the much stronger evidence that has been compiled in the past three years by Brian Hare, Michael Tomasello and Josep Call, but even this work says nothing about the content of a chimpanzee's beliefs.

A second problem is that research on the developing theory of mind goes well beyond the literature reviewed by Keenan, and raises significant problems for his theory. Specifically, it is now clear that for many cognitive capacities, including the theory of mind, children have implicit knowledge long before it is explicit; using an explicit measure such as the mirror test might cause us to miss an earlier capacity. Furthermore, part of the challenge for the child in acquiring an explicit theory of mind is that it requires considerable executive control, something that young children lack because of the relative immaturity of the frontal lobes. This means that a child's inability to understand what others believe is not necessarily a reflection of the challenges it faces in attributing similar or different beliefs to others; rather, the difficulty may stem from the challenge associated with inhibiting personal beliefs in order to make accurate judgements about others.

Third, even if our sense of self is located in the right hemisphere — and there is chauvinism against this side of the brain from neuroscientists who think that the left hemisphere does all the heavy intellectual lifting — this does not help our understanding of how the brain generates a feeling of personal experience, of guilt, awe, shame or despair. It wouldn't help us to understand why Shelby is distraught, or whether medical technology might someday reverse these cases of brain damage.

In the end, however, Keenan and his co-authors have assembled a rich set of evidence that will contribute to what is certainly one of the most interesting topics in the sciences of the mind: our sense of self. At least, that's what I think, I think. ■

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New in paperback

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A flexible theory of evolution

Developmental Plasticity and Evolution
by Mary Jane West-Eberhard
Oxford University Press: 2003. 720 pp. $100, £79.50 (hbk); $49.95, £37.50 (pbk)

Gerdien de Jong and Ross H. Crozier

It is an ancient truism that what evolves is the developmental system, from which it follows that genetics, development and evolution are interwoven. Genetics and evolution were integrated long ago in the synthetic theory of evolution; development has only lately rejoined the evolutionary fold. The field of evolutionary developmental biology thus created is mostly concerned with patterns of evolution, comparing the genetic basis of evolutionary changes in development, rather than with the dynamics of evolutionary changes. Its sister, developmental evolutionary biology, studies how selection works on development to produce the adaptive phenotype, necessarily becoming linked to evolutionary ecology. This is a field worth pursuing, and Mary Jane West-Eberhard's *Developmental Plasticity and Evolution* certainly belongs within it, but the question is whether the book does the field good service.

For West-Eberhard the phenotype is central. But this is not the bleak 'genotype + environment = phenotype' taught to first-year students, but rather a vibrant, living, changing phenotypic whole, far from dreary genetic determinism. The phenotype is developmentally plastic, changing in many ways in response to many environmental challenges. To be alive is to be developmentally plastic. West-Eberhard envisages a synthetic theory of evolution and development in which environmentally induced phenotypic change gives rise to adaptive evolution as readily as, or even more readily than, mutationally induced phenotypic change.

The main evolutionary process, in West-Eberhard's universe, involves environmental change, phenotypic accommodation and genetic accommodation. An environmental change elicits a developmentally plastic response, and phenotypic accommodation — the immediate adjustment to a change resulting from the multidimensional adaptive flexibility of the phenotype — ameliorates its harm to individuals. New phenotypes resulting from this developmental plasticity are selected. A change in allele frequency — genetic accommodation — improves and incorporates the change. In this way the environment becomes a crucial participant in the generation and selection of adaptive design.

In West-Eberhard's view, this sequence of developmental plasticity, phenotypic accommodation and genetic accommodation is the mechanism responsible for (nearly) all

CHRISTIAN LAFORSCH/SCIENCE PHOTO LIBRARY

Spot the difference: the water flea *Daphnia* readily changes shape in response to its environment.

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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 = 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

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