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WHERE TO FROM HERE? THE LANDSCAPE AHEAD IN PRACTICE

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SUMMARY
Animal breeding applies genetics (as well as other disciplines) to improve livestock productivity. Changes in the future will likely involve more complex evaluation procedures, at finer levels than is currently the case. Genomic research effectively aims to improve the accuracy of estimating the genotypic value of a trait, especially in young animals. It is closing in on the tissue/cell/metabolite biological chain. Epigenetics will advance the understanding of the importance and impact of macro/micro/nano environmental influences on animal lifetime performance. Genomics is a means to an end, and the ultimate test is in its implementation in industry breeding programmes. At this level, it is the industry breeders that make genetic improvement happen and producers work to harness their resources to exploit that improvement. Both accept the business risk of doing so. It is important to appreciate that at the end of the day, the ultimate laboratory is in the paddock.

INTRODUCTION
There is more to genetic improvement than increasing the levels of technical sophistication to maximize rates of improvement, exploiting usable genetic variation, and harnessing the power of genomics. "Making it Happen" is an essential component of the process – it is the practical component. At the end of the day, the ultimate laboratory is in the paddock. The ultimate objective is on-farm profitability. And the ultimate outcome is continuing demand for animal products from satisfied markets.

Geneticists "do it with genes", molecular biologists "do it with molecules". For breeders and producers the animal is the unit, not the udder, the fleece, or the degree of muscle development. This does not imply that these components are not important, rather that they are part of the whole production process. Breeders and producers are required to exploit such animal traits to varying degrees of importance and in a total production environment that optimises profitability. They must be combined with other much wider management requirements such as animal nutrition, health and welfare, product safety and quality, capital expenditure, environmental sustainability, etc.

Animal breeding research in its widest sense is important from the perspective of ultimately improving and utilizing the productive potential of the animal. Scientists work to more accurately determine the genetic basis of phenotypic performance; breeders record phenotypic performance; producers manage it. Breeders work to improve the genetic merit of animals (ie, to lift productive potential), and producers work to cost-effectively manipulate their farm's unique combination of physical and financial resources to harness that productive potential. The final business risk is assumed by the implementers – the breeders and the producers.

SELECTION BASED ON GENOTYPE
Animal breeding involves the application of genetics (as well as other disciplines) to improve the performance of animals. As part of this application molecular genetics has recently gained ascendancy in the focus of many animal breeding research programmes. A major objective behind

such programmes has been to improve the accuracy of estimating the genotypic value of a trait, or the aggregate genotypic value of a combination of traits, particularly in young animals and for traits that are difficult or costly to measure. Other objectives include a need to understand the basic biological processes involved in productive traits, to identify genes that have major effects on these traits, and to gain better knowledge of the mechanisms and importance of epistatic and epigenetic effects.

Genomic research programmes have and continue to identify QTLs in a wide range of species and productive traits. From a purely pragmatic industry perspective, the justification behind some of these investigations could have been questioned. If the QTL had a major positive effect on a trait, previous selection for that trait in the industry would have increased the frequency of the QTL to an already high level (or conversely if the QTL had a negative influence). So why endeavour to identify it for the benefit of the industry? Less cynically but probably more commonly, the QTL may not explain a sufficient proportion of the genetic variation, and(or) its effect on realised phenotypic performance may not necessarily make investment cost-effective for the industry. A biologically significant improvement in a trait may not result in a financially significant response. It is noteworthy that at least until two years ago in relation to the dairy industry, known QTL typically accounted for up to 10% of the genetic variation in productive traits, and there had been no published examples of QTL selection enhancing rates of genetic improvement beyond those of traditional quantitative methods (Garrick and Snell 2005).

An area of more recent ascendancy is whole genome selection (Meuwissen *et al*. 2001). Whole genome selection uses thousands of markers (single nucleotide polymorphisms; SNPs) on every chromosomal segment in the genome in a mixed-model system that, along with animal phenotypic records, predicts a “genomic breeding value”. In the dairy industry the high accuracy of the genomic BVs and the opportunity to estimate them at birth offers considerable advantages over progeny testing bulls (eg, Schaeffer, 2006). Opportunities may exist for whole genome selection in the more extensive animal production industries in traits that are difficult/expensive to measure (eg, carcass quality traits), or in sex-limited traits important in maternal lines (eg, fecundity and survival in sheep). Implementation will rely on a background database of phenotypic and genotypic information as well as such factors as a routine for future sampling, a knowledge of which SNPs are informative (and at what stage) and which are not (and at what stage), etc. In the industry, specialised sire-breeding nucleus units would likely be established to concentrate the intensive recording processes on a wide range of phenotypic characteristics and provide elite sires to producers either directly through AI or through multiplier units.

Identification of RNA sequences is another development in genomic research with potential for the animal industries (eg, Pollot, 2006). Intuitively RNA sequencing could be of greater potential value than DNA sequencing has been and currently is in the genetic evaluation of animals. The genome is essentially the same in every cell, but ultimate gene expression is tissue specific and since RNA is a closer predictor of gene expression, RNA sequencing could offer advantages in improving the productive potential of animals. There is even the potential to go beyond the RNA sequence and move to the transcripted protein, or even the metabolite constructed from protein combinations, and ultimately the phenotype to be measured. If gene expression is episodic, important questions to address include which tissues are informative, how they are informative, and when. Animal production industries are still some distance away from benefiting from such gene expression profiling. What is likely is that in the process of gaining knowledge on the RNA/protein/metabolite biological chain, the inevitable complex of interactions between genes or groups of genes, and the impact of environmental effects on gene expression might become more explicit factors in the designs of experiments and animal breeding programmes.

From an animal industry perspective, the challenge is for researchers to appreciate the importance of these genomic technologies as a means to an end, and not an end in itself. There are gene/marker tests available for a range of productive traits, but there needs to be better delivery to the industry than one of merely providing a genotyping service. Genomic investigations must look beyond the science. Breeders and producers in animal production industries should expect such projects to formally incorporate requirements for assessing the economic importance of the technological advance to the industry, and cost-effective methods of implementation in production systems (including for example, diagnostic efficiency and the development of tools that combine qualitative and quantitative information for application in animal breeding programmes).

EPIGENETICS

DNA sequences are not the sole determinant of an individual's potential productivity. Epigenetic factors are mechanisms that induce inherited differences that are not due to differences in DNA sequences (Georges, 2006). Permanent environmental effects are assumed to influence the performance of an individual throughout its lifetime (eg, identical twins do not have identical productivity). At the molecular level, these effects could be due to differences/modification of gene expression. We could expect subtle differences in the environment of the animal to cause permanent non-genetic effects on its performance (eg, periconceptional nutrition on early foetal development; Oliver *et al*. 2007). Regardless of their mechanisms of action, epigenetic effects on gene activation/inactivation are likely to further explain more of the phenotypic variation not attributable to DNA sequence (Garrick and Snell 2005). Epigenetic influences are therefore likely to be implicated in a wide range of current livestock management practices, enabling breeders and producers to exploit the positive effects and better manage the negative ones in order to more accurately predict the genetic merit and ultimate productivity of the animal.

In the quantification of epigenetic effects, measurement of the phenotype and its environment will assume far greater importance (and cost) than is currently the case. While the unit of animal production on-farm is the animal, interference with or impacts on gene expression are likely to be extremely subtle, and could well be mediated at the physiological, or more probably at the cellular or molecular level. In an epigenetic sense the animal may represent a population of tissues/cells/metabolites rather than representing a population of animals (Pollot, 2006). Quantifying variations in phenotypic expression will increasingly require more sophisticated (nano?) measurement technology, and probably more frequent measurements than are currently possible in the paddock of the more extensive animal production industries. Knowledge of the impact of these effects on phenotypic performance will have important consequences for animal husbandry practices. What level and quality of nutrition is appropriate before, during and after mating? How does this impact on the lifetime productivity of the dam and of her offspring? Perhaps industry selection programmes in the future will be uniquely tailored to particular combinations of environmental/production circumstances.

WIDER INDUSTRY CONSIDERATIONS

Successful breeding programmes achieve more than just making genetic improvement happen. Financially profiting from effective genetic improvement is foremost in many breeders' minds. As observed at this conference 26 years ago, "… it would be little comfort to a bankrupt breeder to know that he had the fastest rates of genetic improvement." (Hill, 1981). Historically, this profitability has been more related to marketing ability, good animal husbandry and feed management skills, than to genetic merit. Breeding programmes that have the discipline to stick to well-defined breeding objectives, to make effective decisions based on appropriate selection criteria, and to capitalise on all that through cost-effective mating plans, will be the ones most likely to succeed in the future. Tomorrow's clients will be more knowledgeable and more discerning. They will be more prepared to reward breeders for measurable genetic improvement in traits contributing to producer profitability.

Implementation of genetic improvement programmes will require a change in the manner in which technology is delivered to the industry and to the wider markets. Gathering data is only that. Information is the analysis of that data *and* the output delivery in a form suitable for appropriate decisions to be made. The risk underlying those decisions will remain with the decision maker. Breeders will still need to select parents, record offspring and market them as sires. Producers will have similar responsibilities because in the future, markets will progressively demand more exacting traceability of product. Market signals will be more quickly transferred back to the producer (and breeder) because the economic consequences of production and selection decisions will become more important. There are a few cases at present in New Zealand where British supermarkets are dealing directly with breeders and their producer clients for lamb product, but in the future they will more likely deal with processors. As a consequence supply chain communication through the processor and back to the paddock will need to improve. However, on-farm financial benefit from what might be regarded as this more positive shift in focus is likely to be questionable. Any long-term improvement in "assured" demand for product will be offset by increased costs of compliance for product quality, consumer safety and health, and environmental sustainability (ie, by the "social costs" of animal production). Any premiums for eating quality standards that may exist in meat industries at present would probably erode over time as the standards were achieved by more and more producers.

Currently, well-designed breeding programmes are successful programmes. Implementation of further advancements in design will probably occur in those programmes that are already in the "well-designed" bracket of the industry. Breeders closely integrated with the production sector of the industry will have tailored their breeding objectives to the production circumstances of their sire-purchasing clients and to the market requirements those clients supply. Such breeders will also have established a distinct (ie, marketable) point of differentiation to achieve competitive advantage over their contemporaries.

Breed is unlikely to be a major point of product differentiation in the future. A more likely point of differentiation, at least in some western economies, will be a human interest story associated with the breeding programme which enhances the "dining experience". The successful breeding programme will even move beyond the composite animal to a non-breed specific system, selecting for inherited profit-earning potential regardless of breed or breed composition (eg, Nicoll *et al*. 1992; Nicoll 1995).

It is probable in the more extensive industries that the traditional structure of nucleus sire-breeding units disseminating genetic merit through multiplier units to producers will remain in place, at least in the near future. Advances in reproductive technology may contribute to the dissemination process (eg, use of sexed semen where the sperm cells are known to contain desirable genomic segments). The major difference between now and then will be in the level of complexity of data collection in the nucleus. There will be more detailed measurement of tissue, physiological, cellular and metabolic phenotypes (and at more frequent intervals), as well as of environmental effects.

MAKING GENETIC IMPROVEMENT HAPPEN

Making genetic improvement happen is of benefit to the industry but how the rewards (and costs) are partitioned across the breeding, production, processing and consuming sectors of the industry may be less obvious. Animal production companies that retain ownership of both their sire breeding programmes and their commercial revenue-earning livestock can afford to more rapidly adopt new technology because they receive the full benefit of the advancement. The costs of adoption are spread over a large number of capital livestock (commercial females), but the returns are also generated from a large number of revenue stock.

Current animal industry structures are not as well geared for this to occur. In the more extensive sheep and beef industries, there is a relatively wide "investment gap" between the breeding and production sectors. Breeders investing in new technology must raise their prices over comparatively few sires sold in order to earn a positive return on their investment. Increased cost is often a limitation to adoption of new technology, and producers may not be willing to participate in the investment, despite the opportunity for them to receive some proportion of the benefits of that technology.

CONCLUSIONS

In the future we will not only be able to identify the DNA sequences that determine a given productive trait and the corresponding RNA profile, but we will also be able to trace the encoded proteins through to the metabolic processes controlling the trait, and the nano/mico/macro environmental effects that modify the trait's value. Selection criteria (ie, indexes) and systems will be more complex, but made manageable by improved decision-making tools.

Industry structures may change to closer integration of the breeding and producing sectors, but perhaps having more impact at the production level in response to market demands as a result of the advances in genetic technologies. In the breeding sector of the industry monitoring of phenotypes will become much more complex and costly, but the ultimate means by which genetic improvement will be disseminated will probably not differ greatly from today's systems (other than perhaps through advances in reproductive technologies).

Quantitative genetics is not, and will not be, an out-dated field of endeavour. The industry breeder will remain in effect a practising quantitative geneticist and he must be able to make the most appropriate selection decisions for his benefit and for the benefit of his production industry. Making genetic improvement happen in the future is as close to us as appreciating that the ultimate laboratory is in the paddock.

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