

Future Developments in the Genetic Improvement of Animals

Edited by

J. S. F. Barker

Keith Hammond

A. E. McClintock

Future Developments in the Genetic Improvement of Animals

Edited by

J. S. F. Barker

Department of Animal Science
University of New England
Armidale N.S.W.

Keith Hammond

Animal Genetics and Breeding Unit
University of New England
Armidale N.S.W.

A. E. McClintock

Animal Genetics and Breeding Unit
University of New England
Armidale N.S.W.

1982



ACADEMIC PRESS

A Subsidiary of Harcourt Brace Jovanovich, Publishers

SYDNEY NEW YORK LONDON

PARIS SAN DIEGO SAN FRANCISCO SAO PAULO TOKYO TORONTO

ACADEMIC PRESS AUSTRALIA
CentreCourt, 25-27 Paul Street North
North Ryde, N.S.W. 2113

United States Edition published by
ACADEMIC PRESS INC.
111 Fifth Avenue
New York, New York 10003

United Kingdom Edition published by
ACADEMIC PRESS, INC. (LONDON) LTD.
24/28 Oval Road, London NW1 7DX

Copyright © 1982 by
ACADEMIC PRESS AUSTRALIA

All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopy, recording, or any information storage and retrieval system, without permission in writing from the publisher.

Printed in Australia

National Library of Australia Cataloguing-in-Publication Data

Future developments in the genetic improvement
of animals.

Bibliography.
Includes index.
ISBN 0 12 078830 6.

I. Breeding. 2. Genetics. I. Barker, J. S. F.
(James Stuart Flint), 1931-. II. Hammond,
Keith, 1942-. III. McClintock, A. E.
(Alexander E.).

636.08'21

Library of Congress Catalog Card Number: 82-71824

Academic Press Rapid Manuscript Reproduction

Contributors

Numbers in parentheses indicate the pages on which the authors' contributions begin.

- Anderson, Robert D. (141), Department of Sheep Husbandry, Massey University, Palmerston North, New Zealand.
- Franklin, I. R. (181), Genetics Research Laboratories, CSIRO, P.O. Box 184, North Ryde, N.S.W. 2113, Australia.
- Gauld, I. K. (59), Animal Breeding Research Organisation, West Mains Road, Edinburgh, EH9 3JQ, U.K.
- Hammond, Keith (197, 215), Animal Genetics and Breeding Unit, University of New England, Armidale, N.S.W. 2351, Australia.
- James, J. W. (107), School of Wool and Pastoral Sciences, University of New South Wales, P.O. Box 1, Kensington, N.S.W. 2033, Australia.
- Jones, L. P. (119), Animal Research Institute, Werribee, Vic. 3030, Australia.
- Land, R. B. (59), Animal Breeding Research Organisation, West Mains Road, Edinburgh, EH9 3JQ, U.K.
- Lee, G. J. (59), Animal Breeding Research Organisation, West Mains Road, Edinburgh, EH9 3JQ, U.K.
- Lindsay, David (89), Department of Animal Science and Production, The University of Western Australia, Nedlands, W.A. 6009, Australia.
- McClintock, A. E. (157, 215), Animal Genetics and Breeding Unit, University of New England, Armidale, N.S.W. 2351, Australia.
- Skjervold, Harald (3), Agricultural University of Norway, Institute of Animal Genetics and Breeding, Box 24, 1432 Ås-NLH, Norway.
- Stear, M. J. (45), Department of Immunology, John Curtin School of Medical Research, Australian National University, Canberra, A.C.T. 2601, Australia.
- Taylor, J. F. (157), Animal Genetics and Breeding Unit, University of New England, Armidale, N.S.W. 2351, Australia.
- Ward, K. A. (17), Division of Animal Production, CSIRO, Ian Clunies Ross Animal Research Laboratory, P.O. Box 239, Blacktown, N.S.W. 2148, Australia.
- Webb, R. (59), Animal Breeding Research Organisation, West Mains Road, Edinburgh, EH9 3JQ, U.K.

Invited Symposium Participants

- Barker, J. S. F., Department of Animal Science, University of New England, Armidale, N.S.W. 2351, Australia.
- Bindon, B. M., CSIRO, Private Mail Bag, Armidale, N.S.W. 2350, Australia.

- Frankham, R., School of Biological Sciences, Macquarie University, North Ryde, N.S.W. 2113, Australia.
- Goddard, M. E., Division of Animal Production; Department of Tropical Veterinary Science, James Cook University, Townsville, Qld. 4811, Australia.
- Graser, H-U., Animal Genetics and Breeding Unit, University of New England, Armidale, N.S.W. 2351, Australia.
- Hancock, T. W., Waite Research Institute, University of Adelaide, Adelaide, S.A. 5000, Australia.
- Hetzel, D. J. S., CSIRO, Private Mail Bag, Armidale, N.S.W. 2350, Australia.
- Lewer, R., Animal Research Institute, Department of Agriculture, Katanning District Office, Katanning, W.A. 6317, Australia.
- McPhee, C. P., Animal Research Institute, Yeerongpilly, Qld. 4105, Australia.
- Piper, L. R., CSIRO, Division of Animal Production, Chiswick, N.S.W. 2350, Australia.
- Rathie, K. A. Dairy Cattle Husbandry Branch, Department of Primary Industries, Brisbane, Qld. 4001, Australia.
- Robinson, G., Division of Dairying, Department of Agriculture, Box 4041, G.P.O., Melbourne, Vic. 3001, Australia.
- Sheldon, B. L., CSIRO, Genetics Research Laboratories, Division of Animal Production, P.O. Box 184, North Ryde, N.S.W. 2113, Australia.
- Sheridan, A. K., Poultry Research Station, P.O. Box 11, Seven Hills, N.S.W. 2147, Australia.
- Wickham, B. W., Farm Production Division, New Zealand Dairy Board, P.O. Box 417, Wellington, New Zealand.
- Yoo, B. H., CSIRO, Genetics Research Laboratories, Division of Animal Production, P.O. Box 184, North Ryde, N.S.W. 2113, Australia.

Preface

The intensive application of genetics in animal breeding dates from only about 40 years ago. Over the last 25 years, there has been increasing application of quantitative genetic theory in animal breeding programs. This has been facilitated by:

- 1 experimental validation of that theory and the translation of the theory in the development of appropriate operational procedures for practical animal breeding programs,
- 2 objective measurement of animal performance, the use of computers in large-scale performance recording programs, the application of artificial insemination in and the development of national or regional dairy cattle breeding programs, and the recognition by the animal industries of the cumulative gains possible from genetic improvement.

At the same time, the science of genetics has developed enormously, and expanded and divided into specialized areas including molecular genetics, immunogenetics, quantitative (or statistical) and population genetics. All of these have implications for and applications in the economic improvement of domestic livestock.

Given the relatively short time-span, the contributions of quantitative genetics to improvement in animal production have been substantial. However, it is apparent that future improvements depend not only on this branch of the science. It seemed appropriate then to bring together ideas from various branches of genetics and to consider them, together with recent developments in reproductive biology and physiology and electronics, so as to provide a perspective of their interrelationships and their possible future development and application in the genetic improvement of animals.

This book consists of the invited papers presented by scientists from New Zealand, Norway, U. K. and Australia, and summaries of discussions at a Symposium held at the University of New England, Armidale in February 1982. The objective of the Symposium was to project, from current knowledge, those areas where the most important developments in the application of genetics and associated disciplines could and should take place. The book thus represents a step towards the necessary integration of these branches of genetics and related disciplines.

The Symposium would not have been possible without the generous financial support of the Australian Meat Research Committee and The Angus Society of

Australia. We wish to thank the contributors for their cooperation and excellent papers, and to acknowledge the enthusiasm, views and ideas of all participants in the Symposium. Our thanks also go to Dorothy Cordingley and Jill Parker for their untiring assistance with the preparation of the final manuscripts and index.

Contents

Contributors and Invited Symposium Participants	ix
---	----

Preface	xi
---------	----

Part 1 A General View of Animal Breeding

1 The Results of 20 Years Selection for Production in Cattle, Sheep and Pigs — Which Way Now?	3
Harald Skjervold	
I A Review of the Past 25 Years	3
II Future Developments	9

Part 2 Molecular Genetics

2 Possible Contributions of Molecular Genetics to Animal Improvement	17
K. A. Ward	
I Introduction	17
II Recent Developments in Molecular Biology	19
III The Structure of Eukaryotic Genes	23
IV Techniques for Gene Transfer	26
V Gene Manipulation and Animal Production	28
VI Gene Manipulation and the Rumen	36
VII Gene Detection and Animal Breeding	37
VIII Conclusion	37
Discussion Summary	44

Part 3 Immunogenetics

3	The Future Role of Immunogenetics in Animal Breeding	45
	M. J. Stear	
I	Breeding for Disease Resistance	45
II	Better Characterisation of Genetic Variation	51
	Discussion Summary	55

Part 4 Reproductive Biology

4	Further Possibilities for Manipulating the Reproductive Process	59
	R. B. Land, I. K. Gauld, G. J. Lee and R. Webb	
I	Introduction	60
II	The Possibilities in 1980	61
III	The Endocrine Control of Ovarian Activity	63
IV	Levels of Measurement	65
V	Studied Physiological Criteria of Ovarian Activity	70
VI	Potential Physiological Criteria	73
VII	Embryo Mortality	77
VIII	Interactions with Health and Growth	79
IX	Strategy	80
5	The Significance of Reproductive Biology to the Genetic Improvement of Farm Animals	89
	David Lindsay	
I	Introduction	90
II	Indirect Responses in Reproduction to Selection for Productivity	91
III	Direct Selection for Reproduction	91
IV	The Future of Breeding for Increased Reproduction	100
	Discussion Summary	103

Part 5 Economic Aspects of Developing Breeding Objectives

6	Economic Aspects of Developing Breeding Objectives: General Considerations	107
	J. W. James	
I	Introduction	107
II	Some Basic Problems	109
III	An Economic Model	112
IV	Separation of Objective and Criteria	113

V	Discounting of Returns and Costs	115
VI	How Detailed Should the Objective Be?	116
VII	Conclusion	117
7	Economic Aspects of Developing Breeding Objectives: A Specific Example; Breeding Objectives for Merino Sheep	119
	L. P. Jones	
I	Introduction	119
II	Static Approach	120
III	Dynamic Approach	129
IV	Treating Feed Consumption as an Objective	131
V	Discussion	132
	Discussion Summary	137

Part 6 Mixed Model Theory

8	The Use of Mixed Model Theory in the Estimation of Parameters	141
	Robert D. Anderson	
I	Introduction	141
II	Notation and Mathematical Preliminaries	143
III	Minimum Variance Quadratic Unbiased Estimators	145
IV	ML-Related Quadratic Estimators	150
V	Résumé of Sections II to IV	152
VI	Considerations for the Future	153
9	Developments in the Use of BLUP for Estimation of Genetic Merit	157
	A. E. McClintock and J. F. Taylor	
I	Introduction	157
II	Sire Groups in Relation to Connectedness	158
III	Connectedness	159
IV	Genetic Bases—Fixed or Rolling?	161
V	Methods of Expressing Genetic Merit and the Amount of Information in an Estimate	162
VI	Environmental Correlations (c^2)	166
VII	Categorical Trait Analysis	166
VIII	Economic Evaluation	167
IX	Preadjustment of Data	167
X	Use of Estimated Population (Co)Variances	168
XI	How to Limit Data Processing	173
XII	Conclusions	174
	Discussion Summary	177

Part 7 Population Size

10	Population Size and the Genetic Improvement of Animals	181
	I. R. Franklin	
	I Introduction	181
	II The Theoretical Basis of Selection Response	182
	III Population Size and Animal Improvement	189
	IV Conclusions	194
11	The Significance for Genetic Improvement of the Number of Individuals Available for Breeding	197
	Keith Hammond	
	I Introduction	197
	II Prediction of Responses	198
	III Recent Developments	201
	IV What is Required?	203
	Discussion Summary	209

Part 8 Electronics

12	Implications of Developments in Engineering and Computing for the Genetic Improvement of Animals	215
	Keith Hammond and A. E. McClintock	
	I Introduction	215
	II Production Operations and Application	217
	III Conclusions	221
	Discussion Summary	223
	Index	225

Future Developments in the Genetic Improvement of Animals

Edited by

J. S. F. Barker

Department of Animal Science
University of New England
Armidale N.S.W.

Keith Hammond

Animal Genetics and Breeding Unit
University of New England
Armidale N.S.W.

A. E. McClintock

Animal Genetics and Breeding Unit
University of New England
Armidale N.S.W.

1982



ACADEMIC PRESS

A Subsidiary of Harcourt Brace Jovanovich, Publishers

SYDNEY NEW YORK LONDON

PARIS SAN DIEGO SAN FRANCISCO SAO PAULO TOKYO TORONTO

ACADEMIC PRESS AUSTRALIA
Centre Court, 25-27 Paul Street North
North Ryde, N.S.W. 2113

United States Edition published by
ACADEMIC PRESS INC.
111 Fifth Avenue
New York, New York 10003

United Kingdom Edition published by
ACADEMIC PRESS, INC. (LONDON) LTD.
24/28 Oval Road, London NW1 7DX

Copyright © 1982 by
ACADEMIC PRESS AUSTRALIA

All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopy, recording, or any information storage and retrieval system, without permission in writing from the publisher.

Printed in Australia

National Library of Australia Cataloguing-in-Publication Data

Future developments in the genetic improvement
of animals.

Bibliography.
Includes index.
ISBN 0 12 078830 6.

I. Breeding. 2. Genetics. I. Barker, J. S. F.
(James Stuart Flint), 1931-. II. Hammond,
Keith, 1942-. III. McClintock, A. E.
(Alexander E.).

636.08'21

Library of Congress Catalog Card Number: 82-71824

Academic Press Rapid Manuscript Reproduction

Part 1

A General View of Animal Breeding

The Results of 20 Years Selection for Production in Cattle, Sheep and Pigs — Which Way Now?

Harald Skjervold

Department of Animal Genetics and Breeding
Agricultural University of Norway
Norway

Research, development and implementation of animal breeding techniques over the past 20 years have given good results. The rate of genetic improvement has increased considerably in all farm species.

Despite this success, optimum rates of improvement are, for different reasons, not yet being realised.

The decisions for increased genetic improvement in the later 1980's are now being implemented, but a biological delay precedes the expression of this.

Technical innovations are being researched and developed for use in increasing genetic improvement. Biophysical profiling, embryo manipulation, genetic engineering, computer tomography and multibreed mating strategies are examples of techniques which may become commonplace before the end of the century.

I A Review of the Past 25 Years

Twenty-five years ago, in the 50th anniversary issue of the Journal of Dairy Science, Jay L. Lush reviewed the improvement which had been made in animal breeding during the previous few decades.

Dr. Lush mentioned the development of biometrical methods, the evaluation of different selection methods, and the

introduction of artificial insemination. He remarked: "Some of the parameters are known only within wide limits, and much is uncertain ... but at least a good beginning has been made."

During the last 25 years, animal genetics and breeding has been very productive. The purpose of this address is to review the major components that have contributed to this great progress in animal breeding. The intention is also to venture some predictions.

A. Developmental Work

During the last two decades, we have witnessed accelerated activity within the field of quantitative genetics. This development is especially pronounced in investigations which are of fundamental interest in the applied field of this science, such as:

(1) Estimation of phenotypic and genetic parameters. As shown in Figure 1, this developmental work exhibits an exponential growth. We know these parameters for an increasing number of traits and for an increasing number of populations and the estimations are based on steadily increasing amounts of data.

(2) The last two decades are also characterised by great improvements in the accuracy of estimation of breeding values. Progress is notable in methods of progeny testing bulls, boars and rams. The key-word in this connection is BLUP (Best Linear Unbiased Prediction).

(3) Much work has been done in developing effective selection indices which can be directly applied in practice.

(4) Since the late 50's, the development of integrated breeding schemes has begun. This synthesis of different elements within quantitative genetics has gradually resulted in more efficient breeding strategies being put into use.

B. The Computer

The computer revolution has passed through a handful of "generations" of equipment in the past 20 years, and the rate of change does not seem to decrease.

Thanks to the development of the computer, it has been possible to conduct the enormous quantity of developmental work mentioned above. Without the use of computers, it seems unlikely that quantitative genetics really could have been introduced into animal breeding in the way it has been.

Without computers and with the cost of labour today, it would be impossible to estimate all the parameters and calculate the selection indices, etc. on which animal breeding is based today.

The computer has made it possible to use sophisticated statistical models and to store and utilise all relevant information when evaluating breeding values. Sophisticated evaluations of sires and dams are now possible using BLUP. Thanks to the computer, it has also been possible to practise selection among females based on breeding indices (cow index, sow index and ewe index). Further, all relevant data for each female can be stored in a data bank to have an up-to-date "account" for each animal.

Apart from packaged statistical programs, many other opportunities for aiding research have come about because of progress in computer science. Various aspects of simulation and systems analysis have been useful in different branches of animal science. Such simulations have been very useful in the development of integrated breeding schemes.

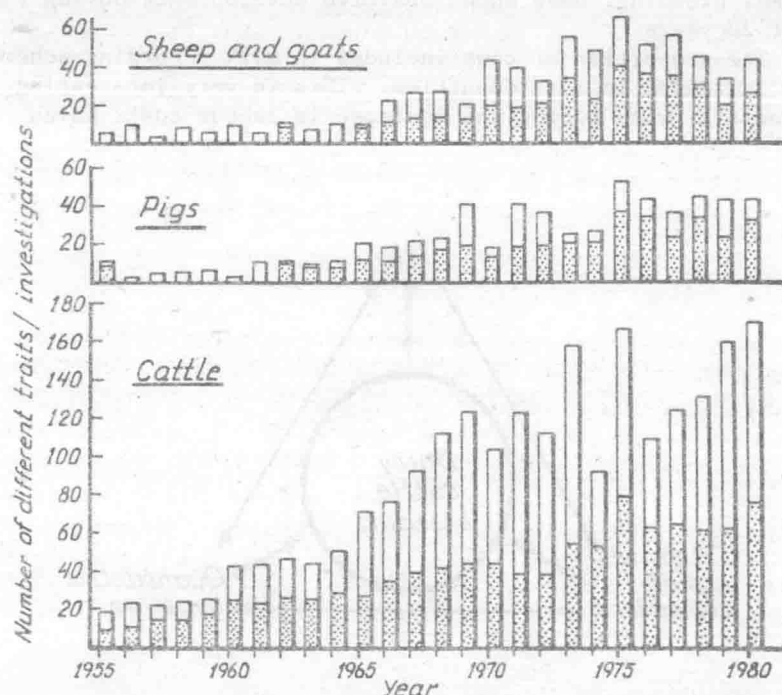


FIGURE 1. Number of publications concerning estimation of heritability 1955-80.

C. The Development of Artificial Insemination

Parallel to the development of applied quantitative genetics we have witnessed a large expansion in AI during the 60's and 70's. Twenty years ago AI was in its "teens" in most countries. During the last two decades AI has become the most important mating method and, moreover, it has given cattle breeding a new dimension (Fig. 2). Its importance in cattle breeding has been further emphasised by the introduction of deep frozen semen.

During the last 20 years AI also has been introduced into pig breeding and in some countries more than half of the services are covered by AI. However, this method has not yet contributed very much to genetic improvement as cryopreservation of semen has not been successful in the pig.

D. Recording Schemes

Recording schemes, which greatly influence the results of animal breeding, have shown positive developments during the last 20 years.

The proportion of cows included in milk recording schemes has increased in most countries. This is very interesting especially when noting the increase in labour costs which

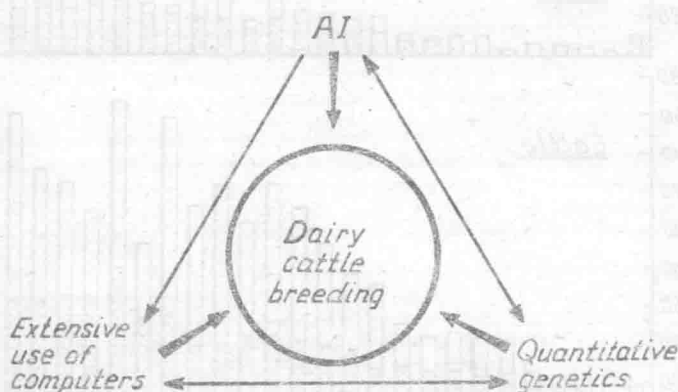


FIGURE 2. Dairy cattle breeding today is a synthesis of artificial insemination, quantitative genetics and extensive use of computers.