sectors producing new technologies and products can be properly managed and publicly overseen to avoid ecological, ethical or human-health mishaps.

Some of this complexity is acknowledged in the final chapter, "A personal note", in which Rifkin writes of using science, and even genetics, in a manner that respects our natural world: "the question is what kind of biotechnologies will we choose in the coming Biotech Century?" Our greatest challenge lies in the social guidance and assessment of biotechnology within a democratic participatory framework and a global awareness.

Rifkin was criticized 20 years ago for exaggerating the untoward paths biotechnology would take and for opposing scientific progress. In hindsight, many of his predictions can hardly be considered hyperbole. Serious discussions are taking place on cloning humans, altering human germ cells, universal genetic screening, mandatory DNA identification and even the unmentionable prospect of 'improving' the human gene pool.

In his role as social critic of biotechnology, Rifkin has become entangled in a paradoxical situation. In an attempt to stir the reader's passions, he overdramatizes in some sections the power of biotechnology: "The biotechnology revolution will affect each of us more directly, forcefully, and intimately than any other technology revolution in history." We must be reminded that the first three main agricultural products of genetic engineering — the Flavr Savr tomato, the Ice Minus bacterium and recombinant bovine growth hormone — have either failed or are failing.

Moreover, like many of the genetic scientists he calls to task, Rifkin at times accepts uncritically a view that vastly overestimates the importance of genes in biological organisms. ("With genetic engineering, we assume control over the hereditary blueprint of life itself.") If he were to question too seriously the ability of science to carry out its "redesign of nature", the book would lose much of its moral force. But, while he plays up the power of genes ("the ultimate exercise of power") in some sections, elsewhere he tempers that view by acknowledging the poverty of genetic reductionism. He points out that, although such a view may be false, it has helped to advance the interests of those involved in molecular biology.

There is no simple reading of this book. A fair-minded reader will agree with some points and disagree with others. At a time when scientific institutions are struggling with the public understanding of science, there is much they can learn from Rifkin's success as a public communicator of scientific and technological trends. □

Sheldon Krimsky is in the Department of Urban and Environmental Policy, Tufts University, 97 Talbot Avenue, Medford, Massachusetts 02155, USA.

Living with dinosaurs

The Rise of Birds: 225 Million Years of Evolution
by Sankar Chatterjee
Johns Hopkins University Press: 1998. Pp. 312. $39.95, £33

The Mistaken Extinction: Dinosaur Evolution and the Origin of Birds
by Lowell Dingus and Timothy Rowe
W. H. Freeman: 1997. Pp. 332. $34.95, £24.95

Taking Wing: *Archaeopteryx* and the Evolution of Bird Flight
by Pat Shipman
Simon and Schuster: 1998. Pp. 336. $25. To be published in the United Kingdom in June by Weidenfeld and Nicolson, £20

José Luis Sanz, Bernardino P. Pérez-Moreno and Francisco J. Poyato-Ariza

In recent years there has been a renaissance in Mesozoic palaeo-ornithology. This kind of reinvigoration is normal in palaeontology, as new discoveries show that old hypotheses are false and give rise to new ones. A large number of Mesozoic avian taxa have been discovered during the past 20 years, so it is perhaps not surprising that three books devoted to Mesozoic palaeo-ornithology have recently been published. They are different in structure and scope, but the main topics of each are the foremost areas of research on the early evolutionary history of birds: the origin and historical diversity of the avian clade, its phylogenetic relationships, and the development of flight.

One of the most stimulating ideas arising from vertebrate palaeontology is the dinosaurian origin of birds. Proposed by Thomas Huxley in 1868, and reformulated by John Ostrom in the 1970s, this hypothesis is now widely accepted, and is supported by a large amount of evidence that increases as new fossil forms are discovered. All three books favour this hypothesis, which is challenged nowadays by just a few researchers. In terms of current phylogenetic systematics, the dinosaurian origin hypothesis implies that birds have to be considered as short-tailed, feathered volant dinosaurs.

The interpretation of birds as present-day dinosaurs leads to the provocative idea that dinosaurs have been around ever since humans appeared on Earth, and therefore represent an important part of our natural, cultural and economic environment. So it is not surprising that palaeontologists are concerned by man's responsibility in the disappearance of extant dinosaurs, given that natural phenomena — the Cretaceous/Tertiary (K/T) biotic crisis — extinguished most of the diversity of Upper Cretaceous dinosaurs (including some avian ones, such as Enantiornithes, Hesperornithiformes and Ichthyornithiformes). Sankar Chatterjee joins Lowell Dingus and Timothy Rowe in adopting a militant point of view, describing how the pressures applied by man have led to the extinction of hundreds of modern dinosaur species. The causes of the K/T extinction are still under debate, but it is clear that man has caused many extinctions in the Holocene.

Chatterjee concludes that the impact hypothesis was the proximate cause of the K/T biotic crisis, while volcanic phenomena increased the climatic stress and enhanced the extinction process. Dingus and Rowe review earlier hypotheses about the K/T biotic crisis, and then contrast the volcanic and impact hypotheses and revise the patterns of extinction and survival. A clear consensus has yet to emerge, but many present-day researchers consider that the extinction of non-avian dinosaurs was caused by a combination of the volcanic/marine regression and impact hypotheses. So large extraterrestrial impacts and massive eruptions of flood basalts have to be considered.

The historical diversity of a group of living organisms is shaped by extinction and diversification, the pattern of which is mapped by a phylogenetic hypothesis. The discovery of new fossils shows that the phylogenetic history of Mesozoic birds is much more complex than previously thought. Chatterjee agrees with Dingus and Rowe — and most palaeo-ornithologists — that the phylogenetic map of birds is shaped by a series of successive sister taxa from *Archaeopteryx* to Neornithes (extant birds). Like that of Dingus and Rowe, the avian phylogenetic hypothesis put forward by Pat Shipman is within the consensus reached by most researchers.

Chatterjee, however, includes a problematic taxon, the Triassic *Protoavis*, which is the core of his book. He positions this enigmatic genus between *Archaeopteryx* and the Enantiornithes, implying that *Protoavis* is a basal bird but is more derived than *Archaeopteryx*. The combination of characters of *Protoavis* is very unusual because, according to Chatterjee's interpretation, it has an ornithothoracine-like pectoral region associated with a very primitive (basal archosaur-like) hand architecture. This combination challenges the transformation sequence of characters in early avian evolutionary history.

If *Protoavis* was a bird (between 60 million and 70 million years older than *Archaeopteryx*), this hypothesis predicts important modifications even in the evolutionary history of non-avian dinosaurs. A problematic consequence is that even derived theropod groups, such as dromaeosaurids, troodontids or tyrannosaurids, must appear during the Lower or Middle Triassic. Chatterjee's answer to this troubling idea is highly classical: imperfection and sampling scarcity in the fossil record. Nevertheless, that tyrannosaurids are about the same age or even older than the first known dinosaurs, such as *Eoraptor* or the herrerasaurids, seems improbable.

So where does *Protoavis* fit in? It could be a taphonomic assemblage of different animals. But there are some bony elements that clearly exhibit bird-like characters. The *Protoavis* evidence could also suggest either the presence in the Upper Triassic of a non-avian theropod or other archosaur with convergent bird traits, or the appearance of the avian clade more than 200 million years ago. Present-day evidence is much more consistent with the first hypothesis.

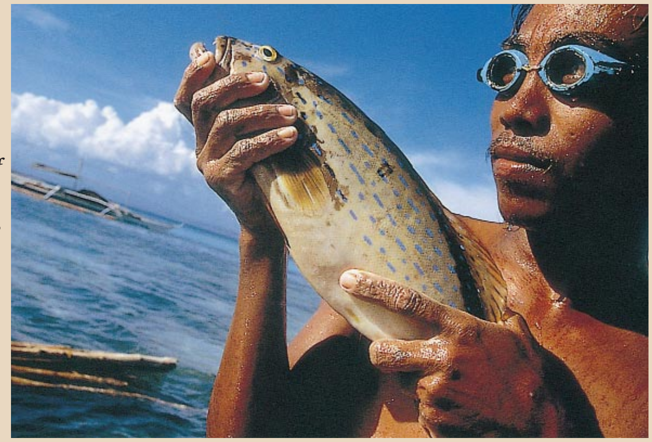
Although all three books fit in with the consensus that birds are flying dinosaurs, there are differences in their proposals about the origin of flight. There are two hypotheses to account for the origin of flight: "from the trees down" (usually associated with a non-dinosaurian ancestor of birds), and "from the ground up" (usually associated with a dinosaurian ancestor of birds). Shipman agrees with Dingus and Rowe in maintaining the consensus on the origin of flight, following the "from the ground up" hypothesis, suggesting that avian flight originated from a cursorial biped (a theropod dinosaur), whereas Chatterjee suggests a new synthesis, proposing a dinosaurian ancestor of birds and a "from the trees down" origin of flight. He considers some theropod clades, commonly thought to be highly cursorial animals, as arboreal ones. This requires new functional interpretations of some structures: for example, the stiffened caudal appendage must be reinterpreted as a climbing prop. Nevertheless, there are no features that clearly indicate an arboreal habitat for theropods such as ornithomimids, whereas nearly every feature indicates that they are extremely well adapted for high-speed running.

Shipman makes an outstanding analysis of the contribution of *Archaeopteryx* to discussions about the origin of flight. She considers the subject from the impartial point of view of someone from another research field. This allows her, after analysing all the hypotheses, to reach a conclusion based mainly on a functional approach: that birds come from a cursorial theropod ancestor.

Shipman's book is an accessible, yet precise, account. It provides a solid background to the importance of *Archaeopteryx* for understanding the origin of avian flight, and is suitable for specialists and non-specialists. Dingus and Rowe focus on dinosaurs, dealing with birds and the origin of flight within the context of the K/T boundary extinctions. They present much information, provide a good phylogenetic background and use familiar language. They construct a hypothetical, conceptual and methodological framework that could be assumed by a large part of the scientific community. Chatterjee takes a more specialist point of view. The other two books present a comprehensive survey of the most relevant alternative hypotheses, but Chatterjee's is different because most of the main hypotheses are his own and are not widely accepted. □

José Luis Sanz, Bernardino P. Pérez-Moreno and Francisco J. Poyato-Ariza are in the Unidad de Paleontología, Departamento de Biología, Facultad de Ciencias, Universidad Autónoma de Madrid, 28049 Madrid, Spain.

Fishing for solutions



"While fisheries around the world are in trouble, it's not too late to turn the tide," we read in *Faces of Fishing: People, Food and the Sea at the Beginning of the 21st Century* (Monterey Bay Aquarium, $19.95). Bradford Matsen presents both the problems and potential remedies, in a book based on images collected for an exhibition held by the Californian aquarium.

Farming forecast

Climate Change and the Global Harvest: Potential Impacts of the Greenhouse Effect on Agriculture
by Cynthia Rosenzweig and Daniel Hillel
Oxford University Press: 1998. Pp. 324. £49.50, $65

Peter D. Moore

The public expect science to be predictive, but most scientists are sufficiently aware of their own ignorance to avoid prediction wherever possible and to qualify it with wide error margins if speculation is unavoidable. Agricultural scientists are among those of whom most is demanded by politicians and the public, yet they face some of the greatest problems in prediction, as they deal with several levels of compounded errors.

They inherit the innate uncertainties of climate prediction and also have to scale up to global levels from small-scale experiments on the responses of crop plants to simulated sets of conditions. They then need to account for the simultaneous responses of weeds, pests and diseases to the new conditions before they can assess the outcome of change on global crop yields. As the geographical pattern of agricultural practice inevitably changes, there are also matters such as soil conservation, wildlife habitat protection and socioeconomic factors to consider, all of which differ from one area to another. Considering all of these variables together, it is a brave author who is willing to write a book about climate change and the global harvest.

A commendable feature of the book by Cynthia Rosenzweig and Daniel Hillel is their readiness to face the complex factors that will influence the agriculture of the future. Consider, for example, the consequences of altered attitudes to energy production resulting from efforts to avoid carbon emissions to the atmosphere. Energy-expensive agrochemicals will be avoided, reduced tillage agriculture will be demanded, biomass energy plantations may compete with food production, extra land may be flooded for hydro-development, and so on. Rosenzweig and Hillel take great pains to document the involvement of agricultural processes in the emission and control of greenhouse gases into the atmosphere and the consequent feedback effects of agricultural change.

The response of a crop to environmental change can be investigated in several ways. The use of controlled environment chambers has many advantages, such as precise factor control, but may not adequately simulate conditions of soil evaporation. Field experiments using open-topped enclosures have been more satisfactory, but even this approach has disadvantages, such as the difficulty in investigating the interactive effect of increased carbon dioxide at different temperatures. There is also the problem of scaling up from such data in a world of varied microclimate and soil conditions. Such soil variations may mean that the potential advantages of higher carbon dioxide levels for plant growth will not occur in many regions because of soil nutrient limitation.

Using recent experience of atmospheric and agricultural change to test the validity of models appears superficially attractive, and one can calculate the expected increase in global agricultural yield as a result of increasing atmospheric carbon dioxide levels from 280 to 360 p.p.m.v. (the observed change over the past 200 years) at 7.5%. The problem is that improved varieties of crops and enhanced input of nitrogen to soils from atmospheric pollution have also influenced