art. Guthrie rightly states that the 'magico-religious' approach, as he calls it, has generated confusion and error, and has "resulted in a derailment of rock art research". It is worth noting that, with a lone exception, not one specialist in Ice Age art takes these shamanistic notions seriously at all. On the other hand, there can be no doubt that some kind of profound religious motivation — however one defines it — does lie behind some cave art. It cannot all be attributed to sex, hunting and teenage scribbling.

In short, this book attempts a far too literal reading of much Palaeolithic art, and contains a great deal of wishful thinking in exaggerating the abundance, clarity and supposed ubiquity of hunting and sexual imagery in the art. Nevertheless, it provides a great number of interesting insights into the nature and behaviour of the species depicted, including humans, and is undeniably thought-provoking and challenging. I can recommend it highly, despite my reservations. ■

Paul G. Bahn is the author of *Journey Through the Ice Age* and *The Cambridge Illustrated History of Prehistoric Art*.

The forgotten mathematician

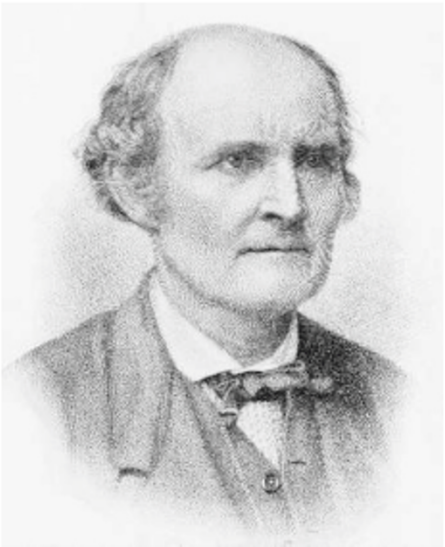
Arthur Cayley: Mathematician Laureate of the Victorian Age
by Tony Crilly
Johns Hopkins University Press: 2005.
784 pp. $69.95, £46.50

A. W. F. Edwards

It is not surprising that Arthur Cayley is a forgotten figure of the Victorian age, but it is wholly admirable that a modern biographer should enquire into his life and work so that we can judge him for ourselves. When Alexander Macfarlane gave his lectures on *Ten British Mathematicians* in 1901–04 he included Cayley; a century later, Ivor Grattan-Guinness edited *Landmark Writings in Western Mathematics 1640 to 1940* and Cayley was missing.

For those mathematicians and scientists not themselves destined to make fundamental contributions to their subjects, there is nothing more intellectually rewarding than the deep study of the work of those who have, what they achieved and how they came to achieve it. Biographers are needed who are proficient in the fields of enquiry that their subjects pursued, and Cayley is fortunate in having captured the attention of Tony Crilly. The problem then arises as to the level at which the subject's contribution is to be expounded: is Cayley to be revealed to mathematicians, or to a general scientific readership unversed in modern algebra? Crilly falls between the two stools. Mathematicians will regret the lack of mathematical detail, while others will risk losing themselves in a nebulous matrix of unfamiliar words (although mitigated by the author's exhaustive "Glossary of Mathematical Terms").

Many *Nature* readers will know about George Peacock, Cayley's teacher and a leading light in the Analytical Society, about William Thomson (Lord Kelvin), Lord Rayleigh and G. G. Stokes; we have read about James Clerk Maxwell and John Couch Adams, and enjoyed biographies of the two remarkable Georges, Boole and Green; we know of William Hamilton and his quaternions, and John Venn and his diagram. Augustus De Morgan, P. G. Tait, H. J. S. Smith, J. W. L. Glaisher, R. L. Ellis and the indefatigable Isaac Todhunter are not unknown to us, and who has not heard of Charles Dodgson and of Francis Galton (whom Cayley taught)? All these men are listed in a helpful appendix, "Arthur Cayley's Social Circle". But who was Arthur Cayley?



Yesterday's man: over the past century, Arthur Cayley has been eclipsed by his colleagues.

BETTMANN/CORBIS

Born in 1821 and senior wrangler in the Cambridge Mathematical Tripos in 1842, when he was elected a fellow of Trinity College, Cayley went to London to train as a barrister, being admitted to the bar in 1849. But he concentrated more on his mathematical than his legal work. Elected a fellow of the Royal Society in 1852, he was rewarded with the new sadlerian professorship of pure mathematics at Cambridge in 1863, which he held for the rest of his life. He played major roles in the London Mathematical Society, the Royal Astronomical Society, and the British Association.

Cayley also led a full life in the affairs of the University of Cambridge and Trinity College. In 1888 he was granted an honorary ScD at the same congregation as Stokes, Adams and Rayleigh. Ever sensitive to the cause of women's education, on the formation of the association governing Newnham College in 1880, Cayley became its first president. When he died at home in 1895 he had every reason to be content at a life well run.

But what of his mathematics? Many will be familiar with the beautiful Cayley–Hamilton theorem (a square matrix satisfies its own characteristic equation) and Cayley's theorem in group theory (any abstract group is isomorphic with a group of transformations). Students of phylogeny are grateful for his enumeration of trees, originally in connection with chemical formulae. But pure mathematics was his bent. His magnum opus was invariant theory, whose slow eclipse has taken Cayley with it. His *Collected Works* in 13 volumes containing 967 items (all single-author) awaits the diligent enquirer.

If one takes a polynomial like $ax^2+2bx+c$ and adds a value u, say, to x, resulting in a new polynomial $a'x^2+2b'x+c'$, it turns out that $a'c'-b'^2=ac-b^2$. In other words, the function of the coefficients typified by $ac-b^2$ is an invariant. There are endless polynomials (Cayley called them 'quantics'), with different orders (quadric, cubic, quartic, and so on) and different numbers of variables (binary, ternary, quaternary, and so on). Boole found an invariant of the binary quintic but then decided that the theory was a "peculiar and rather isolated branch of analysis" and gave up.

But Cayley, and J. J. Sylvester and George Salmon in Dublin, pressed on. Although Crilly does his best to keep track of their developments, the task is nigh impossible at the level of a general biography. We are left to admire Cayley the mathematician at a distance, but Cayley the man we can admire more closely, a painstaking industrious beacon of the Victorian age. Thomson thought he ought to have been made 'mathematician laureate', while Maxwell serenaded him "whose soul, too large for vulgar space/In *n* dimensions flourished unrestricted".

Thus the real subject of Crilly's monumental biography is the surrounding galaxy of British mathematicians listed above and the milieu in which they operated. Centred on Cambridge, with outposts in London, Dublin and Edinburgh and good continental connections, this was the generation that took the torch of British mathematics from George Peacock and the other 'analyticals', and with it illuminated modern algebra and many other mathematical developments. Crilly has researched this period exhaustively, producing a work which will be the starting point for biographies yet to come. Might he himself now tackle Peacock, fascinating for his part in the reform of Cambridge as much as for his advocacy of modern algebra? We can only hope so. ■

A. W. F. Edwards is retired, but is still a fellow of Gonville and Caius College, University of Cambridge, Cambridge CB2 1TA, UK.