BOOKS & ARTS

The supreme problem solver

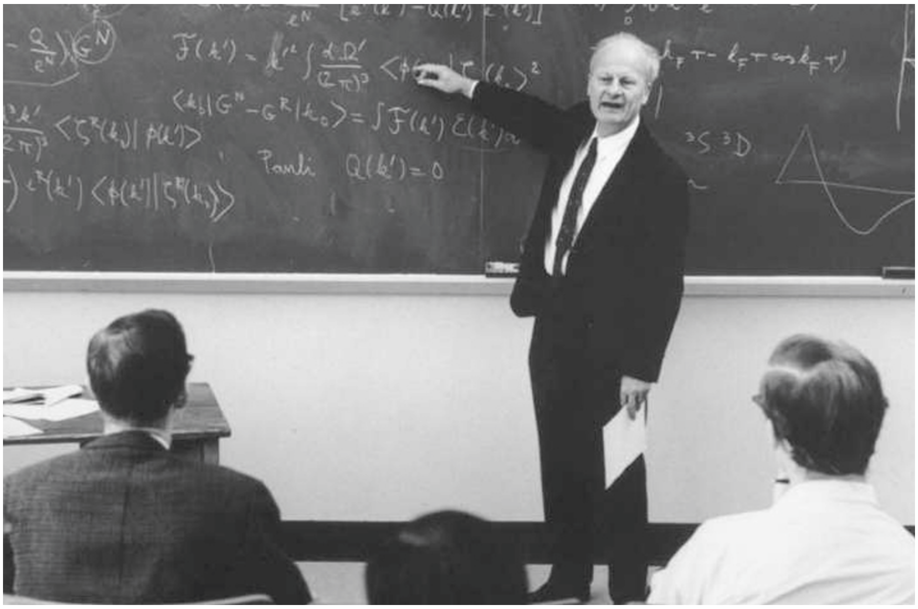
An exploration of the life and science of physicist Hans Bethe.

Hans Bethe and His Physics
edited by Gerald E. Brown & Chang-Hwan Lee
World Scientific Publishing: 2006. 314 pp. $98, £56 (hbk); $38, £22 (pbk)

David Wark

It is almost 20 years since the winter's day when I walked out of West Bridge at the California Institute of Technology from my thesis defence, with blood only slightly diluting the adrenaline in my veins, to deliver my newly approved opus to the registrar and record my PhD. As I swaggered across the concrete arch spanning the fountain in the centre of the campus, an elderly, heavy-set man was slowly making his way up the other side, his face a study in concentration as he peered into the water. I wanted to trigger a conversation to somehow mark my newly fledged status, but the words caught in my throat and I stepped aside. Even in my euphoric state I knew better than to interrupt Hans Bethe when he was thinking. Six years of my effort had produced a pedestrian but passable thesis, whereas an afternoon of Bethe's thinking could transform an entire field of physics.

This awe of Bethe and his work is universal among those who knew him, and the contributors to *Hans Bethe and His Physics* are certainly no exception. Freeman Dyson called him "the supreme problem solver of the twentieth century", and John Bahcall said it looked as if Bethe's output was the result of a conspiracy by several people all signing their work with the same name. His output must be nearly unmatched in duration, too — he published his first paper (with his father) at the age of 18 in 1924, and his last was submitted by his co-authors to the preprint servers six months after his death in March 2005. Along the way he picked up the 1967 Nobel Prize in Physics for work in the 1930s on the energy-production mechanisms of stars; he introduced the Bethe ansatz, which has found applications throughout physics and mathematics; he wrote three long articles for *Reviews of Modern Physics* in 1936–7 that were dubbed the 'Bethe Bible' and are said to contain everything that anybody else knew about nuclear physics and quite a bit more besides; and he gave his name to some now-essential formulae for calculating nuclear masses, the energy loss of charged particles passing through matter, and much more as well.



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Hans Bethe won the physics Nobel prize for work on stars, but he has influenced a wide range of fields.

But it was his 1947 calculation of the Lamb shift that perhaps best shows the power of his direct approach to physics. At a conference on Long Island, Willis Lamb announced that accurate measurements of the fine structure of atomic hydrogen were in conflict with Paul Dirac's prevailing theory of electrodynamics. Many of those present, including such towering figures as Niels Bohr and Robert Oppenheimer, saw this as the demonstration of a profound theoretical crisis that would require revolutionary new developments to resolve. On leaving the conference, Bethe took up the problem and had managed to calculate a value of this 'Lamb shift' that matched the observations before his train had travelled the 75 miles to his destination. He did this not with any revolutionary developments, but by performing the simplest calculation that he thought might match the data. This was the Bethe way, or as he put it: "Learn advanced mathematics in case you need it, but use only the minimum necessary for any particular problem," and "be prepared to make conjectures if it helps". All real problems are solved with approximations, so genius in physics often consists of knowing which mistakes to make, and Bethe was a master of it. His calculation convinced others that the fledgling field of quantum electrodynamics (QED) was on the right track, and helped spur the developments that led to the great success of QED and hence much of modern theoretical physics. His extremely pragmatic attitude to calculation, which he passed on to the legion of students he taught in his 71-year career at Cornell, still influences the field today (although looking at the current state of theoretical physics, perhaps not enough).

As head of the theory division at Los Alamos during the Manhattan Project, Bethe played a key role in constructing the first nuclear weapons. A refugee from Hitler's Germany, he was well aware of the danger that nuclear weapons could pose in the hands of totalitarian regimes. So, like many who had fled fascism, he devoted himself to ensuring that the democracies got these awful weapons first. After the war, Bethe was sensible enough to know that the development of nuclear weapons would continue in the United States whatever he did. He therefore continued his involvement in the belief that he could be a more effective voice for moderation from the inside — although quotes such as "I sometimes wish I was a more consistent idealist" show his ambivalence about such work. He was also an authoritative and effective advocate for arms control and international cooperation.

To fully describe such a formidable list of accomplishments will keep many a scholar busy for the foreseeable future. *Hans Bethe and His Physics* is much too short to even attempt such a task. It grew out of a request by Bethe to Gerry Brown to explain his physics to the world; Brown and Chang-Hwan Lee edited this book. It makes no claim to be a comprehensive biography — it is more like a taster menu drawn from half-a-dozen different restaurants. Like Bethe's work, the chapters range from extremely detailed physics to non-technical consideration of some of the biggest issues facing humanity. Much fascinating insight into some of the key figures can be gained without any scientific background, but some chapters require a knowledge of physics to degree level or beyond. A few of the later articles have a faint echo of axes being ground, but a book with no trace of controversy would be a poor reflection on Bethe's life.

I would especially recommend the book to anyone who has been involved in any way with the events described, as it brings alive many of the physicists that some of us knew only slightly, or by reputation alone. Reading about Bethe's pure pleasure as he bulldozed problem after problem using the simplest tools he could get away with was an inspiration — I wanted to grab a piece of paper and have a go myself. He kept that pleasure to the end. A colleague who gave a seminar at Cornell in the week of Bethe's death told me that Bethe closely followed the talk and obviously enjoyed it. His last words to a younger physicist, quoted in one of the best and most touching articles in the book, were simply "Carry on". We will, Hans. ■

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A bird's-eye view

Bird Coloration: Vol. 1, Mechanisms and Measurement; Vol. 2, Function and Evolution
edited by Geoffrey E. Hill & Kevin J. McGraw
Harvard University Press: 2006.
Vol. 1, 544 pp, £59.95; Vol. 2, 496 pp, £59.95

Andrew T. D. Bennett

Who can fail to be beguiled by the extravagant plumage colours of birds of paradise, peacocks and parrots? But there's more to feathers than showy displays. These remarkable, lightweight structures, which evolved 150 million years ago, perform a range of functions, both within individuals and across species. For example, they are one of the best thermal insulators known; they have several aerodynamic properties, creating refined aerofoil structures, producing lift and reducing drag; they can be waterproof; they are resistant to wear and abrasion, and are self-repairing; they perform a wide variety of sensory functions; and they create humid habitats for parasites and symbionts. Finally — and this is the focus of *Bird Coloration*, a two-volume work edited by Geoffrey Hill and Kevin McGraw — feathers produce a plethora of colours that demand an evolutionary explanation.

Simply put, an animal's coloration results from a trade-off between crypsis, for protection from predators, and gaudiness, for mating advantages. But the whole story is much more fascinating, and understanding it requires a firm grasp of both sexual-selection theory and colour vision. Sexual selection is a term coined by Darwin to explain the evolution of traits — often extravagant ones, such as the peacock's tail — that appear to confer disadvantages in natural selection but offer mating advantages. It was largely ignored for more than a century, but over the past three decades it has been one of the most intellectually vibrant areas of evolutionary biology. Its powerful body of theory now provides evolutionary explanations for a vast range of behaviour, ecology and life-history variation. For example, in humans it can explain mating patterns and even sporting and musical aptitude.

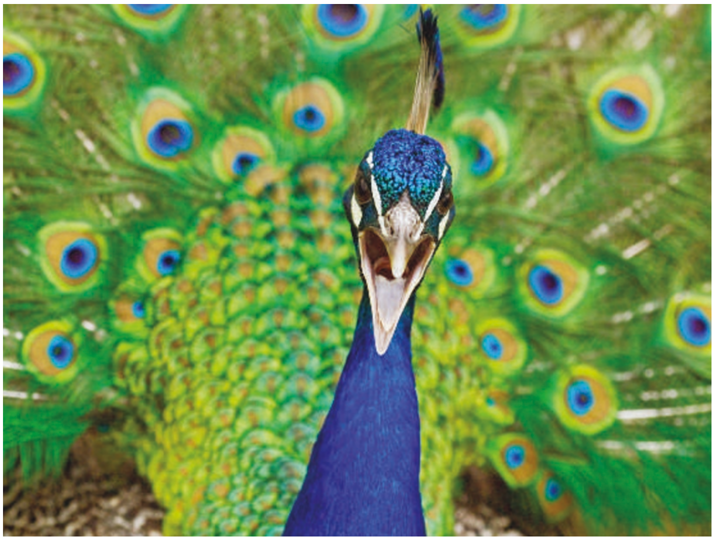
The test-bed for much of the work on sexual selection has been birds and their coloration. Why? Birds have grabbed biologists' attention in a way that nematodes have not, so there is a vast knowledge base on which to draw. In addition, the gaudy coloration and extravagant displays of birds require explanation and are amenable to testing. Vision plays a key role too — indeed, birds have perhaps the most advanced visual system of any vertebrate.

An explosion of interest was fuelled in the early 1980s by Bill Hamilton and Marlene Zuk's remarkable theory that much bird coloration evolves from sexual selection on traits that indicate condition, particularly disease status and heritable resistance to parasites. Many studies have since showed that feathers and fleshy ornaments can be condition dependent, and so provide potential mates with reliable information about quality.

It is surprising that until only a decade ago, the study of avian coloration proceeded in ignorance of colour science. A mini-revolution has since occurred in how colour is considered, measured and analysed in behavioural, ecological and evolutionary studies of birds. This change is reflected in *Bird Coloration*. Previously, almost all studies of avian coloration were made on the assumption that birds see colours in much the same way as humans. This assumption was flawed. We now know that many, if not most, diurnal birds are sensitive to ultraviolet wavelengths, to which humans are blind. Moreover, colour vision in birds arises from four classes of retinal cone cell, whereas humans have only three, probably giving many birds an extra dimension to their colour vision. In addition, experiments have shown that ultraviolet reflectance and illumination invisible to humans influences birds' decision-making in several contexts, including mate choice, foraging and provisioning chicks.

The two volumes of *Bird Coloration* provide an excellent up-to-date overview of the topic. Despite having 20 contributors (including many prominent people in the field), the book is generally well focused, although the editing could have been tighter in places.

The science of bird coloration today is genuinely interdisciplinary, drawing on behaviour, ecology, pigment chemistry, the physics of light, the microstructure of reflectors, physiology, immunology, molecular genetics and vision research. Most of these areas are well represented in the book. I particularly enjoyed the chapters on topics that have had relatively little attention in the past few years, such as the numerous non-sexually selected functions of avian coloration. These also provide a reminder of the many issues that remain to be unravelled. Consider, for example, even well-studied species, such as the zebra finch or the blue tit. There are still no convincing explanations for their combinations of



Putting on a show: a peacock displays its colourful tail.

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