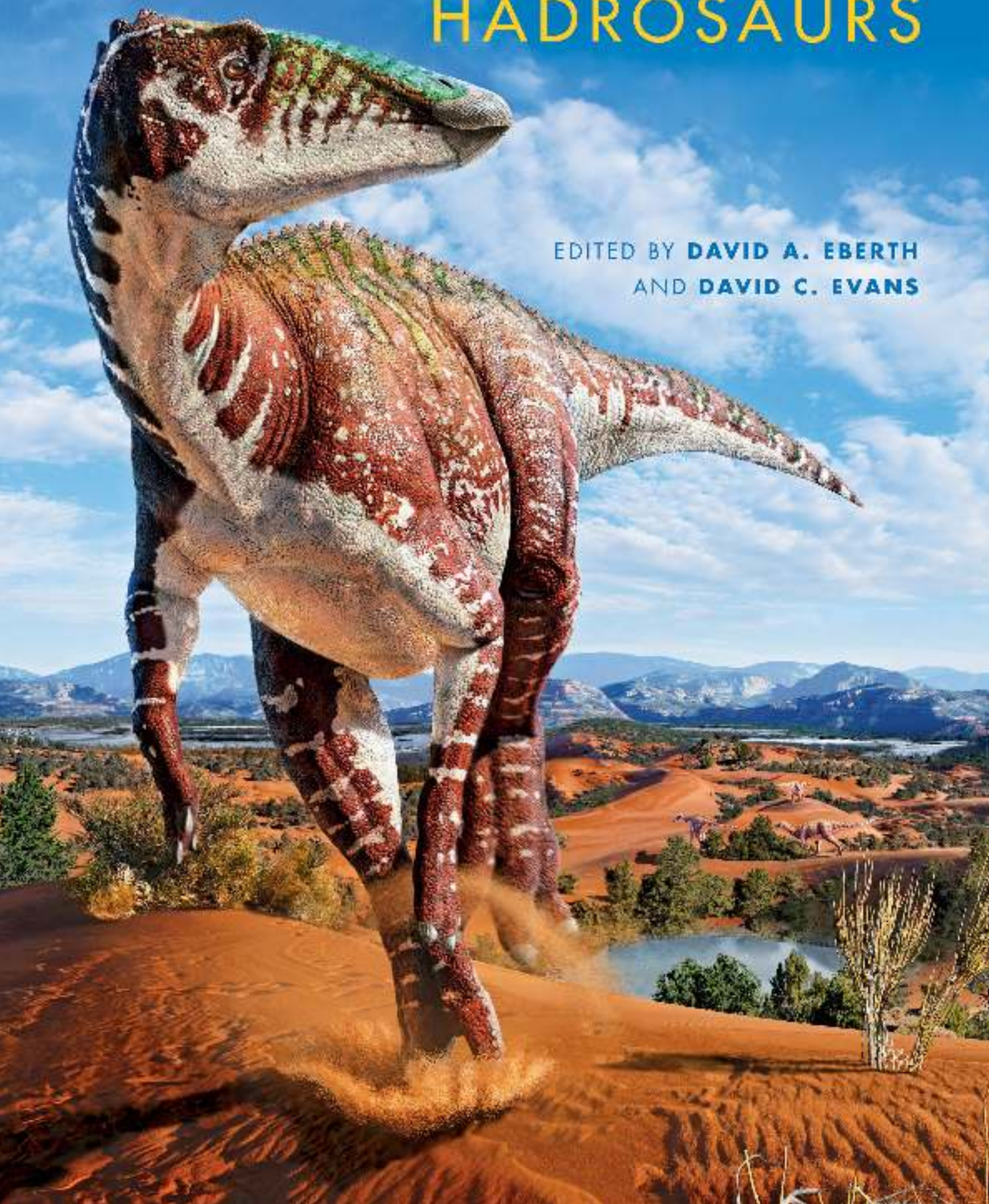


HADROSAURS

EDITED BY **DAVID A. EBERTH**
AND **DAVID C. EVANS**

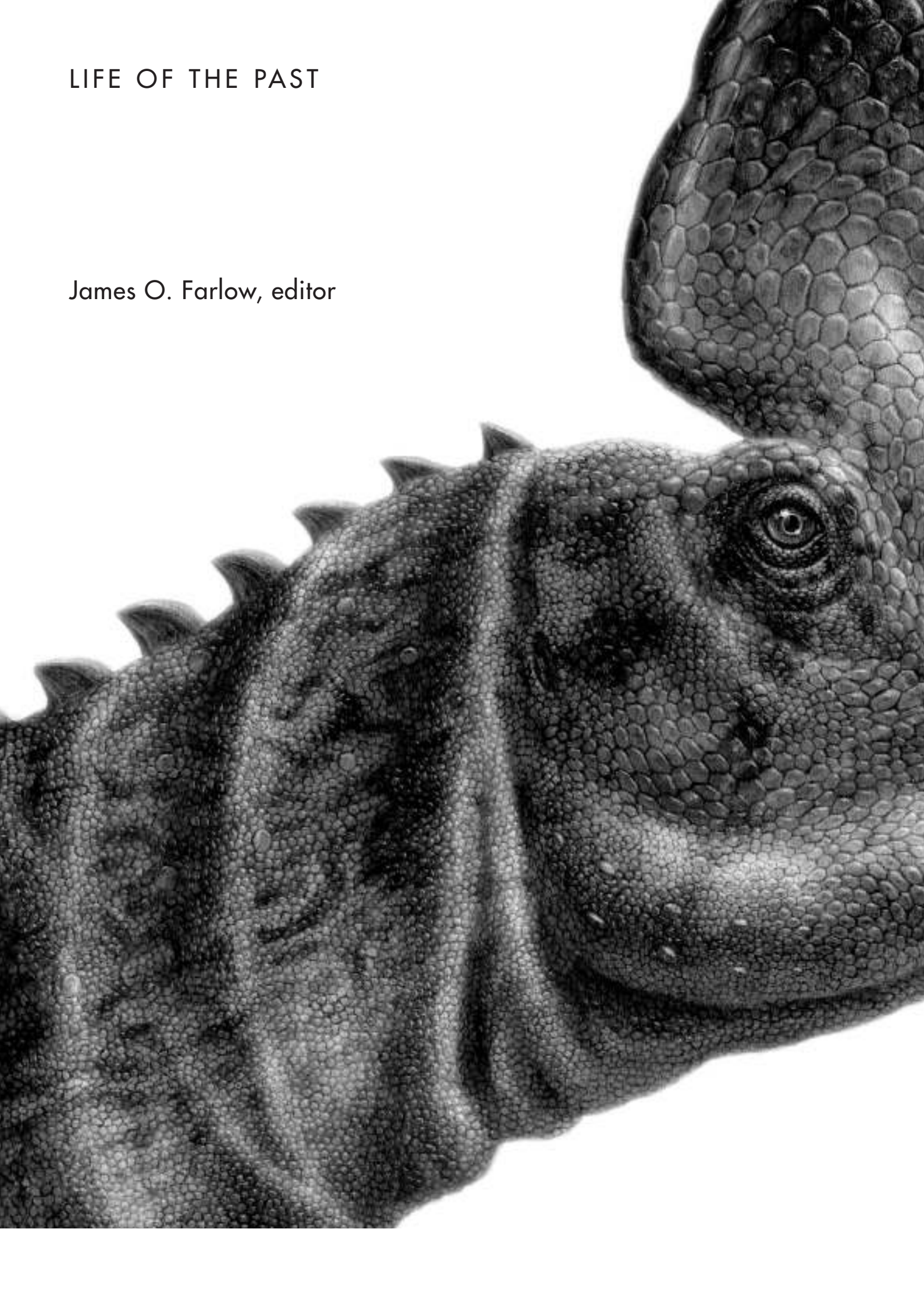


Hadrosaurs



LIFE OF THE PAST

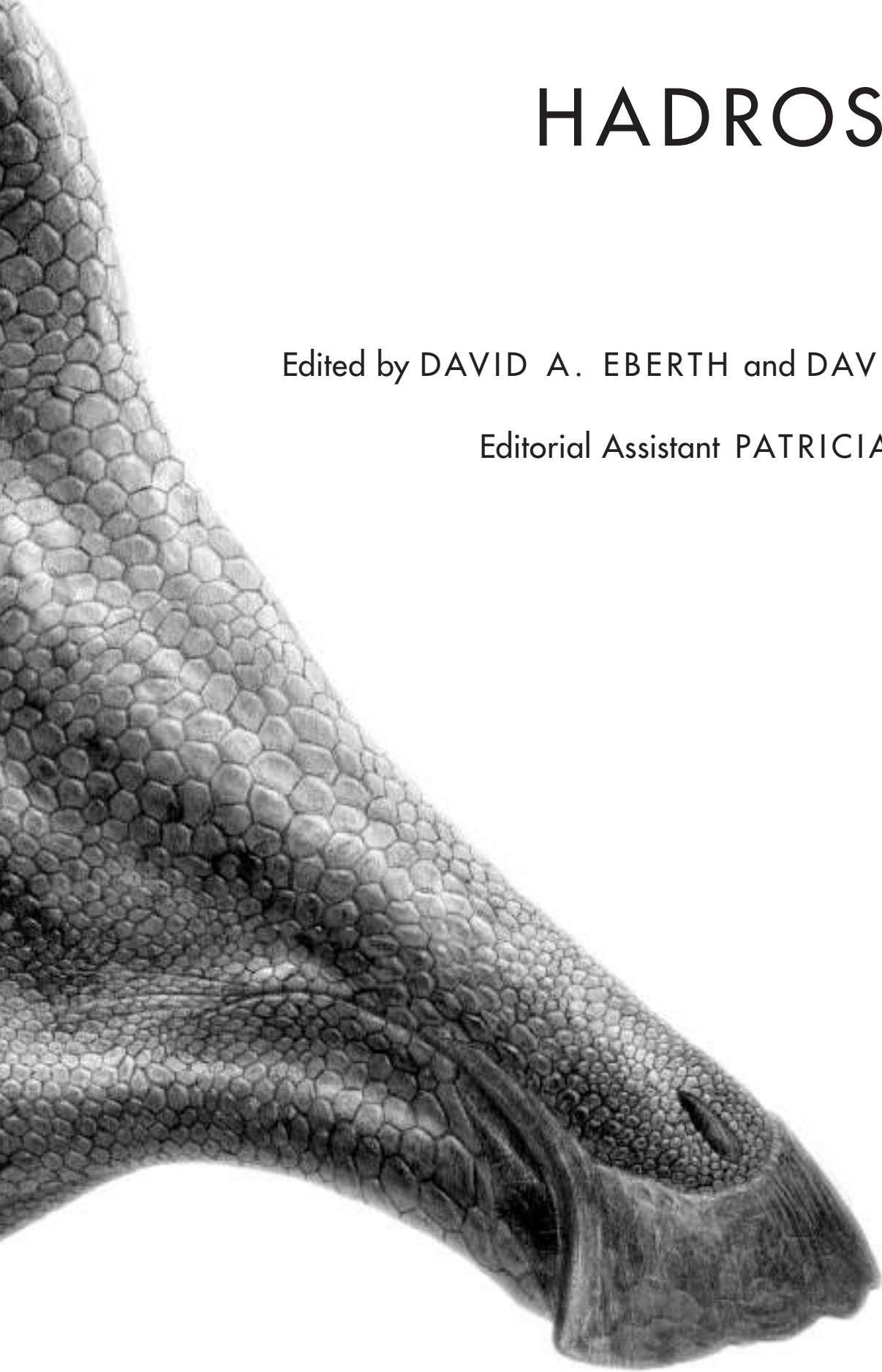
James O. Farlow, editor



HADROSAURS

Edited by DAVID A. EBERTH and DAVID C. EVANS

Editorial Assistant PATRICIA E. RALRICK



INDIANA UNIVERSITY PRESS

Bloomington & Indianapolis

This book is a publication of

Indiana University Press
Office of Scholarly Publishing
Herman B Wells Library 350
1320 East 10th Street
Bloomington, Indiana 47405 USA

iupress.indiana.edu

Telephone 800-842-6796
Fax 812-855-7931

© 2015 by Indiana University Press

All rights reserved

No part of this book may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and recording, or by any information storage and retrieval system, without permission in writing from the publisher. The Association of American University Presses' Resolution on Permissions constitutes the only exception to this prohibition.

∞ The paper used in this publication meets the minimum requirements of the American National Standard for Information Sciences—Permanence of Paper for Printed Library Materials, ANSI Z39.48–1992.

Manufactured in the United States of America

Library of Congress Cataloging-in-Publication Data

Hadrosaurs / edited by David A. Eberth and David C. Evans.

pages cm.—(Life of the past)
Includes bibliographical references and index.
ISBN 978-0-253-01385-9 (cloth : alk.
paper)—ISBN 978-0-253-01390-3 (ebook)

1. Hadrosauridae. 2. Hadrosauridae—Anatomy.
3. Hadrosauridae—Geographical distribution.
4. Dinosaurs. I. Eberth, David A. II. Evans, David C.
(David Christopher), [date]
QE862.O65H33 2014
567.914—dc23

2014011885

1 2 3 4 5 20 19 18 17 16 15

To David Weishampel and all those, from J. Leidy onward, who have contributed to our knowledge of hadrosaurs.

In particular, we recognize the efforts of Derek J. Main, a tireless promoter of Earth Science education and research. We value his contribution to this volume and mourn his all-too-soon passing.

Those animals of other days will give joy and pleasure to generations yet unborn.

Charles H. Sternberg

ix	Contributors		
xi	Reviewers		
xiii	Preface · David A. Eberth and David C. Evans		
xv	Acknowledgments		
	Part 1. Overview		
	A History of the Study of Ornithopods: Where Have We Been? Where Are We Now? and Where Are We Going?		
1	David B. Weishampel		
2			
	Part 2. New Insights into Hadrosaur Origins		
	Iguanodonts from the Wealden of England: Do They Contribute to the Discussion Concerning Hadrosaur Origins?		
10	David B. Norman		
	Osteology of the Basal Hadrosauroid <i>Equijubus normani</i> (Dinosauria, Ornithopoda) from the Early Cretaceous of China		
3	Andrew T. McDonald, Susannah C. R. Maidment, Paul M. Barrett, Hai-lu You, and Peter Dodson		
44			
	<i>Gongpoquansaurus mazongshanensis</i> (Lü, 1997) comb. nov. (Ornithischia: Hadrosauroidea) from the Early Cretaceous of Gansu Province, Northwestern China		
4	Hai-lu You, Da-Qing Li, and Peter Dodson		
73			
	Postcranial Anatomy of a Basal Hadrosauroid (Dinosauria: Ornithopoda) from the Cretaceous (Cenomanian) Woodbine Formation of North Texas		
5	Derek J. Main, Christopher R. Noto, and David B. Weishampel		
77			
	A Re-evaluation of Purported Hadrosaurid Dinosaur Specimens from the “Middle” Cretaceous of England		
6	Paul M. Barrett, David C. Evans, and Jason J. Head		
96			
	A New Hadrosauroid (<i>Plesiohadros djadokhtaensis</i>) from the Late Cretaceous Djadokhtan Fauna of Southern Mongolia		
7	Khishigjav Tsogtbaatar, David B. Weishampel, David C. Evans, and Mahito Watabe		
108			
	Hadrosauroid Material from the Santonian Milk River Formation of Southern Alberta, Canada		
8	Derek W. Larson, Nicolás E. Campione, Caleb M. Brown, David C. Evans, and Michael J. Ryan		
136			
	Part 3. Hadrosaurid Anatomy and Variation		
	New Hadrosaurid (Dinosauria, Ornithopoda) Specimens from the Lower–Middle Campanian Wahweap Formation of Southern Utah		
9	Terry A. Gates, Zubair Jinnah, Carolyn Levitt, and Michael A. Getty		
156			
	New Saurolophine Material from the Upper Campanian–Lower Maastrichtian Wapiti Formation, West-Central Alberta		
10	Phil R. Bell, Robin Sissons, Michael E. Burns, Federico Fanti, and Philip J. Currie		
174			
	Variation in the Skull Roof of the Hadrosaur <i>Gryposaurus</i> Illustrated by a New Specimen from the Kaiparowits Formation (late Campanian) of Southern Utah		
11	Andrew A. Farke and Lucia Herrero		
191			
	A Skull of <i>Prosaurolophus maximus</i> from Southeastern Alberta and the Spatiotemporal Distribution of Faunal Zones in the Dinosaur Park Formation		
12	David C. Evans, Christopher T. McGarrity, and Michael J. Ryan		
200			
	Postcranial Anatomy of <i>Edmontosaurus regalis</i> (Hadrosauridae) from the Horseshoe Canyon Formation, Alberta, Canada		
13	Nicolás E. Campione		
208			
	Cranial Morphology and Variation in <i>Hypacrosaurus stebingeri</i> (Ornithischia: Hadrosauridae)		
14	Kirstin S. Brink, Darla K. Zelenitsky, David C. Evans, John R. Horner, and François Therrien		
245			
	Part 4. Biogeography and Biostratigraphy		
	An Overview of the Latest Cretaceous Hadrosauroid Record in Europe		
15	Fabio M. Dalla Vecchia		
268			
	The Hadrosauroid Record in the Maastrichtian of the Eastern Tremp Syncline (Northern Spain)		
16	Fabio M. Dalla Vecchia, Rodrigo Gaete, Violeta Riera, Oriol Oms, Albert Prieto-Márquez, Bernat Vila, Albert Garcia Sellés, and Àngel Galobart		
298			
	Hadrosaurids from the Far East: Historical Perspective and New <i>Amurosaurus</i> Material from Blagoveschensk (Amur Region, Russia)		
17	Yuri L. Bolotsky, Pascal Godefroit, Ivan Y. Bolotsky, and Andrey Atuchin		
315			
	South American Hadrosaurids: Considerations on Their Diversity		
18	Rodolfo A. Coria		
332			
	The Hadrosaurian Record from Mexico		
19	Angel A. Ramírez-Velasco, René Hernández-Rivera, and Ricardo Servin-Pichardo		
340			
	Stratigraphic Distribution of Hadrosaurids in the Upper Cretaceous Fruitland, Kirtland, and Ojo Alamo Formations, San Juan Basin, New Mexico		
20	Robert M. Sullivan and Spencer G. Lucas		
361			
	Relocating the Lost <i>Gryposaurus incurvimanus</i> Holotype Quarry, Dinosaur Provincial Park, Alberta, Canada		
21	Darren H. Tanke and David C. Evans		
385			

Part 5. Function and Growth	
22	Comparative Ontogenies (Appendicular Skeleton) for Three Hadrosaurids and a Basal Iguanodontian: Divergent Developmental Pathways in Hadrosaurinae and Lambeosaurinae
398	Merrilee F. Guenther
23	The Size-Frequency Distribution of Hadrosaurs from the Dinosaur Park Formation of Alberta, Canada
416	Donald B. Brinkman
24	Osteohistology and Occlusal Morphology of <i>Hypacrosaurus stebingeri</i> Teeth throughout Ontogeny with Comments on Wear-Induced Form and Function
422	Gregory M. Erickson and Darla K. Zelenitsky
25	Three-Dimensional Computational Modeling of Pelvic Locomotor Muscle Moment Arms in <i>Edmontosaurus</i> (Dinosauria, Hadrosauridae) and Comparisons with Other Archosaurs
433	Susannah C. R. Maidment, Karl T. Bates, and Paul M. Barrett
26	Duckbills on the Run: The Cursorial Abilities of Hadrosaurs and Implications for Tyrannosaur-Avoidance Strategies
449	W. Scott Persons IV and Philip J. Currie
27	Duck Soup: The Floating Fates of Hadrosaurs and Ceratopsians at Dinosaur Provincial Park
459	Donald M. Henderson
28	Hadrosauroid Jaw Mechanics and the Functional Significance of the Predeontary Bone
467	Ali Nabavizadeh
Part 6. Preservation, Tracks, and Traces	
29	Debris Flow Origin of an Unusual Late Cretaceous Hadrosaur Bonebed in the Two Medicine Formation of Western Montana
486	James G. Schmitt, Frankie D. Jackson, and Rebecca R. Hanna
30	Occurrence and Taphonomy of the First Documented Hadrosaurid Bonebed from the Dinosaur Park Formation (Belly River Group, Campanian) at Dinosaur Provincial Park, Alberta, Canada
502	David A. Eberth, David C. Evans, and David W. H. Lloyd
31	Body Size Distribution in a Death Assemblage of a Colossal Hadrosaurid from the Upper Cretaceous of Zhucheng, Shandong Province, China
524	David W. E. Hone, Corwin Sullivan, Qi Zhao, Kebai Wang, and Xing Xu
32	First Hadrosaur Trackway from the Upper Cretaceous (Late Campanian) Oldman Formation, Southeastern Alberta
532	François Therrien, Darla K. Zelenitsky, Kohei Tanaka, and Wendy J. Sloboda
33	Paleopathology in Late Cretaceous Hadrosauridae from Alberta, Canada
540	Darren H. Tanke and Bruce M. Rothschild
34	A Review of Hadrosaurid Skin Impressions
572	Phil R. Bell
35	Soft-Tissue Structures of the Nasal Vestibular Region of Saurolophine Hadrosaurids (Dinosauria, Ornithopoda) Revealed in a “Mummified” Specimen of <i>Edmontosaurus annectens</i>
591	Albert Prieto-Márquez and Jonathan R. Wagner
36	The Role and Biochemistry of Melanin Pigment in the Exceptional Preservation of Hadrosaur Skin
600	Phillip L. Manning, Roy A. Wogelius, Bart Van Dongen, Tyler R. Lyson, Uwe Bergmann, Sam Webb, Michael Buckley, Victoria M. Egerton, and William I. Sellers
611	Afterword · John R. Horner
613	Subject Index
615	Locality Index (by country)
616	Stratigraphy Index (by country)
617	Taxonomic Index

Andrey Atuchin, Palaeontological Laboratory of the Institute of Geology and Nature Management, Far East Branch, Russian Academy of Sciences, per. Relochny 1, 675000 Blagoveschensk, Russia

Karl T. Bates, Department of Musculoskeletal Biology II, Institute of Aging and Chronic Disease, University of Liverpool, Sherrington Buildings, Ashton Street, Liverpool, U.K. L69 3GE

Paul M. Barrett, Department of Earth Sciences, Natural History Museum, Cromwell Road, London, U.K. SW7 5BD

Phil R. Bell, School of Environmental and Rural Science, University of New England, Armidale 2351, NSW, Australia

Uwe Bergmann, Stanford Synchrotron Radiation Lightsource, Stanford University, Menlo Park, California 94305

Ivan Y. Bolotsky, Research Center for Paleontology and Stratigraphy, Jilin University, Changchun 130061, China

Yuri L. Bolotsky, Palaeontological Laboratory of the Institute of Geology and Nature Management, Far East Branch, Russian Academy of Sciences, per. Relochny 1, 675000 Blagoveschensk, Russia

Kirstin S. Brink, Department of Ecology and Evolutionary Biology, University of Toronto Mississauga, 3359 Mississauga Road N., Mississauga, Ontario L5L 1C6

Donald B. Brinkman, Royal Tyrrell Museum of Palaeontology, Box 7500, Drumheller, Alberta T0J 0Y0

Caleb M. Brown, Royal Tyrrell Museum of Paleontology, Box 7500, Drumheller, Alberta T0J 0Y0

Michael Buckley, Faculty of Life Sciences, University of Manchester, Manchester, U.K. M13 9PL

Michael E. Burns, Department of Biological Sciences, University of Alberta, Edmonton, Alberta T6G 2E9

Nicolás E. Campione, Departments of Earth Science and Organismal Biology, Uppsala University, Box 256, 751 05 Uppsala, Sweden

Rodolfo A. Coria, CONICET–University of Rio Negro–Museo Carmen Funes, Av. Córdoba 55 (8318) Plaza Huincul, Neuquén, Argentina

Philip J. Currie, Department of Biological Sciences, Zoo. 413, Biological Sciences Building, University of Alberta, Edmonton, Alberta T6G 2E9

Fabio M. Dalla Vecchia, Grup de Recerca del Mesozoic, Institut Català de Paleontologia Miquel Crusafont (ICP), Escola Industrial 23, E-08201 Sabadell, Spain

Peter Dodson, School of Veterinary Medicine, University of Pennsylvania, 3800 Spruce Street, Philadelphia, Pennsylvania 19104-6045

David A. Eberth, Royal Tyrrell Museum of Palaeontology, Box 7500, Drumheller, Alberta T0J 0Y0

Victoria M. Egerton, School of Earth, Atmospheric and Environmental Sciences, University of Manchester, Manchester, U.K. M13 9PL

Gregory M. Erickson, Department of Biological Science, Florida State University, Tallahassee, Florida, 32306-4295

David C. Evans, Department of Natural History, Royal Ontario Museum, 100 Queen's Park, Toronto, Ontario M5S 2C6

Federico Fanti, Dipartimento di Scienze della Terra e Geologico-Ambientali, Università di Bologna, Italy

Andrew A. Farke, Raymond M. Alf Museum of Paleontology, 1175 West Baseline Road, Claremont, California 91711

Rodrigo Gaete, Museu de la Conca Dellà, Carrer del Museu 4, Isona, E-25650, Spain

Àngel Galobart, Grup de Recerca del Mesozoic, Institut Català de Paleontologia Miquel Crusafont (ICP), Escola Industrial 23, E-08201 Sabadell, Spain

Albert Garcia Sellés, Grup de Recerca del Mesozoic, Institut Català de Paleontologia Miquel Crusafont (ICP), Escola Industrial 23, E-08201 Sabadell, Spain

Terry A. Gates, Department of Biological Sciences, North Carolina State University, Raleigh, NC 27695; North Carolina Museum of Natural Sciences, Raleigh, NC 27601

Michael A. Getty, Denver Museum of Nature and Science, 2001 Colorado Boulevard, Denver, Colorado 80205-5732

Pascal Godefroit, Department of Palaeontology, Royal Belgian Institute of Natural Sciences, rue Vautier 29, 1000 Brussels, Belgium

Merrilee F. Guenther, Department of Biology, Elmhurst College, Elmhurst, Illinois 60126

Rebecca R. Hanna, Museum of the Rockies, Montana State University, Bozeman, Montana 59717

Jason J. Head, Department of Earth and Atmospheric Sciences, University of Nebraska–Lincoln, 228 Bessey Hall, Lincoln, Nebraska 68588

Donald M. Henderson, Royal Tyrrell Museum of Palaeontology, Box 7500, Drumheller, Alberta T0J 0Y0

René Hernández-Rivera, Instituto de Geología, Universidad Nacional Autónoma de México, Circuito de Investigación Científica, Ciudad Universitaria, Delegación Coyoacán, 04510 México

Lucia Herrero, The Webb Schools, 1175 West Baseline Road, Claremont, California 91711; Stanford University, 450 Serra Mall, Stanford, California 94305

David W. E. Hone, School of Biological and Chemical Sciences, Queen Mary University of London, Mile End Road, London, U.K. E1 4NS

John R. Horner, Museum of the Rockies, Montana State University, Bozeman, Montana 59717-0040

Frankie D. Jackson, Department of Earth Sciences, Montana State University, Bozeman, Montana 59717

Zubair Jinnah, School of Geosciences, University of the Witwatersrand, Johannesburg, Wits 2050, South Africa

Derek W. Larson, Department of Ecology and Evolutionary Biology, University of Toronto, Toronto, Ontario M5S 2C6

Carolyn Levitt, University of Utah, Department of Geology and Geophysics, Salt Lake City, Utah 84112

Da-Qing Li, Gansu Geological Museum, 6 Tuanjie Road, Chengguan District, Lanzhou, Gansu Province, 730010, China

David W. H. Lloyd, Royal Tyrrell Museum of Palaeontology, Box 7500, Drumheller, Alberta T0J 0Y0

Spencer G. Lucas, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

Tyler R. Lyson, Smithsonian Institution, National Museum of Natural History, Washington, D.C. 20560

Susannah C. R. Maidment, Department of Palaeontology, The Natural History Museum, Cromwell Road, London, U.K. SW7 5BD

Derek J. Main (deceased), Department of Earth and Environmental Sciences, University of Texas at Arlington, Arlington, Texas 76019

Phillip L. Manning, School of Earth, Atmospheric and Environmental Sciences, University of Manchester, Manchester, U.K. M13 9PL

Andrew T. McDonald, Department of Earth and Environmental Science, University of Pennsylvania, 254-b Hayden Hall, 240 South 33rd Street, Philadelphia, Pennsylvania 19104

Christopher T. McGarrity, Department of Ecology and Evolutionary Biology, University of Toronto, 25 Willcocks Street, Toronto, Ontario M5S 3B2

Ali Nabavizadeh, Center for Functional Anatomy and Evolution, Johns Hopkins University School of Medicine, Baltimore, Maryland 21287

David B. Norman, Sedgwick Museum and Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge, U.K. CB2 3EQ

Christopher R. Noto, Department of Biological Sciences, University of Wisconsin–Parkside, Kenosha, Wisconsin 53144

Oriol Oms, Universitat Autònoma de Barcelona, Departament de Geologia, Cerdanyola del Vallés, Barcelona, E-08193, Spain

W. Scott Persons IV, Department of Biological Sciences, Zoo. 418, Biological Sciences Building, University of Alberta, Edmonton, Alberta T6G 2E9

Albert Prieto-Márquez, School of Earth Sciences, University of Bristol, Wills Memorial Building, Queens Road, Bristol, U.K. BS8 1RJ

Angel A. Ramírez-Velasco, Posgrado Facultad de Medicina Veterinaria y Zootecnia, Universidad Nacional Autónoma de México, Circuito de Investigación Científica, Ciudad Universitaria, Delegación Coyoacán, 04510 México

Violeta Riera, Universitat Autònoma de Barcelona, Departament de Geologia, Cerdanyola del Vallés, Barcelona, E-08193, Spain

Bruce M. Rothschild, Department of Vertebrate Paleontology, Carnegie Museum of Natural History, 4400 Forbes Ave. Pittsburgh, Pennsylvania 15213

Michael J. Ryan, Department of Vertebrate Paleontology, Cleveland Museum of Natural History, 1 Wade Oval Drive, University Circle, Cleveland, Ohio 44106

James G. Schmitt, Department of Earth Sciences, Montana State University, Bozeman, Montana 59717

William I. Sellers, Faculty of Life Sciences, University of Manchester, Manchester, U.K. M13 9PL

Ricardo Servin-Pichardo, Facultad de Ciencias, Universidad Nacional Autónoma de México, Circuito de Investigación Científica, Ciudad Universitaria, Delegación Coyoacán, 04510 México

Robin Sissons, Philip J. Currie Dinosaur Museum, Pipestone Creek Dinosaur Initiative, County of Grande Prairie No. 1, 10001 84 Ave., Clairmont, Alberta T0H 0W0

Wendy J. Sloboda, Warner, Alberta T0K 2L0

Corwin Sullivan, Key Laboratory of Vertebrate Evolution and Human Origin, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, PO Box 643, Beijing 100044, China

Robert M. Sullivan, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

Kohei Tanaka, Department of Geoscience, University of Calgary, 2500 University Dr NW, Calgary, Alberta T2N 1N4

Darren H. Tanke, Royal Tyrrell Museum of Palaeontology, Box 7500, Drumheller, Alberta T0J 0Y0

François Therrien, Royal Tyrrell Museum of Palaeontology, Box 7500, Drumheller, Alberta T0J 0Y0

Khishigjav Tsogtbaatar, Mongolian Paleontological Center, Ulaanbaatar 210351, Mongolia

Bart Van Dongen, Williamson Research Centre for Molecular Environmental Science, University of Manchester, Manchester, U.K. M13 9PL

Bernat Vila, Grupo Aragosaurus-Instituto Universitario de Ciencias Ambientales, Paleontología, Facultad de Ciencias, Universidad de Zaragoza, Pedro Cerbuna 12, E-50009 Zaragoza, Spain

Jonathan R. Wagner, Texas State University–San Marcos, Department of Geography ELA 139, 601 University Drive, San Marcos, Texas 78666-4684

Kebai Wang, Key Laboratory of Vertebrate Evolution and Human Origin, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, PO Box 643, Beijing 100044, China

Mahito Watabe, Hayashibara Museum of Natural Science, 2-3. Shimoishii-1, Okayama 700-0907, Japan

Sam Webb, Stanford Synchrotron Radiation Lightsource, Stanford University, Menlo Park, California 94305

David B. Weishampel, Center for Functional Anatomy and Evolution, Johns Hopkins University School of Medicine, Baltimore, Maryland 21287

Roy A. Wogelius, Williamson Research Centre for Molecular Environmental Science, University of Manchester, Manchester, U.K. M13 9PL

Xing Xu, Key Laboratory of Vertebrate Evolution and Human Origin, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, PO Box 643, Beijing 100044, China

Hai-lu You, Key Laboratory of Evolutionary Systematics of Vertebrates, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, 142 Xizhimenwai Street, Beijing 100044, China

Darla K. Zelenitsky, Department of Geoscience, University of Calgary, 2500 University Dr NW, Calgary, Alberta T2N 1N4

Qi Zhao, Key Laboratory of Vertebrate Evolution and Human Origins, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, PO Box 643, Beijing 100044, China

Paul M. Barrett, Department of Earth Sciences, Natural History Museum, Cromwell Road, London, U.K. SW7 5BD

Kirstin S. Brink, Department of Ecology and Evolutionary Biology, University of Toronto Mississauga, 3359 Mississauga Road N., Mississauga, Ontario L5L 1C6

Brooks B. Britt, Department of Geology, Brigham Young University, S-387 ESC, PO Box 24606, Provo, Utah 84602

Caleb M. Brown, Royal Tyrrell Museum of Palaeontology, Box 7500, Drumheller, Alberta T0J 0Y0

Nicolás E. Campione, Departments of Earth Sciences and Organismal Biology, Uppsala University, Box 256, 751 05 Uppsala, Sweden

Katherine Clayton, Paleontology Collections, Natural History Museum of Utah, 301 Wakara Way, Salt Lake City, Utah 84108

Penelope Cruzado-Caballero, Universidad de Zaragoza, Departamento de Ciencias de la Tierra, c/ Pedro Cerbuna, 12 c.p. 50009 Zaragoza, Spain

David Dilkes, Department of Biology and Microbiology, University of Wisconsin Oshkosh, 800 Algona Boulevard, Oshkosh, Wisconsin 54901

Peter Dodson, School of Veterinary Medicine, University of Pennsylvania, 3800 Spruce Street, Philadelphia, Pennsylvania 19104-6045

David A. Eberth, Royal Tyrrell Museum of Palaeontology, Box 7500, Drumheller, Alberta T0J 0Y0

David C. Evans, Department of Natural History, Royal Ontario Museum, 100 Queen's Park, Toronto, Ontario M5S 2C6

Andrew A. Farke, Raymond M. Alf Museum of Paleontology, 1175 West Baseline Road, Claremont, California 91711

Denver Fowler, Museum of the Rockies, Paleontology Department, 600 West Kagy Boulevard, Bozeman, Montana 59717

Roland Gangloff, University of California Museum of Paleontology, 1101 Valley Life Sciences Building, Berkeley, California 94720-4780

James Gardner, Royal Tyrrell Museum of Palaeontology, Box 7500, Drumheller, Alberta T0J 0Y0

Terry A. Gates, Department of Biological Sciences, North Carolina State University, Raleigh, NC 27695; North Carolina Museum of Natural Sciences, Raleigh, NC 27601

Pascal Godefroit, Department of Palaeontology, Royal Belgian Institute of Natural Sciences, rue Vautier 29, 1000 Brussels, Belgium

Merrilee F. Guenther, Department of Biology, Elmhurst College, Elmhurst, Illinois 60126

Jason J. Head, Department of Earth and Atmospheric Sciences, University of Nebraska-Lincoln, 228 Bessey Hall, Lincoln, Nebraska 68588

Donald M. Henderson, Royal Tyrrell Museum of Palaeontology, Box 7500, Drumheller, Alberta T0J 0Y0

Casey Holliday, Department of Pathology and Anatomical Sciences, University of Missouri, M318 Medical Sciences Building, Columbia, Missouri 65212

James Kirkland, Utah Geological Survey, PO Box 146100, Salt Lake City, Utah 84114

Derek W. Larson, Department of Ecology and Evolutionary Biology, University of Toronto, Toronto, Ontario M5S 2C6

Jordan Mallon, Canadian Museum of Nature, Palaeobiology Department, PO Box 3443 Stn. "D," Ottawa, Ontario K1P 6P4

Richard McCrea, Peace Region Palaeontology Research Centre, 255 Murray Drive, Box 1540, Tumbler Ridge, British Columbia V0C 2W0

Andrew T. McDonald, Department of Earth and Environmental Science, University of Pennsylvania, 254-b Hayden Hall, 240 South 33rd Street, Philadelphia, Pennsylvania 19104

David B. Norman, Sedgwick Museum and Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge, U.K. CB2 3EQ

Albert Prieto-Márquez, School of Earth Sciences, University of Bristol, Wills Memorial Building, Queens Road, Bristol, U.K. BS8 1RJ

Patricia E. Ralrick, Royal Tyrrell Museum of Palaeontology, Box 7500, Drumheller, Alberta, T0J 0Y0

Raymond R. Rogers, Geology Department, Macalester College, 1600 Grand Avenue, Saint Paul, Minnesota 55105

Eric Snively, Department of Biology, University of Wisconsin-La Crosse, 1725 State Street, La Crosse, Wisconsin 54601

David Spalding, 1105 Ogden Road, Pender Island, British Columbia V0N 2M1

Daisuke Suzuki, Sapporo Medical University, South 1 West 17, Chuo-ku, Sapporo 060-8556 Japan

François Therrien, Royal Tyrrell Museum of Palaeontology, Box 7500, Drumheller, Alberta T0J 0Y0

Khishigjav Tsogtbaatar, Mongolian Paleontological Center, Ulaanbaatar 210351, Mongolia

David B. Weishampel, Center for Functional Anatomy and Evolution, Johns Hopkins University School of Medicine, Baltimore, Maryland 21287

Lawrence Witmer, Department of Biomedical Sciences, College of Osteopathic Medicine, Ohio University, Life Sciences Building, Room 123, Athens, Ohio 45701

Holly Woodward, Oklahoma State University Center for Health Sciences, 1111 West 17th Street, Tulsa, Oklahoma 74107

Hai-lu You, Key Laboratory of Evolutionary Systematics of Vertebrates, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, 142 Xizhimenwai Street, Beijing 100044, China



HADROSAURIDS (ALSO KNOWN AS DUCK-BILLED DINOZSAURIDS) are one of the best-known groups within Dinosauria due to their relatively recent fossil record, notable diversity, and near global distribution in the Late Cretaceous. Their success was likely driven by a combination of factors that included, most importantly, anatomical, unique and functionally complex innovations that permitted plants were efficiently than those of any “reptile” before or since. Ultimately, the richness of hadrosaur in the Cretaceous fossil record has allowed us to learn more about dinosauran paleobiology and paleoecology than we have from any other group.

In recent years, a number of dinosaur groups have been the subject of renewed scientific interest. In 2007, sauropod studies experienced a similar renaissance with the seminal monograph *The Sauropods: Evolution and Paleobiology* and Indiana University Press’ *Theodor G. Theodor Sauropodomorph Dinosaur*. In 2010, after a decade-long surge of interest, a themed dinosaur group received similar treatment in Indiana University Press’ *New Perspectives on Hadrosaur Dinosaur*. During the last five years it has been the hadrosaur’s time in the spotlight. Due to the rapidly growing fossil record as well as widespread international collaborations, researchers from around the world are now studying new specimens and taxa of hadrosaur to clarify their origins, patterns of evolution, function, paleobiology, paleoecology, and preservation.

It was with this perspective that we (David and I) conceived the “International Hadrosaur Symposium” (September 22–23, 2011). A collaboration between the Royal Tyrrell Museum and the Royal Ontario Museum, the goal of the U.S. was to bring together an international slate of scientists and enthusiasts to share their research on and passion for duck-billed dinosaur. Hosting the event at the Royal Tyrrell Museum made perfect sense. In one of the few places in the world can boast the abundance and quality of hadrosaur fossils as an iconic “classic Upper Cretaceous non-marine strata of southern Alberta, and the Tyrrell’s collections.

Fifty-plus presenters, international hadrosaur specialists and up-and-coming students rounded out two days of hadrosaur acrophilia in paleontology in Peter Daxson for

skilfully ripping off his terminology. In 1948 was also an opportunity for all of us to honor the contributions of David Weishampel (David 4).

Setting the international tone were our five keynote presenters: Rodolfo Coria (Argentina), Pascal Godefroit (Belgium), Jack Horner (U.S.A.), Khishigjav Tsochbaatar (Mongolia), and our international guest, David Weishampel (U.S.A.). The watershed nature of the meeting was recognized by all attendees and, unfortunately, we managed to overcome logistical obstacles such as an impending strike by Air Canada employees, which resulted in last-minute re-routing of flights and late appearances by some attendees. Be it shown that we truly appreciate the effort everyone made to attend the symposium.

This volume comprises a part of the content from the symposium, and more. Because we believe this volume and its contents to be a uniquely comprehensive introduction of hadrosaur, we chose simply to call it *Hadrosaur*. The scope of the volume encompasses not only the well-known hadrosaurids proper, but also Hadrosauridae, which allows the former group to be evaluated in a broader perspective.

The volume’s 28 chapters are organized into the following six parts, all edited by me and written by Jack Horner:

Overview includes only one chapter, written by David Weishampel. David has spent a large part of his career studying dinosauran paleobiology and, arguably, his most significant contribution to science is in paleontology. He has conducted pioneering work on hadrosaurian parental care, feeding, locomotion, functional morphology of the jaw structure, and phylogeny. In this chapter he uses data from the second edition of *The Dinosaurian* to discuss the paleontological research on ornithomorphs over the past two centuries, and uses his wisdom to advise where researchers may be focusing in the future.

New Insights Into Hadrosaur Origins includes six chapters that document new and historical materials that shed light on the evolution and diversity of hadrosauridae before the origins of true hadrosauridae. David Norman (David 4) reviews the data and the implications for the origin of Hadrosauridae, and presents some provocative ideas about the evolution of ornithomorph leading up to hadrosauridae. A

standout chapter by Tsogtbataar et al. describes an exciting new taxon from the Djadokhta Formation of Mongolia, important for understanding the origin of hadrosaurids (it is rendered beautifully on the cover of the book by Julius Csotonyi). McDonald et al., You et al., and Barrett et al. provide new information about known specimens, and help sort out some long-standing questions about these specimens. Similarly, Main et al. and Larson et al. remind us of the importance of the North American hadrosauroid record for understanding the origins of Hadrosauridae.

Hadrosaurid Anatomy and Variation includes contributions by Gates, Bell, Farke and Herrero, Evans, Campione, Brink, and colleagues, and focuses on the anatomy of a variety of hadrosaurid taxa from western North America. Gates, Bell, Farke and Herrero, and colleagues describe new specimens from stratigraphic units that are rapidly proving to be important sources of new information about hadrosaur diversity and distributions, whereas the contributions by Evans, Campione, Brink, and colleagues provide in-depth descriptions and interpretations of known taxa and specimens. The morphological details provided here will lead undoubtedly to improved comparative studies.

Biogeography and Biostratigraphy documents the distribution of hadrosaurids in time and space. Here, chapters by Ramírez-Velasco et al. and Dalla Vecchia and colleagues stand out as exceptionally detailed overviews of hadrosaur occurrences in Mexico and Europe, respectively. Similarly, contributions by Bolotsky et al., Coria, and Sullivan and Lucas go a long way to help improve our understanding of hadrosaurian diversity in eastern Asia, South America, and the Southwestern U.S.A. The contribution by Tanke and Evans underscores the importance of properly documenting locality data for specimens.

Function and Growth includes seven contributions that address function, growth, and life habits. Studies of hadrosaur morphology, locomotion, and function by Maidment et al., Persons and Currie, and Henderson employ evolving techniques in computer modeling and engineering that we hope will spark discussion and renewed interest in this topic. Nabavizadeh revisits the all-important question of jaw kinetics via predeontary morphology, and Guenther's com-

parison of postcrania is a step toward identifying different developmental pathways in hadrosaurs. Erickson and Zelenitsky describe ontogenetic changes in tooth morphology/histology in *Hypacrosaurus stebingeri* that reflect dietary changes during development. Lastly, Brinkman's size-distribution data are the basis of conclusions that challenge conventional wisdom related to growth rates in hadrosaurs.

Preservation, Tracks, and Traces is the last part of the volume and includes eight chapters, including contributions by Manning et al., Prieto-Márquez and Wagner, and Bell on skin and skin traces. Of particular note is the chapter on the origins of the classic *Maiasaura* bonebed by Schmitt et al., which many of us have awaited for years (no pressure anymore, Jim!). Contributions by Eberth et al. and Hone et al. present more evidence that some hadrosaurs lived in large, segregated herds, perhaps rivaling in size those of centrosaurian ceratopsians. Back in Alberta, Therrien et al. provide the first evidence of hadrosaur tracks from the Oldman Formation of Alberta, and Tanke and Rothschild provide an exhaustive survey of paleo-osteopathologies in hadrosaurs from Dinosaur Provincial Park.

Nomenclature note—Unlike most forms of science, taxonomy can be quite democratic. Over the last two decades, numerous clade names and definitions have been proposed for the hadrosaurian part of the ornithomimid family tree. Rather than imposing a particular taxonomic scheme on the book's contributors, we chose to allow contributors to employ their preferred taxonomy. Not surprisingly, the book reveals little consensus. In particular, readers may find differential use of the terms Hadrosauridae, Hadrosaurinae, and Saurolophinae across the book's chapters a bit confusing. In order to address this, and other similar confusions, we asked authors to cite their taxonomic sources where necessary.

In summary, we have tried our best to present a group of well-balanced and consistently edited manuscripts, while allowing the authors to express their individual styles. We hope that you all enjoy the volume and find it useful for years to come.

David A. Eberth

David C. Evans

WE THANK ALL OF THE PARTICIPANTS WHO ATTENDED THE International Hadrosaur Symposium in 2011 and helped us realize that this volume would be a successful venture. We thank the authors for helping provide a cohesive and coherent product, and especially for being so patient as the clock kept ticking. Special thanks to the reviewers who did their jobs in a timely manner and were often willing to look at manuscripts more than once, thus ensuring that contributions were of high quality both scientifically and editorially.

Our sincere gratitude goes to Bob Sloan and Jim Farlow, and the rest of the great team at Indiana University Press for all their help with this project.

We thank our respective home organizations who gave freely of their time, physical resources, and manpower. Special thanks to the Royal Tyrrell Museum for providing the FTP site, printing services, physical layout space, and so much else that was critical to the compilation of this volume. DAE thanks J. Gardner, D. Brinkman, F. Therrien, and D. Henderson for advice on numerous scientific and editorial items, and W. Taylor and D. Braman for editorial assistance. DCE thanks N. Campione and D. Larson for editorial and scientific assistance.

We are particularly grateful to A. Keibel and the Royal Tyrrell Museum Cooperating Society for financial and administrative support during the symposium and throughout this project.

We thank J. Csotonyi for the exceptional cover artwork of *Plesiohadros djadokhtaensis* and the wonderful (and first) artistic rendering of Djadokhtan paleoenvironments during a wet climatic phase. We also thank D. Dufault and L. Panzarin for their original artistic contributions to the volume.

Last, but certainly not least, we recognize P. Ralrick for her colossal contributions to this project. Patty served as our technical editor and editorial assistant, helped review manuscripts, listened to the occasional rant, and also indexed the volume. Without her attention to detail, this project would have taken twice as long and would not have been done half as well. Thanks, Patty, we hope that now you are very satisfied.





A History of the Study of Ornithomorphs: Where Have We Been? Where Are We Now? and Where Are We Going?

David B. Weishampel

ABSTRACT

Where ornithomorph studies have been and where they are going is fascinating. I try to provide answers for the history of the study of ornithomorphs by collecting bibliographic data from the second edition of *The Dinosauria*. The resulting publication trends were examined for initial six factors, nearly all of which increase through the first decade of the twenty-first century. These increases are used to take stock of present-day ornithomorph studies and, finally, to try to predict a future ornithomorph research in this historically contingent world.

INTRODUCTION

From a historical perspective, knowledge about a taxonomic group can be judged by its publication rate. A dramatic rise indicates a momentarily stalled interest in the group or a cessation of interest in a lineage (e.g., *Kobayutia* or *Nepesia*, 1901), while a low rate suggests less than vigorous or at least research-entirely focused, work on the group (e.g., *Elgasia* or when there are few publishing scientists). Finally, a high publication rate may have many reasons, including new discoveries and new taxonomic recognition, and evolutionary convergence, to name a few.

Compilations of taxa are not new to studies of dinosaurs, or even to groups of invertebrates (Sepkoski et al., 1981; Benton, 1987, 1998; Dodson, 1995; Weishampel, 1996; Sepkoski, 2002; Pasterosky et al., 2003; Wang and Dodson, 2004). However, this present compilation and survey differs from previous studies in that it focuses on the number of papers published and the research areas these papers address.

For Ornithomorphs, the most abundant and diverse of which are hadrosaurs—the record of publication begins in 1829 with the publication of Mantel's *Iguanodon*, and finishes with the numerous papers, some being issued via conventional journals as well as in line only journals, with no hard copies, of the present day. What this record looks like is presented in Figure 1. How it was obtained and how it is interpreted are the subjects of this chapter.

Central to this volume is the production of a symposium created predominantly to help research, which includes academic papers as well as hadrosaurs, if it has been reviewed by the organizers to include iguanodontians as well. By stretching it slightly more to include iguanodontians, we are practically drawn to the base of Ornithomorphs. Hence, this chapter is also Hadrosauris and more.

MATERIALS AND METHODS

In order to evaluate the rate of publication of papers dealing with ornithomorph dinosaurs, the number of papers was plotted on a percentage axis from 1829 to 2004 on an archeography of *The Dinosauria*, second edition (Weishampel et al., 2004). Considering published papers to mean even all dinosaurian taxa, this book is likely to be comprehensive enough for our current purposes. Because the decade of 2005–2009 was incomplete in that volume, the remainder of this decade was filled in proportionally since on the approximate representation during the first three and one-half years of the decade. That is, if 2005 produced *n* items are proportions based on tabulations from the first three and one-half years. Total papers and years in each research category (see below) were adjusted by multiplying the number in the first three and one-half years of the 2005–2009 decade by a factor of 2.66 to yield a total proportionally equivalent to other decades. This kind of correction was judged preferable to changing data sources (e.g., Web of Science), which would increase both an inflation of the more obscure literature.

To facilitate the total record, I have then plotted and categorized the papers that went into this total by combining the categories of research (Table 1). I provide general description of these categories, denoted in boldface text below. These categories were usually assessed by title alone, but occasionally it was necessary to consult the paper itself in order to determine which category it belonged. For example, a count of footprints are, eggshell papers, because it was often impossible to assess a unit's of *Ornithomorphs* or *Ornithomorphs* from the title of the paper.

TABLE 1.1. Categories of ornithomorph research identified in this survey

General taxonomy
Functional morphology
Phylogeny
Biostratigraphy and taphonomy
Biogeography
Paleontology
Soft tissue
Control
Incursions

General taxonomy refers to those publications announcing new species or generic taxa, or new taxonomic revisions that correct errors in the handling of phylogeny (see below). For example, Gilmore's (1913) announcement of *Therapsaloxys neglectus* is here considered to be in general taxonomy.

Functional morphology is the category for papers involving a biomechanical or functional interpretation of an ornithomorph anatomical system. An example of a functional morphology study is Alexander's (1985) work on stance and gait in ornithomorphs among other dinosaurs.

Phylogeny refers to those studies that attempt to portray the evolutionary history, or phylogeny, of the group. In recent years, these studies have emphasized cladistics in phylogenetic reconstruction (e.g., Prieto-Marquez, 2002), but also include a number of pre-Hennigian analyses (e.g., Colton, 1977).

Biostratigraphy and taphonomy papers involve the geologic disposition of ornithomorph remains, whether within or among rock units. Rogers (1960) provided an example of how far skeletal taphonomy can provide evidence on long-distance mortality in dinosaurs that include hadrosaurs.

Biogeography includes studies that examine the geographic distribution of ornithomorphs either from a dispersal or vicariance perspective, or both. For example, Casanovas et al. (1999) examined the global distribution of archosauriform lineages, whereas Luchinski et al. (2002) considered the full spectrum of controls on dinosaur diversity, including that of ornithomorphs, as a function of biogeography and biostratigraphy.

Paleontology papers include those of Corrado et al. (1994) on convergence—or lack thereof—among ornithomorphs and ungulate mammals, and Varricchio and Horner (1997) on the significance of "hoofbeats" in paleoecological interpretations, and are intended to address the reconstruction of particular taxonomically bound or free ecosystems in the past.

Soft tissue studies have been generally limited to skin impressions. Examples include Ostrom (1975) on the "imprinting" of *Archioonychia* structures in the American Museum of Natural History.

Growth includes papers associated with aspects of ontogenetic development. The impact of growth on ornithomorph studies is relatively recent. Here I note Dackon (1974) on the taxonomic significance of growth in *Lambeosaurus* and *Corythosaurus*, as well as various studies by Horner and colleagues (e.g., Horner et al., 1999, 2000) focused on the cellular basis of bone growth.

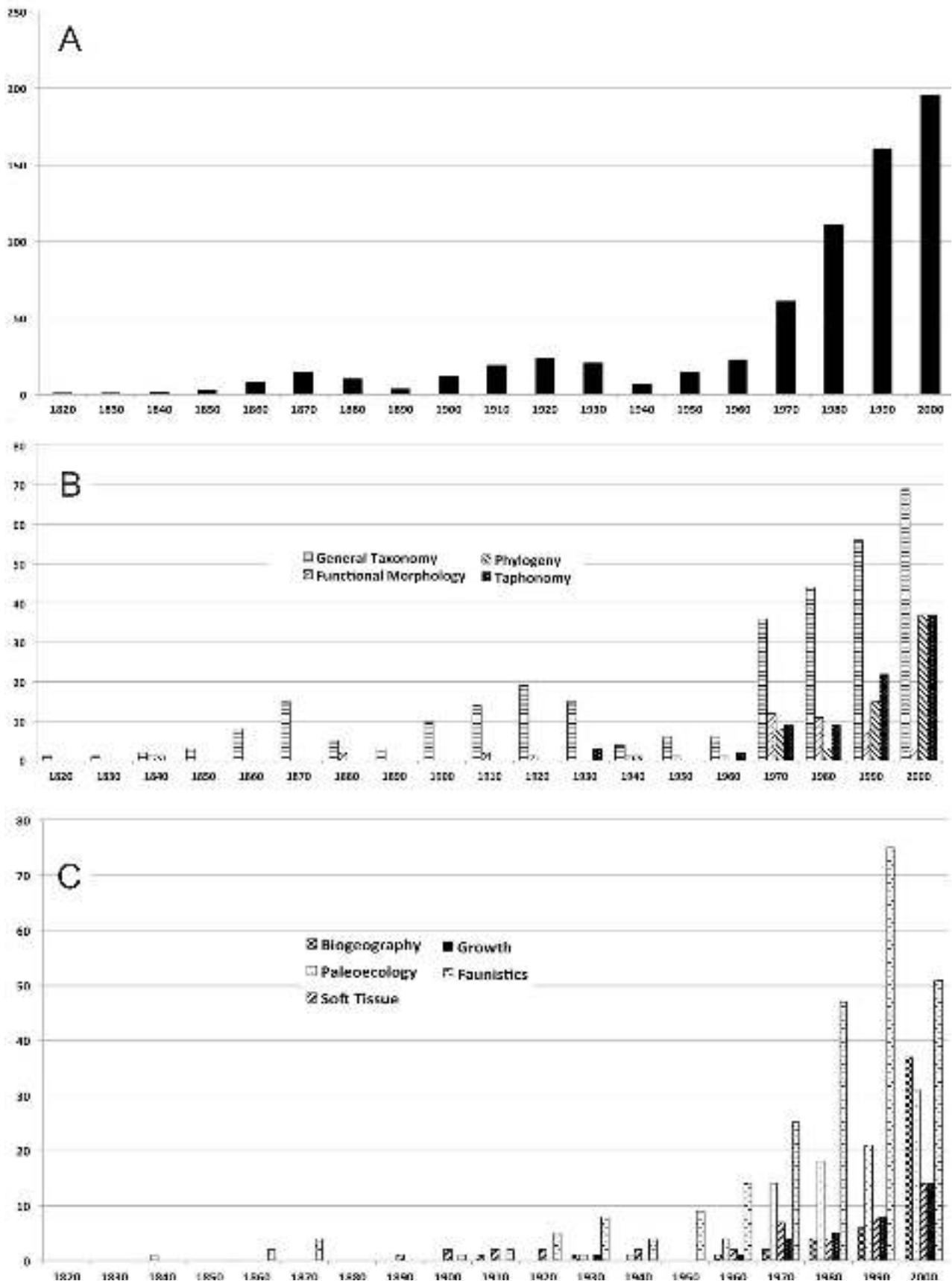
Taxonomies includes papers whose principal purpose is to establish or review a taxonomic nomenclature that include ornithomorphs. For example, Leppert (1969) reviewed the dinosaurs including many ornithomorphs from the "C" continental intercalation of northern Africa.

Usually ornithomorphs were entered into one category. However, a study can contribute here to several categories. For instance, Colton (1977) included dinosaurs in general taxonomy, functional morphology, phylogeny, and other subjects in his major review of North American hadrosaurs, and so it was added to each of these categories.

WHERE HAVE WE BEEN?

Where we have been can be determined by looking at the total curve of ornithomorph publications (Fig. 1.1). Beginning in the 1860s, the number of papers published per decade rises to a high of 5 in the 1870s. It then declines to 1 in the 1890s, and increases again, to 24, in the 1920s. The 1940s see a drop to 7, followed by a persistent, or generally increasing, the decade of the 2000s, which is characterized by nearly 200 papers, amounting to almost 2 papers per month.

Before turning to several intrinsic factors, I want to examine three kinds of extrinsic events that may have influenced these numbers and patterns. For possible influences due to world events, the European revolutions of 1848, the American Civil War, World War I, the Russian Revolution, the fall of communism, and the Arab-Israeli and Afghan wars appear to have no substantial influence on rate of publication, whereas the 1929 stock market crash and subsequent worldwide financial depression followed by World War I are likely factors in the cessation of publications in the 1930s and 1940s. Regarding technological influences, there are no great fluctuations in rate of publication for technological events, except for the last two events. It is probably safe to say that the invention of personal computers, particularly laptop (1960s), in combination with the development of the World Wide Web or e-mail (1970s) made a huge impact on the rate of ornithomorph publications. With the initiation of web publishing, this trend is certain to continue. Finally, seasonal fluctuations probably account for smaller perturbations in the total curve. For example, the absence of the 1960s data assemblage from Bernisart probably accounts for the rise in ornithomorph publications during the 1870s and 1880s. The



1.1. Publication trends on ornithomimid dinosaurs. (A) Total publication record of ornithomimid dinosaurs from 1820 to 2000 tabulated by decade; (B) Total publications of general taxonomy, functional morphology, phylogeny, and biostratigraphy and taphonomy, tabulated by decade; (C) Total publications in biogeography, paleoecology, soft tissue, growth, and faunistics, tabulated by decade.

rise in publication rates during the 1910s, 1920s, and 1930s can certainly be attributed to the Great Canadian Dinosaur Rush in Alberta. Finally, as a personal homage, I consider John H. Ostrom's first monographic publication—his 1961 treatment of the hadrosaurids of North America—to signal the beginning of what has turned out to be a plethora of ornithopod publications to the present day.

Intrinsic factors, on the other hand, are some of the subjects that I am interested in, which also have given Ornithopoda pride of place in the world of dinosaur publishing. General taxonomy and faunistics are the largest contributors to the total sample, whereas the rest have relatively low influence.

General taxonomy (Fig. 1.1B) has as long a history, beginning with the first publication on *Iguanodon* by Mantell (1825) and early on encompassing the first publication on *Hadrosaurus* by Leidy (1858). Furthermore, it mirrors fairly well the total publication curve, with a high point of 69 publications during the decade of 2000–2010.

Functional morphology (Fig. 1.1B) has a long, but patchy history, beginning with the publication of Mantell (1848) on the teeth and jaws of *Iguanodon*. It has never been common, but increases significantly in the 1970s and 1980s, with renewed interest in ornithopod jaw mechanics. Functional morphology has been in decline since this time.

Phylogeny (Fig. 1.1B) also has a long and equally patchy history, beginning with Owen's (1842) christening of Dinosauria. Thereafter, there is a long hiatus until the 1970s, when we see an irregular publication record reflecting the large impact of cladistics on phylogeny estimates. The 1990s and 2000s indicate an important increase in cladistic studies, peaking near 40 publications.

Biostratigraphy and taphonomy (Fig. 1.1B) have a relatively short history, confined to the period of the 1930s to the present, and within this span only relatively abundant since the 1970s, with the publications of Dodson (1971), Rogers (1990), and Varricchio and Horner (1993). There is a steady increase in biostratigraphic and taphonomic publications from the 1980s to the 2000s, indicative of increased interest in the sedimentological aspects of ornithopod fossils.

Biogeography (Fig. 1.1C) is in its infancy, with its concentration of publications only evident from the 1960s onward. This is roughly the same time as the scientific ascendancy of plate tectonics and phylogenetic systematics, and thus, may be a direct product of these two revolutions in the natural sciences (Serenó, 1997, 1999a, 1999b; Upchurch et al., 2002). Biogeography reaches its zenith in the decade of 2000; in all likelihood it will continue to increase.

Paleoecology (Fig. 1.1C) has a relatively short history. With a few notable exceptions (Mantell, 1844; Nopcsa, 1934), the history of paleoecology papers really began in the 1960s.

There has been a steady increase in the number of paleoecology publications since then, to a high of more than 30 publications in the decade of 2000–2010.

Soft tissue (Fig. 1.1C), consisting almost entirely of the study of integumentary impressions, has a reasonable steady and long history, increasing steadily since the 1970s. It is presently on a very large upswing, in large part because of the discovery of exceptionally well preserved specimens (particularly in northeastern China) and a more focused evaluation of variation in integumentary patterns (Bell, this volume).

Growth (Fig. 1.1C) has a very modest history. It has been common only since the 1970s, and appears to be on a steep upswing to nearly a dozen papers for the decade of 2000–2010. This increase probably represents the rise in fossil bone histology studies in ornithopods (e.g., Chinsamy, 1995; Horner et al., 2000).

Finally, **faunistics** (Fig. 1.1C) has a long history, approximately paralleling general taxonomy and the total curve, at least since the 1860s. Faunistics seems to drop off during the decade of the 2000s, but this downturn should be treated with skepticism because it is almost certainly an artifact of sampling extrapolation. Examples taken from the 1990s and 2000s include Csiki (1997), Ryan and Russell (2001), López-Martínez et al. (2001), and Zhou et al. (2003).

WHERE ARE WE NOW?

Before we all assembled for the International Hadrosaur Symposium, we all probably thought we knew where our science was. At a minimum, that was what we came to Drumheller to report on. It was hadrosaur taxonomy, North American, Asian, South American, and European hadrosaurs, and ornithopod brains. It was also hadrosaur gigantism and age, hadrosaur jaws and herbivory, locomotor mechanics, taphonomy, integument, tracks, and various aspects of development. This was where we thought our discipline was as we began the symposium.

Eighty-eight percent of the symposium talks ($n = 34$ talks, 16 posters) fall within the categories discussed here (Braman et al., 2011). Most are taxonomic, phylogenetic, or biogeographic in scope. Another half-dozen or more pertain to functional morphology, growth, and taphonomy—a good sampling of the categories examined here (an acclaim delivered independently twice over—the organizers and I both got it right!).

Symposium percentages are all the same order of magnitude compared to those obtained for the decade of 2000–2010, but there are several differences. General taxonomic presentations at the symposium were nearly 25% fewer than from 2000–2010, phylogeny was 19% fewer, taphonomy was 15% fewer, biogeography was 28% fewer, paleoecology was

19% fewer, and faunistics was 13% fewer. Soft tissue remained approximately the same. Interestingly, functional morphology was 14% more and growth was 6% more than from the decade of 2000–2010. While it is tempting to assign significance to individual percentages, they are probably no more than sampling errors when comparing a very small number of symposium talks with the projected breakdown of categories for an entire decade.

WHERE ARE WE GOING?

I am certainly no prognosticator, even about my own research field. Like all historical sciences, our ability to predict the future is fraught with the kinds of unpredictability that derives from historical contingency. There is little inevitability that guides us in the progress of our science—just as there is little that links the hand-cranked ice-cream maker (1840s) to the electron microscope (1930s), a transition that happened in only nine decades. What about going from the invention of the Band-Aid (1930s) to the home computer in five decades? Who would have predicted these changes?

But the contents of this volume give an inkling of where we are headed, at least in the short run. I see continued fieldwork, the wellspring of our science. Its direct consequences—new species and taxonomic revisions—are likely to be accompanied by a healthy continuance of studies focused on comparative anatomy, both bony and inferred soft tissue. To do so requires a healthy dose of phylogenetic systematics, which now should be part of everyone's toolkit.

In functional morphology, finite element analyses and tooth-wear studies have appeared on the horizon and I hope these will be coupled with cladistic analyses to produce even more outstanding work. Finally, growth studies are very likely to continue in the future: the small bit of bone given up for a thin-section is bound to yield disproportionately much more subtle and profound information than if it were left with the rest of the bone.

Still, things do not always work out that way. Contingency makes history messy. Things come out of left field and WHAM! Someone discovers the most amazing specimen or means by which colors can be inferred from skin impressions. All of a sudden, with no way of predicting, we are all scrambling to do research on the melanosomes of what could turn out to be red-, green-, and yellow-striped ornithopods!

ACKNOWLEDGMENTS

I thank David Eberth and David Evans for their kind invitation to join them at their fantastic first International Hadrosaur Symposium in Drumheller, Alberta, Canada. Their generosity and that of François Therrien and the other hosts at the Royal Tyrrell Museum of Palaeontology are most commendable. And to throw in a bronze plaque of *Corythosaurus intermedius* (ROM 845); well, I sure had a good time! I also thank Ali Nabavizadeh and Cat Sartin for their help on and reading of this manuscript and Jack Horner, Cora Jianu, and Pilar Yagüe for their own individual inspirations.

LITERATURE CITED

- Alexander, R. McN. 1985. Mechanics of posture and gait of some large dinosaurs. *Zoological Journal of the Linnean Society* 83:1–25.
- Bell, P. 2014. A review of hadrosaurid skin impressions; Chapter 25 in D. A. Eberth, and D. C. Evans (eds.), *Hadrosaurs*. Indiana University Press, Bloomington, Indiana.
- Benton, M. J. 1985. Mass extinction among non-marine tetrapods. *Nature* 316:811–814.
- Benton, M. J. 1998. The quality of the fossil record of the vertebrates; pp. 269–303 in S. K. Donovan and C. R. C. Paul (eds.), *The Adequacy of the Fossil Record*. John Wiley & Sons, New York.
- Braman, D., D. A. Eberth, D. C. Evans, and W. Taylor (compilers). 2011. *International Hadrosaur Symposium Abstract Volume*. Royal Tyrrell Museum, Drumheller, Alberta. 171 pp.
- Carrano, M. T., C. M. Janis, and J. J. Sepkoski. 1999. Hadrosaurs as ungulate parallels: lost lifestyles and deficient data. *Acta Palaeontologica Polonica* 44:237–261.
- Casanovas, M. L., X. Pereda-Suberbiola, and D. B. Weishampel. 1999. First lambeosaurine hadrosaurid from Europe: palaeobiogeographical implications. *Geological Magazine* 136:205–211.
- Chinsamy, A. 1995. Ontogenetic changes in the bone histology of the Late Jurassic ornithopod *Dryosaurus lettowvorbecki*. *Journal of Vertebrate Paleontology* 15:96–104.
- Csiki, Z. 1997. Legături paleobiogeografice ale faunei de vertebrate continentale Maastrichtian superioare din Bazinul Hațeg. *Nymphaea* 23–25:45–68.
- Dodson, P. 1971. Sedimentology and taphonomy of the Oldman Formation (Campanian), Dinosaur Provincial Park, Alberta (Canada). *Palaeogeography, Palaeoclimatology, Palaeoecology* 10:21–74.
- Dodson, P. 1975. Taxonomic implications of relative growth in lambeosaurine hadrosaurs. *Systematic Zoology* 24:37–44.
- Dodson, P. 1990. China reaches the top. *American Paleontologist* 17: online supplement. Available at www.museumoftheearth.org/files/pubtext/supplements/suppl_557c.pdf. Accessed summer 2012.
- Fastovsky, D. E., Y. Huang, J. Hsu, J. Martin-McNaughton, P. M. Sheehan, and D. B. Weishampel. 2004. Shape of Mesozoic dinosaur richness. *Geology* 32:877–880.
- Galton, P. M. 1972. Classification and evolution of ornithopod dinosaurs. *Nature* 239:464–466.
- Gilmore, C. W. 1913. A new dinosaur from the Lance Formation of Wyoming. *Smithsonian Miscellaneous Collections* 61:1–5.
- Horner, J. R., A. de Ricqlès, and K. Padian. 1999. Variation in skeletochronological indicators of the hadrosaurid dinosaur *Hypacrosaurus*: implications for age assessment of dinosaurs. *Paleobiology* 25:295–304.
- Horner, J. R., A. de Ricqlès, and K. Padian. 2000. The bone histology of the hadrosaurid dinosaur *Maiasaura peeblesorum*: growth dynamics and physiology based on an ontogenetic series of skeletal elements. *Journal of Vertebrate Paleontology* 20:109–123.
- de Lapparent, A. F. 1960. Les dinosauriens du "Continental intercalaire" du Sahara central. *Memoire de la Société géologique de France* 88A:1–57.
- Leidy, J. 1858. *Hadrosaurus foulkii*, a new saurian from the Cretaceous of New Jersey. *Proceedings of the Academy of Natural Science of Philadelphia* 1859:215–218.
- López-Martínez, N., J. I. Canudo, L. Ardèvol, X. Pereda-Suberbiola, X. Orue-Etxebarria, G. Cuenca-Bescós, J. I. Ruiz-Omeñaca, X. Murilaga, and M. Feist. 2001. New dinosaur sites correlated with upper Maastrichtian pelagic

- deposits in the Spanish Pyrenees: implications for the dinosaur extinction pattern in Europe. *Cretaceous Research* 22:41–61.
- Mantell, G. A. 1825. Notice on the *Iguanodon*, a newly discovered fossil reptile, from the sandstone of the Tilgate Forest, in Sussex. *Philosophical Transactions of the Royal Society of London* 115:179–186.
- Mantell, G. A. 1844. *Medals of Creation*. H. G. Bohn, London, U.K., 289 pp.
- Mantell, G. A. 1848. On the structure of the jaws and teeth of the *Iguanodon*. *Philosophical Transactions of the Royal Society of London* 138:183–202.
- Nopcsa, F. 1901. Synopsis und Abstammung der Dinosaurier. *Földtani Közlöny* 31:247–288.
- Nopcsa, F. 1934. The influence of geological and climatological factors on the distribution of non-marine fossil reptiles and Stegocephalia. *Quarterly Journal of the Geological Society of London* 90:76–140.
- Osborn, H. F. 1912. Integument of the iguanodont dinosaur *Trachodon*. *Memoirs of the American Museum of Natural History* 1:33–54.
- Ostrom, J. H. 1961. Cranial morphology of the hadrosaurian dinosaurs of North America. *Bulletin of the American Museum of Natural History* 122:33–186.
- Owen, R. 1842. Report on British fossil reptiles. Part II. Report of the British Association for the Advancement of Science 1841:60–204.
- Prieto-Márquez, A. 2010. Global phylogeny of Hadrosauridae (Dinosauria: Ornithischia) using parsimony and Bayesian methods. *Zoological Journal of the Linnean Society* 159:435–502.
- Rogers, R. R. 1990. Taphonomy of three dinosaur bone beds in the Upper Cretaceous Two Medicine Formation, northwestern Montana: evidence for drought-related mortality. *Palaios* 5:394–413.
- Ryan, M. J., and A. P. Russell. 2001. Dinosaurs of Alberta (exclusive of Aves); pp. 279–297 in D. H. Tanke, and K. Carpenter (eds.), *Mesozoic Vertebrate Life*. Indiana University Press, Bloomington, Indiana.
- Sepkoski, J. J., Jr. 2002. A compendium of fossil marine animal genera; pp. 1–560 in D. Jablon-ski, and M. Foote (eds.), *Bulletins of American Paleontology*, No. 363. Paleontological Research Institution, Ithaca, New York.
- Sepkoski, J. J., Jr., R. K. Bambach, D. M. Raup, and J. W. Valentine. 1981. Phanerozoic marine diversity and the fossil record. *Nature* 293:435–437.
- Sereno, P. C. 1997. The origin and evolution of dinosaurs. *Annual Review of Earth and Planetary Sciences* 25:435–489.
- Sereno, P. C. 1999a. The evolution of dinosaurs. *Science* 284:2137–2147.
- Sereno, P. C. 1999b. Dinosaurian biogeography: vicariance, dispersal and regional extinction. *National Science Museum of Tokyo Monographs* 15:249–257.
- Upchurch, P., C. A. Hunn, and D. B. Norman. 2002. An analysis of dinosaurian biogeography: evidence for the existence of vicariance and dispersal patterns caused by geological events. *Proceedings of the Royal Society of London* B269:613–621.
- Varricchio, D. J., and J. R. Horner. 1993. Hadrosaurid and lambeosaurid bone beds from the Upper Cretaceous Two Medicine Formation of Montana: taphonomic and biological implications. *Canadian Journal of Earth Sciences* 30:997–1006.
- Wang, S. C., and P. Dodson. 2004. Estimating the diversity of dinosaurs. *Proceedings of the National Academy of Science* 103:13601–13605.
- Weishampel, D. B. 1996. Fossils, phylogeny, and discovery: a cladistic study of the history of tree topologies and ghost lineage durations. *Journal of Vertebrate Paleontology* 16:191–197.
- Weishampel, D. B., P. Dodson, and H. Osmólska (eds.). 2004. *The Dinosauria*, Second Edition. University of California, Berkeley, California, 861 pp.
- Zhou Z., P. R. Barrett, and J. Hilton. 2003. An exceptionally preserved Lower Cretaceous ecosystem. *Nature* 421:807–814.

- [**Reflecting on Cosmetic Surgery : Body image, Shame and Narcissism for free**](#)
- [*Las normas de César Millán for free*](#)
- [download The Founders' Key: The Divine and Natural Connection Between the Declaration and the Constitution and What We Risk by Losing It](#)
- [download Realisationâ€”From Seeing to Understanding: The Origins of Art](#)

- <http://jaythebody.com/freebooks/Fantasy---Science-Fiction--Extended-Edition---March-April-2012-.pdf>
- <http://cambridgebrass.com/?freebooks/The-Music-of-the-Big-Bang--The-Cosmic-Microwave-Background-and-the-New-Cosmology--Astronomers--Universe-.pdf>
- <http://wind-in-herleshausen.de/?freebooks/Deleuze-s-Literary--Clinic-Criticism-and-the-Politics-of-Symptoms--Plateaus---New-Directions-in-Deleuze-Stud>
- <http://berttrotman.com/library/Road--The-Black-Hills-Betrayal-and-Custer-s-Path-to-Little-Bighorn.pdf>