit the environment' than a closer approach to the truth, snd ascribes value to 'wrong theories'.

In the preface to the book there are two perceptive forewords by Peter Atkins and by James Marcum and also, a fairly extensive autobiographical summary of the author's own professional growth as a chemist and philosopher of chemistry. This last provides a valuable insight for the reader into the possible sources of the 'new philosophy of science' that is presaged in the title of the book. Such a section should probably be mandatory in any publication in which new, and possibly controversial, ideas are being propounded.

The 'seven scientists' in the title are each provided a chapter within the main text and their names are John Nicholson; Anton Van den Broek; Richard Abegg; Charles Bury; John D Main Smith; Edmund Stoner and Charles Janet. The main chapter headings are reproduced below, together with a few comments in *italics.*

Chapter 1. Introduction: Intermediate historical figures & how can 'wrong theories' lead to scientific progress?

Chapter 2. The intriguing case of John Nicholson. *This provides examples of some very impressive results from a theory that turned out to have no foundations. It is argued that this work contributed significantly to the conclusions of Niels Bohr – despite being wrong. There seems to be a couple of typographical errors (e.g. in the text, 'c' is given for the speed of light whereas 'a' seem to be used for this within the equations on p16-17), but these are minor faults.*

Chapter 3 Van den Broek and atomic number. *A very good case is made for Van den Broek being the first to recognize the importance of atomic number – rather than atomic weight – in structuring the Periodic Table. I was also fascinated to read that since, within his calculations, hydrogen was anomalous he **omitted** it from his tables!*

Chapter 4: Richard Abegg, an early pioneer of chemical bonding. *Abegg provides a view of the electrical nature of matter that forms a vital link between the work of Mendeleev on valency and G N Lewis's ideas in chemical bonding*

Chapter 5: Charles Bury, and his detailed electronic structures. *Before discussing the contribution of Bury, this chapter provides an accessible historical review of the development of ideas of electronic structure (And the work of Perrin, Nagaoka, Mayer, Thompson, Rutherford, Bohr, Kossell, Lewis, and Langmuir – some of whom I have heard of!) The work of Bury is seen as a particularly important link between Bohr, Langmuir and Lewis. (The 'potential status' of Bury is exemplified by the fact that the chemist Samuel Glasstone refers to 'The Bohr-Bury' atom – one of the few to recognize Bury's contribution. (p99))*

Chapter 6: John Main Smith the chemist who anticipated Stoner. *He seems to have been a particularly neglected contributor to the theory of electronic structures of atoms. His ideas did not always turn out to be 'right', but he helped to progress/connect the ideas of Bohr and others. Personally, I now admire his judgment since he advocated the placing of hydrogen at the top of any of the main groups of the Periodic Table – with some preference for Groups I* ***and*** *VII because of its univalency!*

Chapter 7: Edmund Stoner, pioneer of the 3rd quantum number. *Stoner provided a more rational basis for electronic structures of atoms and improved the link between these and Bohr's 'Aufbau' principle for the elements in the Periodic Table. His work also proved to be an inspiration for Pauli and the Exclusion Principle.*

Chapter 8: Charles Janet, inventor of the left-step periodic table. *Janet was a savant who contributed to a huge variety of scientific and social fields. Impressively he came late to chemistry at age 78 and devised the left-step pattern for the Periodic Table. I personally have major problems with this since it places helium at the head of Group II and hydrogen unambiguously tops Group I. (The chapter would label me as a 'traditionalist'.) The final section of the chapter explores the meaning of the term 'element' as used by Janet – an important issue for teachers and students of chemistry – as to whether they are 'simple substances' or 'basic substances'.*

Chapter 9: Drawing Things Together. *Overall the author argues for a much messier, more organic development of science than is usually presented. There are many twists and turns and mistakes as science develops. Moreover it is an intensely human process and thus contains a multitude of emotions – jealousy, avarice, nationalism, (joy?) etc. although it is argued, that the resulting science organism (Sci-Gaia?) is unaffected in the long run, by error, inconsistency, issues of priority and human foibles. This chapter aims and largely succeeds in putting the authors 'new' philosophy of science in the context of a large number of other philosophers of science including Kuhn; Popper; Lakatos; Merton; Toulmin; Campbell; Lamb and Easton. It would be impossible – and inappropriate – to attempt here to survey the multitude of interactions, similarities and differences to be found in this chapter, suffice to say that it is a challenging read for those of us who have not studied the history of science and philosophers of science in a similar depth as the author. It is, however, a powerful learning experience giving a perspective on some key issues relating to the development of science. Some of these are listed below:*

- *Scientific Revolutions – or not.*
- *Priority Disputes among scientists*
- *Simultaneous or Multiple Discovery*
- *Inconsistency and error in Scientific Theories*
- *Evolutionary Theories of Scientific Development*
- *Truth or fitness.*

The book is also furnished with a section of Notes and an Index.

As I hope I have indicated in some of the comments above, this is an interesting read for anyone wishing to explore the ways in which science might operate and coming to their own provisional conclusions as to the ways in which science progresses. I guess it could be too much of a challenge for anyone not already reasonably versed in chemistry – especially the electronic structure of atoms and the build-up of (the) Periodic Table(s). It is a text that should find itself available in all chemistry departments in higher education – and is sure to promote discussion, argument and alternative perspectives. There may also be some skepticism and suggestion that time and effort would better be engaged in getting on with ***doing*** science! There are a few (typographical) errors and the occasional internal inconsistency, but these do not affect the overall integrity of the book – and indeed are interesting to find since in some ways their existence helps to validate the evolutionary thesis for progress!

The seven scientists, whose work is covered in chapters 2 – 8, although not famous or not appropriately recognized, were deeply engaged in their worlds of science albeit sometimes providing ideas for others, getting things 'wrong' or even getting them right for the wrong reasons. This leads me to wonder: who are the members of this scientific community? What are the conditions for membership of this community? Can it include people who published nothing, or science technicians, or science teachers. Is a PhD a mandatory requirement? Perhaps even people antagonistic towards science are members, if their engagement happened to catalyse progress by others?

Additionally, the proposed relationship between 'organism' science and that of the community of scientists is still not fully clear to me. There are various statements in the book – e.g. p10: "The view of science that I support is an organic one in which scientific knowledge is viewed as on interconnected organism, a living Gaia like creature……." p22: "what really matters is that science, in the form of the scientific community, makes progress as a whole." p212: "I claim that the society of scientists constitute a unified and living organism." Perhaps they are seen as the same thing? If so, is it possible that a community can be identical to the scientific knowledge it has attained, especially if there are disagreements within the community?

I cannot claim the expertise or philosophical background to critique the thesis in depth/detail. There is much to ponder upon and to wonder about. However, I am still not fully convinced that this new philosophy of science is yet sufficiently defined (in my mind) to oust many of the ideas from philosophy that I have gleaned over the years – and from certain perspectives – have found illuminating. For instance the idea of 'scientific revolutions' seems much less accepted for science although personally I feel that, as a science learner, revolutions seem to occur when new links form between concepts and/or when I realise that current understandings are wrong. Perhaps Kuhn should be classed also as a philosopher of Education?

Having read the text a number of times I still find it interesting from multiple perspectives. New questions arise – will be discussed – and I shall read the book again.

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