Extinctions in the History of Life

Extinction is the ultimate fate of all biological species – over 99 per cent of the species that have ever inhabited the Earth are now extinct. The long fossil record of life provides scientists with crucial information about when species became extinct, which species were most vulnerable to extinction and what processes may have brought about extinctions in the geological past. Key aspects of extinctions in the history of life are here reviewed by six leading palaeontologists, providing a source text for geology and biology undergraduates as well as more advanced scholars. Topical issues such as the causes of mass extinctions and how animal and plant life has recovered from these cataclysmic events that have shaped biological evolution are dealt with. This helps us to view the current biodiversity crisis in a broader context, and shows how large-scale extinctions have had profound and long-lasting effects on the Earth's biosphere.

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Born in New York City and educated in geology at Haverford College (B.S. 1973), the State University of New York at Binghampton (M.A. 1976), and Indiana University (Ph.D. 1978), David J. Bottjer began his career as a National Research Council–USGS Postdoctoral Fellow at the National Museum of Natural History, Smithsonian Institution. In 1979 he joined the faculty of the Department of Earth Sciences at the University of Southern California, where he is currently Professor of Paleontology and also a Research Associate at the nearby Natural History Museum of Los Angeles County. Editor-in-Chief of the internationally renowned journal *Palaeogeography, Palaeoclimataology, Palaeoecology*, and co-editor of the book series *Critical Moments and Perspectives in Paleobiology and Earth History*, Dr Bottjer has lectured throughout the world, most recently in Switzerland, New Zealand, Japan and the UK. A 1992–93 Paleontological Society Distinguished Lecturer, a Fellow both of the American Association for the Advancement of Science and the Geological Society of America, and President of the Pacific Coast Section of the Society for Sedimentary Geology, in 2000 he was a Visiting Fellow at CSEOL, UCLA. Dr Bottjer's research centres on the evolutionary palaeoecology of macroinvertebrate animals in the Phanerozoic fossil record.

David Jablonski
Educated in geology at Columbia University (B.A. 1974) and Yale University (M.S. 1976, Ph.D. 1979), David Jablonski became enamoured with fossils at an early age, working as an undergraduate at New York's American Museum of Natural History. Following postdoctoral studies at UC Santa Barbara and UC Berkeley, he spent three years on

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J. William Schopf
Director of UCLA's Center for the Study of Evolution and the Origin of Life (CSEOL) and a member of the Department of Earth and Space Sciences, J. William Schopf received his undergraduate training in geology at Oberlin College, Ohio, and in 1968 his PhD degree in biology from Harvard University. He has edited eight volumes, including two prize-winning monographs on early evolution – his primary research interest – and is author of *Cradle of Life*, awarded Phi Beta Kappa's 2000 national science book prize. At UCLA, he has been honoured as a Distinguished Teacher, a Faculty Research Lecturer, and as recipient of the university-wide Gold Shield Prize for Academic Excellence. A Humboldt Fellow in Germany and a foreign member both of the Linnean Society of London and the Presidium of the Russian Academy of Science's A. N. Bach Institute of Biochemistry, Dr Schopf is a member of the National Academy of Sciences and the American Philosophical Society, a fellow of the American Academy of Arts and Sciences, and current President of the International Society for the Study of the Origin of Life (ISSOL). Listed by *Los Angeles Times Magazine* as among southern California's most outstanding scientists of the twentieth century, he is recipient of medals awarded by ISSOL, the National Academy of Sciences, and the National Science Board, and has twice been awarded Guggenheim Fellowships.

Paul D. Taylor
Born in Hull, England, Paul Taylor received his undergraduate degree (BSc in Geology, 1974) from the University of Durham and stayed there to complete a PhD in 1977. After undertaking a postdoctoral fellowship under the guidance of Derek Ager at the University College of Swansea, in 1979 he joined the staff of the then British Museum (Natural History), now The Natural History Museum, as a researcher in the Department of Palaeontology. From 1990 until 2003 he served as Head of the Invertebrates and Plants Division. Dr Taylor has carried out scientific fieldwork in various parts of the world, including Saudi Arabia, India, New Zealand, Russia, Spitsbergen, several European countries and the USA. He has held Visiting Research positions at the University of Otago (New Zealand), the Museum National d'Histoire Naturelle (Paris), CSEOL (UCLA) and Hokkaido University (Japan). Fellow of the Linnean Society of London and author or editor of four books and more than 150 scientific articles, he has served on various national and international scientific committees and editorial boards, and is currently President of the International Bryozoology Association. In 1992 he was co-recipient of the Paleontological Society's award for the most outstanding monograph in systematic palaeontology. Dr Taylor's research centres on the taxonomy and palaeobiology of bryozoans, a group of colonial marine invertebrates with a rich fossil record.

Paul Wignall
A native of Bradford, England, Paul Wignall received his education in geology at Oxford University (BSc 1985) and the University of Birmingham (PhD 1988). Following a year of postdoctoral research in the laboratory of Professor John Hudson at the University of Leicester, in 1989 he joined the School of Earth Sciences at the University of Leeds where he is now Reader in Palaeoenvironments. An expert on the origin of marine petroleum and the palaeoecology of oil-source rocks, Dr Wignall's research has also focused on the causes of mass extinctions, particularly that at the end of the Permian. This interest has taken him on fieldwork to China, Pakistan, Greenland, Italy, Austria, Spitsbergen, Tibet and the USA. Author of two books (*Black Shales* and *Mass Extinctions and their Aftermath*, the latter co-authored with his doctoral supervisor Professor A. Hallam), and a member of the editorial boards of major international journals, he is a recipient of the President's Award of the Geological Society of London, the

Fearnside's Prize of the Yorkshire Geological Society and the Clough Award of the Edinburgh Geological Society.

Scott L. Wing

A palaeobotanist and palaeoecologist educated in biology at Yale University (B.S. 1976; Ph.D., 1981), Scott L. Wing began his career as a National Research Council–US Geological Survey (USGS) Postdoctoral Fellow (1982–83) and Geologist (1983–84) in the USGS Paleontology and Stratigraphy Branch. In 1984 he joined the staff of the Department of Paleobiology at the National Museum of Natural History (NMNH), Smithsonian Institution, where he has risen through the ranks to his current position of Research Curator, and since 1992 has held a joint appointment in the Department of Earth and Environmental Sciences at the University of Pennsylvania. He served for six years as Co-Editor of *Paleobiology*, the prestigious journal published by the Paleontological Society, has co-edited four major volumes, and is currently a member of the editorial boards of *Evolutionary Ecology Research* and *Annual Reviews of Ecology and Systematics*. Over the past decade, he and his colleagues at the NMNH have organized briefings for Congress and federal agencies as well as symposia at national and international conferences. Dr Wing's main areas of interest are the effects of climate change and global warming on the world's biota, especially the vegetation, as evidenced by the fossil record.

Preface

Extinction is a corollary of life itself. Just as the death of individuals is assured, so the extinction of species can be pretty much guaranteed in the fullness of geological time. Indeed, a leading palaeontologist once famously quipped that to a first approximation life on Earth is extinct. By this he meant that the great majority of species ever to have lived on the planet are no longer with us. Today we are rightly concerned with the threat to the survival of many contemporary species, and we mourn the loss of those that have disappeared in historic times, more especially because their extinction was very often due to overexploitation or habitat destruction by humankind. While the extinctions occurring at the present day may be viewed as atypical and in some respects 'unnatural', taking a broader view across geological time extinction can be seen as a major constructive force in the evolution of life, removing incumbents and allowing other groups of animals and plants to prosper and diversify. A renaissance of interest in extinction has been ignited not only by the contemporary biodiversity crisis, but also by the development of analytical approaches to the fossil record and of new geological techniques that have greatly increased our appreciation of global change. Our understanding of extinctions in the history of life is far better now than it was a few decades ago.

This publication arises from a symposium held at the University of California, Los Angeles and convened by the Center for the Study of Evolution and the Origin of Life (CSEOL). Our aim, both in the symposium and in this book, has been to make accessible – at undergraduate level – key findings and current debates concerning extinctions in the history of life. Chapter 1 introduces the topic and sets the scene for the five chapters that follow. The 'rules' of the extinction game played out during the Precambrian when most life was microbial are shown in Chapter 2 to have been different from those of later times. Continuing

the non-animal theme, Chapter 3 focuses on plants and asks whether they have suffered similar mass extinctions to those that have periodically wreaked havoc among animals. Chapter 4 takes a detailed look at a prolonged interval of geological time characterized by high levels of environmental stress and sustained extinction. The various processes implicated in mass extinctions are reviewed in Chapter 5. Finally, Chapter 6 rounds off the book by considering the evolutionary role of mass extinctions. A glossary of terms has been included to assist the reader.

Gratitude is owed to various people who helped with the symposium and/or the production of this volume: Richard Mantonya, Bill Schopf, Bill Clemmens, Nicole Fraser, Paul Kenrick and Patricia Taylor. Bonnie Dalzell generously allowed reproduction of her magnificent illustration (Figure 6.2) of a gigantic extinct bird.