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Prepared by: Rob Banks
Meat & Livestock Australia

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Locked Bag 991
NORTH SYDNEY NSW 2059

MLA Investment into Beef and Sheep Genetics and Genomics RD&E: Business Plan

2012/13 - 2014/15

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Vision

An integrated Genetics and Genomics R&D and delivery value chain that will double the value of annual genetic gain from c. $50m/yr (sheep $35m, beef $15M) to $100m/yr (sheep $50m, beef $50m) by 2022.

This vision directly addresses the 3.1 Business Plan "Research and development that produces new knowledge, tools and technologies that create opportunities for producers to become more productive and efficient".

The Strategy for 3.1.1 is to enhance rates of genetic improvement in livestock, by providing genetic and genomic evaluation tools and information for cattle, sheep and goat breeding enterprises.

Executive summary

This plan has been developed to identify where MLA should invest in genetics and genomics research, development and extension (RD&E) given a changing operating environment. This plan is embedded within the 3.1 Business Plan and links directly to several of MLA's 15x15 key focus areas including reproduction efficiency, animal welfare improvement, improvement in production efficiency coupled with reduced greenhouse gas emissions, compliance to market specifications and maintaining and improving eating quality.

Key outcomes targeted include:

- Significant improvement in polledness, fertility and eating quality in northern cattle
- Improved models for generating and delivering genetic information in northern breeds
- Improvement in lean meat yield without decline in eating quality in sheep
- Breeding values for methane production in sheep and cattle
- Increases in rate of genetic progress in all sectors, with a focus on traits related to reproduction

MLA's investment in recent years has been a small proportion of overall national RD&E investment (approximately 10%). However, the total national investment is declining, through wind-up of CRCs and declining co-investment. This plan identifies where MLA's investment in genetics and genomics should be prioritised given it will become a larger proportion of the investment.

MLA is committed to working collaboratively within the national RD&E framework, and is expected to play a leadership role in the beef and sheepmeat industries in developing and implementing national RD&E plans. This means working with RD&E partners, service providers and industry to ensure the best possible use of resources, maintenance of critical capability, and maximum return on investment. MLA will maintain a coordination role for the national investment program, in line with the national RD&E framework.

Rapid developments in genomic technologies and in methods for using genomic information to estimate genetic merit will create significant opportunities and challenges for the current systems for delivery of genetic information. MLA will work with service providers to ensure evolution of these systems maintains or improves access, efficiency and quality assurance and confidence in genetic information. Ensuring that a solid platform of quality data is maintained for accuracy of genomic tests and to underpin calculation of breeding values is likely to be challenged as genotyping declines in cost. Development of sustainable mechanisms for funding the necessary performance recording, via both breeders and resource flocks, is essential.

In parallel with evolution of delivery systems, it will be essential to maintain and build skills and capability among breeders and their service providers. This will be supported by co-investment from industry and breeders.

The plan is focussed on four key strategic initiatives:

- Strategic research focussed on scoping the use of genomic sequencing to reduce cost and increase accuracy in implementation of genomic technologies, plus development of breeding values for methane production and potentially key disease traits in sheep
- Applied R&D focussed on the genetics of fertility in northern cattle, animal health and welfare traits in sheep and cattle, mechanisms for stimulating or incentivising performance recording, particularly in hard-to-measure traits, and on development of breeding program and enterprise models to exploit genomic technologies
- Core infrastructure including maintenance of the underpinning analytical software for BREEDPLAN and Sheep Genetics, national databases, and ongoing genetic parameter estimation
- Evolution of the delivery and extension models to increase flexibility in information capture and delivery, continue building capability in breeders and advisors, and accelerate trialling and implantation of new tools and knowledge.

Budget:

The plan for 3.1.1 proposes maintenance of funding at a total of $5m pa, comprising $2m beef cattle funds and $3m lamb and sheep funds. This maintains the level sustained over 2006-2012.

RD&E investments outside 3.1.1 are anticipated, including within the National Livestock Methane Program and ICE.

Conclusion:

This plan for R&D investment for the period to 2015 builds on MLA and partner investments over the period 2001-2011. It addresses outcomes from the Beef and Sheep CRCs, and progresses opportunities arising from both. It specifically identifies core infrastructure which needs to be maintained, while focussing on areas for new R&D that align with several of MLA's 15x15 key focus areas. The plan will maximise the likelihood of a significant acceleration in genetic progress over the coming years, particularly in traits such as fertility in northern cattle and eating quality in both species, that have been very difficult to change previously. The plan provides a structure for appropriate MLA engagement with the RD&E pipeline and facilitation of change, without crowding out research or implementation opportunities, and maintains scope for innovative thinking.

Glossary

ABRI (Agricultural Business Research Institute): a controlled entity of UNE, has the exclusive world-wide license for commercialisation of BREEDPLAN, which includes analytical software and related tools. ABRI delivers BREEDPLAN to stud beef breeders in Australia and internationally via breed societies. It collects approximately $960,000 per year in income for the services delivered to the breed societies. ABRI also delivers pedigree recording and registration services in beef and other species.

AGBU: Animal Genetics and Breeding Unit, a joint venture of UNE and NSW DPI. Provides the underpinning R&D for BREEDPLAN and OVIS. AGBU is funded through a combination of contributions funding key staff made by UNE and NSW DPI, plus R&D contracts in beef, sheep, pigs, trees and minor work in other species. MLA R&D contracts are approximately 40% of total contract funding for AGBU.

BREEDPLAN: Analytical software developed by AGBU and commercialised via ABRI. Produces Estimated Breeding Values (EBVs) and associated genetic information (such as Inbreeding %, $Indexes, genetic trends).

OVIS: Analytical software developed by AGBU and commercialised via Sheep Genetics. Produces estimated Breeding Values in the forms of ASBVs (Across-flock Breeding Values) and FBVs (Flock breeding values) and associated genetic information (such as Inbreeding %, $Indexes, genetic trends). OVIS is simply a name for the software, based on the Latin name for sheep.

SNP: Single nucleotide polymorphism, unit of DNA structure used in analysing animals' genetic makeup – a form of marker for the actual DNA sequence

Sequencing: Reading the actual sequence of nucleotides along chromosomes to get the entire genetic makeup.

Genetic trend: BREEDPLAN and OVIS produce breeding values from animals in different flocks/herds and born in different years. By calculating the average breeding value in each year, and then tracking over time, an estimate of the genetic change in the population is generated. Increasing the rate of genetic progress in beef and sheep in Australia is a KPI of this plan.

$Index: in both sheep and cattle, combined or overall estimates of genetic merit are produced by weighting the individual breeding values by a measure of their economic importance. This assists commercial producers in sourcing sires with the optimal balance of breeding values for the producers' individual production systems and target market, and stud breeders in selecting the animals as parents with the best overall combination of genes for anticipated future demands.

DSE: dry-sheep equivalents, a system for calculating the feed demands of sheep and cattle at different stages of life. In calculations here, a ewe is assumed at 2 DSE and a cow at 20 DSE (both include followers). **Dry Sheep Equivalent** is a standard unit frequently used in Australia to compare the feed requirements of different classes of stock or to assess the carrying capacity and potential productivity of a given farm or area of grazing land. The unit represents the amount of feed required by a two year old, 45 kg (some sources state 50 kg) Merino sheep (wether or non-lactating, non-pregnant ewe) to maintain its weight.

Sheep Genetics: an operational unit of MLA, which manages the performance and pedigree databases for the sheep industry and delivers breeding values and associated information to sheep breeders. It is funded 50% by breeders, 34% from MLA on-farm R&D funds, and 16% from AWI on-farm R&D funds. Sheep Genetics is managed by MLA, under a Management Agreement with AWI which runs to June 2013 when it will be reviewed.

SBTS/TBTS: Southern Beef Technology Service and Tropical Beef Technology Service respectively. Regional (southern and northern) extension and capability-building programs funded through the MLA MDC program – jointly with breed societies.

EBV: estimated breeding value, the unit of genetic merit in the BREEDPLAN language. Breeding value means the value of an animals' genes in terms of the value of the progeny it can breed. Estimated refers to the fact that the EBV is a statistical estimate of the true value of those genes, based on the data available.

ASBV: the equivalent of EBV in sheep, delivered by Sheep Genetics. ASBVs compare animals bred in different flocks, and are only produced when there is a defined level of pedigree linkage between the particular flock and others.

FBV: the equivalent of EBV in sheep, but for the situation where a particular flock is not sufficiently linked to others. FBV stands for Flock Breeding Value. FBVs can only be compared within the flock for which they are produced.

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1. Introduction

One of the key factors allowing commercial producers to become more productive and efficient, maintain or improve product quality, and enhance sustainability of their enterprises, is the level of adoption and effectiveness of use of genetic and genomic evaluation and improvement tools and technologies by the breeding sector – those enterprises that breed (and in the majority of cases) sell, bulls and rams.

Benefits, or return on investment, from RD&E into beef and sheep genetics and genomics, are captured through three paths:

1. Producers being able to make more informed decisions on which bulls or rams to buy (or which studs to buy from) than would otherwise be the case
2. Genetic improvement, which means that the cattle and sheep in commercial flocks and herds are getting steadily better (in terms of productivity, product quality and costs) over time
3. Being able to target specific management to animals with specific genetic merit to meet a market demand (an example is knowing which animals to put into feedlots to produce marbled beef)

All three benefits ultimately depend on stud breeders (people who sell bulls or rams) recording animals' performance, and converting that data into EBVs or ASBVs (estimates of animals' genetic merit). For genetic improvement, this must be combined with selection of genetically superior animals to be parents of future generations.

Genetic differences among animals affect all traits in the value chain – eating quality, nutritional content, cost-of-production (reproduction, growth rate, feed efficiency), animal health, welfare and environmental costs (eg welfare). Genetic range available for producers is typically 33-50% of total range in performance, depending on which trait is considered. In addition, genetic improvement offers the **only** means of continuously improving productivity and product quality

Australian beef breeds' rates of progress (see attachment I for an outline of how genetic progress is measured and valued) are similar to the average of competitors. Sheep breeds' progress is at least as good as in NZ and well ahead of any other countries. There is no technical reason why current annual increment from genetic improvement of approximately $50m pa could not be increased to at least $100m pa. This opportunity cost, of approximately $28m increment pa, is due to lower than ideal recording of hard-to-measure traits, coupled with lower intensity of selection and longer generation intervals than are being achieved by leading breeders.

The development of this strategy has been through widespread consultation including analysis of the current pipelines and consideration of how MLA can contribute to their operation going forward. In particular how MLA should contribute to the management of the R&D and the delivery of outcomes.

2. Situation analysis

Investment in beef and sheep genetic improvement RD&E in Australia is through a pipeline, with stages starting from strategic research through to implementation in the seedstock sector. The stages are:

1. Strategic research: work that will deliver on-farm technologies 7 years or more into the future
2. Applied R&D: work that will deliver on-farm technologies 3-7 years into the future. For simplicity, this stage can be considered to include core infrastructure
3. Service delivery, which includes data analysis, as well as performance recording and extension. In the summary table below, extension is shown separately from data analysis and performance recording, reflecting different funding sources.

The generic RD&E pipeline for beef and sheep genetic improvement RD&E is outlined in Attachment II. The beef and sheep pipelines represented in Attachments III and IV have evolved over the period since the mid-1980s when meat industry R&D in genetic improvement commenced. Average annual investment for 2001-2011 in each stage in beef and sheep is summarised in the following table:

Stage	Beef ($M)			Sheep ($M)		
	Gov'ts	Levies	Breeders	Gov'ts	Levies	Breeders
Strategic R	10.94	0.76		7.89	3.25	
Applied R&D	2.86	0.52		3.09	0.44	
Extension	1.75	0.17	0.33	1.82	0.32	0.29
Data analysis & performance recording	1.13		5.48	1.85	0.32	4.49
Total	16.67	1.45	5.81	14.64	4.33	4.78

Government and levy funds are more heavily focussed at the strategic and applied ends of the RD&E pipeline.

Research & Development:

Investment into genetics and genomics RD&E and implementation has averaged approximately $24m pa in the beef industry and $32m pa in the sheep industry, over the 10-year period for 2002-2011. This included significant investment through the Beef and Sheep CRCs in developing genomic technologies.

Of these totals, approximately 60% in beef and 70% in sheep has been Commonwealth and state government funding through CSIRO, CRCs and matching funds; 24% in beef and 15% in sheep funded by breeders; and the remainder producer levies (6% in beef and 23% in sheep). Note that these proportions are significantly impacted by the Sheep Genomics Program, which ran from 2001-2006.

Some significant outcomes from the RD&E include:

- Genetics (and genomics) of eating quality in sheep – breeding values are now available.
- Strong growth in genetic evaluation in Merinos, now c. 35% of Merino rams being sold or used have breeding values, and animals bred in flocks using MERINOSELECT account for 67% of AI sires. Overall impact of MERINOSELECT is estimated at 50% of all Merino rams used either have breeding values or sired by rams with breeding values.
- The rate of progress in terminal sire sheep breeds has been maintained at c. $0.80 per ewe per year, and has increased from $1.08 per ewe per year to over $1.40 per ewe per year in dual-purpose and Merino breeds between 2001 and 2011.
- Knowledge of the genetics of reproduction in northern cattle, and relationships between carcase traits and female productivity in southern cattle.
- The rate of genetic progress in beef breeds has risen from a 5-year rate of $1.60 per cow in 2001 to $2.54 per cow in 2011.
- Genetic improvement includes both single gene and single trait issues – such as polledness in cattle, labour-reducing improvements, and production efficiency and welfare improvements.

(Attachment V contains details of genetic technologies being delivered in Australia.)

These improvements ultimately have to be packaged together in individual animals – it is basically not useful for individual enterprises or industry to have some animals that are outstanding for one trait and modest for others. An important consequence of this is that in all genetics and genomics R&D, the relationships between numbers traits must be determined: a research project that focusses on one trait without recording and analysing at least key other traits is essentially useless, as those relationships will have to be determined prior to delivery of genetic information in a useful form to breeders and producers.

The end of Beef CRC, and Sheep CRC ending in mid-2014, will reduce funding available for strategic research, which has been major proportion of overall investment since 2001 (estimated at 57% in beef and 31% in sheep). This includes substantial in-kind in both species, from a range of organisations.

MLA will need to seek co-investment in the strategic research area while focussing investment. The R&D proposed in this plan is focussed on harnessing CRC outcomes while scoping improvements in genomic methods for both species. In parallel, MLA will partner with Peak Council and RD&E partners to scope an Extension Bid for the Sheep CRC, which if successful will include work on improvements in genomic methods.

Data analysis:

Analysis of the pedigree, performance and now genotype data collected primarily by breeders utilises BREEDPLAN and OVIS software developed and maintained by AGBU. In beef, the BREEDPLAN software is run by ABRI under license, while in sheep, AGBU conduct the routine analyses for Sheep Genetics.

In beef cattle, analyses are updated at intervals from monthly (Angus) through to quarterly (most breeds). Typical analyses include several million animals, and the computer runs take around 24-36 hours.

In sheep, analyses for meat breeds are conducted fortnightly and for Merinos monthly. The analyses include several million animals, and take upwards of 24 hours to run.

Service Delivery:

Details of the current levels of adoption of BREEDPLAN and Sheep Genetics are presented in Attachment VI. The level of adoption coupled with the genetic trends being achieved correspond to producers' gross margins growing by c. $1.20 per commercial cow and $0.33 per commercial ewe improvement in gross margin per year, or 1.2% improvement in profit per DSE in beef cattle and 2.5% per ewe, <u>across all cows and ewes respectively.</u> Those producers who actively seek bulls with BREEDPLAN information or rams with Sheep Genetics information (approximately 50% overall) are obtaining benefits 50% larger than the overall average, and leading studs in both species are delivering benefit 50% larger again. For those producers who source sires from the leading studs, genetic improvement is ensuring that their enterprises are staying well ahead of the cost-price squeeze.

The achievement of these benefits has been built through over 25 years of sustained RD&E investment coupled with significant contribution from the stud sector – particularly those breeders who have engaged most strongly with the technology and the R&D, and who data collection heavily underpins the entire RD&E and implementation effort. This is a substantial intellectual and implementation achievement, and Australia's record in this area is highly respected world-wide. MLA and key RD&E partners including breeders have been essential to this achievement, as has been the degree of largely informal coordination across the different players in this innovation system.

While genetics and genomics are relatively mature technologies (although cost-effectiveness of genomics is improving exponentially), significant structural challenges for industry will arise in the next 3-5 years, due to:

1. Dependence on volumes of quality data – whether for "genetics" or "genomics"
2. The volume and quality of data generates significant externalities – within the breeding sector and through the value chain.

3. Fragmented value chains mean breeders receive poor price signals for most traits other than growth rate and size. Current service delivery models do not reward either externality. Therefore within the breeding sector investment in recording for the full range of traits is unattractive economically.

The availability of cheap, accurate genotyping could lead to significant declines in the amount of performance recording in both species. Without appropriate quantity and quality performance data, genetic progress is impossible, and genomic tests will decline rapidly in accuracy.

These technologies are now delivered with breeders paying the costs of delivery, including the development and maintenance of the databases needed for use with all 3 types of technology.

In the case of beef, the majority are delivered through an exclusive licence with ABRI, who deliver BREEDPLAN. In the case of sheep, the majority are delivered through Sheep Genetics. It is important to note that all the technologies depend for their full value on some form of integration or analysis with the industry databases maintained through the beef breed societies and through Sheep Genetics.

SWOT:

Strengths:	**Opportunities:**
Strong technology base and technical capability in Australia Strong linkage to international R&D and implementation in beef Strong core of innovative technically adept breeders committed to investment in performance recording and genetic improvement in both species High level of adoption in meat sheep breeds and southern cattle breeds, underpinned by demand from producers for animals with breeding values	Increase in rate of genetic gain in all sectors Access to international R&D, and continuing collaboration with R&D in other species Increased effectiveness of use of technologies in all sectors Supply chain consolidation and integration leading to greater direct investment in genetic improvement. Genomic tools becoming cheap enough to be cost-effective for large operations. Stronger market signals. New investors – within existing supply chains or outside (eg retailers) New pipelines for RD&E and delivery New technologies to support new traits and methods of genetic evaluation over 20 years out.
Weaknesses: Weaker adoption in northern beef industry and Merinos Long lead-time between investment and returns Performance recording funded almost entirely by returns from bull and ram sales Limited understanding in supply chains of benefits of genetic improvement	**Threats:** Limited flow of price signals reduces incentives for investment, particularly in hard-to-measure traits. Scale of investment required for maintaining accuracy of genomic tools. Marketing of uncalibrated genomic tools could undermine existing information systems. Loss of human capability in RD&E with wind-up of CRCs. Reduced funds for RD&E. Australia is a small player globally, with high exposure to export markets. Heavy dependence on imported (US) genetic material in beef cattle Focus on wrong targets e.g. LMY without balance of focus on eating quality

Strategic Issues and Risks:

This section identifies issues and risks that have been taken into consideration in developing the strategic initiatives within this plan. They are simply listed here, with brief comment on how they are addressed in this plan. More discussion of each point is included as Attachment VII.

MLA control and influence

MLA is one investor among many in the genetics and genomics RD&E and implementation system (see p. 5), but MLA cash attracts significant leverage. MLA has significant influence through the licensing and delivery mechanisms for BREEDPLAN and OVIS technology (which includes utilisation of genomic information).

MLA can stimulate system improvement through a combination of setting overall system goals, facilitating interaction and collaboration through the pipeline, ensuring openness and data availability wherever possible, and through investing in capability in breeders, advisors and researchers.

Institutional Change:

There is scope for exploring new institutional arrangements and partnerships. This includes encouraging closer collaboration through the pipeline, and appropriate focus on collaboration across organisations in regional or species-specific programs and projects. At the same time, it must be realised that MLA has no direct or controlling role in any of the partner institutions – including AGBU, ABRI, breed associations, R&D providers - except by funding.

Market failure considerations

The Australian meat industry has invested in developing and delivering genetic evaluation and improvement technologies since the mid-1980s. Throughout that period, levies and matching funds have been used for R&D, with breeders meeting the costs of databases, analysis and delivery of information essentially from 5 years after the start of R&D in each species.

This has been an equitable and reasonably efficient approach, but has one major problem: the flow of price signals for traits such as product quality, feed efficiency, and to some extent reproductive rate, is almost non-existent. The BINs and the Sheep Information Nucleus/Resource Flocks represent a collective investment in addressing this market failure. Scoping other mechanisms to address this issue is a priority for this plan.

Limited co-investment – agencies, AWI

This plan is being developed within the national RD&E framework, although not a formal cross-sectoral strategy. Within that development process, consultation has included exploring co-investment. Within Qld, SmartState funding has been obtained by QAAFI, but may be conditional on MLA co-funding. Vic DPI has indicated availability of research and extension personnel, but this will depend on MLA co-investment. Consultation with Beef CRC researchers has prioritised strategic investments to focus on use of sequence data in genetic evaluation, but progressing this will also depend on MLA co-investment.

There is considerable uncertainty surrounding AWI co-investment in sheep genetics R&D (currently c. $175k pa in AGBU, $1.3m pa in Sheep CRC) and in Sheep Genetics ($175k pa). This is despite strong producer support for investment in this area.

Evolution of the delivery model, and R&D partnership with leading breeders (incl. treatment of recording costs)

As identified earlier, the rapidly dropping genotyping costs could potentially lead to a dramatic reduction in the amount of performance recording. This cannot be predicted definitively, but has potential to significantly impact the business model for BREEDPLAN, and points to the need to change the way new performance records are treated (for example, in the BINs they are half-funded and in the Sheep Information Nucleus, fully funded). Such new data is already, and will become to a greater extent, R&D which has a spin-off benefit of underpinning breeding values in the latest animals. Models whereby the records submitted by leading breeders (those who can be shown objectively to be submitting the most valuable data) are treated as a research cost, will need to be explored (as is the case, noted above in dairy and cereals).

Stimulation of co-investment through the chain

Both through AMPC and ALFA, and through direct supply chain partnership projects (such as the Te Mania MDC project, and the Lean Meat Yield/Eating Quality PDS projects) the program will need to seek and facilitate direct co-investment through the supply chain, particularly into recording hard-to-measure traits.

Simply collecting MSA or sale data is not automatically sufficient – this depends on the control of the management groups that the data is collected on. Livestock Data Link is an attempt to facilitate such data collection, but will not automatically deliver useful information because of the requirement for knowledge of the management groups of animals being delivered.

MLA is in an important position to explore investment into resource populations (Beef Information Nucleus (BINs), sheep resource flocks) via the MSA program, the Climate Change R&D program, animal health R&D and elsewhere. This has the advantages of being most technically efficient because of the genetic makeup of those populations, ensuring that MSA prediction models are as accurate and up-to-date as possible, and providing a means of contributing to reducing the market failure impacts noted above.

Shift from developing tools and knowledge to stimulating effective utilisation

Through the period 1985-2012, R&D has focussed on developing and delivering tools for genetic evaluation and improvement to the approximately 2,500 breeders of beef cattle and sheep who supply genetic material to the meat industry. A very small proportion of the total RD&E effort has gone into helping and encouraging breeders to use the tools effectively, to maximise rate of genetic progress – despite this being overwhelmingly the biggest impact factor for the technology for industry. This is somewhat akin to having built an IKEA factory and simply dumping all the pieces in a warehouse with no assembly instructions or Allen keys and charging people for what they take out.

Along with the challenge of transitioning to full implementation of genomic technologies, and in particularly solving the problem of ensuring there is enough of the right data, the other major challenge for industry from here on is to help and incentivise breeders to significantly increase rates of genetic progress. This will depend on a combination of minimising market failures in feedback, and building capability in breeders and their advisors, public and private. Building capability will increasingly require inputs from personnel with post-graduate training in animal breeding.

Challenge of coordination, and acceleration in "ideas to implementation"

MLA has provided important coordination across and through the RD&E pipeline in both beef and sheep, and there is scope to increase the effectiveness of this (see above). At the same time, it is essential that MLA or its RD&E partners do not crowd out private initiative. Focussing on facilitating through-chain and within-sector linkage and coordination, and building capability, are legitimate areas for collective investment. Getting this balance right will be increasingly important for MLA and this program, but will be essential to achieving dramatic increases in rates of genetic progress in the meat industry. Those dramatic increases are essential simply to maintain viability of the industry.

3. Development of the RD&E Plan for Genetics and Genomics

This plan has been developed through significant consultation over the last 3 years including:

- The Livestock Genomics initiative process, through 2010, which involved all key stakeholders in animal genomics RD&E and was aimed at developing options to maintain R&D effort in this space post-Beef CRC III.
- Development of the Beef CRC Extension bid, which was ultimately unsuccessful but key R&D strategies from that bid have been included in this plan.

- Through 2011, MLA and Beef CRC conducted a consultation with stakeholders focussed on the efficiency of the RD&E pipeline, which produced a Green Paper which has been widely circulated through industry. The submissions to that process, including the Green Paper, have informed this plan.
- Sheep genetics and genomics consultation proceeding through the Sheep Genetics Advisory Committee (which meets 3 times per year) and Technical Committee (3 times a year), and consultation with stakeholders through industry events and workshops jointly with Sheep CRC
- Key researchers were consulted through two strategic genetics and genomics scoping workshops held early 2012, which developed concept proposals for continuing strategic genomics research, and which are included in this plan.
- The northern industry has been consulted on research priorities and possible projects through several workshops held over the period since late 2010.
- The MLA Genetics and Genomics RD&E Roundtable held in September 2012 facilitated by MLA.

Key issues to be resolved/addressed include:

- A strong formal governance structure for the national plan is proposed – as yet we are not at the point of getting binding commitments (section 10).
- The delivery pipeline in both species is likely to change significantly over the next 3-5 years as genomic tools come down in price, and the amount of phenotyping will likely drop significantly. Phenotypic data is critical, regardless of the level of use of genomic testing. We will need to work with AGBU and ABRI to evolve the pipeline in beef, and with AGBU in sheep (section 10).
- There will inevitably be a shift in emphasis away from strategic R (which has been approximately 50-56% of total investment over the last 10 years, via the CRCs and Sheep Genomics) to focus on improving utilisation of tools and knowledge by breeders – who generate the genetic progress. Sheep Genetics and SBTS/TBTS have core roles in capability building for breeders and service providers (sections 7 and 8).
- Mechanisms have to be found to reduce the impact of market failure (poor flow of price signals from consumers and processors back to breeders) on the level of performance recording – which limits the rate of progress that can be achieved in traits like eating quality (section 10).
- MLA investment is via several AOP nodes (including 2.1, 3.1.1, 3.4, 4.1, ICE and others) – we need to ensure internal coordination as well as providing external coordination across the RD&E pipeline (section 10).

4. Key initiatives

Consultation over the last three years has led to the following initiatives to be progressed and managed by MLA:

Strategic Research, focussed on development of genomic technologies and new traits:

- Develop genomic tools and statistical methods to enhance accuracy of breeding value predictions, including capacity for across-breed and composite evaluations (this relates to MLA 3.1 Business Plan, Key Initiative 1, KPI 2, see attachment IV)

- Develop research proposals for understanding the interaction of genetic makeup and nutrition/management in trait expression, focussed on 1-2 key traits (such as eating quality and northern reproduction) (3.1 Business Plan Strategy 1, Key Initiative 1, KPI 2)
- Develop methodologies for prediction of genetic merit for methane production (3.1 Business Plan Strategy 1, Key Initiative 1, KPI 3)
- Further develop approaches for optimisation of phenotyping, genotyping and selection at all stages of beef and sheep value chains (3.1 Business Plan Strategy 1, Key Initiative 1, KPI 4)

Core Applied R&D:

- Work with breeders, breeds and/or breeding organizations to develop new breeding enterprise models that utilize phenotypic and genomic information (3.1 Business Plan Strategy 1, Key Initiative 1, KPI 4)
- Conduct R&D to evaluate optimal reproduction levels in cattle run in low input or stressful environments, building on Beef CRC III Northern Reproduction and Maternal Productivity programs (3.1 Business Plan Strategy 1, Key Initiative 1, KPI 3)
- Continue research into animal health and animal welfare traits in northern and southern cattle, using both phenotype- and genotype based methods (3.1 Business Plan Strategy 1, Key Initiative 1, KPI 3)
- Develop efficient and equitable mechanisms for direct incentivisation of phenotyping (3.1 Business Plan Strategy 1, Key Initiative 1, KPI 1)

Core Infrastructure:

- Maintain the national phenotype-genotype databases (3.1 Business Plan Strategy 1, Key Initiative 1, KPI 1)
- Maintain and develop the core analytical software for BREEDPLAN, LAMBPLAN and MERINOSELECT
- Maintain underpinning genetic parameter estimation, built into breed improvement RD&E programs
- Information nucleus/Resource flocks and herds program transitioned to a) sustainable co-investment model, b) direct involvement of breeders who supply phenotypes (3.1 Business Plan Strategy 1, Key Initiative 1, KPI 1)

Delivery, implementation and capability-building:

- Nationally coordinated capability-building programs for breeders, extension personnel and consultants. This to be a core role for SBTS, TBTS and Sheep Genetics. (3.1 Business Plan Strategy 1, Key Initiative 1, KPI 6)
- Include leading breeders in all R&D projects in advisory and/or trialling role (3.1 Business Plan Strategy 1, Key Initiative 1, KPI 4)
- SBTS, TBTS and Sheep Genetics to develop with AGBU or other R&D providers annually updated “breed development programs” including parameter updating, phenotyping and genotyping strategies, and genetic progress targets (3.1 Business Plan Strategy 1, Key Initiative 1, KPI 4)

- Use PDS programs to enhance supply chain understanding and utilisation of genetics, including in Lean Meat Yield and EQ in sheep, fertility, tenderness and polledness in northern cattle, and EQ and productivity in southern cattle (3.1 Business Plan Strategy 1, Key Initiative 1, KPI 4)
- Nationally coordinated extension programs in southern beef, northern beef and sheep, including co-investment from RD&E partners (3.1 Business Plan Strategy 1, Key Initiative 1, KPI 6)

Activity in these areas and breeds/groups/studs should be prioritised according to the numbers of sires likely to be generated and the average rate of progress across the previous 5 years – those breeds or businesses that have delivered the most genetic improvement should get more resources into R&D.

Key deliverables from the program and sub-programs:

Program/sub-program	Strategy	Key Initiatives	Targets Milestones/KPIs
3.1.1	Enhance rates of genetic improvement in livestock	Provide genetic and genomic evaluation tools and information for cattle, sheep and goat breeding enterprises	Double the value of annual genetic gain from c. $27m (sheep $15m, beef $12M) to $55m (sheep $25m, beef $30m) by 2022.
3.1.1 a	Next generation genomic information	- progress methods to use DNA sequence data - develop and apply the single step method for including genomic information in genetic evaluation - investigate new phenotyping options	Sequence data on key sires in beef and sheep, to support cheaper genomics tests based on smaller chips Single step method implemented in BREEDPLAN and Sheep Genetics New phenotyping methods (eg for feed intake, eating quality and animal health) scoped
	Breeding values for methane production	Measure methane output, feed intake and weights in animals in BINs and Resource flocks, to underpin breeding values for methane output	Breeding Values for methane production delivered on animals in resource populations Trial genomic breeding values for methane production developed
3.1.1 b	Optimal reproduction levels in northern production systems	- Co-invest with breeders and the SmartState project to collect appropriate phenotypes for reproduction traits - Co-invest into selection lines to research potential limits to lifetime reproduction	3,000 records for each of phenotypes prioritised by industry arising from CRC III Northern project collected on herds participating in the SmartState project. Selection line established to allow monitoring of lifetime calving performance in highly fertile northern cattle
	Develop mechanisms for Incentivisation of recording	Projects to scope mechanisms and define value of records	Mechanisms developed for consultation with industry during 2013-14
3.1.1 c	Database infrastructure	Maintain core R&D databases	
	Analytical infrastructure	Maintain BREEDPLAN and OVIS analytical software, including upgrading for new traits and single step method	

Program/sub-program	Strategy	Key Initiatives	Targets Milestones/KPIs
	Resource/reference flocks/herds	Coordinate and manage BINs and Sheep Resource Flocks Develop mechanism for ongoing funding and inclusion of farm and research data	
3.1.1 d	Flock and breed improvement – including capability building, delivery, and service model evolution	Capability building for breeders	Targets within Business Plans for SBTS, TBTS and Sheep Genetics met
		Capability building for service providers	Targets within Business Plans for SBTS, TBTS and Sheep Genetics met
		Annual flock/breed improvement program plans	Defined annual plans, including research tasks, updated annually, and KPIs defined and met
		Evolution of delivery models	Consultation with ABRI, Sheep Genetics and breeder stakeholders completed.

5. Proposed investment 2012-2015

The 3.1 Business Plan allocates approximately $5m pa for 3.1.1. The indicative funding allocations from On-Farm R&D for the years 2012-2015 for beef and sheep are:

Beef 3.1.1:

Initiative	**2012-13 ($M)**	**2013-14 ($M)**	**2014-15 ($M)**
1. Development of genomic technologies and new traits	**1.10**	**0.90**	**0.30**
2. Core applied R&D	**0.20**	**0.25**	**0.20**
3. Core infrastructure	**0.20**	**0.25**	**0.20**
4. Delivery, implementation and capability-building	**0.43**	**0.33**	**0.18**
5. Coordination	**0.07**	**0.07**	**0.07**
Total on-farm R&D (3.1.1)	**2.30**	**1.40**	**0.95**
Available for new projects*	**0.00**	**0.30**	**1.93**

*: assuming $2.00m pa available, based on allocation proportions in 2011/12 budget.

Additional projects through the MDC are:

a) Beef Information Nucleus projects (total = $2.34m pa) (Initiative 3)
b) SBTS and TBTS (total = $1.7m for 2012-16, average annual investment = $0.43m) (Initiative 4)

Additional MLA RD&E funding in beef genetics is likely to include:

a) Extension projects funded through ICE, up to $0.09m/yr (Initiative 4)
b) Methane R&D co-funded through R&D levies and DAFF funds, up to $0.30m/yr (Initiative 1)

Sheep 3.1.1:

Item	**2012-13**	**2013-14**	**2014-15**
1. Development of genomic technologies and new traits	1.00	0.50	0.50
2. Core applied R&D	0.20	0.35	0.26
3. Core infrastructure	1.10	1.10	1.10
4. Delivery, implementation and capability-building	0.35	0.35	0.35
5. Coordination	0.07	0.07	0.07
Total on-farm R&D (3.1.1)	2.70	1.87	1.78
Available for new projects*	0.30	0.65	0.72

*: assuming $3.00m pa available for sheep, based on proportion of funds 2011/12.

Additional MLA RD&E funding in sheep genetics is likely to include:

a) Extension projects funded through ICE, up to $0.09m/yr (Initiative 4)
b) Methane R&D co-funded through R&D levies and DAFF funds, up to $0.30m/yr (Initiative 1)

6. Benefit cost analysis

ACIL Tasman is conducting a comprehensive evaluation of past and potential future investment in this area.

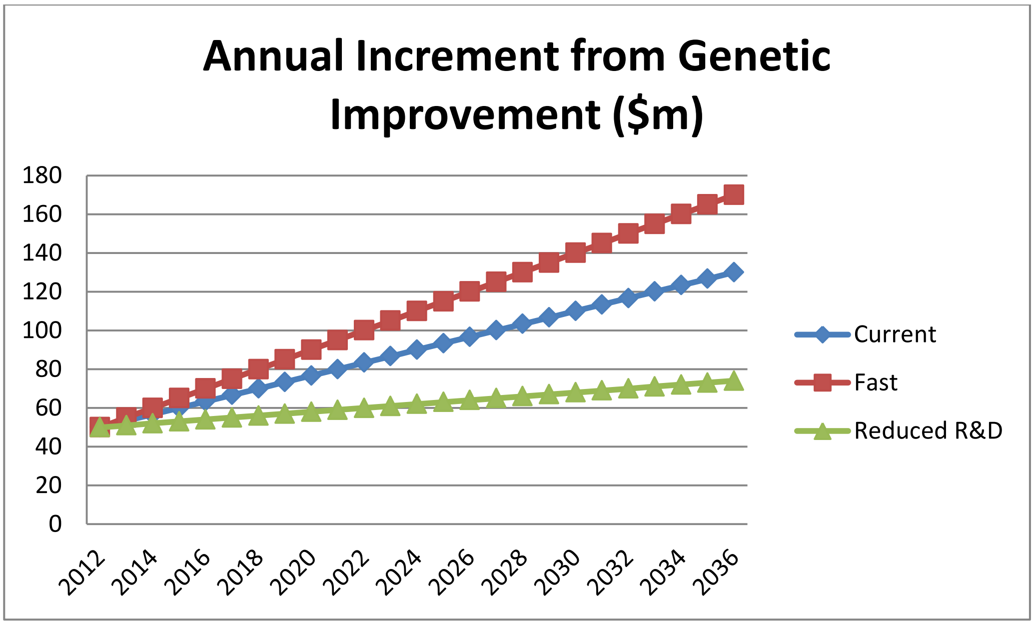
An indicative BCA for the portfolio is as follows:

a. The rate of genetic progress, and hence its value, in both sheep and beef has been steadily rising since 1990. If the trends since 2002 continue, the rate of progress and hence its value will double within 15 years. This represents the counterfactual - the annual increment from genetic improvement, doubles in 15 years, from $50m to $100m. This is the **Current** scenario.

b. The benefit assumed from this plan (RD&E focussed on improving adoption and utilisation in northern beef breeds, better utilisation in southern beef breeds, maintained genetic progress in terminal sire and maternal breeds, and faster progress and increased adoption in Merinos), is that the annual increment from genetic improvement doubles in 10 years rather than 15. This is the **Fast** scenario.

c. A second counter-factual needs to be considered – the case where R&D is reduced. The predicted effect of this is to steadily erode the rate at which genetic progress increases, due to reduced confidence in genomic tools (and so no positive impact from them), and no further growth in effectiveness of use of genetic technologies in general. This is shown as the **Reduced R&D** scenario in the chart below.

The chart shows the value of the annual increment due to genetic gain, under either current rate of increase, or under faster doubling due to focussed and coordinated investment, or under reduced RD&E investment.

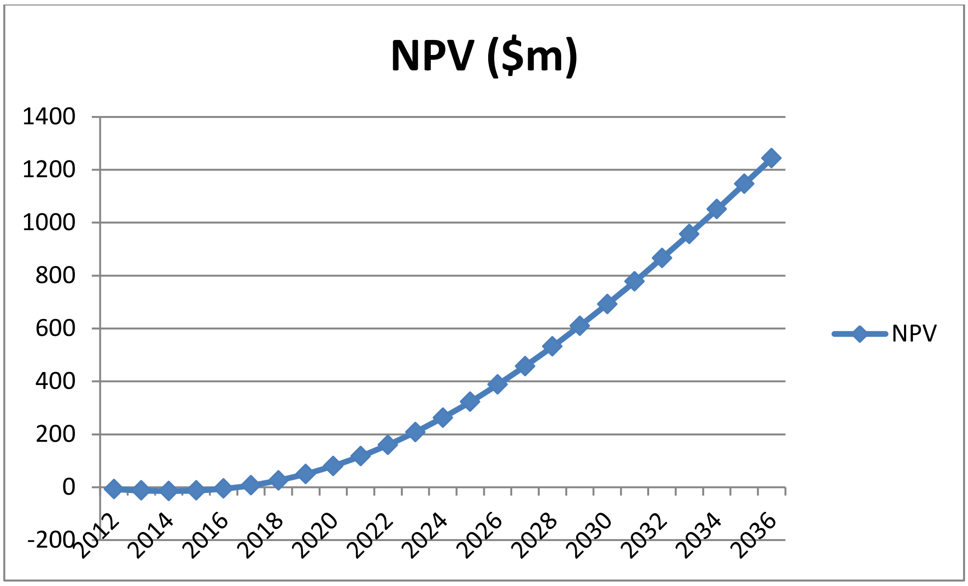


The annual investment assumed is a total of $4.5m on-farm R&D and $3.0m MDC. This does not include other RD&E investment such as CSIRO or the recording costs met by breeders.

The BCA results for this investment and the outcome of faster genetic progress compared with the current scenario are:

NPV (at 7% discount rate, period 2012-2036) = $1,242m
MIRR (at 7% finance rate and 7% reinvestment rate) = 29%
BCR = 14.3:1

The growth of the NPV is as follows:



This shows that the present value of maintaining current investment levels to achieve faster doubling of genetic progress becomes positive within 5 years, and grows exponentially thereafter.

If the "Reduced R&D" scenario is modelled, and a steady reduction of RD&E costs by $0.5m pa assumed, the NPV of the difference between the Current and the Reduced R&D scenarios is $1,825m over 25 years. The MIRR is 26% and the BCR is 42:1.

These values reflect the pessimistic assumption that rate of genetic progress would grow only very slowly under a reduced RD&E investment scenario, so that the difference in genetic merit at any time in the future between the Current and the Reduced R&D scenarios is larger than that between the Fast Progress and Current scenarios.

Both sets of BCA outcomes reflect the importance of rate of genetic progress on returns from the RD&E investment – rate of progress has much greater effect on return on investment than the amount invested.

BCA results

	Scenario	
	Fast v Current **(this estimates the value of doubling the rate and value of genetic progress by making the proposed RD&E investment)**	**Current v Reduced RD&E Investment** **(this estimates the opportunity costs of reducing investment, leading to slower genetic progress)**
NPV 25 years, 7%	**$1,242m**	**$1,825m**
MIRR %	**29**	**26**
BCR	**14:1**	**42:1**

7. Program structure and governance

The program of RD&E work in animal genetics and genomics can be mapped via two dimensions:

a. strategic-applied- extension- implementation (SAEI)
b. by focus species and region (S&R)

Within the SAEI mapping, research is more generic (can be applied to sheep and beef, north and south) at the strategic end of the portfolio. At the same time, at the extension and implementation end, the focus and skills of available personnel are much more regional and species-based.

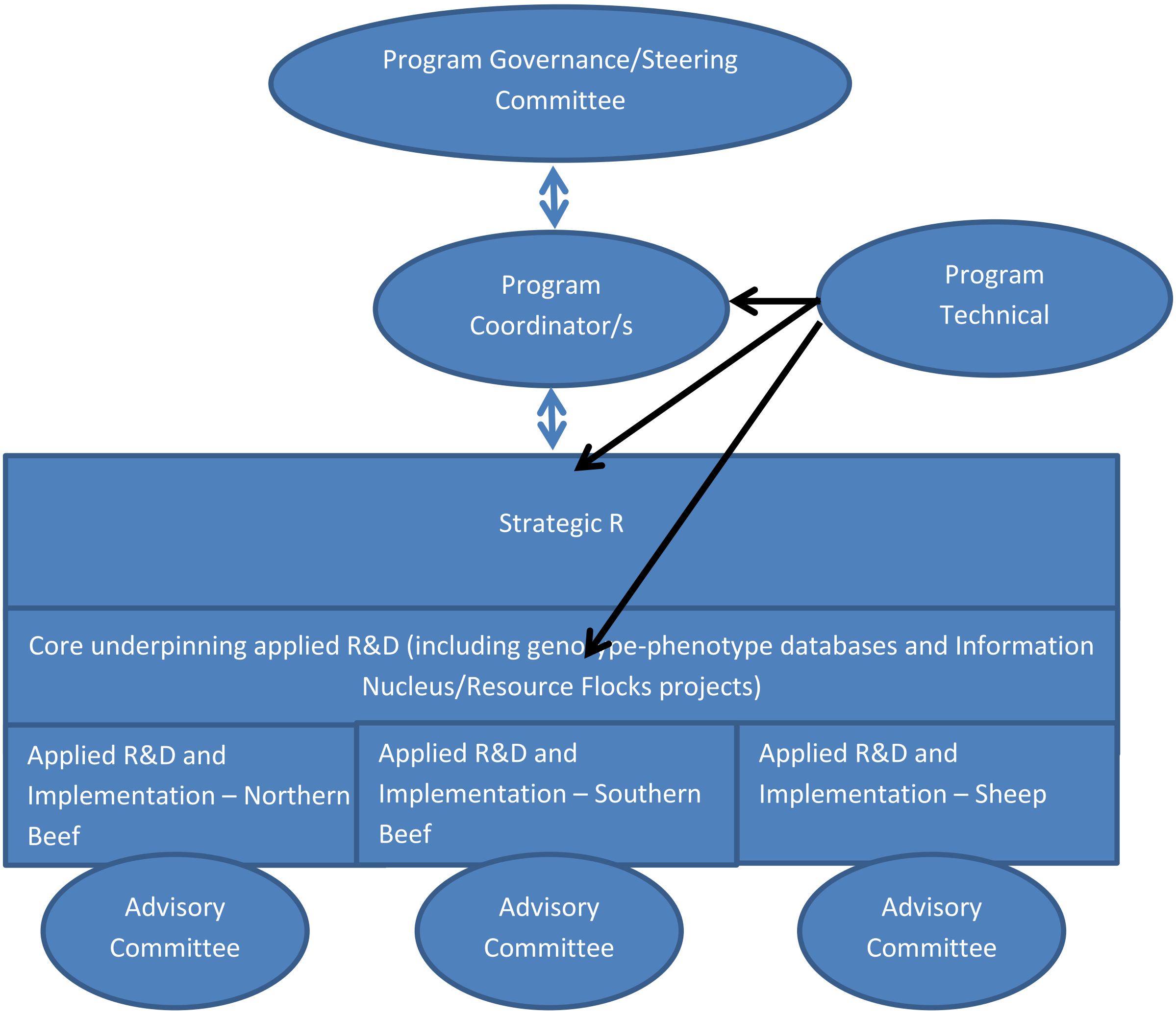
This mapping suggests that a blend of the two approaches is sensible, with 4 sub-programs. These map directly to the Key Initiatives outlined in section 7.

- **Strategic research**
- **Core applied R&D:**
- **Core infrastructure:**
- **Implementation capability building and implementation** in 3 main areas – southern beef, northern beef, and sheep (3-sub programs with some common elements)

Overall coordination across these sub-programs is proposed to involve:

a. an overall Steering Committee, which should involve MLA, CCA, SCA, leading breeders, and those RD&E providers who commit resources to a specified level to the program ie genuine co-investors. The Chair of this committee should either be an MLA Board member, or someone independent selected by MLA and the co-investors
b. A Technical Committee, ideally covering both sheep and cattle issues, to provide advice on project proposals. This should include 3 independent experts (currently scoping 1 European, 1 US-based and 1 Australian).
c. Advisory Committees for each species-region program, to ensure strong engagement of leading breeders in the capability-building, extension and implementation.
d. (The Terms of Reference for the MLA-AGBU Consultative Committee, the Sheep Genetics Technical Committee and the Sheep Genetics Advisory Committee provide a basis for defining TOR for the Technical and Implementation Committees).
e. Program coordination provided by either:
    i. A single overall coordinator/project manager, or
    ii. 2 part-time program coordinators/project managers, one for beef and the other for sheep. This is in the short-term the preferred option.

The overall structure can be summarised graphically (over page):



This structure may seem excessive for a program investment of c. $4.5m On-farm and $3.0m MDC funds per year, but the 2 key points are that:

1. coordination through the RD&E pipeline and from breeder-consumer is the biggest challenge facing this area of RD&E,
2. MLA investments are at least matched by those made by breeders and potential co-investments from state DPIs, key university groups and CSIRO. Total meat industry investment in RD&E and implementation in animal genetics and genomics will be c. $23m pa without the CRCs (and has been c. $63m pa including the CRCs).

Internal coordination: MLA investment in animal genetics and genomics derives from a number of AOP nodes, including 2.1 (Eating Quality), 3.1.1, 3.1.2, 3.4 (Animal Health), 3.5 (Capability Building), 4.1 (Climate Change) and ICE. Funds are also contributed through the MDC program, from ALFA and from AMPC. In addition, MLA is the assignee of genetics and genomics IP developed through Beef CRCs I, II and III, and holds or shares several licenses in this area

Regular internal coordination meetings with standing items to review budgets, milestones and IP matters will be initiated. During the life of the current Sheep Genetics Management Agreement with AWI, and the current Sheep CRC, such meetings will need to include items for coordination with, and reporting to and from, AWI and Sheep CRC.

Process for establishing new projects:

New projects will be sourced via a call conducted in September-October each year, to coincide with an Annual Coordination Forum. That forum will review all RD&E projects, assess progress against KPIs including rates of genetic progress, and include presentation of potential new projects. Project prioritisation should then be via a working party comprising industry and independent experts. This working party should include members of the northern beef, southern beef and sheep program advisory committees (see section 10).

Projects prioritised by the working party should then be considered within the normal LPI planning process, in conjunction with Peak Councils.

Attachment I:

Estimation and valuing of genetic progress

There are 3 steps in outlining how genetic progress is estimated and valued.

The **first** step is to outline how genetic differences amongst animals are estimated. This has 2 elements:

- Measuring difference in performance
- Accounting for the extent to which such differences are passed on to progeny, or are heritable.

In this simple example, we have 2 young bulls, A and B, and we have measured them and their contemporaries (animals born and raised in the same herd and management group) for weight at 44 days. Further, we know from research that 28% of observed differences in this trait are passed on to progeny (the heritability of 400-day weight in this breed is 28%):

Animal or group	Observed 400-day weight	Difference from average of group	Estimated Breeding Value (EBV) for 400-day weight
A	500 kg	+ 75 kg	= 75 x 0.28 = + 21 kg
B	350 kg	- 150 kg	= - 150 x 0.28 = - 42 kg
Average of contemporaries	425 kg	0	

In this simple example, bull A has genes that are worth an extra 21 kg weight at 400 days. If he is mated to cows with average genetic merit, which is an EBV of 0, his progeny will average +10.5 kg extra weight at 400 days (because calves get half their genes from each parent).

Note that by using the differences in performance within contemporary groups – groups of animals that have been run together – we separate the effects of genetic differences from nutritional and other non-genetic effects.

In practice, calculation of EBVs takes into account animals' performance for all traits measured, using knowledge of genetic correlations among traits (the extent to which there are genes affecting both traits of a particular pair), and performance of the animals' relatives. Also, careful recording of birth date and other non-genetic factors assists in ensuring accurate EBVs.

The **second** step is to show how we can compare animals born in different years. In this example, we will assume that a number of bulls, born in different years, have been used and we have measured progeny in each of 3 years. For simplicity, the bulls' progeny averages are expressed as deviations from the average of their contemporaries in the respective years.

Bull ID	Bull progeny average performance – year 1	Bull progeny average performance – year 2	Bull progeny average performance – year 3
01A	435		
01B	445	415	430
01C	400		
02D		420	
02E		425	
02F		430	
03G			430
03H			445
03I			460

In this example, Bull 01B has been used in each of the 3 years, and provides a benchmark. We can therefore show each of the progeny averages as a deviation from those of Bull 01B within the respective year, and then calculate the average for the bulls born in each year (assuming equal numbers of progeny per bull):

Bull ID	Bulls' progeny average performance in year 4	Bulls' progeny average performance in year 5	Bulls' progeny average performance in year 6
01A	-10		
01B	0	0	0
01C	-45		
02D		+ 5	
02E		+10	
02F		+ 15	
03G			0
03H			10
03I			25
Average	**-18.33**	**+ 10**	**+ 11.67**

In this example, the average merit of bulls born in years 1, 2 and 3 is -18.33, 10 and 11.67 respectively. This tells us that substantial progress was made between years 1 and 2, and a smaller amount between years 2 and 3.

As with the first example, because we have used the differences from the averages of contemporaries, we have separated the effects of genetic differences and genetic change, from effects of the environment.

Exactly the same principle is used to estimate the genetic merit of animals born in different flocks or herds in the same year – this is the focus of across-flock or –herd analysis, and allows breeders and producers to identify the highest merit animals born anywhere in Australia in a particular year.

In practice, the EBVs of all animals born in a particular year are calculated (not just the sires) and the average calculated. However, the principle of using animals that have progeny in more than one year as benchmarks as shown in this example is the basis of calculating genetic progress in BREEDPLAN and Sheep Genetics.

Having estimated the genetic progress or trend, the **third** step is to place a value on that genetic progress. This is done by determining the value of each unit change in each trait, usually done by estimating the marginal impact on profit of a unit change in each trait, and then weighting the change in each trait by the respective marginal values.

Clearly this requires some judgement in dealing with the usual situation where prices and costs vary over time, but typically a rolling 5-year average or similar is used.

This can be shown in a simple example, again using beef cattle, with only 3 traits being evaluated. For each trait, we have calculated the marginal impact on profit of a unit change in that trait, and we have estimated the genetic trend for each trait ie the average genetic merit for each trait in each year. 2012 is being used as the base year in this example, so the average genetic merit for each trait is 0 in 2012.

	400-day weight	**Weaning %**	**MSA score**	**Total $ Genetic Merit**
Value of unit change	**$2 per kg**	**$500 per %**	**$12.50 per MSA score per calf**	
Genetic Merit in year				
2012	0 kg	0 %	0 points	$ 0
2013	+ 0.5 kg	+ 0.001 %	+ 0.10 points	$ 2.25
2014	+ 1.0 kg	+ 0.002 %	+ 0.12 points	$ 3.50
2015	+ 1.25 kg	+ 0.003 %	+ 0.15 points	$ 4.38
2016	+ 1.6 kg	+ 0.004 %	+ 0.17 points	$ 5.33

The total $ Genetic Merit column shows the overall $ value of the progress being made in the 3 traits. Each year value in this column is the sum of the year value for each trait multiplied by its respective value of unit change.

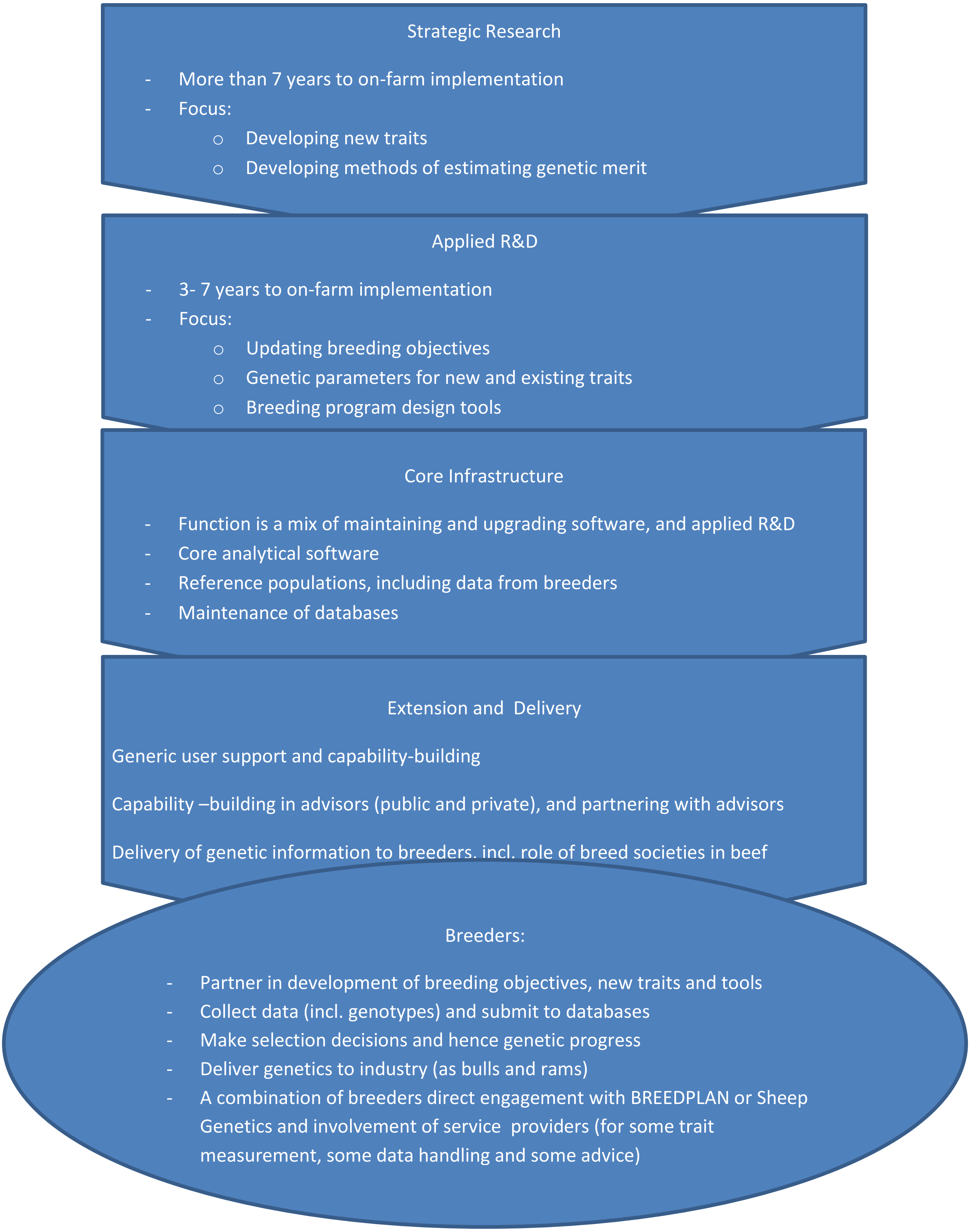
In this example, the value of the genetic merit of the population rises by $5.33 over the 5 years.

We can extend this to calculating the industry value of this genetic trend by multiplying by the number of commercial animals in each year. If (for a simple example) this was 2 million, then the genetic progress being achieved generates $4.5m in 2013, $7m in 2014, $8.76m in 2015 and $10.66m in 2016. To obtain the present value of the progress over the period 2012 to 2016 in this example, we discount each year by the appropriate rate and sum the year values.

This principle of weighting each trait by the marginal value of a unit change in that trait is the basis for Indexes (sometimes referred to as Selection Indexes or $Indexes), which are a standard item of information in BREEDPLAN and Sheep Genetics. Indexes help both in valuing genetic progress and also in steering breeding programs. The latter is because they provide the best overall estimate of the economic value of animals' genes – which animals have the most valuable sets of genes, across all traits being considered.

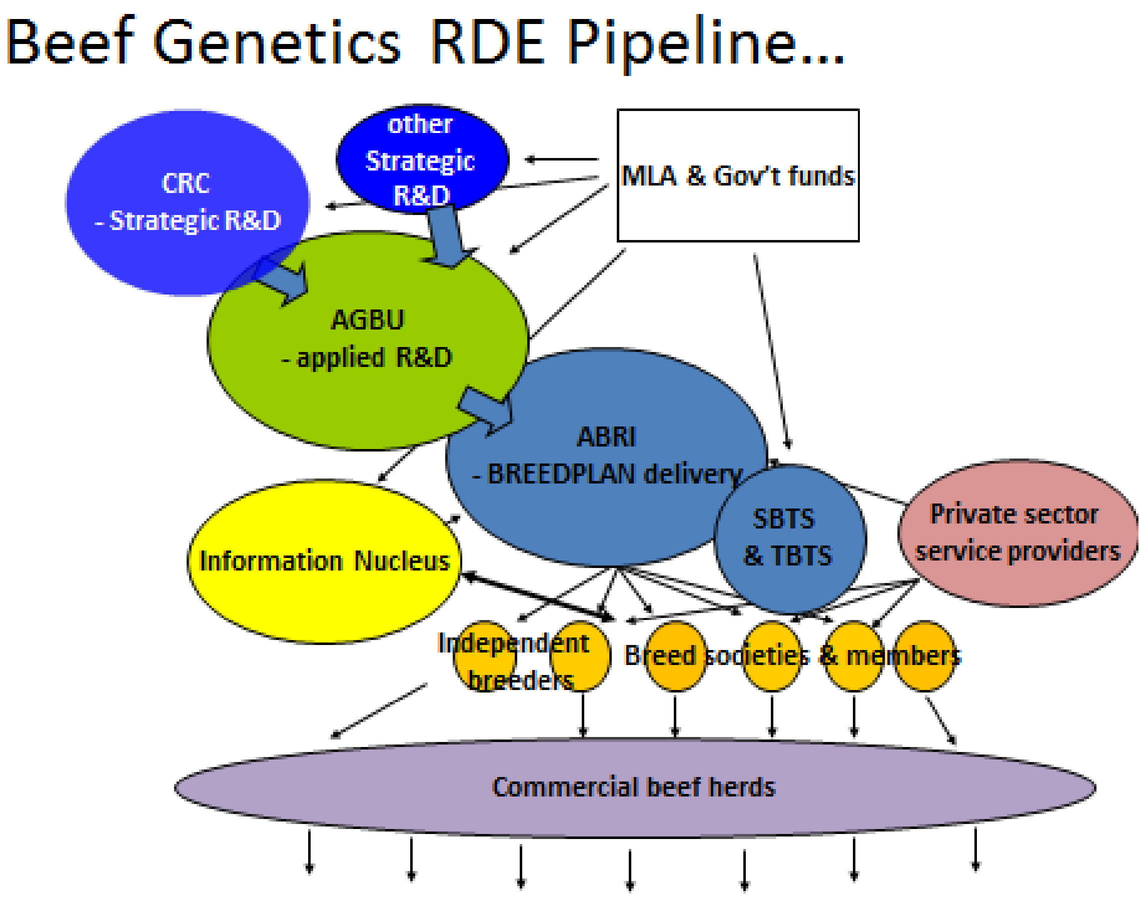
Attachment II:

Schematic of the key elements of the Genetics and Genomics RD&E Pipeline



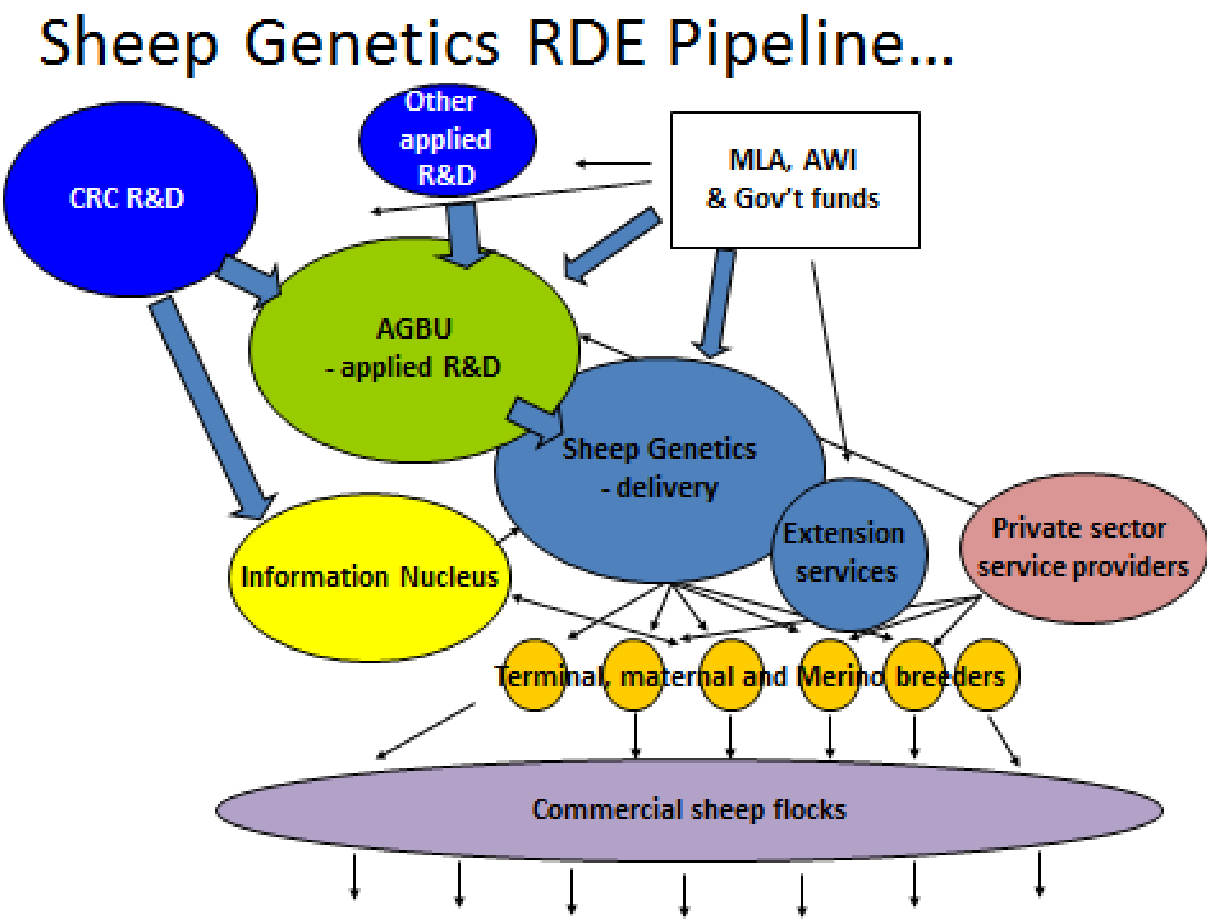
Attachment III:

Schematic of the Beef RD&E & Implementation Pipeline



Attachment IV:

Schematic of the Sheep RD&E & Implementation Pipeline



Attachment V:

Genetic technologies being delivered to Australian beef and sheep breeders and producers

Genetic technologies being used by the Australian beef and sheep industries fall into 3 main types:

- Tools for defining the breeding direction or objective
- Tools for estimating animals genetic merit
    - Based on pedigree and performance
    - Based on pedigree and performance, and/or genotype
- Tools for helping design breeding programs

The main example of each, and method of delivery for each, is summarised as follows:

Technology	Example and delivery method	
	Beef cattle	**Sheep**
Defining the breeding objective	BreedObject Embedded in BREEDPLAN	SheepObject Embedded in LAMBPLAN and MERINOSELECT
Estimating animals' genetic merit. This includes use of genotype information in the estimation, when they may be referred to as genomic breeding values.	EBVs Delivered via BREEDPLAN	ASBVs and FBVs Delivered via LAMBPLAN and MERINOSELECT
Genotyping (both individual gene tests, such as horn/poll, and multi-snp tests to contribute to genomic breeding values	As either genotypes and/or as intermediate estimates of genetic merit: Uni Qld Genotyping Lab Geneseek Pfizer	As genotypes which feed into calculation of ASBVs: Geneseek
Tools for designing breeding programs	TGRM and Matesel Delivered in conjunction with breed society databases	TGRM (Matesel currently under negotiation with UNE) Delivered in conjunction with Sheep Genetics database

MLA and MRC R&D has contributed directly or indirectly to all these technologies. These technologies are now delivered with breeders paying the costs of delivery, including the development and maintenance of the databases needed for use with all 3 types of technology.

In the case of beef, the majority are delivered through an exclusive licence with ABRI, who deliver BREEDPLAN. In the case of sheep, the majority are delivered through Sheep Genetics. It is important to note that all the technologies depend for their full value on some form of integration or analysis with the industry databases maintained through the beef breed societies and through Sheep Genetics.

Attachment VI:

Summary of adoption of BREEDPLAN, LAMBPLAN and MERINOSELECT, and genetic progress in beef and sheep in Australia

Sector	Current adoption (% of bulls or rams with breeding values)	5-year average genetic progress in 2001 per cow/ewe ($/DSE)*	Current rate of genetic progress in $ per cow/ewe ($/DSE)*	Comments
Beef:				
British breeds	Over 70%	$2.06 ($0.10)	$3.09 ($0.15)	
European breeds	Over 60%	$0.60 ($0.03)	$1.60 ($0.08)	Some selection has been on non-$ traits, such as docility
Tropical breeds	15%	$0.48 ($0.24)	$1.08 ($0.05)	Over 50% of bulls either have EBVs or are sired by bulls with EBVs
Sheep:				
Terminal sires	67%	$0.78 ($0.39)	$0.81 ($0.40)	
Maternal/dual-purpose breeds	Over 70%	$1.07 ($0.54)	$1.42 ($0.71)	
Merinos	Over 50%	$1.10 ($0.55)	$1.46 ($0.73)	Includes animals with across-flock and within-flock BVs. Wider impact through AI sires

*: the value in brackets is the genetic trend expressed in $ per DSE per year