

A History of Vector Analysis – The evolution of the idea of a vectorial system. Michael J. Crowe. 1995 edition. Dover Publications, 31 East 2nd Street, Mineola, NY 11501, USA.

It has been some time since I have enjoyed as much reading a book on the history of science. The book's interest stems not just from the striking characters who populate the book but also because it demonstrates clearly how science often works rather than how it is romantically supposed to. In the classroom we are lead to believe that science is a logical process that moves forward in a logical way, that scientists are guided by reason and that the truth is our quest. It does not quite work that way. As any working scientist would have experienced at one time or another, an incremental advance is far more acceptable than a radical new discovery. The scientific community is very conservative and wary of change, of really new ideas. Grassmann's tragic neglect, described in this book, is a case in point; his misfortune was that his first published work was one of pathbreaking genius. If you are not already well established, like Hamilton, it is better that you do not do anything very novel.

I remember when I first came across them as an undergraduate, I could not understand the short proofs of geometrical theorems using vectors. The following year I came to understand these proofs and some time later I began to think that I 'understood' vectors. Now I wonder whether I was fooling myself; there are after all many levels of understanding. Reading this book it came as a real surprise to me that vectors, as we know them, coordinate free, were unknown until the latter half of the 19th century. They gradually arose from the discovery of *quaternions* by W. R. Hamilton (1843) and of the *calculus of extensions* by H. G. Grassmann (1844). I found it puzzling that although we are taught that Newton's laws are vectorial in character, vectors were known as such only a century and a half after Newton's formulation of his laws. Equally so was that it was J. C. Maxwell's electrodynamics, rather than mechanics, that motivated the physicists J. W. Gibbs and O. Heaviside to filter out the physically useful vectors from the somewhat impractical quaternions. There was a surprising amount of argument and acrimony, especially in the last decade of the century

between the vectorists and the quaternionists before the former finally prevailed. With this historical perspective, when we now know how difficult it was for scientists to get used to the idea that a single symbol \vec{a} could represent both magnitude and direction, are we sure we 'understand' vectors?

This history of vector analysis has four stages. The first lies in the early traditions culminating in the work of Hamilton and Grassmann in the 1840s to which the origins can be traced. The second sees the gradual acceptance and development of these mathematical ideas together with an increasing interest on the part of physicists like Clerk Maxwell; leading then, by a process of deletion, refinement and improvement, to modern vector analysis in the 1880s by Josiah Gibbs and Oliver Heaviside. The most interesting third phase in the early 1890s sees a struggle for existence between this work motivated by physical applications and the earlier work of the traditional quaternionists. The final phase in the early part of the last century is one of almost total acceptance of the new system, and its development and generalization in tensor analysis. Michael Crowe gives a very convincing and absorbing account of these developments with many quotations from original works. Reading these, one longs for the past when scientists wrote essays rather than papers – some of which can be read for their prose alone.

Crowe raises and answers a number of interesting questions. Why was it that the works of Hamilton and Grassmann were accorded such different receptions? Primarily because Hamilton was at the height of his fame while Grassmann, though a genius, was an unknown from the remote town of Stettin. But also because of Grassmann's style and the generality and philosophical nature of his classic, *Ausdehnungslehre*. Although Grassmann's work slowly gained critical acclaim from a number of influential mathematicians, he was never able to obtain a professorship in a university. This mild mannered, hard working man not only made important contributions to mathematics and philology, but also published language and mathematics textbooks and wrote on religious and musical matters. A study of Sanskrit begun in 1849 led in the 1870s to the translation of the *Rig Veda* (1123 pages). In the foreword of one of his books he wrote 'For I remain completely confident that the labor which I have expended on the science

presented here and which has demanded a significant part of my life as well as the most strenuous application of my powers, will not be lost . . . For truth is eternal and divine, and no phase in the development of truth, however small may be the region encompassed, can pass on without leaving a trace; truth remains, even though the garment in which poor mortals clothe it may fall to dust'. A truly brilliant mind.

The most interesting characters in the book are Gibbs, Heaviside and P. G. Tait, Hamilton's successor as the principal quaternionist and it is the confrontation between the former two and the latter and his students that lead to the greatest entertainment. Oh, what passion, what prose?! But before that it must be mentioned that Gibbs stands tall as the most logical, the most diplomatic while being uncompromising and finally so creative. There is a fine letter from Gibbs to V. Schlegel in which he explains how he came to quaternions from Maxwell's book, how he realized that it was best to separate out the dot product from the cross product and develop *ab initio* a simpler vector analysis which was printed and distributed but never published, and that he 'sheltered' himself behind the names of Grassmann and Clifford. Is it possible that the great Gibbs seems to feel the need for seeking shelter? Is this science?

The heated debate in the struggle for existence between the different systems takes place mainly on the pages of *Nature* in the early 1890s. Tait concludes one article with 'Even Prof. Willard Gibbs must be ranked as one of the retarders of Quaternion progress, in virtue of his pamphlet on *Vector Analysis*; a sort of hermaphrodite monster, compounded of the notations of Hamilton and of Grassmann'. In a tactful but forceful reply Gibbs says '... The criticism relates particularly to notations, but I believe that there is a deeper question of notions underlying that of notations. Indeed, if my offence had been solely in the matter of notation, it would have been less accurate to describe my production as a monstrosity, than to characterize its dress as uncouth.' Read in contrast A. McAulay, according to Crowe the 'most vociferous mathematician of the century', pleading with the Cambridge student to 'steep' himself in the 'delirious pleasures' of quaternions and promising: 'When you wake up you will have forgotten the Triplos and in the fulness of time will develop into a financial wreck, but in possession of the memory of the

heaven-sent dream you will be a far happier and richer man than the millionest millionaire.'

But the most effective person was Heaviside because, in addition to his vitriolic polemical style, he actually showed in his work on electromagnetic theory how effective vector analysis could be in the solution of physical problems. Crowe says that Heaviside's style can be placed somewhere between brilliant and obnoxious depending on one's point of view; while G. M. Minchin referred to him as the 'Walt Whitman of English Physics'. Certainly he is never dull. Read 'But supposing, as is generally supposed, vector algebra is something "awfully difficult", involving metaphysical considerations of an abstruse nature, only to be thoroughly understood by consummately profound metaphysico-mathematicians, such as Prof. Tait, for example. Well, if so, there would not be the slightest chance for vector algebra and analysis to ever become generally useful.' Or 'And it is a noteworthy fact that ignorant men have long been in advance of the learned about vectors. Ignorant people, like Faraday, naturally think in terms of vectors. They may know nothing of their formal manipulation, but if they think about vectors, they think of them as vectors, that is, directed magnitudes. No ignorant man could or would think about the three components of a vector separately, and disconnected from one another. That is a device of learned mathematicians, to enable them to evade vectors. The device is often useful, especially for calculating purposes, but for general purposes of reasoning the manipulation of the scalar components instead of the vector itself is entirely wrong.' And finally '... I ought to also add that the invention of quaternions must be regarded as a most remarkable feat of human ingenuity. Vector analysis, without quaternions, could have been found by any mathematician by carefully examining the mechanics of the Cartesian mathematics; but to find out quaternions required genius.' This was, of course, tongue in cheek.

Many readers may be surprised to learn that the leading British physicist of the time, Lord Kelvin, and the leading mathematician, Arthur Cayley, were both opposed to the development and use of vector analysis. The fact, however, is that science, or rather the scientific establishment, is conservative and usually opposed to any serious change. When Planck was once asked when the new physics would be accepted

by the older generation of physicists, he is said to have replied that they would never be able to accept it; they would just have die off and the younger generation, brought up with the new ideas, would absorb them without any difficulty.

Crowe's book is not without flaws, but they are too minor to warrant listing here. Whether you wish to learn some history, or you wish to learn how science develops or if you just want to have a few good laughs, the book is an excellent read. The charm lies in the fact that science is an intensely human activity, with all the attendant drama, humour and pathos. I strongly recommend this book.

P. N. SHANKAR

33/1 Kasturba Road Cross,
Bangalore 560 001, India
e-mail: pn_shankar55@rediffmail.com

Photosynthesis in Algae. Anthony Larkum, Susan E. Douglas, John A. Raven, eds. Kluwer Academic Publishers, Dordrecht, The Netherlands. **Advances in Photosynthesis and Respiration.** Govindjee Series Editor. University of Illinois, Urbana-Champaign, USA. Vol. 14. 500 pp. 2004. Hardbound. ISBN 0-7923-6333-7. November, 2003. Price: 255 US Dollars/232.00 Euros/160.00 British Pounds.

In most Indian universities, the undergraduate (BSc) and postgraduate (MSc) courses in botany and plant sciences include algae as a subject. Nowadays, the programmes in life sciences, biotechnology and microbiology also include algae as a major subject. Further, in many universities, phycology is taught as a specialization. However, the course structures on algae in these programmes are mostly limited to discussion on a bit of morphology, systematics and life cycles of some selected algae. The algal physiology, biochemistry, the economic resource aspects and ecology of this important group of plants are rarely discussed. This is largely because of lack of good textbooks on algal biology and biotechnology. If one searches for the new books – both text and reference types, *Photosynthesis in Algae* is a forceful book on this exciting topic.

The first introductory chapter written by the three editors tells about origin and discovery of algae, their diverse photo-

synthetic mechanisms. It discusses various groups of algae like green, red, brown chromophytes, euglenas and chloroachinophytes, and the algal genomes. It also points to rich algal bioresources and one can understand the importance of algae in biotechnological industries. The phylogenetic tree of major plant taxa is instructive. The nature of endosymbiotic origin of algal plastids, fine structure of algal plastids, the route of chlorophyll (Chl) *a/b* binding protein and pigments, chlorophyll *c* as well as appearance of thylakoids in different groups make interesting reading in next chapter.

Prochloron, prochlorothrix and prochlorococcus represent unique type of Chl *a/b* protein-containing oxyphoto prokaryotes. Like cyanobacteria (blue bacteria), these oxyphotobacteria are photosynthetic prokaryotes, but contain Chl *b*. These organisms have unique nature of light harvesting pigment organization and photosynthetic apparatus. They exhibit unusual dynamics of short-term state shifts mechanism as well as long-term acclimation. Molecular phylogeny of chl *b* containing oxyphotobacteria is presented in the third chapter. We owe to algae our current understanding of photosynthesis, the discovery of the prochloron type green oxyphotobacteria. Unicellular algae like *Chlorella*, *Scenedesmus* and *Porphyridium* and cyanobacterium *Anacystis* (*Synechocystis*) have been extensively used for photosynthesis research – both in the investigations of light reactions and of carbon assimilation reactions. These algae were and still are uniquely suitable for biochemical and biophysical studies, and data generated by using these algae led to the foundation of our current knowledge on photosynthesis. Of course, the use of isolated chloroplasts and thylakoids proved valuable for exploring the intricacies of photosynthetic electron flow and related redox reactions. I recall that, in the late 1960s, hand-drawn pictures of damsels by Fred Cho who did his Ph D with Govindjee, were pasted on the walls near Eugene Rabinowitch's office. These pictures were that of *Anacystis*, *Chlorella* and *Porphyridium*. Such was the influence of algae on photosynthesis research in the bygone era (!!!). Thus the book under review is an important book in current AIPH series.

The book contains 19 chapters, contributed by 25 experts besides the three editors. These chapters deal with the following five major aspects: general structure, molecular genetics, biochemistry–physio-