evolutionary novelty, adaptive radiation, speciation and macroevolution. Evolution proceeds through adaptive developmental phenotypic plasticity.

Mainstream evolutionary biology is riddled with genetic determinism, blocking a biological view of the organic phenotype, West-Eberhard suggests. However, many of the biological studies she adduces in her support belong to the mainstream. Nobody objects to "a unified Darwinian theory that relates developmental plasticity to genetic change", but it is a matter of proportion. West-Eberhard sees too much unwarranted emphasis on genes; many will see an unwarranted role for developmental plasticity in her argument, as the description of phenotypic plasticity itself is too general and vague to get to grips with.

West-Eberhard's conviction of the primacy of the environment as the inducer of new phenotypic variation runs through the book, making her ask for a coherent evolutionary theory that uncompromisingly includes the environment alongside the genome in all aspects of evolutionary thought. She accepts that genetic change accompanies evolution, but only as genetic accommodation follows environmental induction; evolution as genetic change "is left hanging by a tenuous thread". In this view, genes are followers, not leaders.

How plausible is all this? Not very. No convincing evidence is presented for adaptive phenotypic accommodation to a new environment. Genetic accommodation is just a classical adaptive change in gene frequency. Developmental plasticity exists and is important in nature, but for it to be the dominant evolutionary factor, one has to show that developmental plasticity is predominantly adaptive and precedes genetic adaptation.

West-Eberhard refers to much good biology, but fails on the major point: developmental plasticity as the initiating factor of adaptive novelty preceding genetic change. The evidence shows that much developmental plasticity exists and has a genetic basis, no more and no less. West-Eberhard concedes that direct examples of adaptive environmental induction are lacking, but she labels many cases as indirect evidence reflecting the process. Whether the environment is the main player in eliciting adaptive developmental plasticity, and thereby in all other evolutionary processes, remains a question of faith. No crucial laboratory experiment is suggested that would test whether environmental induction leads to adaptive evolution. Actually, some tests for phenotypic accommodation (as 'beneficial acclimation') have been done by Raymond Huey's group at the University of Washington, and were negative.

In one of the first studies of phenotypic plasticity, Richard Woltereck defined the reaction norm as the range of the phenotypes that an individual could exhibit over all environments. The original insight was: "*Genotypus* 4 *Reaktionsnorm*", the genotype being the information for developmental plasticity. Woltereck transplanted *Daphnia* from Denmark to Italy to investigate whether the environment modified the reaction norm: it didn't. Later, dissatisfied with 'materialism' but impressed with phenotypic plasticity, Woltereck wrote two books, unfortunately incomprehensible, expressing a holistic view. In reading West-Eberhard's *Developmental Plasticity and Evolution*, one also often struggles with the verbal arguments: what does this mean, and how, precisely, would that work? West-Eberhard asserts a vision but presents little analysis. A major new synthesis and research programme this book is not. ■

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The finger of Galileo

The Oxford Companion to the History of Modern Science
Edited by J. L. Heilbron
Oxford University Press: 2003. 960 pp. $110, £40

Ryan J. Huxtable

The value of a person's life is not to be judged by the length of the obituary. However, more than 100 biographies of scientists in *The Oxford Companion to the History of Modern Science* are all approximately one page in length, regardless of the achievement of the scientist or the amount of information available about the person. This modified egalitarianism is illuminating not only of the subject at issue, but of current attitudes towards personal achievement and great men or women. Linus Pauling, who uniquely won two individual Nobel prizes, made enormous contributions to several areas, including insights into the nature of the chemical bond, and lived to a ripe age of 93, still working on controversial issues. Rosalind Franklin made an important, but single, contribution to the elucidation of the structure of DNA, and died at the early age of 37. These two scientists get the same consideration as Galileo.

By almost any measure, modern science begins with Galileo Galilei (1564–1642). He made enormous theoretical and practical contributions to areas as disparate as astronomy and the measurement of time. He tore down the dusty shed of aristotelian physics

Galileo Galilei: making plans for the future.

BETTMANN/CORBIS

that had blocked the daylight for so long. He was also one of the first rational investigators to fall foul of government and orthodoxy. His entry in this book describes him as the father of modern science, and the preface to the book begins with a quotation from him.

Conspicuously absent is an entry on Giordano Bruno, who was burnt at the stake for his iconoclastic but rational views of astronomy a few years before Galileo faced the Inquisition. Who can doubt that Galileo's recanting of his 'heresies' of heliocentrism was fuelled by the fire that consumed Bruno? Bruno receives three mentions *en passant*, on the influences on him, and on his views of an infinite Universe and stellar distances. Bruno was a hermeticist. Hermeticism, which does get a deserved entry in this book, was a part rational, part mystical system of thought, significant in the development of modern science. However, Galileo was surely the first modern scientist.

The editor-in-chief, J. L. Heilbron, is a witty and erudite contributor. His entry on 'ether' begins: "A possibly nonexistent entity", a description that in itself conjures up various philosophical issues. Are Plato's 'ideal horses' entities? Heilbron is aided by 5 editors, 7 consultants and 217 contributors, in producing almost a thousand pages of double-column text.

The thematic listing at the front of the volume of main headings and subheadings was more useful than the index. Thus, an index entry of page 357 for 'civil rights' leaves the reader scanning two densely printed columns in search of the elusive reference.

Some of the entries, such as that on 'progress', seem overly general. Others seem non-intuitive, such as 'tacit knowledge', 'shift

Science in culture

Seeing sense

Annie Cattrell's sculptures of the five senses are on display at the Royal Institution in London.

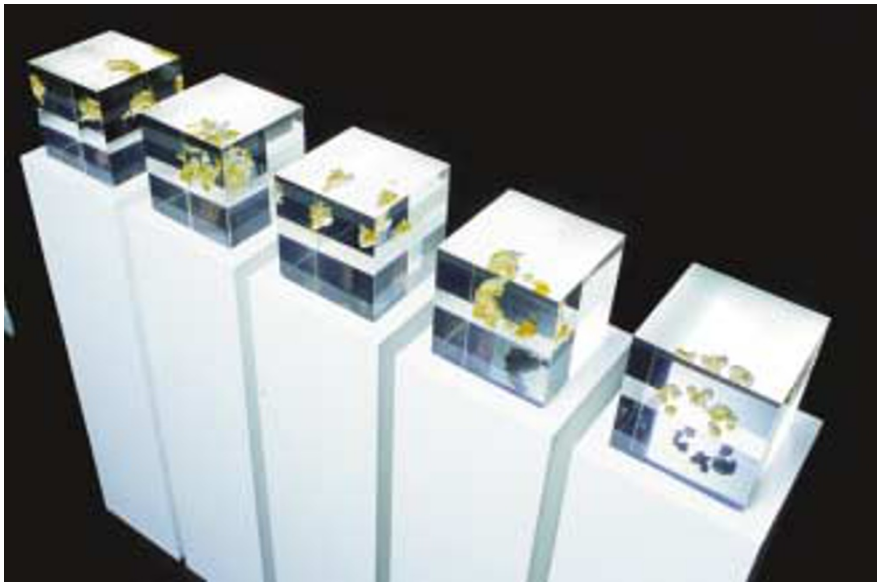
Martin Kemp

The mission of the Royal Institution, founded in 1799, focuses on the aspiration to "diffuse knowledge, and, through philosophical lectures and experiments, apply science for the common purposes of life". Visual demonstration has always been central to this aim, not least through the popular discourses delivered by Michael Faraday in the nineteenth century. Faraday was apprenticed to a book-binder before rising to become the greatest hands-on scientist of his generation.

Among the visual wonders that Faraday demonstrated at the Royal Institution were the first exhibited 'photogenic drawings' (early photographs) by William Henry Fox Talbot. Their rushed display in January 1839 was triggered by the startling French announcement at the Academy of Sciences two weeks earlier of Louis-Jacques-Mandé Daguerre's 'invention' of what came to be called photography.

Fittingly, the exhibition "From Within" by Annie Cattrell, the Royal Institution's artist in residence last year, includes photograms (direct exposures) in the manner of Talbot. She has made images of a sectioned human skull, created by exposing the skull and its cranial cap directly over photographic paper and flooding its interior with light from a hand-held torch. The negative reversal inherent in these photograms eerily maps the contours and orifices of the cranium against a black substratum, and seems to reveal its cavernous interior as a radiant source of mental illumination. In the spirit of Faraday, Cattrell has also prepared a video of magnetized iron filings, ingenious visualizations in cut paper of frictional forces, and a small installation of images of water placed between the faces of cut diamonds and subjected to extreme pressures.

The brain itself is the subject of Cattrell's most sustained exploration of how abstract visualizations in science can be turned into tangible reality. Her set of cubic sculptures *The Five Senses* is the culmination of three years of intense research. Two of the sculptures were finished in time for the "Head On" exhibition at the Science Museum in London last year, and now all five are complete. They rework a long-standing iconographical theme, which proved particularly popular in prints from the Renaissance onwards.



P. CATTRELL

In *The Five Senses*, Annie Cattrell explores the physical underpinnings of consciousness.

Among the texts that Cattrell studied was *The Human Brain* by Susan Greenfield, the Royal Institution's current director. Cattrell also discussed the work and collaborated with various brain scientists, including Steve Smith and Morten Kringelbach of the University of Oxford, and Mark Lythgoe of the Institute of Child Health in London, who granted her access to brain activity data generated by functional magnetic resonance imaging. The technique of rapid prototyping, courtesy of Californian company 3D Systems, translated the data into three-dimensional form.

Cattrell is seeking to grasp the "physicality of consciousness" by exploring the "delicate dialogue between the exterior world and our individual blueprint". She models this dialogue by casting in resin the morphological patterns of brain activity that correspond to the stimulation of each of the five senses. Neural activity is transformed into glistening apparitions that float in the cranial cavity like a kind of mental plasma. The refractive and reflective crystalline cubes, within which the skull is by implication inscribed, optically slice the golden configurations into shifting interplays of plans and elevations as the spectator moves past them.

In imaging the brain by casting and modelling, Cattrell stands in a long line going back to Leonardo da Vinci, who cast the ventricles of an ox brain, believing that the fluid in the ventricles was the medium within which the mental faculties operated. Of particular fascination to Cattrell are the almost unbelievably refined creations of the great wax modellers of the eighteenth and nineteenth centuries, including wax brains created by Joseph Towne that are in the Gordon Museum at Guy's Hospital, London. But whereas Towne's demonstrations can be characterized as pedagogy charged with beauty, Cattrell is in no sense working as an illustrator. Rather, as an artist she imaginatively translates the technical data, in all its awesome detail, into perceptible and beautiful forms that do full justice to the scientists' own excitement in creative visualization.

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Annie Cattrell's exhibition "From Within" can be seen at the Faraday Museum of the Royal Institution, London, until mid-September.

of hegemony', 'diffusion in the east' (which has nothing to do with gases), or 'brain drains and paperclip operations'. 'Standard model' discusses GUTs and TOEs but not body parts (TOEs being 'theories of everything' and GUTs referring to 'grand unified theories'). The value of the thematic listing is shown by finding 'tacit knowledge' as a subheading of 'Epistemology and methodology', which, in turn, is an entry under 'The body of scientific knowledge'.

This volume is the culmination of much scholarship and enormous effort (one rare error is a reference to the "noble" prize in the preface). The result is delightful to browse, but it is difficult to see how the book could be used systematically. It is of no help, for example, in tracing the history of anaesthesia. Unintentional insight into the planned use of the book is perhaps given by repeated phrases such as "depicts for a general audience", indicating an emphasis more on seeing and hearing than on reading. Indeed, I cannot escape a feeling that the time for print publication of such texts is passing. Electronic publication would provide easier searching and updating, and could more easily accommodate changing fashions. In short, this is one of those useful books for which it may be hard to find a use. ■

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