

Introduction To Quantitative Genetics By Falconer Mackay

Maize is used in an endless list of products that are directly or indirectly related to human nutrition and food security. Maize is grown in producer farms, farmers depend on genetically improved cultivars, and maize breeders develop improved maize cultivars for farmers. Nikolai I. Vavilov defined plant breeding as plant evolution directed by man. Among crops, maize is one of the most successful examples for breeder-directed evolution. Maize is a cross-pollinated species with unique and separate male and female organs allowing techniques from both self and cross-pollinated crops to be utilized. As a consequence, a diverse set of breeding methods can be utilized for the development of various maize cultivar types for all economic conditions (e.g., improved populations, inbred lines, and their hybrids for different types of markets). Maize breeding is the science of maize cultivar development. Public investment in maize breeding from 1865 to 1996 was \$3 billion (Crosbie et al., 2004) and the return on investment was \$260 billion as a consequence of applied maize breeding, even without full understanding of the genetic basis of heterosis. The principles of quantitative genetics have been successfully applied by maize breeders worldwide to adapt and improve germplasm sources of cultivars for very simple traits (e.g. maize flowering) and very complex ones (e.g., grain yield). For instance, genomic efforts have isolated early-maturing genes and QTL for potential MAS but very simple and low cost phenotypic efforts have caused significant and fast genetic progress across genotypes moving elite tropical and late temperate maize northward with minimal investment. Quantitative genetics has allowed the integration of pre-breeding with cultivar

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development by characterizing populations genetically, adapting them to places never thought of (e.g., tropical to short-seasons), improving them by all sorts of intra- and inter-population recurrent selection methods, extracting lines with more probability of success, and exploiting inbreeding and heterosis. Quantitative genetics in maize breeding has improved the odds of developing outstanding maize cultivars from genetically broad based improved populations such as B73. The inbred-hybrid concept in maize was a public sector invention 100 years ago and it is still considered one of the greatest achievements in plant breeding. Maize hybrids grown by farmers today are still produced following this methodology and there is still no limit to genetic improvement when most genes are targeted in the breeding process. Heterotic effects are unique for each hybrid and exotic genetic materials (e.g., tropical, early maturing) carry useful alleles for complex traits not present in the B73 genome just sequenced while increasing the genetic diversity of U.S. hybrids. Breeding programs based on classical quantitative genetics and selection methods will be the basis for proving theoretical approaches on breeding plans based on molecular markers. Mating designs still offer large sample sizes when compared to QTL approaches and there is still a need to successful integration of these methods. There is a need to increase the genetic diversity of maize hybrids available in the market (e.g., there is a need to increase the number of early maturing testers in the northern U.S.). Public programs can still develop new and genetically diverse products not available in industry. However, public U.S. maize breeding programs have either been discontinued or are eroding because of decreasing state and federal funding toward basic science. Future significant genetic gains in maize are dependent on the incorporation of useful and unique genetic diversity not available in industry (e.g., NDSU EarlyGEM

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lines). The integration of pre-breeding methods with cultivar development should enhance future breeding efforts to maintain active public breeding programs not only adapting and improving genetically broad-based germplasm but also developing unique products and training the next generation of maize breeders producing research dissertations directly linked to breeding programs. This is especially important in areas where commercial hybrids are not locally bred. More than ever public and private institutions are encouraged to cooperate in order to share breeding rights, research goals, winter nurseries, managed stress environments, and latest technology for the benefit of producing the best possible hybrids for farmers with the least cost. We have the opportunity to link both classical and modern technology for the benefit of breeding in close cooperation with industry without the need for investing in academic labs and time (e.g., industry labs take a week vs months/years in academic labs for the same work). This volume, as part of the Handbook of Plant Breeding series, aims to increase awareness of the relative value and impact of maize breeding for food, feed, and fuel security. Without breeding programs continuously developing improved germplasm, no technology can develop improved cultivars. Quantitative Genetics in Maize Breeding presents principles and data that can be applied to maximize genetic improvement of germplasm and develop superior genotypes in different crops. The topics included should be of interest of graduate students and breeders conducting research not only on breeding and selection methods but also developing pure lines and hybrid cultivars in crop species. This volume is a unique and permanent contribution to breeders, geneticists, students, policy makers, and land-grant institutions still promoting quality research in applied plant breeding as opposed to promoting grant monies and indirect costs at any short-term

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cost. The book is dedicated to those who envision the development of the next generation of cultivars with less need of water and inputs, with better nutrition; and with higher percentages of exotic germplasm as well as those that pursue independent research goals before searching for funding. Scientists are encouraged to use all possible breeding methodologies available (e.g., transgenics, classical breeding, MAS, and all possible combinations could be used with specific sound long and short-term goals on mind) once germplasm is chosen making wise decisions with proven and scientifically sound technologies for assisting current breeding efforts depending on the particular trait under selection. Arnel R. Hallauer is C. F. Curtiss Distinguished Professor in Agriculture (Emeritus) at Iowa State University (ISU). Dr. Hallauer has led maize-breeding research for mid-season maturity at ISU since 1958. His work has had a worldwide impact on plant-breeding programs, industry, and students and was named a member of the National Academy of Sciences. Hallauer is a native of Kansas, USA. José B. Miranda Filho is full-professor in the Department of Genetics, Escola Superior de Agricultura Luiz de Queiroz - University of São Paulo located at Piracicaba, Brazil. His research interests have emphasized development of quantitative genetic theory and its application to maize breeding. Miranda Filho is native of Pirassununga, São Paulo, Brazil. M.J. Carena is professor of plant sciences at North Dakota State University (NDSU). Dr. Carena has led maize-breeding research for short-season maturity at NDSU since 1999. This program is currently one the of the few public U.S. programs left integrating pre-breeding with cultivar development and training in applied maize breeding. He teaches Quantitative Genetics and Crop Breeding Techniques at NDSU. Carena is a native of Buenos Aires, Argentina.

<http://www.ag.ndsu.nodak.edu/plantsci/faculty/Carena.htm>

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The impetus for this book arose out of my previous book, *The Evolution of Life Histories* (Roff, 1992). In that book I presented a single chapter on quantitative genetic theory. However, as the book was concerned with the evolution of life histories and traits connected to this, the presence of quantitative genetic variation was an underlying theme throughout. Much of the focus was placed on optimality theory, for it is this approach that has proven to be extremely successful in the analysis of life history variation. But quantitative genetics cannot be ignored, because there are some questions for which optimality approaches are inappropriate; for example, although optimality modeling can address the question of the maintenance of phenotypic variation, it cannot say anything about genetic variation, on which further evolution clearly depends. The present book is, thus, a natural extension of the first. I have approached the problem not from the point of view of an animal or plant breeder but from that of one interested in understanding the evolution of quantitative traits in wild populations. The subject is large with a considerable body of theory: I generally present the assumptions underlying the analysis and the results, giving the relevant references for those interested in the intervening mathematics. My interest is in what quantitative genetics tells me about evolutionary processes; therefore, I have concentrated on areas of research most relevant to field studies.

An up-to-date, accessible guide to the main concepts and applications of quantitative genetics.

The latest edition of this classic text continues to provide the basis for understanding the genetic principles behind quantitative differences in phenotypes and how they apply to animal and plant improvement and evolution. It extends these concepts to the segregation of genes that cause genetic variation in quantitative traits. Key techniques and methods

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are also covered.

Across these fields, there is increasing appreciation of the need to quantify the genetic - rather than just the phenotypic - basis and diversity of key traits, the genetic basis of the associations between traits, and the interaction between these genetic effects and the environment. This research activity has been fuelled by methodological advances in both molecular genetics and statistics, as well as by exciting results emerging from laboratory studies of evolutionary quantitative genetics, and the increasing availability of suitable long-term datasets collected in natural populations, especially in animals. *Quantitative Genetics in the Wild* is the first book to synthesize the current level of knowledge in this exciting and rapidly-expanding area.

This text provides a guide to the experimental and analytical methodologies available to study quantitative traits, a review of the genetic control of quantitative traits, and a discussion of how this knowledge can be applied to breeding problems and evolution.

Taken together, these studies document both the benefits and pitfalls of quantitative genetics.

Introduction to Quantitative Genetics Longman Scientific and Technical

A comprehensive introduction to modern applied statistical genetic data analysis, accessible to those without a background in molecular biology or genetics. Human genetic research is now relevant beyond biology, epidemiology, and the medical sciences, with applications in such fields as psychology, psychiatry, statistics, demography, sociology, and economics. With advances in computing power, the availability of data, and new techniques, it is now possible to integrate large-scale molecular genetic information into research across

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a broad range of topics. This book offers the first comprehensive introduction to modern applied statistical genetic data analysis that covers theory, data preparation, and analysis of molecular genetic data, with hands-on computer exercises. It is accessible to students and researchers in any empirically oriented medical, biological, or social science discipline; a background in molecular biology or genetics is not required. The book first provides foundations for statistical genetic data analysis, including a survey of fundamental concepts, primers on statistics and human evolution, and an introduction to polygenic scores. It then covers the practicalities of working with genetic data, discussing such topics as analytical challenges and data management. Finally, the book presents applications and advanced topics, including polygenic score and gene-environment interaction applications, Mendelian Randomization and instrumental variables, and ethical issues. The software and data used in the book are freely available and can be found on the book's website.

Genetic constitution of a population; Changes of gene frequency; Small populations: I. Changes of genes frequency under simplified conditions, II. Less simplified conditions, III. Pedigreed populations and close inbreeding; Continuous variation; Values and means; Variance; Resemblance between relatives; Heritability; Selection: I. The response and its prediction, II. The results of experiments, III. Information from relatives; Inbreeding and crossbreeding: I. Changes of mean value, II. Changes of variance, III. The utilisation of heterosis; Scale; Threshold characters; Correlated

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characters; Metric characters under natural selection. The concepts of veterinary genetics are crucial to understanding and controlling many diseases and disorders in animals. They are also crucial to enhancing animal production. Accessible and clearly presented, *Introduction to Veterinary Genetics* provides a succinct introduction to the aspects of genetics relevant to animal diseases and production. Now in its third edition, this is the only introductory level textbook on genetics that has been written specifically for veterinary and animal science students. Coverage includes: basic genetics, molecular biology, genomics, cytogenetics, immunogenetics, population genetics, quantitative genetics, biotechnology, and the use of molecular tools in the control of inherited disorders. This book describes in detail how genetics is being applied to artificial selection in animal production. It also covers the conservation of genetic diversity in both domesticated and wild animals. New for the Third Edition: End-of-chapter summaries provide quick recaps. Covers new topics: epigenetics, genomics and bioinformatics. Thoroughly revised according to recent advances in genetics. *Introduction to Veterinary Genetics* is still the only introductory genetics textbook for students of veterinary and animal science and will continue to be an indispensable reference tool for veterinary students and practitioners alike.

Population genetics is an inherently quantitative discipline, yet often focuses upon abstract concepts which can be difficult to conceptualize and appropriately visualize at first glance. This book focuses on applying

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the hugely popular R software specifically to the field, offering an accessible, step-by-step guide to tackling the challenges of achieving effective data interpretation and summary. The authors adopt an engaging "learning by doing" approach that will enable readers to develop an intuitive understanding of key population genetics concepts through the use of R. Beginning with the groundwork of installing and using R (including CRAN and the RStudio IDE), the book works through the use of basic commands for data manipulation. An introduction to basic terminology in population genetics follows, clearly explaining how these fundamental assumptions can provide insights and form basic inferences for real populations. The focus then moves onto statistical tests including writing and running algorithms as functions. Subsequent chapters examine genetic variation, adaptation, and natural selection as well as different approaches to population differences. Importantly, the accompanying set of practical exercises demonstrate that implementing all of these concepts via programming can actually help greatly in understanding them, even if they may at first seem insurmountably complex. Finally, this accessible textbook points the way forwards to other key concepts that are important to understanding modern day population genetics research (in particular coalescent theory) and offers the reader useful launching points for further learning. Population Genetics with R is aimed at students ranging from undergraduate to postgraduate level in the fields of population genetics, ecology, evolutionary biology, conservation genetics, computational biology, and biostatistics.

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"A text for a one-semester course in population genetics. It introduces students to classical population genetics (in terms of allele and haplotype frequencies) and modern population genetics (in terms of coalescent theory). It presents numerous applications of population genetic methods to practical problems, including testing for natural selection, detecting genetic hitchhiking and inferring the history of populations"--Provided by publisher.

Updated to include two new chapters, a modified Part II structure, more recent empirical examples, and online spreadsheet simulations.

This book covers those areas of theoretical population genetics that can be investigated rigorously by elementary mathematical methods. I have tried to formulate the various models fairly generally and to state the biological assumptions quite explicitly. I hope the choice and treatment of topics will enable the reader to understand and evaluate detailed analyses of many specific models and applications in the literature. Models in population genetics are highly idealized, often even over idealized, and their connection with observation is frequently remote. Furthermore, it is not practicable to measure the parameters and variables in these models with high accuracy. These regrettable circumstances amply justify the use of appropriate, lucid, and rigorous approximations in the analysis of our models, and such approximations are often illuminating even when exact solutions are available. However, our empirical and theoretical limitations justify neither opaque, incomplete formulations nor unconvincing, inadequate analyses, for these may produce uninterpretable, misleading, or erroneous results. Intuition is a principal source of ideas for the construction and investigation of models, but it can replace neither clear formulation nor

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careful analysis. Fisher (1930; 1958, pp. x, 23-24, 38) not only espoused similar ideas, but he recognized also that our concepts of intuition and rigor must evolve in time. The book is neither a review of the literature nor a compendium of results. The material is almost entirely self-contained. The first eight chapters are a thoroughly revised and greatly extended version of my published lecture notes (Nagylaki, 1977a).

The advances made possible by the development of molecular techniques have in recent years revolutionized quantitative genetics and its relevance for population genetics. Population Genetics and Microevolutionary Theory takes a modern approach to population genetics, incorporating modern molecular biology, species-level evolutionary biology, and a thorough acknowledgment of quantitative genetics as the theoretical basis for population genetics. Logically organized into three main sections on population structure and history, genotype-phenotype interactions, and selection/adaptation Extensive use of real examples to illustrate concepts Written in a clear and accessible manner and devoid of complex mathematical equations Includes the author's introduction to background material as well as a conclusion for a handy overview of the field and its modern applications Each chapter ends with a set of review questions and answers Offers helpful general references and Internet links

This concise introduction addresses the theories behind population genetics and relevant empirical evidence, genetic drift, natural selection, nonrandom mating, quantitative genetics, and the evolutionary advantage of sex.

Professors Lynch and Walsh bring together the diverse array of theoretical and empirical applications of quantitative genetics in a work that is comprehensive and accessible to anyone with a rudimentary understanding of statistics and

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genetics.

Quantitative traits—be they morphological or physiological characters, aspects of behavior, or genome-level features such as the amount of RNA or protein expression for a specific gene—usually show considerable variation within and among populations. Quantitative genetics, also referred to as the genetics of complex traits, is the study of such characters and is based on mathematical models of evolution in which many genes influence the trait and in which non-genetic factors may also be important. *Evolution and Selection of Quantitative Traits* presents a holistic treatment of the subject, showing the interplay between theory and data with extensive discussions on statistical issues relating to the estimation of the biologically relevant parameters for these models.

Quantitative genetics is viewed as the bridge between complex mathematical models of trait evolution and real-world data, and the authors have clearly framed their treatment as such. This is the second volume in a planned trilogy that summarizes the modern field of quantitative genetics, informed by empirical observations from wide-ranging fields (agriculture, evolution, ecology, and human biology) as well as population genetics, statistical theory, mathematical modeling, genetics, and genomics. Whilst volume 1 (1998) dealt with the genetics of such traits, the main focus of volume 2 is on their evolution, with a special emphasis on detecting selection (ranging from the use of genomic and historical data through to ecological field data) and examining its consequences.

This edition has been revised to take account of the fact that quantitative genetics is merging with molecular genetics. Accordingly, a new chapter has been added on quantitative trait loci (QTLs).

Genomics, the mapping of the entire genetic complement of an organism, is the new frontier in biology. This handbook on

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the statistical issues of genomics covers current methods and the tried-and-true classical approaches.

"Animal genetics is a central topic in upper-level animal science programs. Filling a void in existing literature on animal science, Animal Genetics introduces genetic principles and presents their application in production and companion animals. The book details population and quantitative genetics, epigenetics, biotechnology, and breeding among other topics. Useful in upper-level studies, Animal Genetics is an irreplaceable educational resource"--Provided by publisher.

The revised edition of the bestselling textbook, covering both classical and molecular plant breeding Principles of Plant Genetics and Breeding integrates theory and practice to provide an insightful examination of the fundamental principles and advanced techniques of modern plant breeding. Combining both classical and molecular tools, this comprehensive textbook describes the multidisciplinary strategies used to produce new varieties of crops and plants, particularly in response to the increasing demands to of growing populations. Illustrated chapters cover a wide range of topics, including plant reproductive systems, germplasm for breeding, molecular breeding, the common objectives of plant breeders, marketing and societal issues, and more. Now in its third edition, this essential textbook contains extensively revised content that reflects recent advances and current practices. Substantial updates have been made to its molecular genetics and breeding sections, including discussions of new breeding techniques such as zinc finger nuclease, oligonucleotide directed mutagenesis, RNA-dependent DNA methylation, reverse breeding, genome editing, and others. A new table enables efficient comparison of an expanded list of molecular markers, including Allozyme, RFLPs, RAPD, SSR, ISSR, DAMD, AFLP, SNPs and ESTs.

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Also, new and updated “Industry Highlights” sections provide examples of the practical application of plant breeding methods to real-world problems. This new edition: Organizes topics to reflect the stages of an actual breeding project Incorporates the most recent technologies in the field, such as CRISPR genome editing and grafting on GM stock Includes numerous illustrations and end-of-chapter self-assessment questions, key references, suggested readings, and links to relevant websites Features a companion website containing additional artwork and instructor resources Principles of Plant Genetics and Breeding offers researchers and professionals an invaluable resource and remains the ideal textbook for advanced undergraduates and graduates in plant science, particularly those studying plant breeding, biotechnology, and genetics.

This impressive author team brings the wealth of advances in conservation genetics into the new edition of this introductory text, including new chapters on population genomics and genetic issues in introduced and invasive species. They continue the strong learning features for students - main points in the margin, chapter summaries, vital support with the mathematics, and further reading - and now guide the reader to software and databases. Many new references reflect the expansion of this field. With examples from mammals, birds,...

Making the theory of population genetics relevant to readers, this book explains the related mathematics with a logical organization. It presents the quantitative aspects of population genetics, and employs examples of human genetics, medical evolution, human evolution, and endangered species. For an introduction to, and understanding of, population genetics.

Learn the data skills necessary for turning large sequencing datasets into reproducible and robust biological findings. With

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this practical guide, you'll learn how to use freely available open source tools to extract meaning from large complex biological data sets. At no other point in human history has our ability to understand life's complexities been so dependent on our skills to work with and analyze data. This intermediate-level book teaches the general computational and data skills you need to analyze biological data. If you have experience with a scripting language like Python, you're ready to get started. Go from handling small problems with messy scripts to tackling large problems with clever methods and tools Process bioinformatics data with powerful Unix pipelines and data tools Learn how to use exploratory data analysis techniques in the R language Use efficient methods to work with genomic range data and range operations Work with common genomics data file formats like FASTA, FASTQ, SAM, and BAM Manage your bioinformatics project with the Git version control system Tackle tedious data processing tasks with with Bash scripts and Makefiles

Statistical genomics is a rapidly developing field, with more and more people involved in this area. However, a lack of synthetic reference books and textbooks in statistical genomics has become a major hurdle on the development of the field. Although many books have been published recently in bioinformatics, most of them emphasize DNA sequence analysis under a deterministic approach. Principles of Statistical Genomics synthesizes the state-of-the-art statistical methodologies (stochastic approaches) applied to genome study. It facilitates understanding of the statistical models and methods behind the major bioinformatics software packages, which will help researchers choose the optimal algorithm to analyze their data and better interpret the results of their analyses. Understanding existing statistical models and algorithms assists researchers to develop improved statistical methods to extract maximum information

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from their data. Resourceful and easy to use, Principles of Statistical Genomics is a comprehensive reference for researchers and graduate students studying statistical genomics.

This book fills the gap between textbooks of quantitative genetic theory, and software manuals that provide details on analytical methods but little context or perspective on which methods may be most appropriate for a particular application. Accordingly this book is composed of two sections. The first section (Chapters 1 to 8) covers topics of classical phenotypic data analysis for prediction of breeding values in animal and plant breeding programs. In the second section (Chapters 9 to 13) we provide the concept and overall review of available tools for using DNA markers for predictions of genetic merits in breeding populations. With advances in DNA sequencing technologies, genomic data, especially single nucleotide polymorphism (SNP) markers, have become available for animal and plant breeding programs in recent years. Analysis of DNA markers for prediction of genetic merit is a relatively new and active research area. The algorithms and software to implement these algorithms are changing rapidly. This section represents state-of-the-art knowledge on the tools and technologies available for genetic analysis of plants and animals. However, readers should be aware that the methods or statistical packages covered here may not be available or they might be out of date in a few years. Ultimately the book is intended for professional breeders interested in utilizing these tools and approaches in their breeding programs. Lastly, we anticipate the usage of this volume for advanced level graduate courses in agricultural and breeding courses. The new edition of *Introducing Genetics* is a clear, concise, and accessible guide to inheritance and variation in individuals and populations. It first

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establishes the principles of Mendelian inheritance and the nature of chromosomes, before tackling quantitative and population genetics. The final three chapters introduce the molecular mechanisms t

"It is close to being a masterpiece...could well be the classic presentation of the area." Warren J. Ewens, University of Pennsylvania, USA Population genetics is concerned with the study of the genetic, ecological, and evolutionary factors that influence and change the genetic composition of populations. The emphasis here is on models that have a direct bearing on evolutionary quantitative genetics. Applications concerning the maintenance of genetic variation in quantitative traits and their dynamics under selection are treated in detail. *

Provides a unified, self-contained and in-depth study of the theory of multilocus systems * Introduces the basic population-genetic models * Explores the dynamical and equilibrium properties of the distribution of quantitative traits under selection * Summarizes important results from more demanding sections in a comprehensible way * Employs a clear and logical presentation style

Following an introduction to elementary population genetics and discussion of the general theory of selection at two or more loci, the author considers a number of mutation-selection models, and derives the dynamical equations for polygenic traits under general selective regimes. The final chapters are concerned with the maintenance of quantitative-genetic variation, the response to directional selection, the evolutionary role of deleterious mutations, and other topics. Graduate students and researchers in population genetics,

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evolutionary theory, and biomathematics will benefit from the in-depth coverage. This text will make an excellent reference volume for the fields of quantitative genetics, population and theoretical biology.

This book introduces the basic concepts and methods that are useful in the statistical analysis and modeling of the DNA-based marker and phenotypic data that arise in agriculture, forestry, experimental biology, and other fields. It concentrates on the linkage analysis of markers, map construction and quantitative trait locus (QTL) mapping, and assumes a background in regression analysis and maximum likelihood approaches. The strength of this book lies in the construction of general models and algorithms for linkage analysis, as well as in QTL mapping in any kind of crossed pedigrees initiated with inbred lines of crops.

The prediction of producing desirable traits in offspring such as increased growth rate, or superior meat, milk and wool production is a vital economic tool to the animal scientist. Summarising the latest developments in genomics relating to animal breeding values and design of breeding programmes, this new edition includes models of survival analysis, social interaction and sire and dam models, as well as advancements in the use of SNPs in the computation of genomic breeding values.

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