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Genetic Engineering of Livestock Improvement

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GENETIC ENGINEERING OF LIVESTOCK IMPROVEMENT

Gordon E. Dickerson*, U.S.A.

SUMMARY

Genetic engineering requires clearly defined objectives, adequate genetic variability and effective methods of selection. In a given production-marketing system, relative importance of genetic change in alternative traits can be estimated from expected effects on cost per unit of output, using available biological and economic information. Diversity among existing breeds and their crosses is a primary and quickly usable genetic resource, and its management for future needs is a public concern. Better physiological and biochemical understanding of the genetic controls of animal development and function is important to permit more effective selection for efficiency of animal production under diverse environments. Long-term selection experiments indicate gene numbers, limits of response, the role of natural mutations and pleiotropic associations among traits. New reproductive technology permits more intense selection among females and promises effective new nuclear breeding systems. New techniques for manipulating bits of DNA also stimulate many questions about potential applications in animal breeding. All of the above, provide background for critical evaluation of industry breeding programs, which also involves educational and organizational efforts. Contributions from all specialties within the animal breeding fraternity, as well as from our colleagues in related disciplines, are needed for continued progress in livestock improvement.

WELCOME

In these days of continuing international rivalry, it is a special privilege for the staff of The Meat Animal Research Center and of the Animal Science Department of the University to host an international scientific organization dedicated to cooperation in research and education and focused on increasing the availability and affordability of high quality food and fiber products from domestic animals throughout the world.

We cannot hope to match the programming or the hospitality we have experienced at the earlier Madrid Congresses and at those on Sheep and Beef Cattle Breeding in New Zealand and South Africa. But, we are grateful for the fine pattern you have set for us and for the wholehearted cooperation we have received from you in the planning of this Congress. We are mindful of the financial burden for overseas participants and have attempted to keep attendance costs low.

As we begin, I would like to share a bit of the philosophy that has guided us in developing the Technical Program for this Congress. In this process, suggestions from members of the International Committee, as well as from many key representatives of countries around the world, have been most helpful.

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GENETIC ENGINEERING

Engineering involves architecture, materials and methodology. Genetic engineering requires defined phenotypic goals, suitable genetic and environmental variability and effective tools to produce the desired changes in genotype and environment. In wild animals, the phenotypic goal is reproductive fitness, genetic variability is that between and within species, and the environmental effects on survival and reproduction direct adaptive genotypic change. In domesticated animals, man modifies the phenotypic goals, changes the environment greatly, and also can increase the accuracy and intensity, and thus the effectiveness, of selection for the desired genetic change.

Recently, the term "genetic engineering" has been used widely, but loosely, to describe direct manipulation of DNA fragments. Such manipulation becomes "engineering" only to the extent that it can produce phenotypic changes in a desired direction. Thus direct DNA manipulation is simply another potential tool for creating genetic change in phenotypic expression. Its utility will be determined by its effectiveness in producing desired <u>phenotypic</u> change relative to methods of selection based directly upon the phenotypic expression of genotype. Both approaches rely heavily upon the degree of association between phenotype and genotype. Several papers in this Congress should help to clarify the potential role of DNA manipulation in the genetic engineering of livestock improvement.

LIVESTOCK IMPROVEMENT

"Livestock improvement" is as old as the domestication of animals. Man has only extended nature's genetic molding of adaptation to environment in directions more useful or pleasing to the human family. As geneticists, we have developed increasingly effective statistical and biological tools for accelerating any desired genetic changes but we have been a bit slow to clarify the kinds of possible genetic changes in livestock species which would be most meaningful for biological and economic efficiency of animal production.

Perhaps we should not be too critical of the emphasis placed by earlier breeders on pleasing color patterns, horns, and beauty of conformation. Such intangible esthetic rewards for the breeders' efforts are not as easily snatched away by the unfeeling laws of supply and demand, as are the returns from increased efficiency of production. However, to the extent that our role is to help reduce costs of animal products to consumers, and to thus maintain or increase markets for livestock producers, we do need to focus on those genetic changes in form and function that are most relevant.

Any serious attempt to evaluate potential effects of alternative genetic changes in performance must include both biological and economic input as well as output, and also consider the effects of likely limitations on input. Much of the potential improvement of animal efficiency comes from using more input per animal to spread large maintenance and other relatively fixed costs over more units of output. Predicting such genetic effects on input/output requires use of much accumulated information on the components of animal production systems: energy metabolism, nutrition; reproductive, environmental and general physiology; meats; economics; and management. Such use of simulated production systems is a "presumptious" task for animal breeders, but it is possible with the collaboration of colleagues in these related disciplines. After all, the livestock

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producer must integrate information from these diverse disciplines, so we need to approach genetic improvement in a similar realistic manner.

The initial sessions of this Congress on the Economic Evaluation of Breeding Objectives were planned to review the current status of this basic step for each of the major livestock species.

GENETIC DIVERSITY

Animal breeders have always recognized the importance of breed differences-witness the enormous literature on this subject. However, in the last few decades, we have developed greater precision in describing the components of individual, maternal and paternal average and heterosis effects of breeds in crosses. Also under evaluation is the adequacy of a purely additive plus dominance model in predicting results for alternative crossbreeding systems from breed composition and the expected retention of the F_1 increase in heterozygosity.

The justification of so much research on use of breed differences is their great magnitude and accuracy for selecting among alternative breeds and crossing systems to accomplish quick adaptation to particular production marketing systems. The alternative of achieving comparable genetic change from selection within breeds is simply too slow and expensive to warrant consideration.

What then is the essential role of within-breed slection? Surely it must be primarily to improve existing or new composite breeds beyond the limits of the better crosses of existing breeds in those functional traits that are important for further gains in productive efficiency. Some examples might be disease and parasite resistance, twinning or litter size in maternal breeds of cattle, sheep and swine, further increases in leanness and meat quality of market animals in all meat species, and even in maternal stocks of swine and poultry. Appropriate simulation of alternative industry production and breeding systems can be used to identify the most promising directions. Progress in these areas is reported in the Congress sessions on Use of Breed Resources and on Design of Breeding Programs.

Inadequate evaluation of breed or cross adaptation to present, and especially to future production environments, can jeopardize the availability of genetic resources to meet future needs. How can we manage the preservation of those genetic resources likely to be important for future livestock production? This difficult question has been studied and discussed for several decades at earlier Congresses, in many FAO sponsored Workshops and in other national and international meetings. The search for workable and affordable approaches is intensifying, and progress is summarized in sessions of this Congress.

GENETIC CONTROL OF ANIMAL PERFORMANCE

Meaningful genetic improvement in the efficiency of animal production systems certainly involves genetic changes in a number of different but interrelated physiological systems. Each of the major developmental or functional traits is composed of a number of measurable component traits, even ignoring the underlying physiological mechanisms, and their genic controls. There is always the probability that a better understanding of the genetic components of major traits and their inter relationships under varying environments may permit more effective selection for the desired genetic changes. Examples are ovulation rate and embryo survival for litter size; also protein and fat deposition, basal metabolism and energy requirements for gain in body weight. Immune systems or cellular and phagocytic resistance to infectious diseases may be very important for the difficult task of increasing genetic resistance to "lowly heritable" diseases. The genetics of physiological adaptation to diverse environments is especially important in tropical areas and for species maintained with minimal protection from environmental extremes.

Better understanding of the underlying physiological and biochemical pathways controlling economically important functional traits is especially important for any hope of selecting directly for a desired DNA code, instead of relying on associations between restriction fragment markers and phenotypic variation. Several major sessions of the Congress are devoted to the Genetics of Reproduction, Lactation, Growth, Resistance to Disease and Parasites and Adaptation to Environments.

The limits for genetic change and the possible role of natural mutation in sustaining genetic variability are beyond the time span of most experiments with the larger domestic animals, but fortunately much has been learned from long term experiments with rapidly reproducing laboratory species. However, some of the longer-term controlled selection experiments with poultry, and even with swine and sheep, do provide valuable evidence concerning both sustained response and realized correlations among traits and with reproductive fitness. Both laboratory and domestic animal selection experiments are reviewed in Congress sessions.

ACCURACY AND INTENSITY OF SELECTION

Improvements in the accuracy of selection, by using information on relatives to minimize environmental error in estimating breeding values from field data, has been a major contribution of quantitative animal breeders to the potential rate of genetic change in livestock populations. Given "the right load and a sophisticated driver, these statistical horses" can speed genetic improvement more than ever before. However, the reproductive technique of artificial insemination and semen storage has been a major factor permitting more accurate estimation of breeding values and much more intense selection of sires as well. Now additional reproductive technologies, such as induced multiple ovulation, embryo transer and splitting, are promising further major increases of selection intensity among females in cattle, and a greater possible role for industry nucleus breeding programs as opposed to the current field AI-progeny test programs. Even cloning of adult animals and sperm sorting to control sex of offspring might be around the next corner. Two Congress sessions examine the sure and the potential factors affecting accuracy and intensity of selection.

DIRECT CHROMOSOMAL (DNA) SELECTION

No Congress on livestock improvement would be complete today without careful examination of the potential applications of gene transfer technology. Dairy cattle breeders must be wondering if their massive data processing efforts are to

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be replaced by metered hormonal infusions merchandized by the drug industry! Application of gene evaluation and transfer technology to improvement of quantitative traits in livestock raises many other interesting questions, such as:

1. How much of the genetic variation in a trait needs to be predictable from one or more segregating restriction fragment locus polymorphisms (RFLP's) to be detected with reasonable precision and thus useful in selection?

2. Is crossing-over between markers and quantitative trait loci within a RFLP rare enough that the predictive association will persist for more than one generation from the disequilibrium identified in parent animals?

3. How effectively can a gene or genes with major useful effect be located and isolated for transfer?

4. Is it important to identify the DNA structure of desired genes in order to probe for the gene itself rather than rely on linkage with a RFLP marker?

5. What are the likely relative cost/benefits for predicting breeding values from summations of predicted RFLP effects rather than from the phenotypic summations of all gene effects, with environmental error minimized?

If nothing more, molecular genetics and gene-transfer experiments undoubtedly will contribute much to understanding genic control of development and function and thus of the model upon which quantitative genetics rests. Single-gene genetics was still in vogue when I was a graduate student in the 1930s and now it's back again. I also observed the discouraging search for blood group or electrophoretically detected genes that would control economically important traits. Perhaps there will be a special usefulness of single gene approaches to improve resistance to specific diseases?

The Congress Sessions on Molecular Genetics should be most stimulating!

INDUSTRY BREEDING PROGRAMS

It seems fitting that the last day of the Congress should focus on Evaluation of Industry Breeding Programs. The prior exposure to consideration of breeding objectives, use of breed and heterosis effects, genetic controls of variation in economic traits, and tools for increasing accuracy and intensity of selection, should be excellent background for assessing the strengths and weaknesses of applied breeding programs.

Fortunately or otherwise, more than genetics is involved in our industry programs. The best knowledge, without effective dissemination, organization and financial incentives, is likely to be under-used. We need to cooperate fully with our extension personnel, with the media and with industry organizations. And we need to <u>listen</u> to them too. We might learn something that is missing in our formulas!

STRENGTH IN DIVERSITY

The need for diversity in genetic potential that is essential for further genetic improvement also applies to diversity in approaches within our animal breeding fraternity. We need individuals who enjoy exploring statistical refinements for more accurate estimation of breeding values from field data. We also need those interested in utilization of breed diversity, inbreeding effects, physiological components of performance traits, alternative designs of breeding programs and clarification of breeding objectives - all these and many more. We need to understand each other, and in addition we need to keep in touch with those in other disciplines concerned with the environments in which livestock reproduce, grow and function. Only then are we most likely to visualize the ways in which our particular abilities can contribute most to livestock improvement.