

# DINOSAURS

THE TEXTBOOK



SPENCER G. LUCAS



# DINOSAURS

THE TEXTBOOK

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SPENCER G. LUCAS

NEW MEXICO MUSEUM OF NATURAL HISTORY  
UNIVERSITY OF NEW MEXICO



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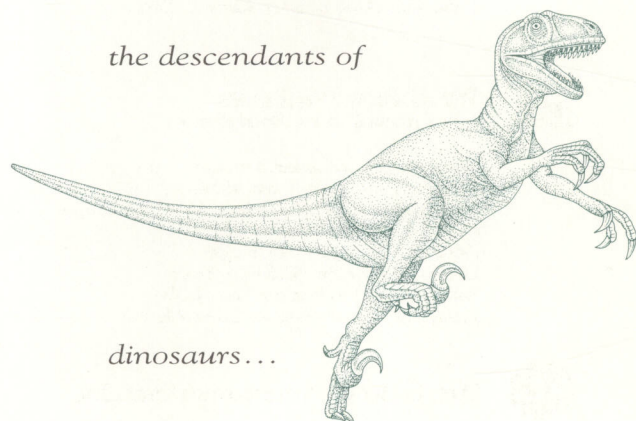
*Toons, Henry,*

*Dickens, and the City*

*Kitty, keen students of*

*the descendants of*

*dinosaurs...*







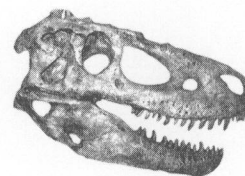
Dinosaurs have been a source of fascination for students of all ages since their discovery over 150 years ago. For a hundred years dinosaurs epitomized failure. But as we now know, it was simply a failure of science to recognize the group's successes. In the early years of discovery, interpretation of dinosaurs as animals was based on preconceived notions concerning reptiles. Reptiles were generally thought of as stupid, sluggish animals that had survived almost accidentally. Dinosaurs, thought of at the time as "good reptiles," were burdened with the same misconceived notions of science as were other reptiles. Reptiles drag their tails when they walk, so dinosaurs must also have dragged their tails. Reptiles are cold-blooded and sluggish in cool weather, so dinosaurs must also have been cold-blooded and sluggish. But, reptiles survived and the dinosaurs did not, so in the minds of many, dinosaurs were thought of as unfit animals that were simply waiting for a place in time to go extinct.

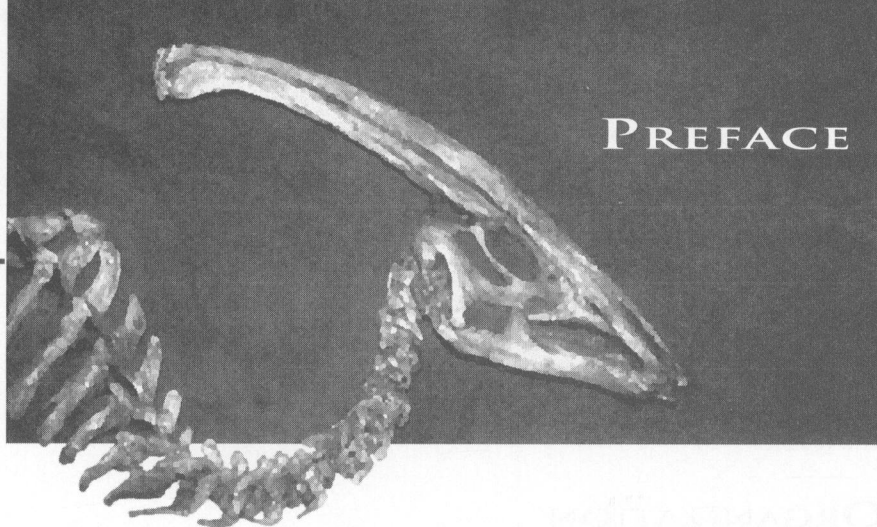
Fortunately, over the years many more dinosaur specimens were found, and together with some very careful studies of their morphology, phylogeny, and ecology, it has been determined that dinosaurs were a highly specialized group of animals related not only to other reptiles, but also to birds. And although the dinosaurs are extinct, we now know that they represented one of the greatest evolutionary success stories of all time. Dinosaurs: The textbook is a monument to our present understanding of these wonderful creatures. It is a book that will take the student on a journey through nearly every aspect of dinosaur biology, geology, and the history of their discovery. It is a text that presents facts together with current ideas, notions and controversies. Dr. Lucas presents dinosaurs as successful, living creatures that were merely different in appearance than animals living today.

Dr. Lucas has written a comprehensive book that is easily read and understood by students with little scientific background—a book that teaches students not only how to use scientific methods, but how to synthesize data to create their own ideas. In contrast with many dinosaur books from the past, Dr. Lucas, although indicating his own views, allows students the opportunity to think for themselves.

This is an incredible achievement for future learning about past mysteries.

John R. Horner  
Curator of Paleontology  
Museum of the Rockies  
Montana State University  
Bozeman, Montana





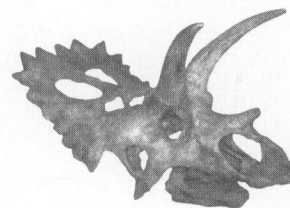
## PREFACE

Seven years ago the geology faculty at the University of New Mexico, at my suggestion, initiated an introductory level course on dinosaurs. As the lone vertebrate paleontologist on campus, I of course, was to teach this course. I had several years of teaching introductory geology—both physical and historical geology—under my belt. But now a problem faced me: no textbook existed for a dinosaur course. Furthermore, in a decade-long stint as a university student—from freshman to doctorate—I never took a course on dinosaurs. Few colleagues were teaching dinosaur courses at that time, and all they could offer was a syllabus with a suggested list of readings. Not fully satisfied with their offerings, I set out to design a course and provide reading material from available sources to suit my own prejudices about how to teach college freshmen and sophomores about dinosaurs.

Although the students were enthusiastic the first time I taught the course, I was not satisfied. I had tried to teach about dinosaurs within the broader context of vertebrate evolution and used Edwin Colbert's excellent survey book, *EVOLUTION OF THE VERTEBRATES*, as the text. But it seemed to me the course was too diffuse—not enough of a focus on dinosaurs—and the book lacked needed depth on the drawing card of the course, the dinosaurs themselves. So, I shifted gears and subsequently taught a course more focused on dinosaurs using Alan Charig's stimulating book, *A NEW LOOK AT THE DINOSAURS*. This worked better, but after a couple of years, I realized that Charig's book was neither broad enough nor sufficiently detailed to suit the course. Fortunately, David Norman's outstanding *THE ILLUSTRATED ENCYCLOPEDIA OF THE DINOSAURS* appeared. It is the one dinosaur book I hope to have if ever marooned on a desert island. Norman's book provided excellent coverage of dinosaur details and lore for the students. But, it did not meet head on the most interesting topics—dinosaur extinction, hot-blooded dinosaurs, and so forth—that had become the causes celebres of my course.

The book I have written is the semester-long course I teach as it has been honed down by years of experimentation and student feedback to a lean but comprehensive introduction to the dinosaurs. This book thus fulfills my selfish need for a textbook, but I also believe that it will meet the needs of the growing number of paleontologists teaching introductory-level dinosaur courses across the United States. My reviewers share this belief, and I hope we are right.

There is, however, a second reason why I wrote this book. It represents my attempt to slog through the available morass of information and ideas about dinosaurs, some controversial, others ridiculous, to stand on the firm ground of established facts and reasonable inference. Much of what Americans think they know about dinosaurs is wrong, and some of what they are being told today, in some popular books by "experts," is baloney. This book tries to right the wrongs and slices up





the baloney by going out of its way to not promote unreasonable speculation about dinosaurs. Not everything in it is above debate, but nothing here is science fiction. As such, I want this book to teach many people about dinosaurs and the science of studying dinosaurs as few other books do.

These are heady times for dinosaur science. Almost daily, new discoveries, novel methods, and innovative ideas are pushing forward the frontiers of our knowledge of dinosaurs. Americans seem to have an insatiable appetite for information on dinosaurs. This book provides a “first course,” and I hope it fosters an accurate understanding of the dinosaurs and a deep appreciation of dinosaur science in all who read it.

## ORGANIZATION

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The Table of Contents essentially divides the book into three parts. The first part, Chapters 1–5, is designed to provide the beginning student with the minimum background in geological, biological, and anatomical concepts necessary to understand the remainder of the text. In the second part, Chapters 6–10, I have you “meet the dinosaurs.” These chapters review each group of dinosaurs. Each chapter focuses on two or three well-known taxa that are exemplary of the group. The remaining discussion covers aspects of phylogeny, diversity, distribution, and functional morphology. The third part, Chapters 11–18, covers a variety of thought-provoking “topics.” These chapters discuss everything from the history of the great dinosaur hunters to the extinction of the dinosaurs. The emphasis in many of the chapters will be on concepts of broad applicability, in other words, concepts also relevant to subjects other than dinosaurs. Thus, for example, I believe that the history of dinosaur collecting and study can be used to tell the student much about how scientific perceptions change through time. Finally, I have included a Dinosaur Dictionary and a Glossary for ease in locating definitions and identifying information.

I have strived to present a balanced review of competing ideas in controversial areas. For example, I believe the weight of evidence suggests that some dinosaurs had a higher metabolic rate than that of living ectotherms, whereas there is no evidence of such a heightened metabolic rate in other dinosaur groups. I intend to present the range of evidence on this subject, not push a particular point of view not justified by the evidence.

## ACKNOWLEDGMENTS

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I wish to extend my thanks and appreciation to the reviewers whose thoughtful comments, criticisms, and encouragement have helped tremendously in revising and improving the final draft. They are: Bonnie Blackwell, Purdue University; Matthew J. James, Department of Geology, Sonoma State University; Norman R. King, University of Southern Indiana; John H. Ostrom, Yale University; John M. Rensberger, Department of Geological Sciences and Burke Museum, University of Washington; J. Keith Rigby, Jr., University of Notre Dame; André Wyss, Department of Geological Sciences, University of California–Santa Barbara; William J. Zinsmeister, Department of Earth & Atmospheric Sciences, Purdue University.

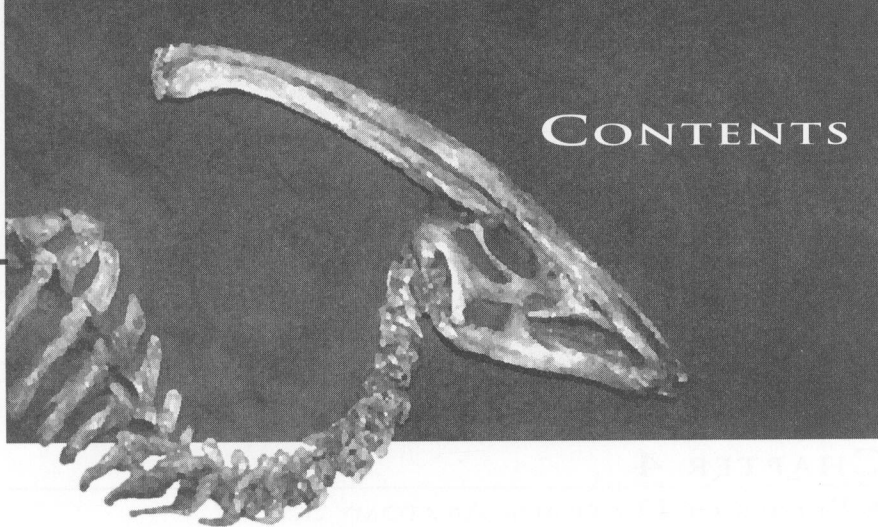
Several colleagues, museums, and other institutions provided photographs that add to the quality of instruction in this textbook. Their contributions are acknowledged, where appropriate, throughout the text.

Many people at Wm. C. Brown Publishers helped make this book possible. I owe a special thanks to Bob Fenchel for his wise and patient counsel and friendship. His thoughtful suggestions and writing schedule made it possible for my wife, Mimi, to set deadlines for my writing and hold me to them. She also listened patiently to my chatter and provided much needed emotional support. Four house cats taught me the fascination of birds and also "were there" when I needed them. Extra catnip is on order.

Over the years, I learned much about dinosaurs from my colleagues and students. Heavy hitters on my scorecard in this regard are John Ostrom, who long ago tried to convince me, without success, that dinosaurs are more interesting than mammals; Adrian Hunt, with whom I have dug and studied many dinosaurs; Barry Kues and Jeff Froehich, who first taught me vertebrate paleontology and still put up with me; Niall Mateer, who has kept me in touch with the Cretaceous; Bob Sullivan, who forced me to think hard about dinosaur extinction after I had ceased to care; Jack McIntosh, who taught me everything I know about sauropods; J. Keith Rigby, Jr., and Bob Sloan, who believe in Paleocene dinosaurs and know that I don't; Martin Lockley, who convinced me that dinosaur footprints really are important; and Zhen Shuonan, who opened up the world of Chinese dinosaurs to me. Each of the aforementioned have made invaluable comments and suggestions throughout the development of this project. To the rest of you who collect dinosaurs, do the research, give the talks and write the papers, thanks for teaching me so much. Finally, I thank the hundreds of undergraduate students at the University of New Mexico who have sat through my dinosaur course. You were the guinea pigs upon which I experimented. This is the book you asked for.

*Spencer G. Lucas*





*Foreword XV*

*Preface XVII*

## CHAPTER 1

### INTRODUCTION 1

WHAT ARE DINOSAURS? 1

WHEN AND WHERE DID DINOSAURS LIVE? 2

WHY STUDY DINOSAURS? 3

*Key Terms 5*

*Review Questions 5*

## CHAPTER 2

### EVOLUTION, PHYLOGENY, AND CLASSIFICATION 7

EVOLUTION 7

PHYLOGENY 8

CLASSIFICATION 13

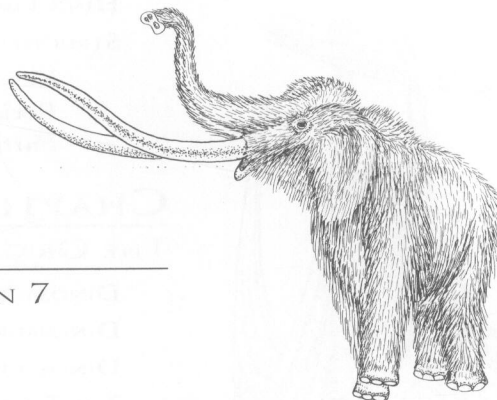
DINOSAURS AND EVOLUTION 15

*Summary 15*

*Key Terms 16*

*Review Questions 16*

*Further Reading 16*



## CHAPTER 3

### FOSSILS, SEDIMENTARY ENVIRONMENTS, AND GEOLOGIC TIME 17

FOSSILS 17

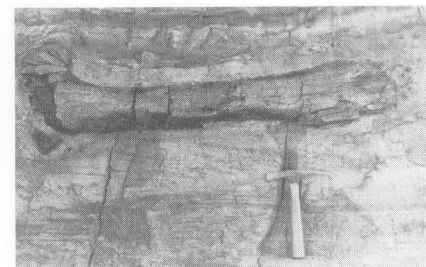
SEDIMENTARY ENVIRONMENTS 22

Fluvial Environments 23

Lacustrine Environments 23

Eolian Environments 25

Deltaic Environments 25



## GEOLOGIC TIME 26

The Triassic Period 28

The Jurassic Period 28

The Cretaceous Period 28

Numerical Ages 29

*Summary* 30

*Key Terms* 30

*Review Questions* 30

*Further Reading* 31

## CHAPTER 4

---

### A PRIMER OF DINOSAUR ANATOMY 33

POSTURE AND ORIENTATION 33

SKULL, LOWER JAW, AND TEETH 35

BACKBONE 36

FORELIMB 38

HIND LIMB 38

STRUCTURE AND FUNCTION 38

*Key Terms* 41

*Review Questions* 41

*Further Reading* 41

## CHAPTER 5

---

### THE ORIGIN OF DINOSAURS 43

DINOSAURS AS REPTILES 43

DINOSAURS AS DIAPSIDS 44

DINOSAURS AS ARCHOSAURS 46

THE THECODONT ANCESTRY OF DINOSAURS 47

PHYLOGENY OF DINOSAURS 49

THE OLDEST DINOSAURS 53

*Summary* 56

*Key Terms* 56

*Review Questions* 56

*Further Reading* 57

## CHAPTER 6

---

### PREDATORY DINOSAURS 59

THEROPOD FOSSILS AND PHYLOGENY 59

WHAT IS A THEROPOD? 61

CERATOSAURS 63

TETANURAE 64

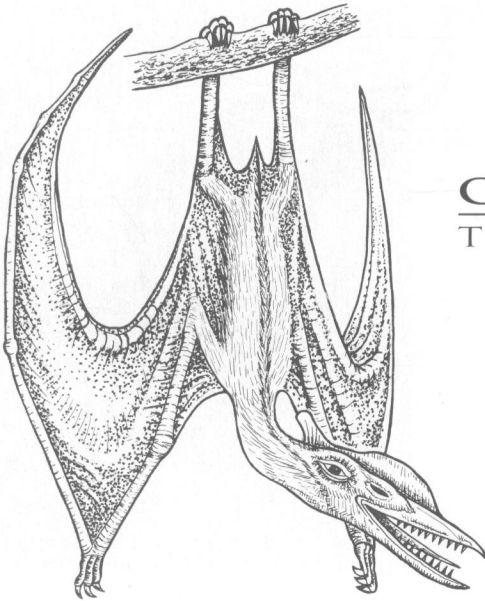
CARNOSAURS 64

Allosauridae 65

Tyrannosauridae 66

Other Carnosaurs 68

CARNOSAUR BEHAVIOR 69





COELUROSAURS 71

Ornithomimidae 71

Dromaeosauridae 72

Other Coelurosaurs 73

THEROPOD EVOLUTION 75

*Summary* 75

*Key Terms* 76

*Review Questions* 76

*Further Reading* 76

## CHAPTER 7

### SAUROPODOMORPHS 77

PROSAUROPODS 77

The Genus *Plateosaurus* 78

Prosauropod Lifestyles 79

The Genus *Mussaurus* 80

Prosauropod Evolution 80

SAUROPODS 81

Diplodocidae 82

Camarasauridae 85

Other Sauropods 86

How Large Was the Largest? 88

Sauropod Lifestyles 90

*Diet* 90

*Metabolism* 90

*Locomotion and Habitat Preferences* 92

*Reproduction* 93

*Social Behavior* 93

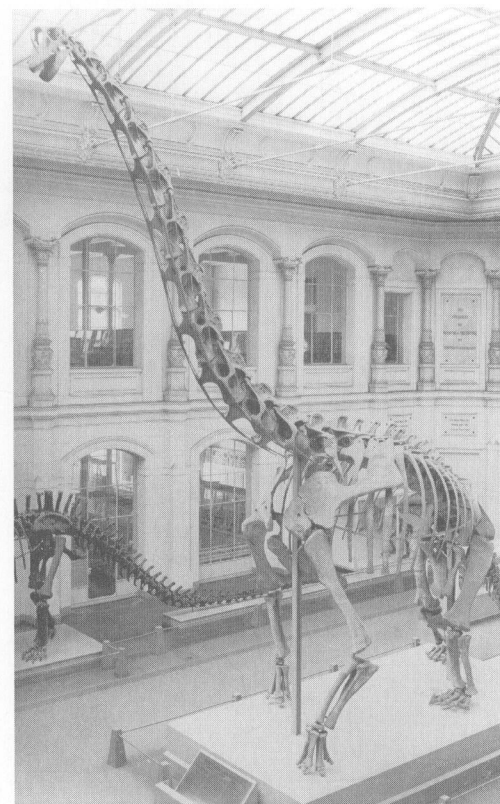
Sauropod Evolution 93

*Summary* 95

*Key Terms* 95

*Review Questions* 96

*Further Reading* 96



## CHAPTER 8

### ORNITHOPODS 97

HETERODONTOSAURIDAE 97

HYPSILOPHODONTIDAE 99

IGUANODONTIDAE 103

HADROSAURIDAE 104

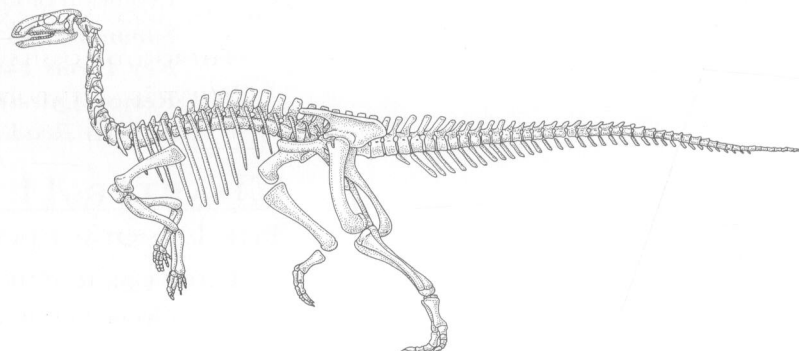
EVOLUTION OF THE ORNITHOPODS 109

*Summary* 110

*Key Terms* 110

*Review Questions* 110

*Further Reading* 111



## CHAPTER 9

### STEGOSAURS AND ANKYLOSAURS 113

#### PRIMITIVE THYREOPHORANS 113

#### STEGOSAURIA 115

The Genus *Huayangosaurus* 115

Stegosauridae 116

The Genus *Stegosaurus* 116

Function of the Plates of *Stegosaurus* 119

Stegosaur Lifestyles and Evolution 122

#### ANKYLOSAURIA 123

Nodosauridae 123

Ankylosauridae 124

Ankylosaurs: Mesozoic Tanks 126

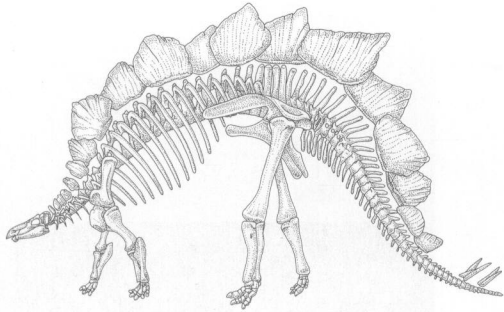
Ankylosaur Evolution 127

**Summary 128**

**Key Terms 128**

**Review Questions 128**

**Further Reading 129**



## CHAPTER 10

### CERATOPSAINS AND PACHYCEPHALOSAURS 131

#### CERATOPSIA 131

The Genus *Psittacosaurus* 132

Neoceratopsia 133

*Protoceratopsidae* 134

Lifestyle of Protoceratops 134

*Ceratopsidae* 135

The Genus *Triceratops* 137

Function of the Horns and Frill 138

Ceratopsian Evolution 140

#### PACHYCEPHALOSAURIA 140

Homalocephalidae 140

Pachycephalosauridae 141

Head Butting 143

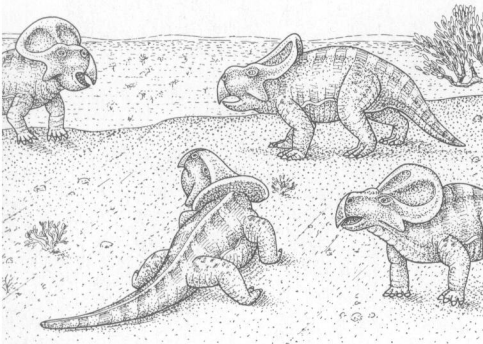
Evolution of Pachycephalosaurs 144

**Summary 146**

**Key Terms 146**

**Review Questions 146**

**Further Reading 147**



## CHAPTER 11

### THE DINOSAURIAN WORLD 149

#### LATE TRIASSIC: THE BEGINNING OF THE AGE OF DINOSAURS 149

Geography and Climate 149

Life in the Sea 150

Vegetation 151

Vertebrates 151

Dinosaurs 151

**EARLY-MIDDLE JURASSIC: THE DINOSAURS DOMINATE 152**

Geography and Climate 154

Life in the Sea 155

Vegetation 155

Dinosaurs and Other Vertebrates 156

**LATE JURASSIC: THE GOLDEN AGE OF DINOSAURS 156**

Geography and Climate 157

Life in the Sea; Vegetation 157

Dinosaurs and Other Vertebrates 157

**EARLY CRETACEOUS: A TRANSITION 158**

Geography and Climate 158

Life in the Sea 159

Vegetation 160

Dinosaurs and Other Vertebrates 160

**MIDDLE AND LATE CRETACEOUS: THE LAST DINOSAURS 161**

Geography and Climate 161

Life in the Sea 162

Vegetation 162

Dinosaurs and Other Vertebrates 162

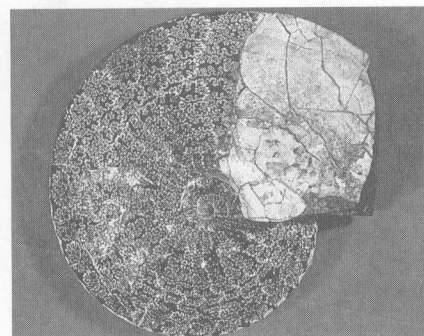
**FIVE DINOSAUR FAUNAS 164**

*Summary 164*

*Key Terms 164*

*Review Questions 165*

*Further Reading 165*



## **CHAPTER 12**

### **DINOSAUR HUNTERS 167**

**EARLIEST DISCOVERIES 167**

**COMPLETE SKELETONS 169**

**TWO GREAT EXPEDITIONS 175**

**THE CALM BEFORE THE STORM? 176**

**THE DINOSAUR RENNAISSANCE 177**

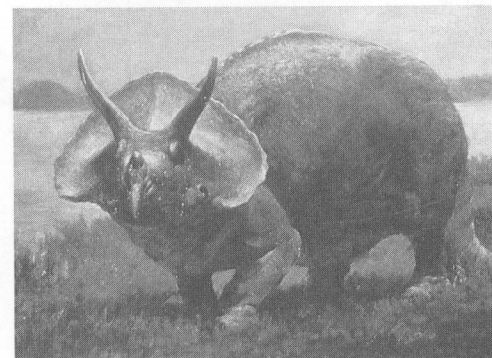
**CHANGING IDEAS IN DINOSAUR SCIENCE 179**

*Summary 180*

*Key Terms 181*

*Review Questions 181*

*Further Reading 181*



## **CHAPTER 13**

### **DINOSAUR TRACE FOSSILS 183**

**DINOSAUR FOOTPRINTS 184**

Understanding Dinosaur Footprints 184

Interpreting Dinosaur Footprints 187

Speed Estimates from Dinosaur Footprints 187

Footprint Myths 189

**DINOSAUR EGGS 191**

**DINOSAUR GASTROLITHS 194**

**DINOSAUR COPROLITES 194**



*Summary* 196  
*Key Terms* 196  
*Review Questions* 196  
*Further Reading* 197

## CHAPTER 14

### DINOSAUR BIOLOGY AND BEHAVIOR 199

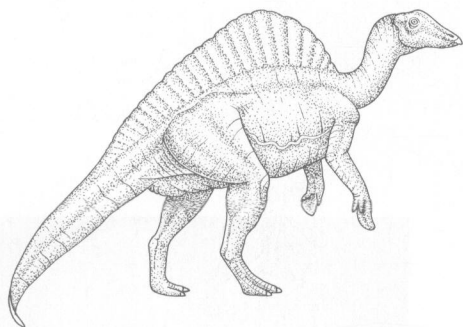
#### DINOSAUR BIOLOGY 199

External Appearance 199  
Weight 201  
Growth and Longevity 202

#### DINOSAUR BEHAVIOR 204

Feeding and Locomotion 205  
Reproduction and Parenting 206  
Attack and Defense 207  
Group Behavior 210

*Summary* 213  
*Key Terms* 213  
*Review Questions* 213  
*Further Reading* 214



## CHAPTER 15

### HOT-BLOODED DINOSAURS? 215

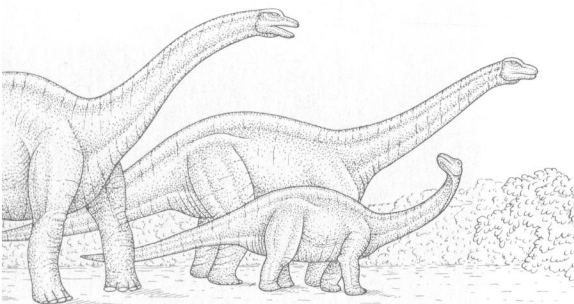
#### SOME TERMS AND CONCEPTS 215

#### THE INFORMATION 216

Posture and Gait 217  
Speed, Levels of Activity and Agility 218  
Feeding Adaptations 220  
Bone Microstructure 221  
Blood Pressure 221  
Geographic Distribution 224  
Bird Ancestry 226  
Social Behavior 226  
Predator-Prey Ratios 226  
Body Size 228

#### WHAT TYPE OF METABOLISM(S) DID DINOSAURS HAVE? 229

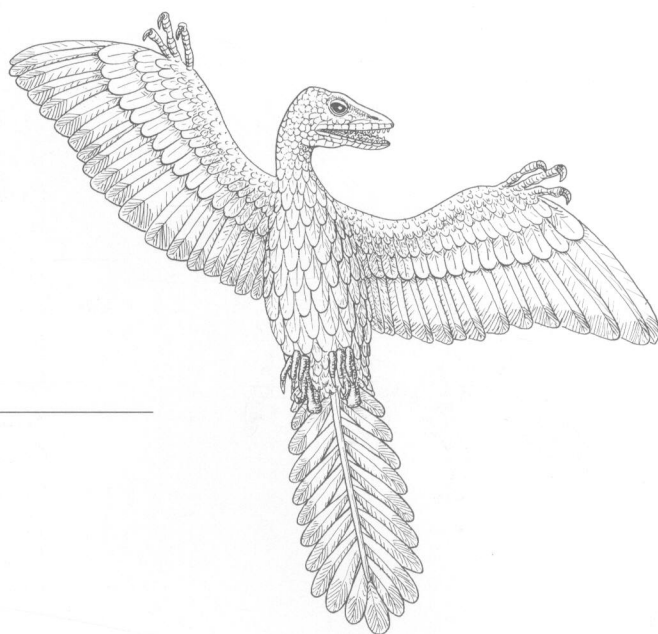
*Summary* 231  
*Key Terms* 231  
*Review Questions* 231  
*Further Reading* 232



## CHAPTER 16

### THE ORIGIN OF BIRDS 233

- WHAT IS A BIRD? 233
- THE FIRST BIRD: *ARCHAEOPTERYX* 235
- OTHER POSSIBLE ANCESTORS OF BIRDS 239
- ORIGIN AND EVOLUTION OF AVIAN FLIGHT 240
- EVOLUTION OF BIRDS 241
- SIGNIFICANCE OF DINOSAURS AS BIRD ANCESTORS 243
  - Summary* 244
  - Key Terms* 245
  - Review Questions* 246
  - Further Reading* 246



## CHAPTER 17

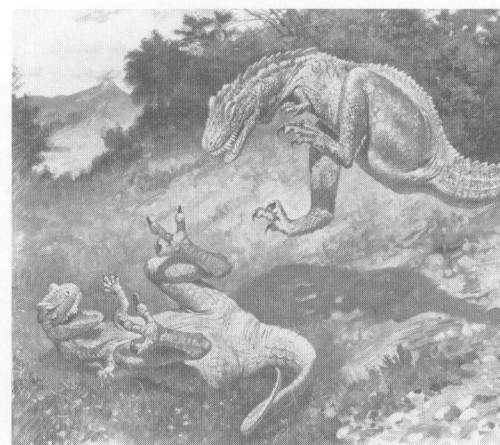
### DINOSAUR EXTINCTION 247

- THE TERMINAL CRETACEOUS EXTINCTION 247
- NATURE OF THE EVIDENCE 250
- BOLIDE IMPACT 255
- GRADUAL EXTINCTION 257
- MINIMIZING THE DAMAGE 258
- ANSWER THE QUESTION! 260
  - Summary* 261
  - Key Terms* 261
  - Review Questions* 261
  - Further Reading* 262

## CHAPTER 18

### DINOSAURS IN THE PUBLIC EYE 263

- DINOSAURS: DENOTATION AND CONNOTATION 263
- DINOSAURS IN THE NEWS 264
- DINOSAUR BOOKS 265
- DINOSAUR ART 268
- DINOSAUR TOYS 270
- DINOSAUR CARTOONS AND MOVIES 270
- DINOSAUR SCIENCE AND PUBLIC DINOSAURS 273
  - Summary* 275
  - Key Terms* 275
  - Review Questions* 275
  - Further Reading* 276



### A DINOSAUR DICTIONARY 277

### GLOSSARY 281

### CREDITS 285

### INDEX 287

# INTRODUCTION

In 1842, British comparative anatomist **Richard Owen** (1804–1892) coined the word **dinosaur**, from the Greek words *deinos*, meaning “terrible” and *sauros*, meaning “lizard” or “reptile.” To Owen, the “terrible lizards” were large, extinct reptiles known from only a handful of fossils discovered in western Europe since the 1820s. Today, dinosaur fossils are known from all the continents and represent hundreds of distinct types of dinosaurs.

In this chapter, we briefly answer some very basic questions about dinosaurs and introduce some topics discussed at greater length later in this book.

## WHAT ARE DINOSAURS?

Many people apply the term dinosaur to any large, extinct animal. To most people, any large extinct reptile qualifies as a dinosaur. Many people even identify large, extinct mammals, such as woolly mammoths, as dinosaurs (figure 1.1). Some authors and toy manufacturers perpetuate inaccurate ideas about what is a dinosaur by presenting to the public a variety of non-dinosaurs as dinosaurs. The mammal-like reptile *Dimetrodon* and the flying reptile *Pteranodon* are examples.

Dinosaurs are most easily thought of as a group of extinct reptiles having an **upright posture**. They first appeared about 225 million years ago and became extinct 66 million years ago. Birds, the descendants of dinosaurs, are still with us. Dinosaurs can be identified as reptiles because of their reptilian skeletal features and because dinosaurs, like many other reptiles, reproduced by laying hard-shelled eggs. Dinosaur’s upright posture, in which the legs extend directly underneath the body, distinguishes them from reptiles that hold their limbs out to their sides in a **sprawling posture** (figure 1.2). Largeness is not a prerequisite for being a dinosaur; some dinosaurs were no larger than a chicken. In fact, skeletal features of one group of dinosaurs are remarkably like those of modern birds, which indicates that dinosaurs were the ancestors of birds. Other skeletal features unique to dinosaurs will be discussed in Chapter 5. But for now, we can define dinosaurs as reptiles having an upright posture, and thereby identify them as a natural group with an evolutionary history distinct from that of other reptiles.

## OUTLINE

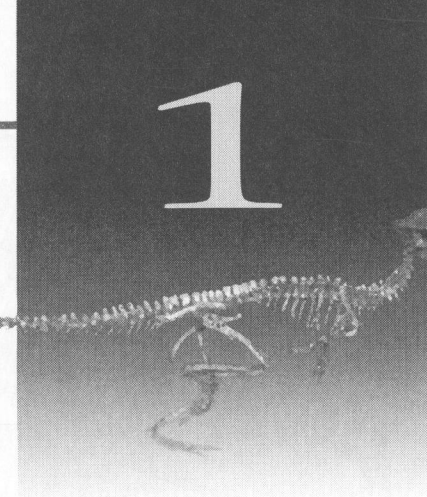
WHAT ARE DINOSAURS? 1

WHEN AND WHERE DID DINOSAURS LIVE? 2

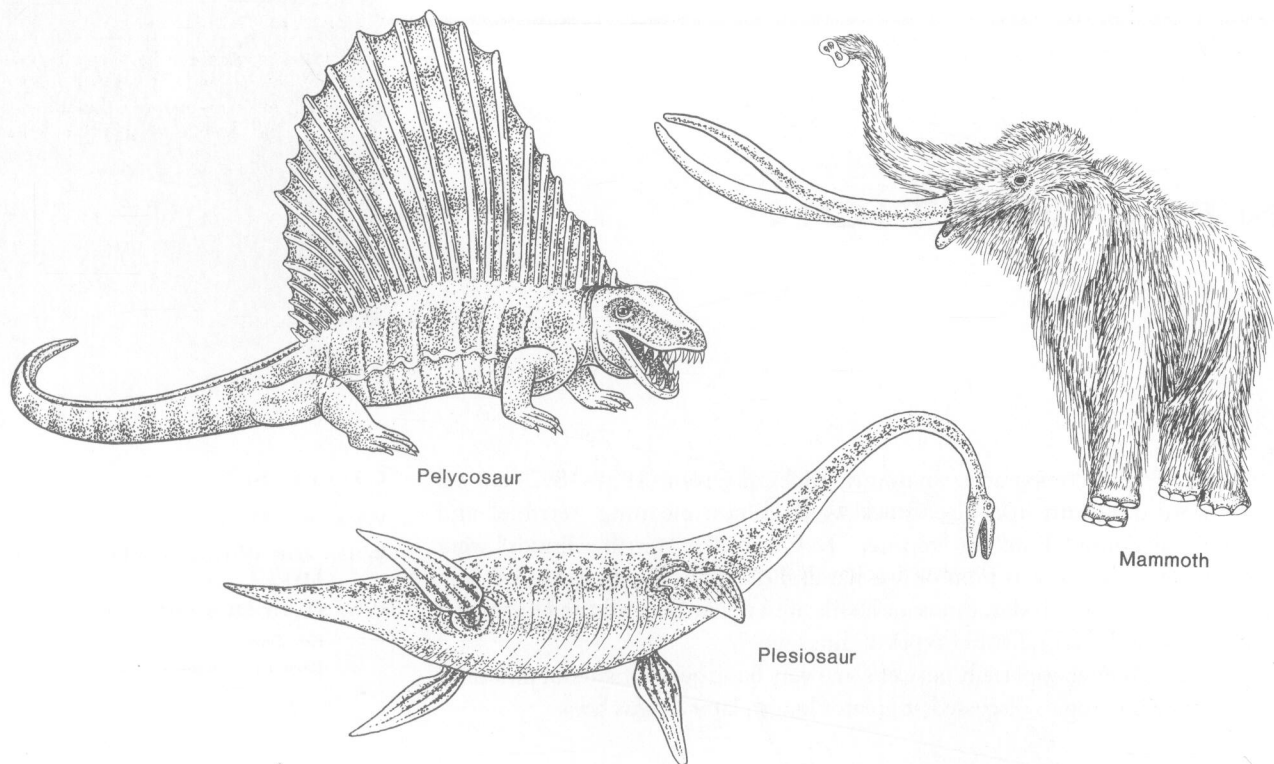
WHY STUDY DINOSAURS? 3

Key Terms 5

Review Questions 5







**FIGURE 1.1**

Although these kinds of animals are thought by many people to be dinosaurs, they are not.

## WHEN AND WHERE DID DINOSAURS LIVE?

We have already noted that dinosaurs first appeared about 225 million years ago and became extinct 66 million years ago, which means that dinosaurs lived on Earth for about 160 million years (figure 1.3). Most paleontologists date the origin of humans at 2 or 3 million years before the present. This means that dinosaurs persisted 50 to 80 times as long as we have been on Earth. Movies and cartoons that portray humans and dinosaurs living side by side are, therefore, inaccurate.

The first discovery of dinosaur remains in Antarctica was in 1989, so that we now have dinosaur fossils from all the continents (figure 1.4). The broad geographic distribution, survival for about 160 million years, variety in shapes and sizes, and, in many instances, extremely large size identify dinosaurs as one of the most successful groups of land animals in the history of life.