Preface

For Everyone

For 36 years I taught a course called "History of Life" at the University of California, Davis. This book, now entering its fifth edition, was originally written for that course. But it is meant not just for students, but for everyone interested in the history of life on our planet. Fortunately, paleontology (=paleobiology), is accessible to the average person without deep scientific training. My aim is ambitious: I try to take you to the edges of our knowledge in paleontology, showing you how life has evolved on Earth, and how we have reconstructed the history of that evolution from the record of rocks and fossils.

However, there is a snag. Human history is never simple, even when we try to describe events that happened last year. It's even worse when we ask **why** events happened. It's not likely that any account of the history of life is going to be simple or easy either. The living world today contains all kinds of creatures that do unexpected things. There are frogs that fly and birds that can't. There are mammals that lay eggs, reptiles that have live birth, and amphibians that suckle their young. There are fishes that breathe air and mammals that never touch the land. We have to expect that there were complex and unusual ways of life in the past, and that evolution took some unexpected turns at times.

The challenge of teaching paleontology, and the challenge of writing a book like this, is to present a complex story in a way that is simple enough to grasp, yet true enough to real events that it paints a reasonable picture of what happened and why. I believe it can be done, and done so that you can learn enough to appreciate what's going on in current research projects.

Paleontologists can reconstruct how evolution happened and how the creatures of the past lived. We can't always prove it, any more than we can prove what really motivated George Washington. But we can state clearly what we know and don't know, we can suggest why certain events happened, and we can describe the evidence we used and the thoughts behind our suggestions. Then people can accept the ideas or not, as they wish.

Paleontologists have been collecting fossils, studying the rocks they came from, and assembling those data into a coherent framework, for over 200 years. At this point I think we are limited more by a lack of good ideas than by the facts available about the fossil record. I have not been shy about offering explanations of events as well as descriptions of them. Mostly they are other people's explanations, but now and again I've suggested some of my own. You can accept these or not, as you wish. The question you face is that facing a jury member: is this idea sound "beyond all reasonable doubt?" If you don't accept an explanation for an event, you can leave it as an abominable mystery, with no explanation at all, or you can suggest a better explanation yourself.

There is one caution, however. No one is allowed to dream up any old explanation for past events. A scientific suggestion (a hypothesis) has to fit the available evidence, and it has to fit with the laws of physics and chemistry, and with the principles of biology, ecology, and engineering that have been pieced together over the past 200 years of scientific investigation.

There's yet another wrinkle. A jury decides on a case, once and for all, with the evidence available. But in science, the jury is always out, and new evidence comes in all the time. You may have to change a verdict—without regret, because you made the best (wrong) decision you could based on the old evidence. Some of the ideas in the earlier editions are wrong, and you won't find them here; you'll find better ones. Sometimes the new answer is more complex, sometimes it is simpler. Always, however, the new idea fits the evidence better. That's the way science works: not on belief, not on emotional clinging to a favorite idea (even if it is your own), but on evidence.

I never expect to be able to write the final solution to the major questions about the history of life, but I do expect to be able to provide better answers this year than I could last year. If my lectures are the same this year as they were last year, then something is wrong with our science, or something is wrong with me. Paleontology is exciting because it is advancing so quickly.

Since paleontology is so fast-moving as a science, this book has changed too. I have radically re-written the sections on the origin of life, on extinctions, and on the origin and radiation of metazoan animals, of dinosaurs, of birds, and of humans. I have recognized more clearly that life evolved on an evolving planet, with changing chemistry, changing geography, and changing climate, and have tried to weave these threads into the tapestry as well. Every other section has been fine-tuned to reflect new research.

As I write, the full development of the Internet in publishing and educating and informing is in the early stages of a revolution. The Web site for this book, at http://mygeologypage.ucdavis.edu/cowen/HistoryofLife/ and at www.wiley.com/go/cowen/historyoflife allows me to add enriching material for which I could not find space in the printed page. It also allows me to connect you to other Internet sites for more illustrations, more detailed accounts of research projects, and snappy news articles. The Web site is meant to add real background and further details and perspectives for those who are interested. The essays and mini-essays are written in the same style as the book; the trivia are irresistible; and the Web links lead you to sites that are often richly illustrated in a way that no book can match.

I have written the book so that it stands alone without the Web site; but the Web pages are extensively linked back to the book. Over time, the Web page will also contain updates of material, new references, and new information.

To My Teaching Colleagues

The course for which this book was written serves three audiences at the same time: it is an introduction to paleontology; it is a "general education" course to introduce nonspecialists to science and scientific thought; and it can serve as an introduction to the history of life to biologists who know a lot about the present and little about the past. Therefore, the style and language of this book are aimed at accessibility. I do not use scientific jargon unless it is useful. I have tried to show how we reason out our conclusions—how we choose between bad ideas and good ones. I have not diluted the English language down to pidgin to make my points. In short, I have aimed this book at the intelligent nonspecialist.

I have not covered the fossil record evenly. I have tried to write compact essays on what I think are the most important events and processes that have molded the history of life. They illustrate the most important ways we go about reconstructing the life of the past. I've used case studies from vertebrates more than from other groups simply because those are the animals with which we are most familiar. Most fossils are marine invertebrates, and most paleontologists, including myself, are invertebrate specialists. I have tried to write briefly about invertebrates at an introductory level. They are not the easiest vehicles to use at this level, and that thought has controlled my choice of subject matter.

I'm pleased with the text of this book: I believe it communicates a lot about our science in the space available. But it's impossible to communicate paleontology well without a much greater visual component than can be included in a relatively inexpensive book format. So this book is better illustrated than previous editions, yet I use a lot more images in my classes than I can include in a book, in an attempt to bring fossil and living organisms into the classroom, and to give life to the words and names. The Web pages contain many sources for on-line illustrations that can be downloaded into your favorite presentation medium.

The references are a careful mixture of important books, primary literature, news reports, and review articles that bring the latest work into this edition as it went to press. I have deliberately skewed the lists to include items likely to be found in small college and city libraries.

If this book contained nothing controversial, it would be very dull and far from representing the state of paleontology as it stands today. I have tried to present arguments for and against particular ideas in case studies that are presented in some detail, such as major extinctions and major evolutionary innovations. Often, however, space or conviction has led me to present only one side of an argument. Please share your dissatisfaction and/or more complete knowledge with your students, and tell them why my treatment is one-sided or just plain wrong. That way everyone wins by exposure to the give and take of scientific argument as it ought to be practiced between colleagues.

To Students

Several thousand people like you have voted with their comments, questions, body language, and formal written evaluations on the content of my course. Students had more influence on the style and content of this book than anyone else. So you and your peers at the University of California, Davis, can take whatever credit is due for the style in which the material is presented.

After all the thanks, however, I do have another point to make. You don't have to take any of the interpretations in this book at face value. Facts are facts, but ideas are only suggestions. If you can come up with a better idea than one of those I've included here, then work on it, starting with the literature references. It would make a great term paper, and (more important) you might be right. The 1960s slogan "Question Authority!" is still valid. Your suggestion wouldn't be the first time that a student found a new and better idea for interpreting the fossil record.

Why do I, and why should you, bother with the past? If we don't understand the past, how can we deal intelligently with the present? We and our environment are reaching such a state of crisis that we need all the help we can get. Nature has run a series of experiments over the last 3.5 billion years on this planet, changing climate and geography, and introducing new kinds of organisms. If we can read the results of those experiments from the fossil record,

we can perhaps define the limits to which we can stretch our present biosphere before a biological disaster happens.

The real pay-off from paleontology for me is the fun involved in reconstructing extinct organisms and ancient communities, but if one needs a concrete reason for looking at the fossil record, the future of the human race is surely important enough for anyone.

This Book

I begin this book with the formation of Earth and the great unsolved problem of the origin of life. Then I describe an early Earth populated entirely by bacteria, so strange in its chemistry and ecology that it might well be another planet. Eventually, living things so alter their world that we begin to recognize environments and organisms that seem much more familiar. I describe the evolution of animals and begin to worry about their physical and ecological environment. By now, we are dealing with a world whose geography we can begin to reconstruct, which leads to chapters on plate tectonics and the climates of the past, and how they might have affected living things.

The vast record of invertebrates allows us to measure the diversity of life through time, which shows that there have been times of high diversity, and times of dramatic extinctions. I deal with extinction, mainly to look at the crises or "mass extinctions" that have occurred sporadically through time. Then I turn largely to the history of vertebrates, following some of the great anatomical, physiological, and ecological innovations by which fishes gradually evolved into the major classes of tetrapods on the land, including ourselves.

Some of my colleagues are dubious about evolutionary "progress," but I regard the evidence for it as overwhelming, and present many examples. I have not tried to write a simple historical catalog of fossils. Instead, I have tried to set interesting episodes in Earth history into a global picture. For example, the tragedy that overtook Mesozoic communities 65 million years ago has to be seen in terms of their success until that time, and the subsequent radiation of the mammals can only be appreciated against a background of changing planetary geography and climate. Finally, the rise to ecological dominance of humans has its counterpart in the massive changes in land faunas that accompanied it, all set in the context of the ice ages.

Further Reading

I have tried to list widely sold paperbacks and articles in journals such as *Nature*, *Science*, *Discover*, *Scientific American*, *National Geographic Magazine*, and *American Scientist*, perhaps the six most widely distributed journals that deal with all aspects of science. I also list books and articles in specialized journals: generally the writing is more detailed and more technical in such journals.

Important earlier work is often summarized in more recent articles I have selected. Always, however, you should be able to work quickly backward to older papers from the references in recent articles.

An increasing number of scientists publish in open-access journals that are available on the Web, and/or they place their publications in Web-accessible sites associated with their labs or their courses. I have tried to refer to these often.

For more references, references available freely on the Web, further reading, notes, extra stories and mini-essays by RC, sources for classroom images, and updates, see the Web site for this book: http://www.wiley.com/go/cowen/historyoflife, mirrored at http://mygeologypage.ucdavis.edu/cowen/HistoryofLife/

Thanks

I thank all those reviewers who have given careful and calm advice over the years. I hope they recognize their contribution, and I apologize for churlishly ignoring some of them. I owe a great deal to the people at Blackwell/Wiley who have encouraged and helped me over the years. For this edition, it has been a delight to work with Ian Francis, Kelvin Matthews, and Delia Sandford. None of these people should be blamed for deficiencies: please complain directly to me at rcowen@ucdavis.edu.

Finally, I thank once again my wife Jo for tolerating my neglect of our home and property while all this was in process.

Winters, California June 2012