Evolution of the Rodents

Advances in Phylogeny, Functional Morphology and Development

The widespread use of mouse models in developmental, behavioural and genetic studies has sparked wider interest in rodent biology as a whole. This book brings together the latest research on rodents to better understand the evolution of both living and extinct members of this fascinating group.

Topics analysed include: the role of molecular techniques in the determination of a robust phylogenetic framework; how geometric morphometric methods help quantify and analyse variation in shape; and the role of developmental biology in elucidating the origins of skeletal elements and the teeth. The editors unite these disciplines to present the current state of knowledge in rodent biology, while setting the landscape for future research.

This book highlights interdisciplinary links across palaeontology, developmental biology, functional morphology, phylogenetics and biomechanics, making it a valuable resource for evolutionary biologists in all fields.

Philip G. Cox is a lecturer at the Department of Archaeology, University of York, and the Hull York Medical School, and a researcher into the functional morphology and evolution of mammals, particularly rodents. Much of his research has involved the application of sophisticated engineering techniques, namely finite element analysis, to rodent skulls and mandibles in order to understand the biomechanics of feeding in these species.

Lionel Hautier is a researcher (CR2) at the Centre National de Recherche Scientifique (CNRS) posted at the Institut des Sciences de l' Evolution de Montpellier (ISEM). He is a vertebrate palaeontologist, specialising in mammals and notably rodents. His research interests include the evolution of the masticatory apparatus of extinct and extant rodents, studied using morphological (osteological and myological), morphometrical and palaeontological evidence.

Cambridge Studies in Morphology and Molecules: New Paradigms in Evolutionary Biology

This new Cambridge series addresses the interface between morphological and molecular studies in living and extinct organisms. Areas of coverage include evolutionary development, systematic biology, evolutionary patterns and diversity, molecular systematics, evolutionary genetics, rates of evolution, new approaches in vertebrate palaeontology, invertebrate palaeontology, palaeobotany and studies of evolutionary functional morphology. The series invites proposals demonstrating innovative evolutionary approaches to the study of extant and extinct organisms that include some aspect of both morphological and molecular information. In recent years the conflict between 'molecules vs. morphology' has given way to more open consideration of both sources of data from each side making this series especially timely.

Carnivoran Evolution: New Views on Phylogeny, Form and Function
Edited by Anjali Goswami and Anthony Friscia
Evolutionary History of Bats: Fossils, Molecules and Morphology
Edited by Gregg F. Gunnell and Nancy B. Simmons
Evolution of the House Mouse
Edited by Miloš Macholán, Stuart J. E. Baird, Pavel Munclinger and Jaroslav Piálek
From Clone to Bone: The Synergy of Morphological and Molecular Tools in Paleobiology
Edited by Robert J. Asher and Johannes Müller

Evolution of the Rodents

Advances in Phylogeny, Functional Morphology and Development

EDITED BY

Philip G. Cox
Department of Archaeology, University of York, and the Hull York Medical School

and

Lionel Hautier
Institut des Sciences de l' Evolution de Montpellier (ISEM), Université de Montpellier

CAMBRIDGE UNIVERSITY PRESS

CAMBRIDGE
UNIVERSITY PRESS

University Printing House, Cambridge CB2 8BS, United Kingdom

Cambridge University Press is part of the University of Cambridge.

It furthers the University's mission by disseminating knowledge in the pursuit of
education, learning and research at the highest international levels of excellence.

www.cambridge.org
Information on this title: www.cambridge.org/9781107044333

First published 2015

Printed in the United Kingdom by TJ International Ltd. Padstow Cornwall

A catalogue record for this publication is available from the British Library

Library of Congress Cataloguing in Publication data
Evolution of the rodents : advances in phylogeny, functional morphology, and development / edited by
Philip G. Cox, Department of Archaeology, University of York, and the Hull York Medical School, and
Lionel Hautier, Institut of Evolutionary Sciences (ISEM), Université de Montpellier II.
pages cm. – (Cambridge studies in morphology and molecules)
Includes bibliographical references.
ISBN 978-1-107-04433-3 (Hardback)
1. Rodents–Evolution. I. Cox, Philip G. II. Hautier, Lionel.
QL737.R6E934 2015
599.35–dc23 2014037660

ISBN 978-1-107-04433-3 Hardback

Contents

Contributors

Franck Barbière, Institut des Sciences de l'Évolution de Montpellier, Universite Montpellier, Montpellier, France

R. Ernesto Blanco, Instituto de Física, Facultad de Ciencias, Montevideo, Uruguay

Andrea Cardini, Dipartimento di Scienze Chimiche e Geologiche, Universitá di Modena e Reggio Emilia, Modena, Italy, and Centre for Forensic Science, The University of Western Australia, Crawley, WA, Australia

Cyril Charles, Institut de Génomique Fonctionnelle de Lyon, Ecole Normale Supérieure de Lyon, Lyon, France

Philip G. Cox, Department of Archaeology, University of York, and Hull York Medical School, York, UK

Edward B. Davis, Museum of Natural and Cultural History and Department of Geology, University of Oregon, Eugene, OR, USA

Mary R. Dawson, Carnegie Museum of Natural History, Pittsburgh, PA, USA

Christiane Denys, Department of Systematics and Evolution, Muséum National d'Histoire Naturelle, Paris, France

Emmanuel J. P. Douzery, Institut des Sciences de l'Évolution de Montpellier, Universite Montpellier, Montpellier, France

Robert E. Druzinsky, Department of Oral Biology, College of Dentistry, University of Illinois at Chicago, Chicago, IL, USA

Adélaïde Euriat, Institut de Paléoprimatologie, Paléontologie Humaine: Evolution et Paléoenvironnements, Université de Poitiers, Poitiers, France

Pierre-Henri Fabre, Institut des Sciences de l'Evolution de Montpellier, Université de Montpellier, Montpellier, France

Madeleine Geiger, Paläontologisches Institut und Museum, University of Zürich, Zürich, Switzerland

Helder Gomes Rodrigues, Institut des Sciences de l'Évolution de Montpellier, Universite Montpellier 2, Montpellier, France

Franck Guy, Institut de Paléoprimatologie, Paléontologie Humaine: Evolution et Paléoenvironnements, Université de Poitiers, Poitiers, France

Lionel Hautier, Institut des Sciences de l'Évolution de Montpellier, Université de Montpellier, Montpellier, France

Nathan Jeffery, Department of Musculoskeletal Biology, Institute of Ageing and Chronic Disease, University of Liverpool, Liverpool, UK

Vincent Lazzari, Institut de Paléoprimatologie, Paléontologie Humaine: Evolution et Paléoenvironnements, Université de Poitiers, Poitiers, France

Renaud Lebrun, Institut des Sciences de l'Évolution de Montpellier, Universite Montpellier, Montpellier, France

Laurent Marivaux, Institut des Sciences de l'Évolution de Montpellier, Universite Montpellier, Montpellier, France

Matthew J. Mason, Department of Physiology, Development and Neuroscience, University of Cambridge, Cambridge, UK

John M. Mercer, Biology Department, Duke University, Durham, NC, USA

Jacques Michaux, Ecole Pratique des Hautes Etudes et Institut des Sciences de l'Évolution de Montpellier, Universite Montpellier, Montpellier, France

Johan R. Michaux, Unité de Génétique de la Conservation, Institut de Botanique, Université de Liège, Liège, Belgium

Sophie Montuire, Laboratoire Paléobiodiversité et Evolution de l'Ecole Pratique des Hautes Etudes, Biogéosciences, Université de Bourgogne, Dijon, France

Cecilia C. Morgan, Sección Mastozoología, Museo de La Plata, La Plata, Argentina

A. Itatí Olivares, Sección Mastozoología, Museo de La Plata, La Plata, Argentina

P. David Polly, Department of Geological Science, Biology and Anthropology, Indiana University, Bloomington, IN, USA

Jean-Pierre Quéré, Institut National de la Recherche Agronomique, Centre de Biologie et Gestion des Populations, Campus International de Baillarguet Montferrier-sur-Lez, France

Sabrina Renaud, Laboratoire de Biométrie et Biologie Evolutive, Centre Nationale de la Recherche Scientifique, Université Lyon 1, Villeurbanne, France

Elodie Renvoisé, Evolutionary and Developmental Biology Laboratory, Institute of Biotechnology, University of Helsinki, Helsinki, Finland

Andrés Rinderknecht, Museo Nacional de Historia Natural, Montevideo, Uruguay

V. Louise Roth, Biology Department, Duke University, Durham, NC, USA

Pierre-Emmanuel Salais, Institut de Paléoprimatologie, Paléontologie Humaine: Evolution et Paléoenvironnements, Université de Poitiers, Poitiers, France

Scott J. Steppan, Department of Biological Science, Florida State University, Tallahassee, FL, USA

Paul Tafforeau, European Synchrotron Radiation Facility, Grenoble, France

Diego H. Verzi, Sección Mastozoología, Museo de La Plata, La Plata, Argentina

Monique Vianey-Liaud, Institut des Sciences de l'Évolution de Montpellier, Universite Montpellier, Montpellier, France

Laurent Viriot, Institut de Génomique Fonctionnelle de Lyon, Université Claude Bernard Lyon 1, Lyon, France

Laura A. B. Wilson, School of Biological, Earth and Environmental Sciences, University of New South Wales, Sydney, Australia

Alisa Winkler, Roy M. Huttington Department of Earth Sciences, Southern Methodist University, Dallas, TX, USA

Foreword

Because it reflects the volume *Evolutionary Relationships Among Rodents: a Multidisciplinary Approach* that we edited in 1985, nearly 30 years ago, it is a great pleasure for us to introduce this new book, which updates many of the same topics and introduces new approaches, especially in the area of functional morphology.

Our publication followed a meeting held in Paris in the spring of 1984, with about 50 participants coming from different disciplines and countries, but all interested in the palaeontology, biology and evolutionary relationships of families from the orders Rodentia and Lagomorpha.[1] It was a very friendly meeting, with four days in Paris at the Centre National de la Recherche Scientifique, on the banks of the Seine and its nearby *bistrots*, allowing extensive scientific exchanges. Unfortunately, some Eastern colleagues could not join us for obscure political reasons: N. N. Vorontsov was not allowed to leave Moscow for a few days; the same was true for D. Dashzeveg from Oulan Bator. Fortunately, exchanges between international scientists are much easier today.

Our book was dedicated to two leading authorities on the subject at the time: René Lavocat (1909–2007) and Albert Elmer Wood (1910–2002). The book has received good success, even though it was highly priced, despite the fact that WPL and JLH did most of the editing work including the 'camera ready' *mise en page*; the publishers also had received some financial support from NATO (North Atlantic Treaty Organisation).

Two main topics for challenge and discussion were the Glires concept, which was at this time an open question, and the relationships of African rodents with their possible relatives in South America. Also, for some families, a documented review was proposed by different specialists, with the notable exception of the murids.

It must be added that, at the time, relationships and communications between palaeontologists and other biologists were poor: a type of reciprocal ignorance between the two communities was the rule. Thus, the meeting contributed notably to breaching the barrier between fossil specialists and those biologists studying the living world.

[1] List of participants and authors in the 1984 Paris meeting: Jaap Beintema, François Bonhomme, Gehrard Braunitzer, Jorgen Bugge, Percy M. Butler, Ernesto Capanna, Jean Chaline, Brigitte Coiffait, John Czelusniak, Wilfried De Jong, Christiane Denys, Volker Fahlbusch, Lawrence J. Flynn, Wilma George, Morris Goodman, Jean-Louis Hartenberger, John Hermanson, Djoko Iskandar, Louis Jacobs, Jean-Jacques Jaeger, Wighart von Koenigswald, René Lavocat, Li Chuan Kuei, Everett Lindsay, W. Patrick Luckett, Nieves Lopez Martinez, Jacques Michaux, Michael Novacek, Jean-Pierre Parent, Francis Petter, Ashok Sahni, Vincent Sarich, Jeheskel Shoshani, Frederick Szalay, Louis Thaler, Su Yin Ting, Monique Vianey-Liaud, John Wahlert, Albert E. Wood, and Charles Woods.

Studies of genetics and molecular phylogeny were still in the early stages: techniques allowing exploitation of the molecular clock concept (1965) had only recently been solved.

One of the main results of the meeting was that the Glires concept of a sister-group relationship between Rodentia and Lagomorpha received good support from both paleontologists and some neontologists. However, four contributions from molecular biologists in the book provided no support for the Glires hypothesis, even though most did not directly address the subject. These studies dealt with analyses of amino acids or immunological distance data from only a few groups of rodents. Nevertheless, one author (Vincent Sarich) boldly asserted that 'I know of no molecular data which would suggest any rodent–lagomorph affinities, and there are appreciable, if not sufficient, data to in fact reject the rodent–lagomorph hypothesis'. Molecular phylogenetic studies were still in early development, with little analysis of nucleotide data, and other authors were less provocative and more open to discussion. Subsequent studies of molecular evolution in rodents during recent decades, with greater emphasis on increased taxon sampling, as well as newer methods of analysing nuclear protein-coding genes, have resulted in near-uniform support for the monophyly of Glires.

At present, the Glires concept is stronger than ever. Thanks first to the very significant discoveries and interpretations concerning Palaeocene Mongolian and Chinese primitive lagomorphs and rodents. In addition, newer techniques in molecular studies and analyses have been developed, and Pierre-Henri Fabre and his colleagues give here a refreshing *mise au point* concerning the molecular phylogeny of Rodentia. In some ways their conclusions are in total agreement with recent results concerning the tempo and mode of placental mammal radiations. It is now demonstrated that the radiation of Glires, as the emergence of *all* modern orders of mammals, is a post-Cretaceous/Palaeogene event. Extending these results about the origins of Rodentia, Mary Dawson gives an overview concerning the question: what really is a primitive rodent?

Concerning possible relationships between African and South American rodents, the monophyly of Hystricognathi has now received nearly universal support from both palaeontologists and neontologists. At the time of the Paris meeting, the importance of the Ctenodactylidae was emerging, and some participants were convinced that African Hystricognathi could be rooted in the Asian early Eocene Ctenodactyloidea. Indeed, in our summary of the conference, we presented as a working hypothesis the possible sister-group relationship between Hystricognathi and Ctenodactyloidea. This hypothesis subsequently received strong support from molecular analyses, and resulted in the naming of a new higher taxon Ctenohystrica. This hypothesis also reflects the importance of Tethys sea margins for biogeographical exchanges. This allowed East–West faunal exchanges on both sides of Tethys from Eastern Asia to Africa, Europe and America. Not only were marine mammals (Sirenia and Archeoceta) involved in these migrations, but terrestrial mammals were also involved.

In fact, what is really new from the time of the Paris congress is that new methods and tools have opened new perspectives and approaches for students in evolutionary biology.

The building of phylogenetic trees using molecular and morphological data are now codified, so that matrices of characters are always open to discussion and modification in a way that all workers are aware of modifications; these data are available in Morphobank and Genbank. Also digital libraries have opened new perspectives. Many of these are highly priced, but they generate new facilities for workers, and we older investigators must confess that we are in some ways a little envious regarding our younger colleagues.

For morphological observations, there has been a numerical revolution since the end of the century: scanners, 3D, digimorph studies, high-resolution X-ray computed tomography and tomo-densitometry techniques provide spectacular imagery and animations for rare fragile fossil or living specimens. Thus, morphological data are more acute and, in some cases, developmental and embryological studies provide new windows for evolutionary studies. The counterpart of this is that there are almost too many publications and papers. The 'publish or perish' constraint seems too high. Also, it could be noted that there are too many multi-authored papers, but this is also the consequence of the use of sophisticated techniques and must be considered a necessity.

We hope the new book will invite younger students to study more aspects of rodent biology and evolution; with more than 2000 species, the order needs more attention than any other, including ours!

JEAN-LOUIS HARTENBERGER
and
W. PATRICK LUCKETT