HELEN NEWTON TURNER MEDALLIST ORATION

ANIMAL BREEDING AND GENETICS IN A CHANGING WORLD

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I found it a very special feeling to be notified of this award by the Trust. A thrill, flashes of times with Helen at the office, on an overseas visit, and at her special home, her strong commitment and substantial work in Australia, and also in developing countries. Flashes too of the distance one has travelled over several decades, of the many strong shoulders of support during this journey, of surprise, even some confusion!

"Confusion", or possibly just difficulty in accepting the notification by the Trust, because, in conceiving the award some 15 years ago and drafting its specifications, I had intended that it recognize people from science, technology and industry who are making outstanding contributions to Animal Genetics and Breeding, and by this also encouraging others to contribute. Self-analysis is important, but also embodies potential dangers. However, I see myself as one who simply enjoys thinking about the development directions being taken by our species, enjoying also the beauty about us, the wonders of inheritance, how best to apply our conglomerate science, and as one who enjoys helping to make potential applications happen.

"Surprise" because, as with many people, I prefer to focus on what needs to be done and work along with colleagues to realize what is required, rather than ponder accomplishments.

The "shoulders of support" over the decades have been many, institutions and people in Australia as well as a number of other countries, providing opportunities for me, helping to generate ideas and otherwise progressing research and development activity, strongly influential in many ways. To list them for the purpose of recognition could be unfair, for I'm not confident that any short list I produced would be sufficient. They no doubt are aware, and this award must surely also recognize their fine support. I elect to make mention of one person only, my primary support, my wife, Pam. From the shoulders of these many supporters, I am very honoured to accept this award, also on behalf.

This support to me over the years also includes quite a number of breeders from the animal industries. Rarely does one leave a discussion with one or more involved and thoughtful breeders without thinking seriously about the meaning of the discussion and the implications for the science and its application. In conceiving AAABG this fact was one of my key drives, to create a further opportunity for breeders and geneticists to mix closely over several days, encouraging both to contribute. I openly admit, for me, and no doubt for the rest of the small team of breeders and geneticists who helped initiate the Association, it is a thrill to note its ongoing success.

Perhaps the most significant challenge for humankind this new century is to successfully manage change, whilst psychological research confirms that the majority of humans do not cope well at all

with change. Australian livestock production and marketing will also need to respond to substantial change in production environments during the coming years and decades, including change in domestic and international demand for product quantity of varied quality.

Markets will be further segmented, based upon better information and demand for an increasing range of product quality attributes. International competition is eventually likely to be keener as a result of progressing World Trade Organization negotiations. The expected doubling in global demand for livestock product for human food over the next 15 to 20 years will also impact on Australian and New Zealand animal production. Most of this increase is projected to originate in the Asian countries to the north of Australia, i.e. markets within our region, as a result of the increasing purchasing power in those communities. Our livestock sectors currently posses the capability to be profitable with just 4% public sector support, compared with support to the livestock sectors of other significant exporting countries ranging between 15% and 55%. The intention of the Doha Round of World Trade Organization negotiations is to eventually remove this massive support. Perhaps when this occurs, it will contribute an important market advantage to the Australasian animal product export industries for a decade or more.

I take this opportunity to raise a number of strategic issues concerned with change impacting Animal Genetics and livestock production, change which may be particularly significant to the potential future development of the Australasian production environments.

Several of these issues concern the developing excitement in Animal Genetics. The range of powerful informatic and molecular genetic tools now in our possession offer us, for the first time, the potential to rapidly and cost-effectively understand **all** levels of functional biology down to the DNA code itself, and concerned with animal production, processing and marketing. This is feasible for **all** animal species and breeds used to produce food and agriculture, and for **all** major production environments. Increasingly also over the next decade or two, we should possess the potential to cost-effectively obtain these differences in function for individual animals in the production system. This information could be available for each of the substantial number of traits of importance to the efficient and consistent production of product. The information must also account for the range of important differences in product quality attributes depending upon the specifications of the market segment being supplied. Note that the understanding for each production environment needs to be obtained for **all** traits in the breeding goal or objective, enabling development of a range of non-genetic interventions as well as improved designs, including more effective selection indexes, for increased and more efficient genetic gains.

(Here also, I use the term "functional biology" rather than physiology to better encompass the elements of each level of function in the biological systems involved; with these "levels" including intra-cellular, tissue, organ, individual and population; and I use the term "production environment" to encompass all elements of the on-farm and off-farm sectors which are required to efficiently and consistently produce a specified product. So, breeding through to marketing must be included, as well as all natural elements impacting production, together with those arising from human intervention. I have elsewhere (Hammond 2006) termed production environment the "supply chain package" to help to better involve all important down-stream influences through to the consumer.)

1. The fundamental longer-term strategic need for livestock industries: Understand the functional biology of the production environments

Yes, the matrix of possibilities is large, spanning production systems, species, breeds and end products. The amount of research required is also substantial, realizing that genomes, genes and their alleles are likely to respond differently amongst many of the cells of this matrix. But for the first time the research is feasible. Recall also that we are here dealing with industries each of which, when competitively successful, generates annually billions of dollars. When their production and marketing is not so successful they rapidly fall into the "red", that is they tend to be fragile industries which, for survival, must remain proactive. Remember also that success for these industries in both the domestic and international market place will increasingly be technology-driven. Finally, the majority of the work required to understand biological function should need to be done only once.

Understanding function within each cell of the matrix as well as the functional differences between cells will serve to be extremely powerful indeed. This understanding would be at the heart of virtually all further development decisions for the industry. It would offer major ongoing potential to improve productivity and product quality, enabling:

- ✓ Production of lower-cost and more consistent product; and
- ✓ Lower-cost and rapid improvement in efficiency of production, product quality and consistency;
- ✓ Development of the broad range of advanced measuring and sensing equipment and procedures which are low-cost, reliable, accurate and precise, able to be automated and provide for more timely observation than is currently possible;
- ✓ Greatly increased flexibility to respond to change in product specification; and here we can be confident that there will be substantial further change in product specification in each industry. Markets will further segment, based on product quality as, for example, we learn how to customize human nutrition to the level of the individual, thereby improving life-style, and reducing the massive health costs on the community associated particularly with the so-called life-style diseases; and
- ✓ Greatly improved ability to meet future change in the production environment resulting, for example, from altered conditions of animal disease and other biosecurity elements, changes of policy on animal welfare, and on managing the environment.

Now that it is feasible, this need to much better understand the functional biology of production environments is, for each industry, by far the most important research activity in the areas of technology development and production understanding. The overall outcome will not only result in a gain in efficiency, etc at one point in time, it will also provide most of the information required for the development over time of necessary serial gains in efficiency.

The research involved to realize these benefits would consume 1 to 2 decades of effort if treated as high priority. Along the way this work would be accompanied by a range of important outcomes for industry use, and of course considerable satisfaction for those involved.

Perhaps during the second half of this century we will have acquired the very high level of understanding of this functional biology to enable many of the animal products to be cultured *in vitro* – although, human nature being as it is, the result may well be a demand structure for the cultured

product operating in parallel with that for the "natural" equivalent, thereby further perpetuating livestock production for food and agriculture.

In relation to this call for greater research focus on understanding the functional biology of production environments, the increasingly frantic search for Quantitative Trait Loci (QTLs) in each livestock sector of many countries for the prime purpose of the industry using these QTLs directly in genetic improvement activity, seems to be firing off on a very costly tangent. Of course, there is no magic, so there will be some benefits to the industry from this form of QTL work, although its long-term cost-effectiveness remains questionable. To summarize: research designed primarily to identify QTLs for direct use in genetic improvement, treating the need to understand biological function of candidate areas simply as an added windfall:

- ✓ Is unduly tying up resources, financial resources, technical capacity and consuming precious time in each industries' effort to remain competitive;
- ✓ Involves different design emphasis to that primarily directed at identification and use of QTLs for understanding biological function;
- ✓ Slows the development of multi-disciplinary teams and the convergence of disciplines required in the effective study of biological function;
- ✓ Inadequately emphasizes the need for research to utilize multi-species information, including the need to involve expertise and results from the massive research effort underway for the human species, especially for the lower levels of this research effort;
- ✓ Delays by years and perhaps even decades the ability of industry to recoup major benefits, as summarized earlier, from work focused on understanding biological function – and here recall that QTL research primarily aimed at direct QTL use in selection programs, has already been underway for more than a decade with negligible industry benefit to date;
- ✓ The approach is being facilitated by public and private sector demands for rapid return on their investment in the research; and
- ✓ Is also being promoted by the emphasis on marker patenting and the creation of private assaying business.

Patenting and the development of private businesses in marker-QTL assaying, unless very carefully done by the animal industry, carries with it the added risk of privatizing ownership of more of the genome of a species. The corporate objectives of the small number of businesses involved may well differ substantially from the breeding goals required for the livestock sector to stay competitive in international markets. Recall that these goals must be based upon the economics of the commercial product producing sector, not the economics of the breeding sector.

It is interesting to also note other concern for these matters. For example the recent review by the Late Professor Gene Namkoong and Professors Richard Lewontin and Alvin Yanchuk (Namkoong et al., 2005) considered "The next investments in quantitative and qualitative genetics". Whilst they primarily addressed the issue for plant breeding and improved crop and forestry productivity, they also included domestic animals in their comments. They point out:

"The value of molecular genetics in techniques such as locating quantitative trait loci (QTL) is less in that they can be used for direct selection as much as they may locate candidate regions for further investigation of the genes that affect measurable traits."

and

"The more that we analyze single genes, the more it becomes apparent that their processes of activation and transcription are strongly environmentally affected and dependent on other genetic loci."
and further
"The effect of genes on even simple traits is thus not one-to-one, and to understand and use genes involves interactions at higher levels of organization."
They go on to point out that for the management of gene effects on productivity traits, field population level breeding is required. They conclude that whilst investment in molecular genetic technology will bring some benefits, it is critical that this technology not replace or even limit the expansion of more traditional breeding activities, and
"New technologies that solely rely on simple genetic manipulations, in the long run, will end up costing society much more than any benefits they will provide, with the benefits usually flowing to a narrow group of investors."

2. Provide to increase technical support

A rough count suggests that the number of post-graduate students now studying Animal Genetics is very small, approximately half what it was 2 decades ago, and more of those involved today are on study visas, particularly from developing countries. Whilst Australia's increased contribution to developing country capacity building is admirable, perhaps we have here somewhat of paradox. We've noted that quantitative and molecular genetics are beginning to be integrated with increasing excitement in Animal Genetics research and its application. Why then do we find fewer students involved in understanding the science sufficiently to contribute effectively to research, development and extension support in Animal Genetics and Breeding?

A second, associated paradox is the reduction in the number of experienced technicians involved in research and direct industry field support. The issue has industry by Mr Bob Freer, Mr Wayne Upton and Mr Don Nicol; who also involved in their analysis a broad panel of experienced field personnel (Freer et al., 2003). Commonly, it appears recently been very well described for field extension support in the Australian beef that the public sector, state Departments of Agriculture, universities and the CSIRO have moved substantially away from the Animal Sciences. This has occurred as on-farm and off-farm decision-making and future competitive success of each animal industry is increasingly reliant on advances in and direct use of often quite sophisticated technology. It is occurring despite the prediction of a doubling over the next 1.5 to 2 decades in global demand for animal products for human food. Recall also that education and training of the necessary expertise requires at least a decade to realize the necessary level of competency.

What parties in the Nation will educate, train and support in the field this technical support infrastructure? Or is this the early indications that Australian Animal Production with its annual value currently running at more than $15 billion, will forgo its 30% to 60% export market, by reverting to supply only the domestic market? Not a very realistic scenario for, as costs increased, the industries would still need to increase efficiency to stay profitable, as well as respond to other community demands for change. Surely the livestock industries need to consider as a matter of urgency how to overcome the looming deficiency of technical expertise.

3. Enable the breeding sector to recoup sufficient benefit from its investment in genetic improvement

The breeding sector of each industry exists for the sole purposes of assisting the much larger commercial sector to compete, remain profitable, address public policies relating to animal welfare, biosecurity and environmental management, and minimize prices to the consumer.

The very nature of genetic improvement means that the vast majority of the benefit flow from genetic improvement will be recouped by the commercial production and consumer sectors, whilst the breeding sector is likely to account for the vast majority of investment required to generate genetic change. Economic studies of the Australasian industries which partition benefits to this level of detail appear not to have been done in recent times. However, it is quite likely that this flow of benefit to the breeding sector of an industry will be insufficient.

The breeding sector must be prepared to invest sufficiently in genetic improvement to reliably achieve ongoing, rapid genetic improvement for the breeding goal(s), as well as to assist in the rapid dissemination of these gains throughout the commercial sector, whilst remaining profitable. Under these circumstances a commercial industry seeking rapid, ongoing genetic gain should consider managing the benefit flow to enable the breeding sector to generate and help best disseminate rapid genetic improvement for industry agreed goals. I have recently considered elsewhere this issue for the Australian beef industry (Hammond 2006).

4. Preparing for increased climatic variability

It is obviously important that industries further consider the potential impact of climate change on future directions in genetic improvement and geographic restructuring of particularly the pastoral-based animal industries of Australia.

Over the next 2 decades plus the industry should perhaps be less concerned with such climatic variables as mean temperature trends than with the projected increase in variability of climate which much of the climate change modelling predicts. This means more serious flooding and, of greater significance to these pastoral industries, more intense and longer droughts. Because the majority of the farmed and pastoral land of Australia already suffers from very low rainfall expectancy, any further increase in climatic variability is likely to impact over large areas, perhaps seriously, the profitability of cropping, and animal production and breeding. The predicted impact varies between regions of the Country (For regional reports see: http://www.dar.csiro.au/impacts/consult.html). I thank the Climatic Impacts Group of CSIRO's Marine and Atmospheric Research Division for assisting by providing the latest information on the matter.

We are likely to experience over the next 2 to 4 decades considerable geographic restructuring of the cattle and sheep industries, including their breeding sectors. The pastoral-based animal industries in particular could benefit from the preparation of a report on the likely impact of climate change on production, processing and marketing. The study should cover the broad Australian regions of animal production, and account for market segmentation. It could usefully be updated at 5-yearly intervals.

5. Exporting genetic material, a 'red-herring'

Every so often one hears discussion of the considerable value of an export market for Australian-bred genetic material. From time to time one or other breeder will return a profit from such exports. However, in an industry context, such activity is little more than a distraction to the breeding sector. The breeding sector should be focused on maximizing improvement for the local commercial industry, based upon agreed local breeding goals.

Increasingly, it is likely to be in the interests of each Australasian animal industry to ensure its continuous access to an efficient and effective local breeding service.

6. Develop National public policy for domestic livestock

Finally, since returning to Australia, I have further understood that National matters of policy concerning the animal industries beyond Quarantine and Biosecurity, are left by the Federal Government, primarily to each industry's quasi-governmental body, the MLA, AWI, etc. There exists comparatively brief mention of livestock in the policy of several Government Departments, mainly in the context of a negative impact of farmed animals on the environment. Most Federal Government policy concerned with Agriculture appears to be focused on the plant and forestry sectors.

This situation became increasingly apparent to me during a decade of work with the Food and Agriculture Organization of the United Nations. Australia was always able to intervene very usefully in the many debates at the intergovernmental level on plant and forestry matters, but Australia's delegations appeared to require undue guidance by others when animal production and animal genetic items were being debated. Here, perhaps the Country is somewhat out of step with most other OECD countries. In this era of so-called "globalization", an expanding range of bilateral and multilateral intergovernmental matters concerning animal agriculture are on the table. Agriculture is considered an important negotiating area in the WTO Doha Round, and a range of other international agreements relevant to Agriculture are being initiated, signed or are already ratified and so active. The feasibility of a treaty on animal genetic resources is to be examined.

Surely, it is in this Nation's interest for the Federal Government to always be in a proactive position for such a large export earner as livestock? This can only be done well by Government developing a comprehensive, over-sighting strategic policy for its livestock sector.

Conclusion

Dr Helen Turner strove over 5 decades, against considerable odds to realize the broad application of Genetics to the sheep sector. We have now arrived at the position where we can confidently say that this broad application of Genetics to each of the Australian animal industries has begun!

However, there exists very considerable potential in all industries for further improvement in efficiency and effectiveness of genetic improvement activity. Rapid, ongoing improvement will very likely be required for each industry to remain competitive in this changing world. The vagaries of Australian climate, demand by consumers and processors for more consistent, even tighter product specifications, together with intense international competition, surely provide strong argument for the

continued development of highly effective local breeding sectors and, ideally, several of these sectors per industry.

We can anticipate increasing excitement in Animal Genetic research and development over at least the next couple of decades. Useful project work will be increasingly convergent, utilizing both quantitative and molecular genetic techniques and procedures and involve large technical teams. It will also incorporate the multiple of non-genetic disciplines, and increasingly partially distributed geographically.

There remains an important need to firmly establish longer-term strategic direction in research and development for each industry, particularly in relation to the rapidly developing molecular genetic area and its further integration with the more classical animal sciences, and in relation to the serious training and infrastructural needs for field technical support throughout each industry.
The central strategic issue must be to obtain a far better understanding of the functional biology for each production environment (supply chain package), with the large commitment to Quantitative Trait Loci (QTL) research in the first instance serving this purpose, rather than the purpose of discovering QTLs for direct use in genetic improvement activity. There is need to ensure that this research effort progresses rapidly, to enable further improvement in productivity and product quality; to retain a competitive edge in the market, and restrain prices to the consumer.
The animal industries will increasingly rely on the development and broad application of advanced technology to compete successfully. At this point, industries could usefully further consider the adequacy of their education and training programs, planning strategically over a 20 year time horizon, for the level of expertise required takes time to develop.

It is in their direct interest for industries to ensure that the flow of benefits to the breeding sector from this relatively small sector's investment in breeding is more than adequate to provide for reliable, rapid genetic improvement in industry-agreed breeding goals.

Australia's animal industries are mainly located in rather fragile environments. They should further consider the restructuring which may be required as a result of the potentially serious impact on production economics of the increased variability of climate associated with climate change.

In an industry context, the value of developing export markets for Australian genetic material is likely to be small and even counter-productive. All focus by the breeding and other sectors of each industry should be on the development of local, highly effective and efficient improvement activity, on rapidly and widely disseminating the resulting genetic gains, and on better utilizing non-genetic improvement outcomes from the multi-disciplinary research effort.

To be well positioned to discuss and negotiate livestock policy issues in intergovernmental forums, and also co-ordinate nationally at the higher levels the maintenance and development of livestock, the Federal Government should develop and execute a comprehensive strategic over-sighting policy which addresses the livestock sector as a whole.

REFERENCES

Freer, R. E., Nicol, D. N and Upton W. H. (2003) A National Beef Genetics Extension Foresight Plan. MLA Final Report, Project # BFEGEN.017.

Hammond K, (2006) *Aust. J. Exp. Agric.* **46**:183-198.

Namkoong G, Lewontin RC, Yanchuck AD (2005) *Genetic Resources and Crop Evolution* **51**(8): 853-862.