MANAGING NEW TECHNOLOGIES

A. HARRISON

Primary Industries Research Victoria, Department of Primary Industries, Attwood, Vic 3049

SUMMARY

Factors impinging upon new technologies are not new, merely more complex, more dynamic and more expensive. The additive effect of these factors calls for management attention. Genetic and genomic technologies are used to illustrate key issues in managing new technologies. The starting point for analysis is the market; who buys, what is bought and why, are key considerations. Fundamental to the new technologies is instrumentation that has magnified the scale and rate at which discoveries can be made. New cross-over disciplines, such as bioinformatics, have emerged to manage huge volumes of data. Never-the-less, the capability to exemplify gene function remains a competitive advantage. Complexity as it applies to science, the research organisation and to collaboration is discussed. Commercialisation is explored in relation to Intellectual Property, social and political acceptability and commercial returns. Benefits to industry are potentially high, but need to take into account attrition due to variables that were not envisaged or insufficiently quantified. Commercial benefits are difficult to capture, and returns are likely to be low. Applied research skills will be necessary to optimise new technologies within the total farming system. Four case studies are used to illustrate the various factors at work.

INTRODUCTION

There is a vast array of new technologies benefiting animal scientists in their research and being applied on farms. In his Underwood Lecture, John MacRae (MacRae 2004) has provided an excellent overview of advances in the so called ‘new biosciences’, while Matt Lucy (Lusy 2004) has reviewed the numerous advances in, and potential of, next generation reproductive technologies. Undoubtedly many other new technologies including micro technologies, remote sensing and electronic recording will offer significant opportunities for the livestock industries. For the purposes of this paper, genetic and genomic technologies have been singled out as the subject for exploring ‘new technologies’, and the issues and principles involved in managing them. The factors affecting genetic and genomic technologies will be developed and discussed and then applied in a selection of case studies. The intent is to provide an understanding of principles that can then be applied more widely, to other technologies.

FACTORS AFFECTING NEW TECHNOLOGIES

The market

There are numerous approaches to solving problems, as any scientist will tell you. As a manager of technology, my approach, and 1 that I can honestly say has never let me down, is to use a marketing approach. At its most fundamental, marketing is about understanding 3 things:

- Who Buys - the customer,
- What is bought - the product, and
- Why - the benefit.

	Productivity Products	Processing Products	Animal Health Products	Human Health Products
Producer	e.g. efficient feed conversion			
Service Provider			e.g. disease prevention	
Processor		e.g. increased product yield		
Consumer				e.g. peace of mind

Figure 1. Customer segment by product segment with benefit intersect.

For the purposes of this discussion, the benefits of genetic and genomic technologies can be broadly segmented as illustrated in Figure 1. The segmentation is not intended to be comprehensive, merely illustrative. Further, it will be noted that the benefits are inter-related, for example, an animal health benefit rolls up to a productivity benefit that, in turn, rolls up to an economic benefit. As an aside, I have found that all benefits roll up to either an economic or a social benefit. Even the environmental component of the so-called 'triple bottom line' can, in my view, be split into economic and social benefits.

In the process of developing a technology, it is useful to have in mind a precise and specific product that will end up in the market. The nature of research means that this outcome might not be achieved, but it is an important element in designing and managing a research project. Specific product examples from the technology portfolio with which I am currently associated are:

- A vaccine against nematodes in sheep,
- A white clover cultivar resistant to a specific viral disease,
- A genetic marker for a specific component of milk able to be used to select for naturally occurring variability in the dairy cattle,
- A rapid diagnostic test for anthrax in cattle, and
- A ryegrass cultivar with increased soluble carbohydrate concentration.

Marketing is a discipline in its own right and much, much more could be said. However, before I move on I need to make the somewhat obvious point that benefits segment into:

- Consumer benefits, and
- Producer benefits.

In this paper I will focus on the benefits to the producer, but in doing so will keep an eye on the benefits the producer's customer will ultimately expect.

The nature of the technology

What is it about recent advances that differentiate and define genetic and genomic technologies as they are applied today? From my perspective as a manager, it is the quantum shift in knowledge and understanding of genes, coupled with the new and emerging investigative tools. This has lead to the ability to undertake research characterised by the dimensions of:

- Scale, and
- Rate.

Whereas 10 years ago, 1 gene per scientist per year could be isolated, sequenced and expressed, due to high throughput sequencing and microarray technology, there is now a 10,000-fold increase in rate for this same set of steps.

It is worth noting here that although the initial discovery phase has accelerated significantly, the exemplification of gene function has not accelerated at the same rate. Research teams that have capability in the exemplification, or 'proof of function', phase will have an advantage in securing a patent position. Unfortunately, the high throughput industrial scale sequencing capacity of modern instrumentation has lulled some research groups into pursuing poorly conceived strategies. They can generate a mass of data, but lack equivalent capability to interpret and ultimately develop a product. In spite of this last comment, a distinguishing feature of new genetic and genomic technologies is the ability to generate and process a mass of DNA sequence data.

Capital cost, maintenance and replacement of instrumentation are key issues. As with computer technology, every 2 to 3 years, instrument sequencing capacity goes up. In 1 of the genomic programs I manage, we are on to our third instrument, with a 4-fold increase in rate for a similar base cost. Similarly, bioinformatics capability, an essential co-discipline in genomics research, is highly dependant on serious computing power. I am associated with 2 genomics programs, and we are currently investing in the order of $2 million in bioinformatics capability. Fortunately, both DNA sequencing and bioinformatics are platform technologies with wide application and ability to underpin a diverse range of research projects and product development.

Managing dynamic complexity

In their elucidation of strategic analysis, Johnson and Scholes (1984) identify 2 key variables that impact upon management:

- Complexity *v*. simplicity, and
- Dynamic *v*. static.

The new technologies are unquestionably complex and dynamic. Dynamism requires little further explanation other than to say that, of all of the fields of science, genetics and genomics would currently be 1 of, if not the most, dynamic.

Complexity does, however, require some further discussion within the context of new technologies, and can be examined as scientific, organisational and collaborative complexity, noting that there are compounding interactions between. Much could be said about scientific complexity and by persons better qualified than myself to say it. From my perspective in managing a genetics and genomics program, scientific complexity impacts upon the availability of appropriate expertise and the consequent ability to attract and retain this scarce resource, a topic given considerable thought and attention by Bob Clements (Clements 2004).

Organisational complexity is about assembling sufficient critical mass to have an impact on the task in hand, relative to other groups that are working internationally in the field. Disciplines such as bioinformatics and proteomics, for example, are still in formation, being syntheses of other disciplines. Managing the interface between new and established disciplines in multi-discipline teams is a challenge. My organisation has recently moved to a management structure based on platform capability, which in turn comprises related disciplines or sub-disciplines. For all of the pros and cons, this structure very well suits research programs deploying new technologies at the strategic end of the pipeline. I would add that it less well suits applied research at the other end of the pipeline, which has traditionally been organised through multi-discipline institutes. Further, if I might be permitted to continue the analysis, the platform structure suits cross-industry research whereas applied research, almost by definition, delivers benefit to a particular customer (industry) segment.

Collaborations have become progressively the ideology, the fashion and the mantra, but with insufficient attention being paid to the management complexity that collaboration brings in my view. There are sound reasons for collaborations, and these are nothing new in science, but the new technologies, because of the need for critical mass, cost, and funding policies to name but a few, are driving collaboration. My experience with collaborations, many of which make scientific good sense, is that they take an inordinate amount of management time which goes up exponentially as the number of participants increases. Participants include research collaborators, but more particularly potential investors. This management time is required largely in the formative stages and is essential if the collaboration is to avoid dysfunctionality. The problem is that it comes at a cost, and the challenge is to optimise the spend between the management and the science. Our direct legal costs in establishing 1 overly-complex collaboration I was recently associated with came in at close to $200,000 and, while this was a large undertaking, the money would have been better spent elsewhere. Managing collaborations is a topic in its own right, but it is sufficient here to finish by saying that collaborations are a means to an end, not an end in themselves. There must be a congruence of objectives between the collaborators and each must add value.

Project Management as a discipline is well established in professions such as engineering, but in my view, is under-done in scientific research. The reasons are largely to do with certainty of outcomes, but that notwithstanding, the principles of project management offer the means by which complexity can be controlled. If I had to single out 2 things for project management attention, they would be:

- clear and explicit understanding of the of the proposed outputs and products of the research project, shared between researchers and collaborators, and
- clear and explicit documentation of scope (what's in and what's not in) and control of creep, drift and variation.

Managing commercialisation

In managing the commercialisation of technology, and genetic and genomic technologies in particular, the following areas require particular attention:

- Intellectual Property (IP) management,
- Political and social acceptability, and
- Commercial returns.

If all findings from genetic and genomic research went into the public domain via journal publication, life would be easy. The reason IP is protected is to attempt to capture benefit, driven in large part by the large investment that is needed for its creation. Patents and licenses are part and parcel of most commercialisation activity, but are made more difficult in the field of genetics and genomics by the evolving nature as to what the patent office will accept. For example, as recently as 3 to 4 years ago, blocks of sequence data were being filed for provisional patent. As the patent office tightened its criteria, and more sequence data appeared in the public domain, strategies shifted. More attention was given to in-depth exemplification, and less to breadth of claim. These issues are global in nature, and have increased the need to invest in scanning for patents and in staying abreast of the rules. Within collaborations, IP ownership considerations occupy too much management time, particularly where the commercial benefits are small and hard to capture, as is usually the case in agricultural research. It is much more sensible for collaborators to focus on what particular rights they each want, and then to seek to achieve their objectives through license arrangements.

Political and social acceptability is bound up with any proposed application of genetic and genomic technologies. My personal approach to management is to accept the verdict of the market place, be this political or consumer driven, and not to divert too much of my precious resources to trying to change the market. In the case of genetic and genomic technologies, it is important to keep a long-term perspective, and to argue vigorously for the benefits of having some options for when the market changes, as an act of faith tells me it will.

There are undoubted economic benefits to be gained from the technologies being developed. Most Net Present Value (NPV) financial analysis (based on known variables for which reasonable assumptions can be made) show these economic benefits to be large. However, more problematic is:

- who will capture the benefit?
- how will the benefit be captured? and
- what is the net benefit as opposed to the gross benefit?

Most of the benefits in agricultural genetic and genomic research, particularly in the area in which I work, will flow to industry, with the benefit generally being captured by individual farmers through greater or more efficient production. Provided industry pays, this is not a problem. However, if an investor seeks to make a commercial or 'free cash flow' return, then there is a problem as there is no clear point of transaction where any sort of margin likely to justify the original investment can be collected.

I once calculated, based on industry benefit for a new grass cultivar, a NPV of $24 million over 20 years. I then talked to my marketing manager and assessed the likely price the seed would sell for (sale of seed being the point of transaction at which a premium could be extracted), and ran the calculation again. Coincidentally, I again got $24 million, but unfortunately, this time it was a negative NPV.

Most analysis of economic benefit stops at the gross level, largely because the factors that reduce gross to net have not been identified, or are difficult to quantify. For example, it is relatively straight forward in most cases to calculate the gross benefit from an increase in water soluble carbohydrate concentration or digestible energy from a new ryegrass cultivar. It is much harder to calculate the nature and magnitude of loss of benefits through to field application. I have had said to me by sensible applied researchers, "What's going to happen when insects, fungi and viruses get stuck into that sweet tasty grass, let alone the potential for increased sub-clinical acidosis?"

Economists talk about total factor productivity, meaning in my mind the total system picture rather than a snap-shot of a component. In an agricultural context, this is about the total outputs from a farm in relation to total inputs. This is important as many scientists think in terms of partial productivity measures, such as production per cow or production per labour unit. Genetics continue to make significant contributions to per cow production, but at the same time, reproductive performance in the Holstein has declined to the point where it is difficult to maintain strictly seasonal calving systems. To paraphrase an applied researcher, "When the geneticists have developed this super, high productive cow using the latest technologies, how are we going to get her pregnant?" Again, a sensible comment recognising that lactational demands are already compromising physiological systems in ordinary high productive cows.

CASE STUDIES

The following case studies will illustrate how the factors and issues discussed above impinge on the management of new technologies.

Nematode vaccine

This project, in its ninth year, aims to develop antigen candidates against nematode parasites of sheep. The project is unusual in my experience and is, in fact, quite the reverse of most projects in that it has:

- a very large potential market,
- a pre-confirmed commercial partner with established route to market, but
- lacks certainty in the science.

The anthelmintic market is a multimillion dollar one, and with the development of increasing anthelmintic resistance, the opportunity for product substitution is clear. One of the world's largest animal health pharmaceutical companies is an investor and collaborator and a potential licensee to manufacture and market the product. While the science is world leading, and encouraging results have been obtained, there is no certainty that an antigen able to translate to an effective vaccine will eventuate. The point of transaction for taking a return is the sale of a dose of vaccine, and at a margin and volume that will repay the investment, and make an attractive profit for the investor. I compare this with other projects in my commercialisation portfolio where the attractiveness of the opportunity has been insufficient to attract commercial investment, there is no signed up licensee, but the science outcome is almost assured. The issue in the Nematode project is that time frames are long, risk is high and, understandably, after nearly 10 years, investors are getting fidgety.

Collaborative complexity has been low to date due to the limited number of parties who have highly congruent objectives. Complexity has recently increased with the addition of new investors and collaborators. Scientific complexity has been kept low, with standard and repetitive techniques having been deployed, honed and refined to perfection. It is a numbers game, and provided enough candidate antigens are screened, an effective 1 will be found. Acceptability is high since there is a clear producer, consumer and environmental benefit, and the end product is not controversial.

Virus resistant white clover

Significant benefits to the dairy industry have been estimated for the development of disease resistant white clover via increased production of dry matter. The gross benefit has been estimated at $20 million per annum, but adoption rates, effective utilisation of the extra dry matter, and other variables affecting the capture of these benefits need to be netted off. The product is genetically modified and will enter the food chain, so consumer sensitivities will be high, and release affected by government legislation. In contrast to the potential industry benefit, the direct financial return to an investor is low. Sale of seed will not stand a premium commensurate with what is necessary to justify a commercial investment.

While the inventive step is of a high order, the scientific complexity is moderate beyond this step. Organisational complexity is moderate with a manageable number of parties, a key 1 being a commercial partner's involvement at an early stage. Complexity will come with the number of stacked genes that are put into the released cultivar, and the consequent IP positions and royalty splits that will have to be negotiated between the various gene owners.

Genes affecting bovine lactation

Specific products are identifiable in this case, for example a marker for genetic selection of economically important milk composition traits. These traits are known to all, and will be a major target for a number of research groups throughout the world. Milk is a major high value product worldwide and, consequently, there are many well-resourced groups active in the field. The race to get to a patent position is intense and competitor intelligence is sparse.

A patent position is seen as important for creating options to protect the Australasian dairy industry's least cost of production competitive advantage by contributing to productivity gains. Collaborative complexity is managed by keeping core partners tight. The research program is highly dependent upon industrial scale instrumentation that is expensive. *In vivo* experimentation is expensive and, logistically, more complex than, say, in plant gene discovery. Gene markers will have high acceptability, but transgenic applications, even within species, for example adding a casein gene, are ahead of the market. Pharmaceutical targets aside, the returns to an investor will not justify the investment. Benefits have to be justified at an industry level.

Gene discovery in rye grass

This case provides similar issues and factors to gene discovery in dairy cattle. Targets are clearer and scientific complexity is reduced by being able to experiment with large numbers of low value organisms. The targets are easier to define, but what is apparent is that not all of the genes in a metabolic pathway leading to a target will be discovered and owned by the same entity. This will add a high degree of freedom to operate, but there will be complexity both in understanding the position and negotiating a deal. A key strategy is to endeavor to identify the critical control point in the pathway and make that a target. Ryegrass is a niche market, therefore, the relative competitive pressures are less, vis-à-vis lactational genomics. Similarly world competitors are more easily identified, and their competitive positions are more easily predicted. Transgenic pasture might rationally be expected to be more acceptable to the market as it only indirectly (through an animal) gets into the food chain. But I do not need to tell you that the market is not obliged to be rational.

CONCLUSION

Factors affecting the management of new technologies are not new. What has changed is the degree to which intrinsic and extrinsic influences has become increasingly additive (a form of negative synergy) to make the task of managing the new technologies more complex. Put another way, there are more compounding variables.

The new 'omic' technologies are exciting and fashionable. They have attracted significant research funds because of the opportunities for new products and quantum improvements in productivity. This has put funding pressure on the traditional, and now less fashionable, disciplines at the applied end of the research continuum. I suspect that few in this audience will doubt the relevance of these skills for the future, and will understand their importance for integrating the new technologies into production systems. The challenge for research organisations, and managers like myself, is to maintain a core capability until such time as the market recognises the need for these skills, and is prepared to fund the necessary research. In my own organisation, we have made good progress in getting our internal investors to fund projects in animal nutrition primarily to ensure future capability.

The new technologies are specialist in nature while the skills to translate and apply them are integrative and, by necessity, generalist. When working with the 'whole', be it an animal, a farm or an organisation, an understanding of all of the components, systems or disciplines is required. From my personal experience as a manager of science and technology, I need sufficient knowledge of the various management disciplines to be able to manage them rather than to practice them. Similarly with the scientist responsible for application of the new technologies within production systems, they will need to be a 'specialist generalist'.

REFERENCES

CLEMENTS, R. (2004). *Anim. Prod. Aust.* **25**, 342-348.
JOHNSON, G. and SCHOLES, K. (1984). 'Exploring Corporate Strategy.' (Prentice-Hall: New Jersey.)
LUCY, M.C. (2004). *Anim. Prod. Aust.* **25**, 363-373.
MACRAE, J.C. (2004). *Anim. Prod. Aust.* **25**, 374-385.

Email: Alan.Harrison@dpi.vic.gov.au