

THE GENETICS

*of Cattle*



THE GENETICS  
*of Cattle*

*Edited by*

**R. FRIES**

*Lehrstuhl für Tierzucht  
Technische Universität München  
Freising-Weihenstephan  
Germany*

*and*

**A. RUVINSKY**

*Animal Sciences, SRSNR  
University of New England  
Armidale  
Australia*

CABI Publishing

*CABI Publishing is a division of CAB International*

CABI Publishing  
CAB International  
Wallingford  
Oxon OX10 8DE  
UK

Tel: +44 (0)1491 832111  
Fax: +44 (0)1491 833508  
Email: [cabi@cabi.org](mailto:cabi@cabi.org)

CABI Publishing  
10 E 40th Street  
Suite 3203  
New York, NY 10016  
USA

Tel: +1 212 481 7018  
Fax: +1 212 686 7993  
Email: [cabi-nao@cabi.org](mailto:cabi-nao@cabi.org)

© CAB *International* 1999. All rights reserved. No part of this publication may be reproduced in any form or by any means, electronically, mechanically, by photocopying, recording or otherwise, without the prior permission of the copyright owners.

A catalogue record for this book is available from the British Library, London, UK

**Library of Congress Cataloging-in-Publication Data**

The genetics of cattle/edited by R. Fries and A. Ruvinsky.

p. cm.

Includes bibliographical references and index.

ISBN 0-85199-258-7 (alk. paper)

I. Cattle--Genetics. 2. Cattle--Breeding. I. Fries, R. (Ruedi).

II. Ruvinsky, Anatoly. III. C.A.B. International.

SF201.G45 1999

636.2'08'21--dc21

98-45203

CIP

ISBN 0 85199 258 7

Typeset in Garamond by AMA DataSet Ltd  
Printed and bound in the UK by Biddles Ltd, Guildford and King's Lynn

# Contents

Preface	vii
<i>R. Fries and A. Ruwinsky</i>	
1. Systematics and Phylogeny of Cattle	1
<i>J.A. Lenstra and D.G. Bradley</i>	
2. Genetic Aspects of Domestication	15
<i>D.G. Bradley and E.P. Cunningham</i>	
3. Genetics of Colour Variation	33
<i>T.A. Olson</i>	
4. Genetics of Morphological Traits and Inherited Disorders	55
<i>F.W. Nicholas</i>	
5. Blood Groups and Biochemical Polymorphisms	77
<i>H.C. Hines</i>	
6. The Molecular Genetics of Cattle	123
<i>D. Vaiman</i>	
7. Molecular Genetics of Molecules with Immunological Functions: Major Histocompatibility Complex, Immunoglobulins, T-cell Receptors, Cytokines and their Receptors	163
<i>H.A. Lewin, M. Amills and V.K. Ramiya</i>	
8. Genetics of Disease Resistance	199
<i>A.J. Teale</i>	
9. Molecular Biology and Genetics of Bovine Spongiform Encephalopathy	229
<i>N. Hunter</i>	
10. Cytogenetics and Physical Chromosome Maps	247
<i>R. Fries and P. Popescu</i>	
11. Genetic Linkage Mapping, the Gene Maps of Cattle and the Lists of Loci	329
<i>W. Barendse and R. Fries</i>	
12. Genetics of Behaviour in Cattle	365
<i>D. Buchenauer</i>	

13.	Genetics and Biology of Reproduction in Cattle <i>B.W. Kirkpatrick</i>	391
14.	Reproductive Technologies and Transgenics <i>N.L. First, M. Mitalipova and M. Kent First</i>	411
15.	Developmental Genetics <i>A. Ruvinsky and L.J. Spicer</i>	437
16.	Genetic Resources and Conservation <i>D.L. Simon</i>	475
17.	Marker-assisted Selection <i>M.R. Dentine</i>	497
18.	Genetic Improvement of Dairy Cattle <i>M.E. Goddard and G.R. Wiggans</i>	511
19.	Molecular Genetics of Milk Production <i>W.S. Bawden and K.R. Nicholas</i>	539
20.	Genetic Improvement of Beef Cattle <i>B.P. Kinghorn and G. Simm</i>	577
21.	Genetics of Meat Quality <i>D.M. Marshall</i>	605
22.	Genetic Aspects of Cattle Adaptation in the Tropics <i>S. Newman and S.G. Coffey</i>	637
23.	Standardized Genetic Nomenclature for Cattle <i>C.H.S. Dolling</i>	657
24.	Breeds of Cattle <i>D.S. Buchanan and S.L. Dolezal</i>	667
	Index	697

# *Preface*

Since the time of domestication about 10,000 years ago, cattle have played an increasingly important role in the development of human civilizations around the world. It is not easy to find a country that does not have a more or less significant population of cattle. Certainly, traditions and climatic and economic conditions modify the way cattle are used, bred and kept. However, cattle have always provided essential human requirements, such as food, clothing, draught power, soil improvement and many others, including cultural and religious necessities. The unique features of cattle as ruminants, with their ability to effectively digest rough plant mass, allow cattle to occupy a special ecological position in the human environment. The current number of cattle worldwide exceeds 1200 million and continues to grow.

Cattle are among the largest domesticated species and certainly the process of domestication was a great challenge for neolithic communities. It seems likely that the traction power of the ox in the earliest stages of its domestication marked a turning-point in the development of agriculture. Over time, cow's milk steadily became a staple source of food in many geographical areas. This process is continuing and milk and numerous milk products are spreading into countries where they were not traditional. The total world production of cow's milk was 467 million t in 1997. Another very important product is beef. Worldwide production of beef and veal is approaching 50 million t year<sup>-1</sup>.

Progress in cattle breeding and selection during the last century has been impressive. Breeding programmes based on principles of quantitative genetics, artificial insemination and embryo transfer, as well as the computerization of the industry, are the main reasons for the tremendous intensification in milk production. However, a genomic revolution and biotechnology promise new developments. Just a decade ago, the location of only a few genes on the cattle chromosomes were known. At the time of publication of this book, this number has reached 2200 loci. Previously separated, quantitative and molecular genetics are now taking a united approach to the identification of loci underlying important cattle traits, so called quantitative trait loci (QTL), and

are expected to provide new tools for cattle breeding in the near future. Cloning and other new reproduction technologies will also benefit the cattle industry enormously.

The main purpose of this book is to collect essential data concerning cattle genetics and bring together previously non-united areas of research. The 24 chapters of this book can be partitioned into four sections. The first four chapters cover the systematics and phylogeny of cattle, domestication and factorial genetics. Chapters 5–11 present information about biochemical polymorphism, immunogenetics and disease resistance, genome structure and gene mapping. The third section discusses genetics of reproduction, development and behaviour. Finally, Chapters 16–22 are devoted to genetics applied to cattle improvement. Standard genetic nomenclature for cattle is presented in Chapter 23 and cattle breeds in Chapter 24.

The authors of this book have made every attempt to highlight the most important publications in the area of cattle genetics for the last several decades, with emphasis on the most recent papers, reviews and books. However, we realize that omissions and errors are very difficult to avoid and apologize for possible mistakes. This book is addressed to a broad audience, which includes researchers, lecturers, students, farmers and specialists working in the industry. *The Genetics of Cattle* is the third book in a series of monographs on mammalian genetics published by CAB International. Two other books, *The Genetics of Sheep* (1997) and *The Genetics of the Pig* (1998), are based on similar ideas and structure. *The Genetics of the Horse* will continue this series.

This book is a result of truly international cooperation. Scientists from several European countries, USA and Australia put a lot of effort into this book. The editors are very grateful to all of them. It is our pleasure and debt to thank many people who helped tremendously in reviewing the book: A.J. Ball, J.S.F. Barker, T.K. Bell, A.M. Crawford, M. Enns, I.R. Franklin, D. Gallagher, H.-U. Graser, G.N. Hinch, F. Hughes, J.K. Lunney, C. Moran, L. Piper, B.C. Powell, J.E.O. Rege, H.W. Radsma, G. Rogers, D.P. Sponenberg and P. Wynn.

It is our hope that this book will be useful for many people throughout the world interested in cattle genetics and perhaps will support consolidation and further progress of this field of science.

**Ruedi Fries**  
**Anatoly Ruvinsky**