Optimising Beef Genetic Selection in Northern Australia

A report for

By Rebecca Burnham

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Supported by:

Scholar Contact Details

Rebecca Burnham

REB Grazing

"Burenda"

1642 Mt Tabor Rd

Augathella QLD 4477

Phone: 0419 776 249

Email: REBgrazing@gmail.com

In submitting this report, the Scholar has agreed to Nuffield Australia publishing this material in its edited form.

NUFFIELD AUSTRALIA Contact Details

Nuffield Australia

Telephone: 0402 453 299

Email: enquiries@nuffield.com.au

Address: PO Box 495, Kyogle, NSW 2474

Executive Summary

This report examines selection techniques and modern technologies that are assisting in gathering information to match or supersede prevailing genetic improvement methods. Particular focus is given to how to optimise genetic progress in profit-driving traits, not recognisable by eye. e.g. fertility, feed efficiency, carcass yield and eating quality.

In the author's visits to production enterprises around the world, extraordinary genetic gains were observed in beef and across all animal species. Commonalities identified were: (a) clearly defined 'long-term' breeding objectives; (b) excellent herd and grazing management (c) ongoing animal phenotypic measurement (d) genotyping; (e) genetic evaluation; (f) and the use of all the selection tools available. Globally, it was noted that leading livestock operations were focussed on breeding animals that not only achieved profitability yet fulfilled environmental and consumer expectation goals.

There are currently many genetic selection tools available in the Australian cattle breeders' toolbox. These could be summarised as visual selection, pedigree, physical measurements and genetic analysis. BREEDPLAN was released for beef industry use 36 years ago, however only 15% of sale bulls presented in Northern Australia are currently presented with genetic analysis information for selection (Banks, 2019) most often with low accuracy.

In Australia, genotyping tests became available as early as 1963, then in 1993 with micro satellite technology and more recently Single Nucleotide Polymorphism technology (SNP) in 2011-13. The rate of adoption of these tools has increased significantly since 2018. Genotyping offered diagnostic results for parent verification or genetic disorders in early years. Nowadays genomics can evaluate the genetics of an animal by combining information on pedigree, phenotype and genotype to produce a breeding value (BV) providing more genetic information than ever before for improved selection accuracy.

Given the recent surge of interest in genotyping Australian beef cattle, this study aimed to review what this modern genetic technology and others can offer the industry, especially in optimising selection. The author's investigation uncovered the importance of collecting phenotypic measurements to support genotyping, as without continual physical animal measurement, genomics will be meaningless (Hayes, 2018).

It was observed that in addition to establishing an efficient management template for grazing land and herd management, Australian beef producers can optimise business profit by using ALL the genetic selection tools available, especially when introducing bulls. It was observed in global livestock breeding examples, if it can be measured, it can be managed.

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Abbreviations

Acronym	Acronym Expansion
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
AGBU	Animal Genetics and Breeding Unit
ABRI	Agricultural Business Research Institute
ACCC	Australian Competition & Consumer Commission
AI	Artificial Insemination
BBSE	Bull Breeding Soundness Evaluation
BIN	Brahman Information Nucleus
BLUP	Best Linear Unbiased Prediction
BV	Breeding Value (Generic reference ie same as EPD and EBV)
CEIP	Special Certificate of Identification and Production (Brazil)
CFS 46	Committee on World Food Security Meeting 46
CRC	Cooperative Research Centre
CSC	Nuffield Contemporary Scholars Conference
DNA	Deoxyribonucleic acid
EBIT	Earnings Before Interest and Tax
EBV	Estimated Breeding Value (AUS, NZ)
EPD	Expected Progeny Differences (USA, Brazil)
EQ	Eating Quality
ET	Embryo Transfer
FAO	Food and Agricultural Organisation
GAR	Gardiner Angus Ranch
GE	Genetic Evaluation
GEBV	Genomic Enhanced Estimated Breeding Values
GEPD	Genomic Enhanced Expected Progeny Differences
GFP	Global Focus Program
GHG	Green House Gas
HTMT	Hard to Measure Traits
ICBF	Irish Cattle Breeders Federation
LDL	Livestock Data Link
MCW	Mature Cow Weight
MLA	Meat and Livestock Australia
MSA	Meat Standards Australia
NGS	Next Generation Sequencing
NLIS	National Livestock Identification Scheme
PIC	Pig Improvement Company
PUFA	Polyunsaturated Fatty Acids

RMAC	Red Meat Advisory Council
TBTS	Tropical Breed Technical Services
TSU	Tissue Sample Unit
UN	United Nations
SBTS	Southern Breed Technical Services
SDGs	United Nations Sustainable Development Goals
SNP	Single Nucleotide Polymorphisms
USA	United States of America
WGS	Whole Genome Sequencing
WOW	Walk Over Weighing

Foreword

I developed an interest in 'the cattle that could do the job' as a child, working in our family business, Boogal Cattle Co, located just outside Monto in Central Queensland. Our grazing and herd management was strict - cows that did not bring in a calf at branding or returned a negative annual pregnancy test were culled, leaving only the more fertile cows that thrived in our environment. This management continued to produce well- adapted, low input progeny.

I was curious how bulls could be selected that would further improve this current herd management, ensuring genetic progress in those traits that make a business profitable, but are not visible. e.g. fertility, constitution, feed efficiency, yield and eating quality.

Whilst at university and as a consumer, I experienced wide variation in the eating quality of beef. I left my family's seedstock business and spent 15 years co-managing a commercial beef breeding and fattening business. During this experience, herd management changes of our Bos indicus breeders resulted in fewer inputs and more calves from the same number of cows, along with increased weight gain and improvement in the Meat Standards Australia (MSA) index. In short, more profit from management change. I learned that the combination of environmental and herd management changes had a big impact on production.

While these improvements were satisfying, I knew that fertility and eating quality could be further improved with genetic selection. The difficulty I encountered was sourcing bulls for the above-mentioned 'hard to measure' traits (HTMTs) that would meet our management improvement and breeding objectives. The purchase of bulls was one of our larger annual expenses, yet these purchases had previously been made with little attention to return on investment. Bull buying seemed to be a gamble. I wanted to be sure that an introduced bull would improve our profitability.

We are driven to question things when motivated by a greater need or want. Does Jan Bonsma's dictum of a 'man must measure' epitomise the future direction for Australian beef breeding? Hence, I decided to apply for a Nuffield Scholarship to research world best practices in selecting and breeding for profit.

My individual research was conducted in Colombia, Kenya, New Zealand, Canada, USA, Brazil, Ireland, Italy and Australia. I interviewed producers and researchers, visited universities, research stations and genetic centres, and read many articles, research papers and books. This report is a summary of my extraordinary learning experience to date.

Acknowledgments

"Alone we can do so little; together we can do so much."
(Helen Keller)

Thank you to Nuffield Australia and The Yulgilbar Foundation for the investment in myself and my research topic. It has been a learning experience of a lifetime.

I thank every person who welcomed me into their business or home and privileged me with their precious time. I look forward to returning the hospitality in Australia for years to come.

I am grateful for the support received from friends and family that made my scholarship journey possible. A special mention to Tex & Bronwyn Burnham (Mum & Dad), Lance & Janelle Burnham, Grant & Carly Burnham and Dan Radel for managing my cattle while I was travelling. Despite the dry conditions, you all managed to find pasture for my core herd of breeders. I will always be grateful for the sacrifices you made for me during my year of Nuffield travel.

An important part of my learning came from the Nuffield group of nine International Nuffield Scholar companions during my six-week Africa Global Focus Program (GFP). Thank you for the challenging conversations, cross-industry questioning of 'why' or 'why not' and global perspectives. Our GFP group travelled the world together analysing agricultural practice in the USA, Czech Republic, Romania, Bulgaria, Qatar and Kenya. Thank you 'Team Africa'.

Figure 1 : Nuffield Global Focus Program - Africa Members. April 2019.

Pictured at Stuart Bardon's Cropping Enterprise, Nairobi, Kenya. ***BACK****: Susan Truehart Garey USA, Pat O'Meara IRE, Stuart Bardon (Owner), Ben Hancock NZ, Mark Glover (CSIRO), Athur Falcette BRZ* ***FRONT****: Rebecca Burnham (Author), Clare Peltzer AUS, Tom Green AUS, Scott Holtman CAN (Author, 2019).*

A huge thank you to my mentors and friends who have guided my thinking and cattle breeding business decisions over the years. Following the completion of my Nuffield travels, your guidance distilling and wording such an overwhelming amount of learning was invaluable.

It is with the help of those mentioned above that I have not only been able to complete my Nuffield Scholarship travels and commitments, but also to continue to work towards my goal to breed profitable, measured, benchmarked, improving genetics, suitable for northern Australia.

"Success is not the key to happiness.
Happiness is the key to success.
If you love what you are doing, you will be successful."
(Albert Schweitzer)

Figure 2 : The Boogal Team. Bronwyn Burnham taking the photo, Janelle, Lance and Tex Burnham with the author Bec Burnham *(Burnham, 2020)*

Objectives

This report researched the theme of ‘How to optimise beef genetic selection in Northern Australia’.

The report objectives were:

- Reporting on the tools that global livestock breeders used to breed profitable cattle.
- Identifying modern technologies that are assisting objective livestock measurement (phenotyping and genotyping) for hard-to-measure, profit-driving traits.

Introduction

Of the national beef herd, 64% is located in northern Australia (Queensland, Northern Territory and northern Western Australia), and the remaining 36% inhabit southern Australia (ABARES, 2019).

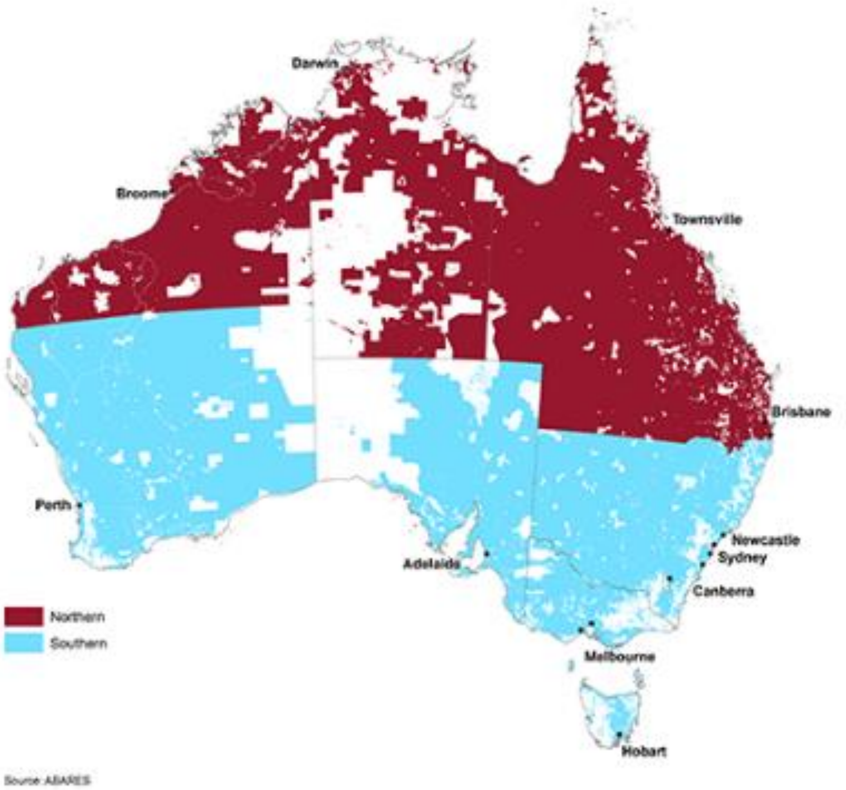

Figure 3: MLA Beef Regions – Northern and southern Australia (ABARES, 2019)

The Meat and Livestock Australia (MLA) Global Agri Benchmark Network reports that Australian cow-calf finishing systems have moderate to low weaning rates and productivity per cow, especially in northern systems which have comparatively low reproductive rates, high mortality rates, extended generation intervals and lower growth rates and turn-off weights, when compared with southern herds. The differences between northern and southern Australian beef operations range from climatic differences, pasture quality, scale and proximity to markets. All are contributing factors to the moderate and low results observed (MLA, 2019).

The Beef CRC results show low weaning rates of 62% and 78% for Brahman and Tropical Composite respectively, suggesting opportunity to improve reproduction rates, and thus productivity and profitability for northern beef breeders (CRC, 2003).

Northern Australia can benefit from improving reproductive rate, sale weight and decreasing mortality, within the limitations of carrying capacity and available markets as shown in Table 1 (Holmes & McLean, 2017). These authors also found that the top 25% of producers in the northern region, despite these challenges, have a significantly higher Earnings Before Interest and Tax (EBIT).

Table 1 : Potential for improvement in northern Australia *(Holmes & McLean, 2017)*

	Area of Performance	Income Increase	Physical Result (Holmes & McLean, 2017)
5% increase	Reproductive rate	7%	Extra five weaners from every 100 cows
1% decrease	Mortality rate	2%	One less death per 100 cattle run
5% increase	Average sale kgs	4%	Average sale kgs of all animals sold increases by 5%

Australian beef producers operate in varying environments. However, there is potential to manage what we can control. The Australian Beef Report 2017 stated two barriers to profit in the beef industry are: -

1. Operating scale (Number of animal units)
2. Operating efficiency

Assuming an adequate operating scale and number of animal units, three factors that influence operating efficiencies and are able to be managed by producers:

a) Grazing land management
b) Herd management
c) Genetics (Holmes & McLean, 2017)

While the importance of grazing land and herd management in overall business profitability can never be underestimated, it is the intention of this report to generate awareness of the role focussed genetic selection has played in global examples to complement existing best practice management and improvement to overall business profit and sustainability.

Chapter 1: Animal Breeding

1.1 Definitions

Animal breeding began with the domestication of wildlife by human through visual selection. Over the centuries, animal breeding has evolved from the subsistence needed to sustain a farmer and family, to feeding many families past the farm gate utilising advances in technology to aid selection to improve production efficiencies.

Animal breeding can be described as the management of both genetic and non-genetic *differences* to breed a desired animal. The key aspects of animal breeding were summarised concisely at the beginning of the authors research journey, at the Animal Genetics and Breeding Unit (AGBU), Armidale Australia, by this basic formula (Johnson, Wolcott, & Walmsley, 2019).

Phenotype = Genotype + Environment

Phenotype is the measurable and visual traits, which are the expression of the genes that are distributed to the progeny as a result of the sire and dam pairing.

Genotype refers to the genetic make-up of an animal, its DNA, or the distribution of genes from relatives.

Environment is the effect that the quality of pasture or nutrition, climate or health status has on the chosen genetics, or ‘E’ for everything else (Johnson, Wolcott, & Walmsley, 2019).

An example of the importance of environmental management is shown below in Figure 2. A doubling of production efficiency in the dairy industry, over a 48-year period, has shown that improving the environmental management (shown in grey) resulted in 70% of production improvement, whilst genetics (shown in orange) was responsible for 30% (Pryce, 2020).

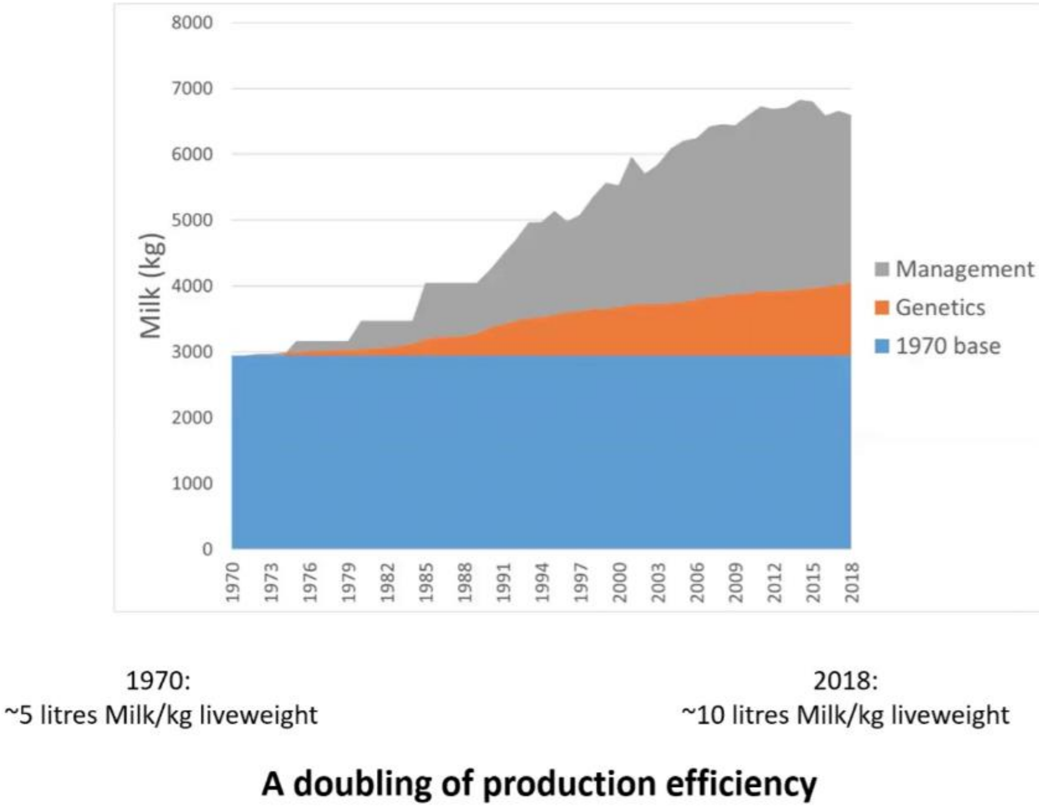

***Figure 4: Environmental Management 70% and Genetic Improvement 30% to achieve a doubling in production efficiency** (Pryce, 2020)*

An example of the importance of herd and pasture management is that environment can alter the expression of existing genes (Bailey, 2018). This is known as epigenetics. Dr. Bailey suggested targeted supplementation for pregnant cows to prevent the occurrence of gene methylation, highlights how epigenetics can affect breeding programs in variable environmental landscapes, like northern Australia. Epigenetics is something to consider, when introducing new stock; It raises the questions, is the environment that genetics have been raised in similar or dissimilar to what they will be 'working' in? Will the tough genes be 'switched on'?

Extensive beef production does not regulate the environment in which the animal is conceived and raised, unlike in dairy and other intensive protein production systems. However, it has been observed that profitable beef breeders aim to select genetics to thrive in their particular environment, with least inputs, to produce the optimum performing animal, or phenotype (Pharo, 2019).

1.2 Breeding Objectives

Quality can mean many things to many people. To a profitable beef business, quality cattle are cattle that make you money.

Dr Donagh Berry, Teagsac, Ireland suggested all beef breeders consider this over-arching mission statement when formulating specific farm breeding objectives.

'Producing beef at a PROFIT in a humane, socially and environmentally proactive manner' (Berry, 2019)

Donagh asserted that the breeding objective is based on the 'ideal' animal for an individual enterprise. The number of kilograms your country can produce annually, seasonal variability, operating costs and target market will determine the profitability of an enterprise. Optimal breeding objectives to achieve profitability will vary between businesses to achieve optimal profits.

1.3 The Beef Cow of the Future

When formulating breeding objectives, it may be useful to consider what global work is being done to design the beef cow of the future, such as novel traits currently being measured and why. The following beliefs surfaced often in most international interviews.

World population is increasing by 81 million people annually and is estimated to reach nine billion by 2050. There will be a need to feed 35% more people by 2050 (UN, 2019). There is a need to produce more food from the same amount of agricultural land. Producing' more from less' was a common ideal.

Whether a climate change believer or not, the United Nations 2030 agenda, underpinned by the 17 Sustainable Development Goals (SDGs) (UN FAO CFS46, 2019) has led Australia to commit to carbon neutrality in Beef by 2030 (RMAC, 2019). Producers can improve profit through genetic selection, whilst addressing several SDGs.

To maintain market share, consumer trust is necessary. The changing demography and competitive pressures from other protein sources must be acknowledged. MLA suggest that a targeted message on provenance, quality, environmental credentials and animal welfare, along with food integrity and transparency will be important to enhance the consumer choice for red meat (MLA, 2019). There is a need to foster consumer trust by acknowledging social concerns and being proactive with our breeding choices.

Australia is amongst the largest three exporters globally. Domestic consumption accounts for 30% of Australia's beef production, with the remainder being exported (MLA, 2019). Australia's reputation for producing clean, green and safe red meat products is a major factor underpinning its domestic and export market success. There is a need to maintain these markets and continue to produce a consistent quality product.

Chapter 2: Genetic Gain

2.1 Definitions

Genetic gain occurs when the average genetic value of the progeny (e.g. current calves) is higher than the average genetic value of the previous generation from which the parents were selected (BREEDPLAN, 2020).

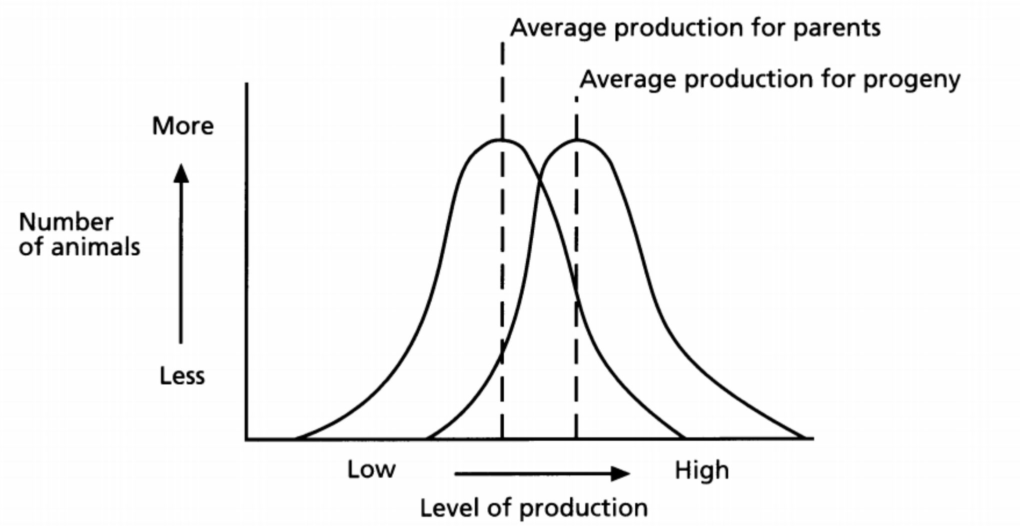

Figure 5: Genetic Gain - The production distribution curves for parents and progeny (DPI, 2000)

The factors that influence the rate of genetic progress in a beef breeding herd are selection intensity, accuracy of selection, genetic variation and generation length, summarised into this formula below.

$$\textbf{Genetic Gain} = \frac{\textbf{Selection Intensity} \times \textbf{Selection Accuracy} \times \textbf{Genetic Variation}}{\textbf{Generation Length}}$$

Genetic gain can be calculated for an individual trait, selection index (refer 3.7) or an overall breeding objective.

Selection intensity

Refers to the size of the selection group and number of animals chosen or is the difference in the average genetic value of the animals selected for breeding compared to the average of all the animals in the population (BREEDPLAN, 2020). *For example*, the special Certificate of Identification and Production (CEIP) granted in Brazil only allows the top 1% of bulls to be used in artificial breeding programs (refer 5.4).

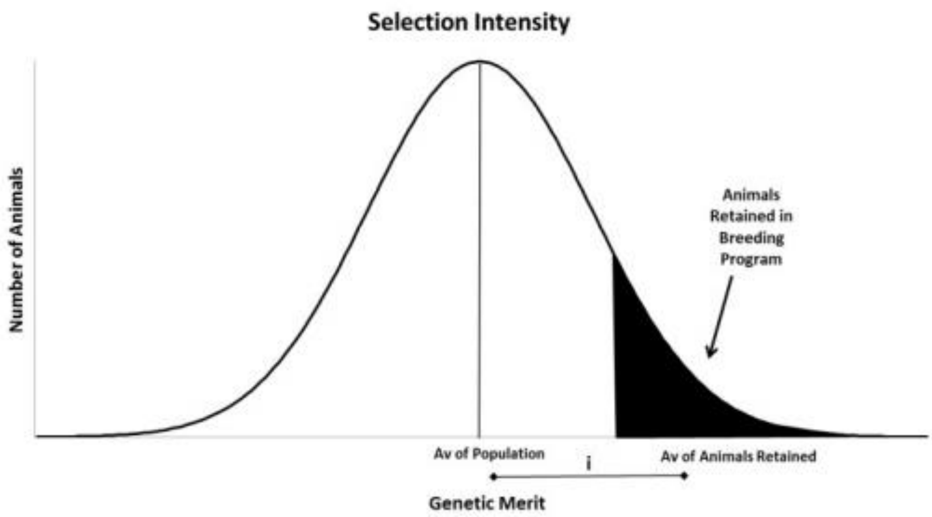

Figure 6: Selection Intensity focus on animals retained (DPI, 2000)

Accuracy of selection

Accuracy is higher when more animals are measured, as shown in Table 2 and the heritability of the trait is higher *(Also refer to 3.11 and Table 4)*.

Table 2 : More measures improve the accuracy of EBVs *(Sheep Genetics, 2020)*

Info used. h2 = 0.25	Accuracy of EBV
Sire + Dam	0.35
Prog Tested Sire + Dam	0.49
… …………………… + Own Record	0.63
……………………………………… + DNA markers	0.71
………………………………………… . + 30 progeny	0.85
………………………………………… + 1000 progeny	0.99

Genetic variation

In a population with large variability, there are more chances to find animals on either end of the spectrum that match the breeding goal than in a population with low variability. For many traits, there is often more variation genetically within a breed, than there is between breeds. *For example*, Australian research presented in Table 5 outlines a range for heifers reaching age of puberty from 11 - 40mths showcasing the large range of genetic variation within breed.

Generation length

This is defined as the average age of the parents when their progeny are born, which determines the rate of introduction of new genes, ensuring the next generation will be genetically superior (BREEDPLAN, 2020). *For example*, RA Brown Angus, Texas and Gardiner Angus Ranch, Kansas USA, breed their replacement females only twice before selling pregnant four-year old cows at their annual sales, to ensure rapid genetic progress (refer 5.2). Genomic technology has been key in identifying superior genetics at a younger age.

2.2 How to achieve Genetic Gain

The purchase and introduction of superior bulls is one of the quickest ways to achieve genetic change in a herd. Sires have a larger number of offspring per year (approximately 20) compared to females who on average have less than a single calf per year. The effect of bull selection will persist in the herd for generations to come as outlined below.

Figure 7: Timeline for Beef Breeding *(Rayner, 2019)*

When sourcing a bull, it is advisable to buy from a similar or superior herd in both management and performance. Having found such herds, always take into consideration breeding goals, selection criteria, traits of economic importance, market requirements, herd production targets and current herd performance (Future Beef, 2020).

In Australia, more than 70% of southern Australian bulls offered for sale are supported by EBVs, whereas in northern Australia only 15% of sale bulls are accompanied by EBVs. Therefore, it is not surprising that, on average, the current rate of genetic progress in British breeds is just over $4/cow joined/year, compared to the herd of Northern Australia's rate of genetic progress being $1/cow joined/year (Banks, 2019). Southern seedstock producers are showing that the use of all the tools available can enable genetic gain and profit for their clients. 70% of southern seedstock producers submit phenotypic measurement for genetic evaluation compared to less than 10% of northern, tropically adapted, seedstock producers (Skinner, 2020). Increased measurement in the north will improve the selection toolbox.

Genetic selection tools are listed in Chapter 3. Selection is never based on one attribute alone. As Mark Gardiner from Gardiner Angus, Kansas USA said '*Why not select the bulls that will make you the most money?*' and he adds '*Just use ALL the tools available*!' (Gardiner, 2019).

Chapter 3: Beef Cattle Selection Toolbox

3.1 Visual selection

Historically livestock breeders have valued traits in animals that can be seen. Butchers had to assess eating quality by eye alone in the past. Consequently, a butcher built a reputation for a high-quality product or otherwise, dependent on their visual selection alone. Some of these visual assessments were still discussed globally in selection, however a common drawback was the subjective nature of the selection. Visual assessment of traits such as temperament and structural soundness is vital, however objective measurements and evaluations now exist to strengthen visual appraisal for important characteristics.

Figure 8: World Brahman Congress 2018 Bucaramanga, Colombia *(Author, 2018)*

3.2 Pedigree

Pedigree refers to the identification of the Sire and Dam of a calf, and its relatives. The progeny carry half of the sire and half of the dam's genetics. Genetic estimates were calculated this way before modern technologies such as genotyping revealed the distribution of genes from relatives. Ireland has mandatory pedigree recording within a fortnight of date of birth for its Beef Suckler Herd (refer 5.3).

3.3 Raw data

Raw data is often displayed on sale day but it is difficult to rank that individual animal alongside his peers at multi-vendor sales, taking into account the differing pre-sale nutrition and environmental variations from birth. Some traits, like scrotal size, are threshold traits to be measured at 400 days. This measurement at a later age is not as meaningful, in its relationship to age of puberty or in variation (Burns, Corbet, McGowan, & Holroyd, 2014). Raw data is unable to account for all the genetic and environmental factors, paving the way for genetic evaluation using more sophisticated statistical analysis, such as available in BREEDPLAN.

3.4 Measurements

There is no substitute for good phenotypic measurement (Leachman, 2019). All global leading seedstock operations were adamant that measurement of phenotype was still king, in the era of genotyping. Similar trait measurements as outlined below were seen to be collected globally, but rarely used as ratios without genetic evaluation.

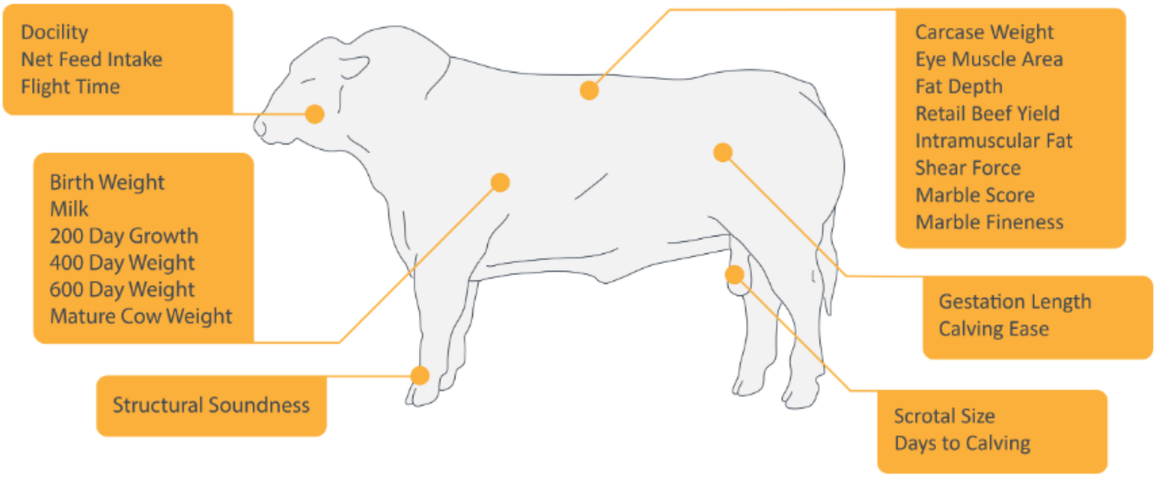

Figure 9 : Economically important traits that are being analysed by BREEDPLAN** (ABRI, 2020)**. NB Not all breeds offer all traits.

3.5 Within breed genetic evaluation

The number of evaluation systems used within the same breed, in the same country, worldwide, was overwhelming. The differing systems seemed to evaluate similar traits, with different names, to produce Breeding Values and indexes however were produced in individual 'silos', making it difficult and confusing to compare BVs of the same breed, in the same country!

***Figure 10 : Australia's own genetic evaluation service** (ABRI, 2020)*

Australia is fortunate in having a major national genetic evaluation (GE) system that is underpinned by Australian research and development. Recent years have seen some smaller population breeds in Australia moving to other GE systems to belong to bigger reference populations overseas to access more accurate genotyping e.g. shorthorn. BREEDPLAN was released in 1985 and is the most widely used GE service internationally. BREEDPLAN uses Best Linear Unbiased Prediction (BLUP) technology to produce EBVs of performance recorded cattle for a range of traits (Figure 9) and takes into consideration the fixed effects and environmental influences, so that the genetics alone are being measured (ABRI, 2020).

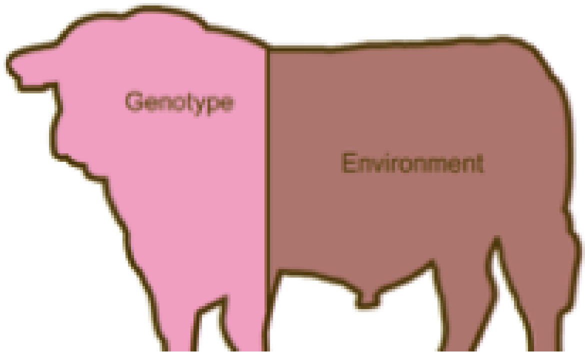

Figure 11 : Genetic evaluations take measurement and predict the genetic component of an animal separate from their environment *(ABRI, 2020)*

3.6 Breeding Values (BVs)

In Australia, an EBV is the most common Breeding Value used. An EBV estimates of an animal's genetic merit for a trait and assumes half of the parents EBV will be passed on, as an indication of how an animal's progeny will perform relative to their contemporaries. All EBVs are reported in the units in which the trait is measured. The calculation of EBVs for each animal includes consideration of:

- pedigree and phenotype measurement of the animal
- measurement of relatives
- measurement of progeny
- the known relationship between traits
- genomic information (BREEDPLAN, 2020).

An exciting development for Northern Australia in 2018, has been the recent introduction of single step for some breeds, which adds accuracy to the EBVs with the inclusion of genomic information to an EBV. This modern technology is providing information about genetic merit on cattle, where there was none!

January 2020 Brahman BREEDPLAN																		
	Gestation Length (days)	Birth Wt. (kg)	200 Day Wt (kg)	400 Day Wt (kg)	600 Day Wt (kg)	Mat Cow Wt (kg)	Milk (kg)	Scrotal Size (cm)	Days to Calving (days)	Carcase Wt (kg)	Eye Muscle Area (sq.cm)	Rib Fat (mm)	Rump Fat (mm)	Retail Beef Yield (%)	IMF (%)	Percent Normal Sperm (%)	Flight Time (secs)	Shear Force (kgs)
EBV	-0.6	+0.3	+16	+29	+41	+30	0	+3.7	-8.2	+12	+3.2	+1.0	+1.8	+0.5	+0.2	+1.6	+0.29	-0.46
Acc	48%	80%	84%	86%	88%	81%	67%	83%	48%	72%	55%	54%	60%	42%	51%	27%	64%	55%
Breed Avg. EBVs for 2018 Born Calves Click for Percentiles																		
EBV	-0.3	+2.6	+19	+27	+37	+42	-2	+0.8	-1.5	+22	+2.4	-0.4	-0.5	+0.6	-0.1	+0.0	+0.01	+0.00

Traits Observed: BWT,200WT,400WT,600WT,SS,Genomics
Statistics: Number of Herds: **1**, Progeny Analysed: **21**, Number of Dtrs: **8**

Figure 12: Example of a single breed evaluation. The Australian Brahman Breeders Association EBV display. *(ABRI, 2020)*

EBVs can also be viewed in a table (Figure 12) or graphical format (Figure 13), showing where the animal ranks in comparison to the average. The centre of the graph is the 50th percentile or the median.

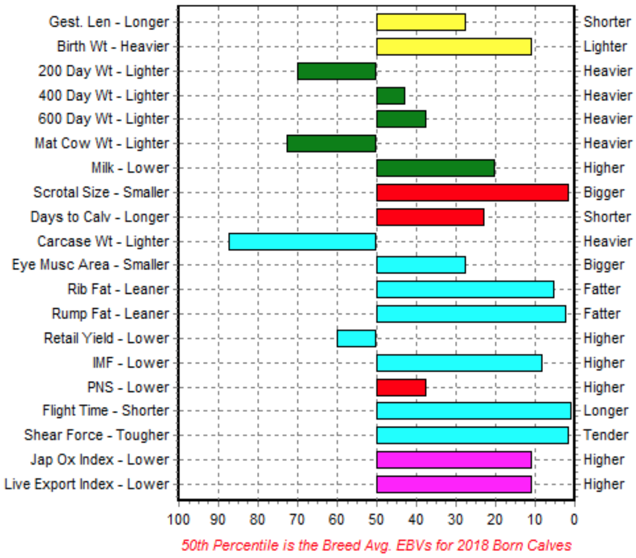

Figure 13 : The EBV graph format visually summarises genetic merit *(ABRI, 2020)**.***

3.7 Selection Index

History has shown that selection using BVs has achieved vast improvement in the dairy sector for milk production, pig industry for lean meat and in the sheep industry for wool quality and quantity. However, it was observed in these examples that the single trait improvement, accelerated unintended genetic changes in other traits (Johnson, Wolcott, & Walmsley, 2019). These examples typify the dangers of single trait selection.

The solution is the use of a Selection Index, enabling producers to make “balanced” selection decisions. Optimum production is the point at which net profits are maximised (Pharo, 2019). For example, the best growth EBVs may not correlate to birth and re-conception ease. A selection index takes into account relationships between all traits and weights them accordingly, to identify an animal that is most profitable for a specified production system and target market. Indexes assist in decision making, when selecting for profit. Selection Indexes are expressed in dollars as “net profit per cow mated”.

SELECTION INDEX VALUES		
Market Target	Index Value	Breed Average
Jap Ox Index ($)	+$ 49	+$ 29
Live Export Index ($)	+$ 46	+$ 26

Figure 14: An example of the Australian Brahman Breeders Weighted Indexes for balanced selection (ABBA, 2020)

Star Rating (within Salers breed)	Economic Indexes	Purpose	€uro value	Index reliability	Star Rating (across all beef breeds)
★★★★★	Replacement (per daughter lactation)	To breed future cows for the suckler herd	€252	73% (High)	★★★★★
★★★★★	Terminal	To breed beef animals from the suckler herd that are destined for slaughter	€120	86% (V High)	★★★★☆
★★★★★	Dairy Beef	To breed beef animals from the dairy herd that are destined for slaughter	€139	65% (High)	★★★★★

Figure 15: An example of the Irish HerdPlus Selection Indexes (ICBF, 2019)

If the trait weightings of a Selection Index do not suit a herd's breeding objectives, Australian beef breeders can design their own selection index using the BreedObject Program (TBTS, 2020). For more information: https://breedplan.une.edu.au/products/breedobject/

When interviewing global breeders, most used the following selection strategy, when valuing the selection index information: -

1. Identify the selection index of most relevance
2. Rank animals on the selection index
3. Consider the individual EBV traits of importance to the herd
4. Create a list of animals ranking high on this data
5. Assess physical traits (structure, temperament, BBSE, poll)
6. Buy an animal from the above list!

It was observed that selection indexes were one of the central tools utilised for genetic selection and benchmarking of leading global livestock genetic progress.

3.8 Genetic Evaluation Sorting Aids

When faced with so many facts and figures such as indexes, 24 traits on a single animal and then 150 bulls in a catalogue, how is it possible to sort through all the data?

Internet solutions can be accessed through the BREEDPLAN website under the SEARCH & LOGIN tab and then selecting the Breed database of interest. Entire sale catalogues can be sorted using this function. See: https://breedplan.une.edu.au/media/ww2myeni/internet-solutions-flyer.pdf

A simplified phone app, RamSELECT, has been successful to aid ram selection as it easily sorts ASBV data (Australian Sheep Breeding Values, the sheep EBV equivalent). Australian sheep breeders have experienced significant genetic progress (van der Werf, 2019) since increasing their reliance on measurement and selection tool use.

The equivalent for cattle is in development in Australia. The DeSireBull™ platform hopes to increase the number of bull buyers who utilize genetic performance information (Penrose, 2019). The USA also has an application in progress for Beef called iGENDEC (Spangler, 2019). In Case Study 5.4, the CEIP system offered in Brazil discusses how this certification simplifies the identification of high-performance animals with a symbol brand on the shoulder. If all of this is overwhelming, it is understandable!

The author noted a difference between northern beef producers' beliefs and the beliefs of scholars from all other sectors of agriculture. Most paid outside contractors to assist with specialist decisions. This resulted in more profit, e.g. the use of agronomists in the cropping world. In Australia, free breeding consultancy is available from Tropical (and Southern) Breed Technical Services (TBTS & STBS). For more information. https://tbts.une.edu.au/contacts/

3.9 Genotyping (refer 5.6 for additional definitions)

In Australian beef the use of genotyping is new. Genotyping tests became available as early as 1963, then in 1993 with micro satellite technology and more recently Single Nucleotide Polymorphism technology (SNP) in 2011-13. However, adoption has increased significantly since 2018. Genotyping offered diagnostic results for parent verification or genetic disorders in early years. Nowadays with sufficient phenotypes, genomics evaluates the genetics of an animal by combining information on pedigree, phenotype and genotype to produce a Breeding Value (BV).

The greatest benefit of genomics is providing genetic information for cattle without prior measurement. Also providing information on traits that are hard to measure, expensive to measure, observed later in life, single-sex or have a low heritability. Referring back to Chapter 2, genomics can influence the rate of genetic progress in a breeding herd by improving selection intensity, accuracy of selection, genetic variation and can reduce generation interval by allowing the use of younger animals.

Although easy to collect and seen to be a 'silver bullet', genomic evaluations cannot exist without the physical measurements with which to compare or reference population. Utilising one platform of measurement for genetic evaluation is not as accurate as combining all platforms; phenotype, pedigree and genotype (Bertram, 2018).

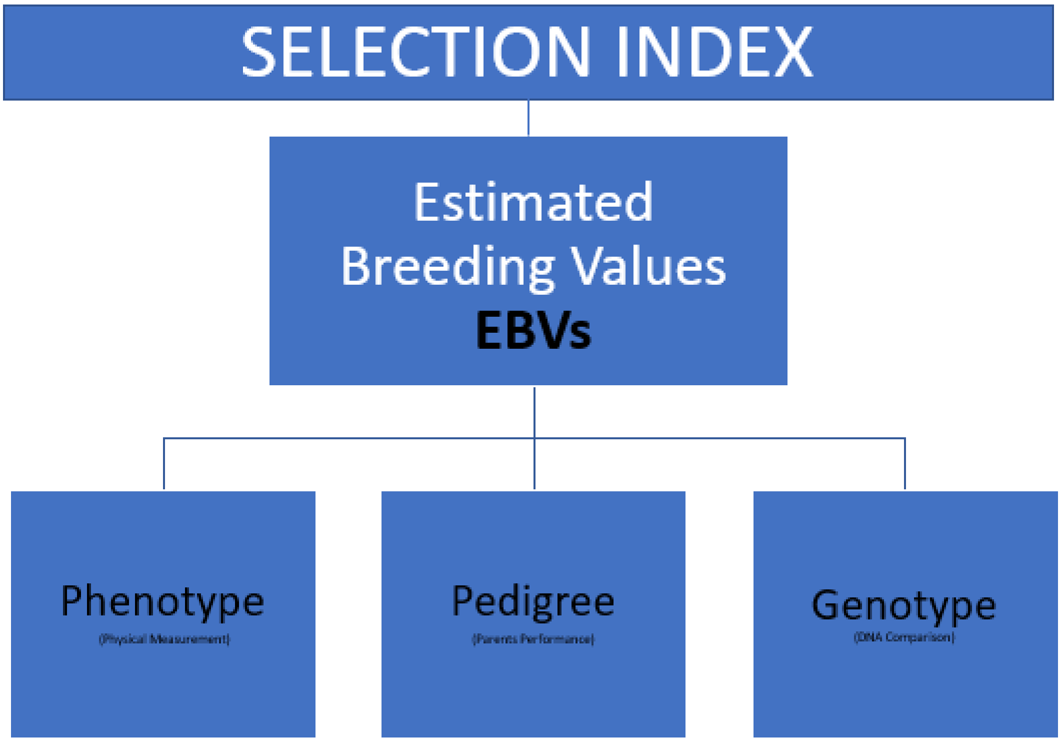

Figure 16: Increasing the selection accuracy using multiple sources of information *(Bertram, 2018)*

Currently genotyping provides information on most Australian cattle for:

a) Diagnostic Tests (test for a specific SNP or group of SNPs)

- Genetic defects e.g. E7 or Pompe's disease in Brahman
- Horn or Poll Status
- Coat Colour
- Tenderness
- Sire Verification
- Parent verification

b) Breeding Values

(Assuming individuals evaluated are related to a sufficiently large reference population for estimates to have useful accuracy. Eg. Angus, Brahman, Droughmaster, Waygu only in 2020).

- EBV on a commercial animal with no prior recording.
- A genomic EBV provides the same amount of information as 10-20 progeny tests. (Spangler, 2019)
- Available at birth, if samples are collected and analysed at that stage.
- Provide information on hard to measure or expensive traits that drive profit
- eg. Fertility, feed efficiency, eating quality etc.

(Commercial cattleman please note that this requires financial membership to both the relevant Breed Society and Breedplan to obtain EBVs on unmeasured cattle in 2020. Other avenues to access genomic BVs will become available)

c) Breed Value Ranking of Commercial Animals

- Igenity® Beef released by Neogen, provides a ranking of 1 – 10, for 16 traits and three indexes. Available for use in Australian Angus in 2019 and a Tropical Igenity is under development. Nelore in Brazil were using an Igenity product in 2019.
- Inherit Select™ released by Zoetis for use in USA and NZ in 2020, is a multi-breed genomic test, providing percentile rankings over 16 traits and three indexes, as well as sire parentage and breed composition.

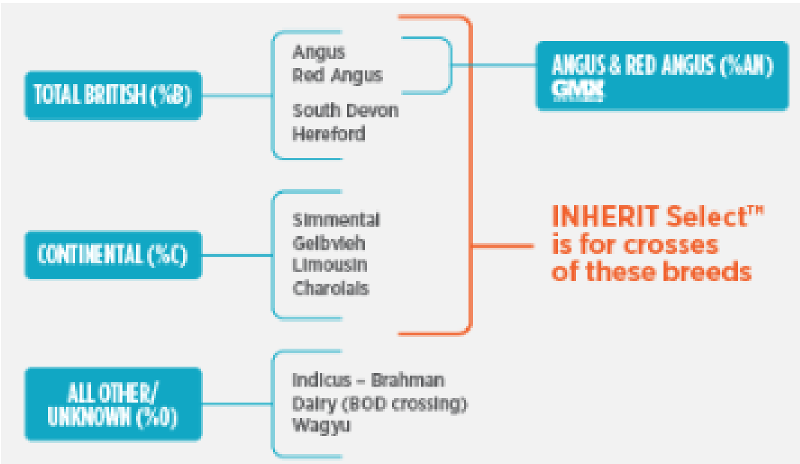

***Figure 17: INHERIT Select offers a* multibreed breed analysis for the above breeds** (Zoetis, 2020)

d) Additional information genomics can provide

- Inbreeding
- Breed composition (possible but not yet routinely offered)
- Permanent animal identification records
- DNA is tamper-proof and permanent, making it an ideal way tracing food from paddock to plate.

Genotyping will not only benefit the beef producer by improving the accuracy of selection but will benefit the entire industry chain.

e) How to genotype?

Australian beef producers can currently collect DNA using the following methods:

- Tissue Sample Unit (TSU)
- Blood Sample
- Tail Hair Sample
- Used Semen Straw

Figure 18: The author measuring calf weight, tagging and taking DNA within 24hrs of birth at Rissington Cattle Company, NZ. The right-hand picture shows TSU Gun (blue), Visual Tags, TSU and NAIT ID Tag *(Author, 2019)*

After visiting the Neogen Lab in both Gatton, Australia and Lincoln, Nebraska USA, it was observed that TSU was the preferred sample to process. It delivered a higher rate of successful processing due to the superior sample quality, more secure animal identification method and will be cheaper (Neogen, 2019). Currently TSU ($2.80/unit) is cheaper than hair sampling ($4/unit) for Brahmans in Australia. Also, after assisting in DNA collection at Rissington, New Zealand, it was observed that collecting DNA via TSU was a simple process, much like using a set of tagging pliers.

3.10 Multiple Breed Evaluations

It was noted that some GE systems were more able to handle heterosis or multi-breed comparisons, e.g. Leachmans $Profit®. In the USA, the ongoing USMARC Germplasm Evaluation Project enables the beef producer to compare animals across breeds by generating an across-breed EPD adjustment factor that can be applied at multi breed bull sales (refer 5.1).

Currently in Australia genetic evaluations are performed within breed only. Pending research is generating genomic prediction methods that are valid for all breeds and environments, focusing on female reproduction traits and temperament in northern Australia. It is also high priority for BREEDPLAN to incorporate Multibreed Evaluation as soon as the coming year (Skinner, 2020) allowing sire selection to fulfil breeding objectives and comply with market signals rather than just be breed focused, in selection.

3.11 Cross Breeding Selection

The future release of a Multi Breed EBV in Australia promises objective data to compare genetic merit across breeds. Cross breeding is widely used in northern Australia however the annual decision around what breed selection to make is mostly an internal and guesswork decision. It was observed in Florida, USA that well consulted and planned rotational breeding systems were breeding progeny to handle harsh conditions similar to northern Australia. The reasons to crossbreed, or use it as a tool were:

- Heterosis (or Hybrid Vigour) e.g. Improving growth rate, fertility and yield of crossbred progeny over those of its parents.
- Breed complementarity e.g. One breed's strengths can complement the other.

It was learnt that varying levels of heterosis are achievable within different cross breeding programs as shown below.

Table 3 : Cross Breeding Systems, Heterosis retained and benefits *(MLA, 2006)*

Mating System	Maximum Heterosis retained		Superiority over parent breeds	
	Individual %	Maternal %	Increased weight of calf weight weaned/ cow exposed %	Increased value of calf weight weaned/ cow exposed at $1.30/ kg liveweight gain $
2 breed cross, eg A x B	100	0	8.5	16.50
3 breed cross, eg (A x B) x C	100	100	23.3	45.00
Rotational crosses*				
eg 2 breed	33	67	12.7	25.00
3 breed	86	86	20.0	40.00
4 breed	93	93	21.7	42.00
Composite crossbreed				
eg 2 breed	50	50	11.6	22.50
3 breed	67	67	15.6	30.50
4 breed	75	75	17.5	34.00
5 breed	80	80	18.6	36.00
6 breed	83	83	19.3	37.50

* After this breeding system has been used for about seven (7) different matings and also refers to Bos taurus to Bos taurus or Sanga x Bos taurus crosses.

Heritability values vary between traits. The higher the heritability or likelihood that a trait can be passed onto progeny, the greater the genetic progress that can be achieved (BREEDPLAN, 2020). Table 4, although dated, provides an outline of the heritability of certain traits.

Table 4: Heritability estimates for some character in beef cattle
(Hammond, Graser, & McDonald, 1992)

Character	Heritability Range	Heritability (%)	
		Temperate	Tropical
Reproduction			
Conception	low	0 - 5	5 - 20
Calving interval	low	0 - 10	na
Calving ease(heifers)	medium - high	15 - 50	na
Semen quality	medium	25 - 40	6 - 44 •
Scrotal circumference (18 mth)	medium - high	20 - 50 •	28 - 36 •
Serving capacity (18 months)	low - high	15 - 60	na
Maternal ability	medium	20 - 40	na
Gestation length	medium	15 - 25	na
Conformation and Growth			
Weaning score	medium	25 - 35	na
Body length	medium	25 - 45	na
Chest girth	medium - high	25 - 55	na
Wither height	medium - high	30 - 50	na
Birth weight	medium	35 - 45	35 - 45
Milk yield	medium	20 - 25	na
Weaning weight	medium	20 - 30	3 - 50 •
Gain - birth to weaning	medium	25 - 30	30 - 40 •
Yearling gain (pasture)	medium	30 - 45	20
18 month weight (pasture)	medium - high	40 - 50	30
Mature cow weight	high	50 - 70	25 - 40 •
Dry season gain	medium	na	30
Wet season gain	low	na	18
Carcase (US)			
Dressing percent	medium - high	30 - 50	na
Carcass weight/day of age	medium	25 - 45	na
Tenderness	high	50 - 70	na
Rump fat P8 site	medium - high	30 - 40	na
Eye Muscle Area	medium	20 - 25	na
Other traits			
Cancer eye susceptibility	medium	20 - 40	na
Eyelid pigmentation	high	45 - 60	na
Temperament	medium - high	25 - 50	25 - 50 •
Tick resistance	medium	na	20 - 35
Worm resistance	medium	na	25 - 30
Buffalo fly resistance	medium	na	20 - 30

The author saw the following diagram (Figure 19) at Deseret Ranch and it summarises visually what traits can be managed by breed change (heterosis) or what traits can be managed best within breed selection (heritability).

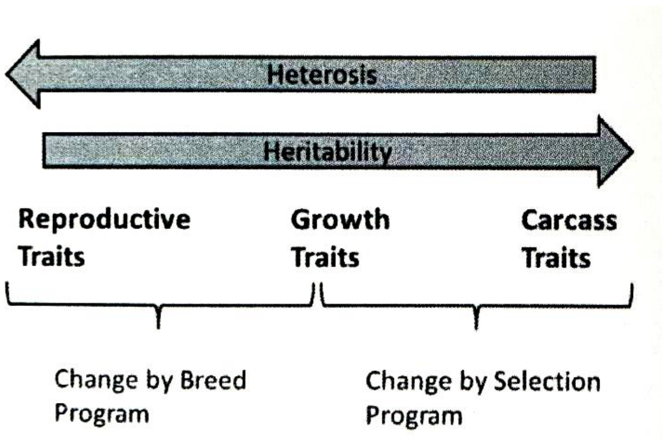

Figure 19: Genetic Variation *(Deseret Cattle, 2019)*

The following are examples of three breed rotational cross breeding systems from Florida, USA that have planned to retain 86% heterosis, as shown in Table 3. This system has improved low heritability traits by capitalising on the breed complementarity. The *Deseret Red* is a composite of Brahman, Red Poll and South Devon.

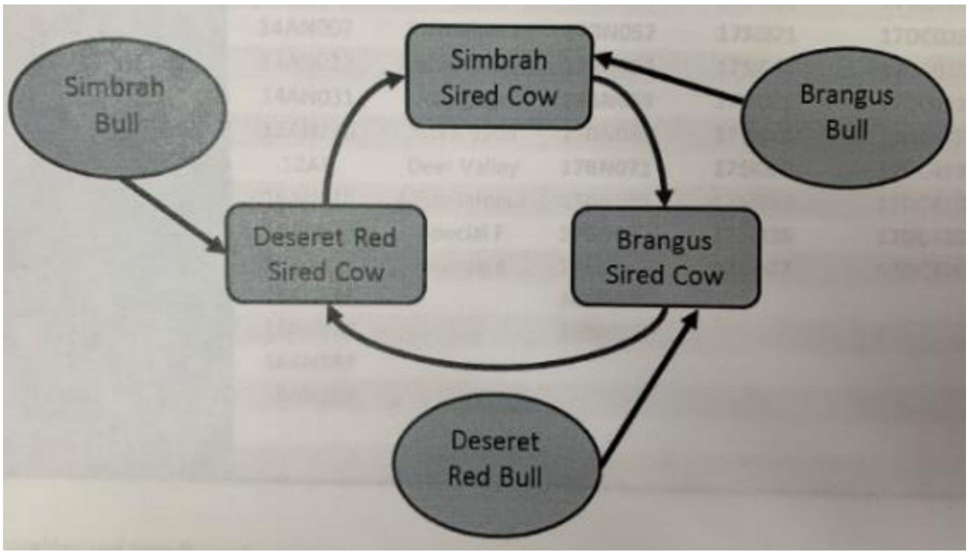

Figure 20: Deseret cattle commercial herd. Three breed rotational cross breeding model *(Deseret Cattle, 2019)*

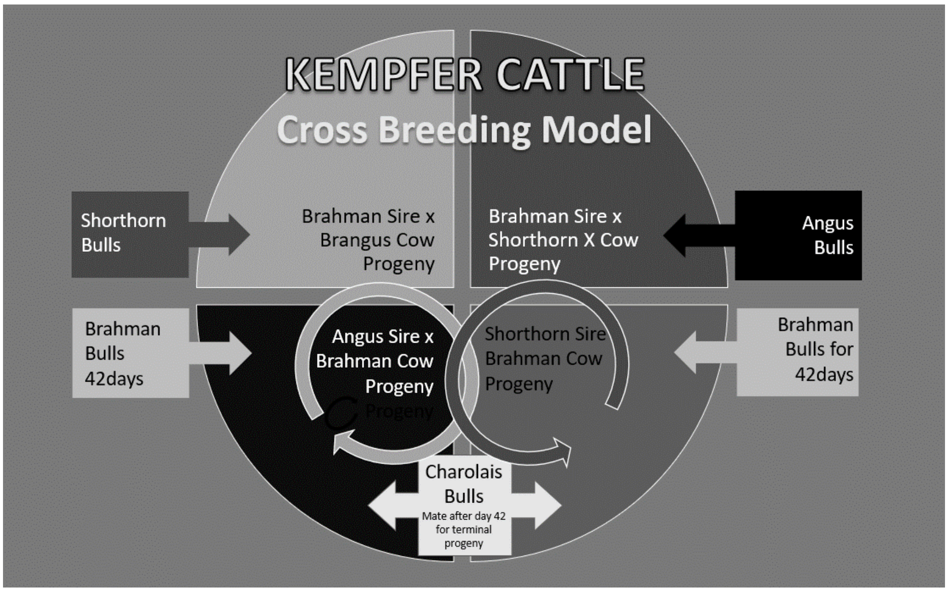

Figure 21: Kempfer Cattle rotational cross breeding model *(Author, 2019)*

It should be highlighted that the above cross breeding programs were designed with the help of outside specialists. These intensive breeding programs are another consideration for Australian producers to access assistance to optimise their herd's genetic performance, however the author observes that strict herd management would need to prevail for these rotational crossbreeding systems to work. For more information. http://tbts.une.edu.au/contacts/

Chapter 4: Measurement Technology and Modern Traits

As many traits that drive profitability are hard to measure and not visible to the eye, proactive research to define these traits is occurring worldwide and in Australia. Even basic phenotypes such as date of birth are difficult to record in the extensive and rough terrain in which northern Australian cattle exist. The following is a snapshot of some new technology that may help to select and breed the beef cow of the future for northern Australia.

The integration of modern technology for animal measurement was observed at dairies, research stations and universities globally, mostly in an intensive situation. The collection of animal data could be divided into the manual or automatic collection of phenotype and genotype. The main types of automatic measurement observed were:

- Individual animal management and monitoring e.g. On-animal sensors collecting behaviour, state and location

Figure 22: Various smart tags and collars observed *(Ceres Tags, 2020) (Author, 2018)*

- Paddock-based management and monitoring systems e.g. Walk Over Weighing (WOW), Auto-drafting

Figure 23: Remote Australian WOW at a water yard (Central Station, 2020)

4.1 Fertility

Age at puberty and lactation anoestrus interval are some of many HTMTs that contribute to the complex profit driving trait of fertility. Research performed in the Cooperative Research Centre (CRC) for Beef illustrated the genetic variation in age at puberty as shown in Table 4 (BREEDPLAN, 2020). Currently Australian research projects are measuring by internal ultrasound monthly to provide information to incorporate fertility information as breeding values for tropical breeds and across breeds. Developments were observed which measure oestrus with automatic modern technology such as individual collars and tags, promising to replace the current labour intensive ovarian scanning for Northern Beef fertility phenotyping.

Table 5: Mean & range for all heifers at age of puberty and age at 1st Corpeus Luteum (CL) or 1st egg development *(TBTS, 2020)*

Trait	Mean	Range
Age at 1st CL (Months)	23	11-40
Weight at 1st CL (kg)	332	196 - 485

4.2 Date of Birth

Date of birth is a trait that is difficult and time consuming for seedstock producers to capture in the extensive paddocks of Northern Australia. To be seven days out on date of birth results in a 4% inaccuracy on the 200day weight EBV (Hudson, 2020) and distorts the accuracy of the EBV trait of Days to Calving. Calf Alert is a telemetric device placed in the vagina of a pregnant cow with 100% tested retention for at least six months. It is capable of identifying the time and location of calving events and alerting the producer via SMS or computer messaging. (Stephen, D Menzies, Patison, Corbet, & Norman, 2019) Raoul Boughton of University of Florida had also tested a similar product, VIT or vaginal implant transmitters (Broughton, 2019).

Figure 24: Telemetric Calf Alert Device in the authors hand *(Author, 2019)*

CQU Precision Livestock Management technology integrates on-farm walk-over-weighing systems (WOW), low bandwidth data transmission technology and sophisticated analysis systems to deliver real time information about individual animals and infrastructure direct to a mobile app. The project aims to record several phenotypic measurements for inclusion in national genetic evaluation programs such as BREEDPLAN. It will also enable commercial producers to manage individual animals with targeted nutritional supplementation, temporal sequencing for age of puberty with cameras and video recognition etc. The date of birth for more than 120 calves has been successfully captured at AgForce's Belmont Research Station, QLD, Australia. See https://www.datamuster.net.au/

However, easier than the above-mentioned modern technology and part of routine management in northern Australia, may be considering the use of foetal aging at pregnancy diagnosis to ascertain date of birth.

4.3 Feed Efficiency

Lee Leachman, principal of Leachman Cattle Company and president of the USA Beef Improvement Federation (BIF) says, the profitability of a herd is impacted by two input traits: mature cow weight (MCW) and feed efficiency. Most other traits measured are output traits. MCW is relatively easy to measure, however, feed efficiency is a HTMT. The GrowSafe System he used, offers a method to measure feed efficiency, helping to produce more beef with less feed, forage and land. Several other units measuring feed efficiency were seen on leading seedstock operations and research stations in Australia, NZ, Canada, USA and Ireland. The discussion around pasture to lot-fed relevance for measured feed efficiency, shows the measure is relative, with a larger distribution enabling better selection (Leachman, 2019). Most of the leading seedstock producers visited had these facilities on site (Brown, 2019). Feedlots even rented the technology (Jones, 2019). This is a real possibility for the Australian seedstock and feedlot sectors.

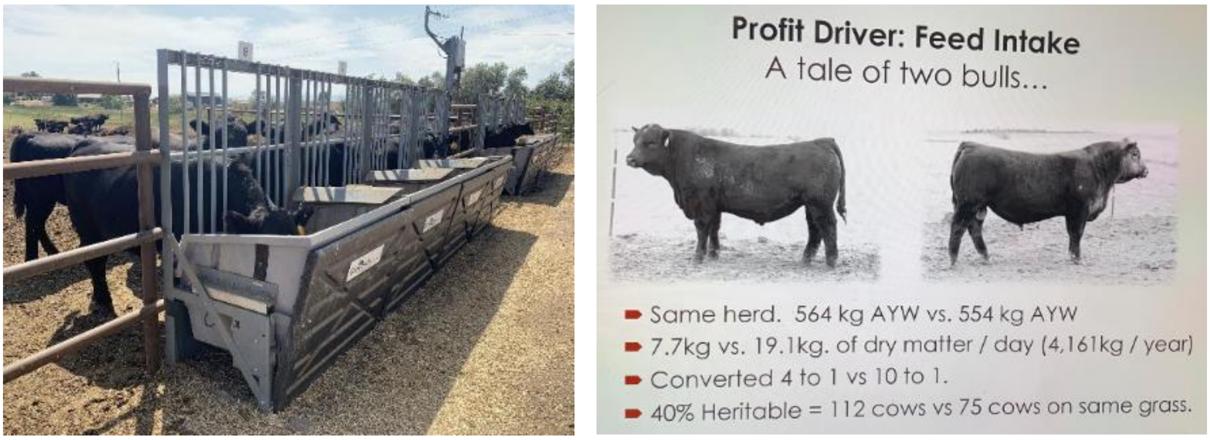

Figure 25: GrowSafe Units measuring Feed efficiency for Leachman Cattle Company $Profit® and the Tale of two bulls shows the results of focussed selection *(Leachman, 2019)*.

4.4 Eating Quality

Eating Quality (EQ) traits are marbling, tenderness, juiciness and flavour: all these are complex traits controlled by many genes and by the environment and are measured after slaughter (Mateescu, 2019). Dr Raluca G Mateescu and her team are finding genomic selection is the best strategy for genetic improvement of this complex HTMT (Sarlo Davila, 2019). This research supports the need for an objective and reliable indicator of eating quality to align with measurable traits on farm for all breeds in Australia.

An observation unique to Australian cattle, was the fantastic eating quality carcase data set that Meat Standards Australia (MSA) collects. Annually two million head are measured in the MSA system. Approximately only 500 animals are used in the Australian Breedplan analysis for carcase EBVs (Polkinghorne, 2018). There is big potential to integrate this phenotype data to strengthen EQ BVs. The aim of improving beef quality can be seen as a global issue to ensure beef eating experiences worldwide are positive. Currently collaboration is occurring to develop a standardised set of tools to collect EQ data in a standard format to be recorded in one big international database (Polkinghorn, 2018).

Figure 26: University of Florida, Gainsville Campus, USA. Audy Spell, the author, Tracy Scheffer and Kaitlyn Sarlo Davila discussing how to objectively measure eating quality to allow accurate selection to occur *(Author, 2019)**.***

4.5 Thermotolerance

The "slick" gene, originally identified by the University of Florida, in Senepol cattle, is a genetic variation that leads to shorter haired cattle which are more able to thermoregulate over 26ºC (Mateescu, 2019). The slick gene features in the Savanna Breed, seen at Rissington Farms, New Zealand. More than 50% of the world's cattle population is maintained in hot environments. By selecting for heat tolerance, genomic selection provides a viable and effective strategy to mitigate the negative effect of heat stress on beef productivity addressing consumer concerns around climate change.

The author also witnessed data collected in dairies in Brazil measuring panting frequency (Wallace, 2019). Sensors may assist the collection of heat tolerance phenotype information for extensive beef (Pryce, 2020).

Figure 27: 'Becky', a Savanna calf born at Rissington, NZ with the author *(Author, 2019)*

4.6 Green House Gas Emissions

The proactive response to environmental concerns by the Australian beef industry has seen a commitment to zero net emissions by 2030 (RMAC, 2019). The measurement of greenhouse gas emissions observed at the Tully Progeny Test Centre in Ireland has shown that more feed efficient cattle also emit less GHG. The Australian agricultural sector is in a unique position. While reducing emissions, through genetics and management changes, it also has the potential to be recognised for the grazing interaction with the environment that sequesters carbon. This is something that is not accounted for most GHGe reports (Mitloehner, 2019).

Figure 28: Author pictured at Tully Progeny Test Centre, Ireland (ICBF, 2019).

4.7 Consumer Nutritional Value

Healthfulness or consumer nutritional value were identified by Rabobank Director Berry Martiin as a future consumer trend requirement. Beef is a naturally nutrient-rich food source. Dr Raluca G Mateescu is developing a phenotypic database for healthfulness traits such as fatty acid composition at University of Florida. It has been discovered that as Bos indicus content increases, so does the healthy fatty acid profile or polyunsaturated fatty acids (PUFA) (Mateescu, 2019). Genomic selection is the preferred way of identifying and supplying healthier beef, which is good news for north Australian beef with a predominately Bos indicus base.

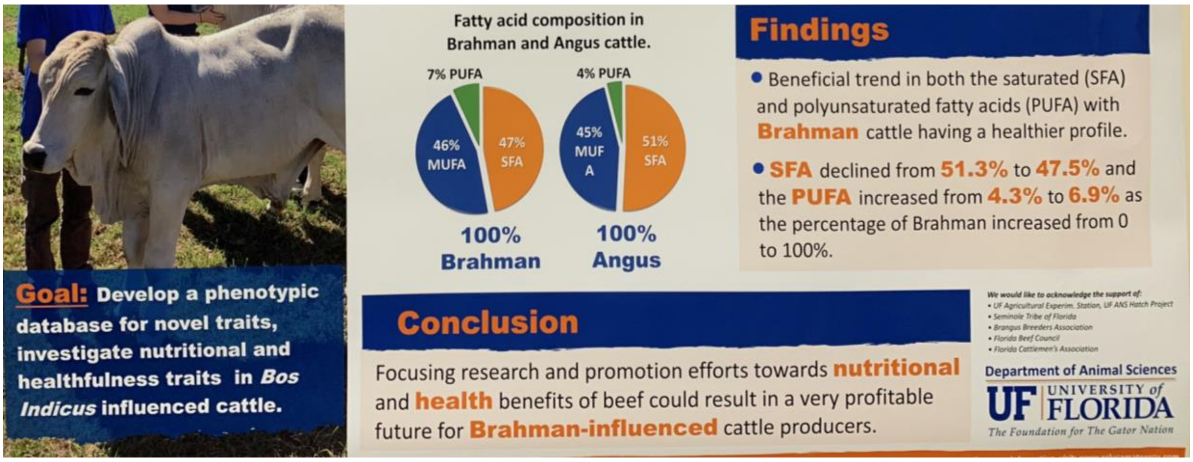

Figure 29: Fatty acid levels in Brahman and Angus *(Mateescu, 2019)*

Ian Hill, Jacarazhino, Brazil, touted facial recognition and video recognition measures as the future of all animal trait collection (Hill, 2019), which has the potential to be cheaper and more accurate than tags. The author observed video recognition trials in pig and dairy research. Also, in Brazil the CEIP program was conducting research to increase objectivity in measuring gait and structure. The possibilities for animal trait measurement are only limited by the imagination. The cost benefit and workability of new technology and a standard livestock language will be some of the factors to consider in adoption.

Until developments in modern technology are trialled adequately and are cost effective to implement on farm, breed initiatives such as the Angus Sire Benchmarking Program (ASBP) or Breed Information Nucleus (BIN) or other industry research projects offer the best way to access measurement on these HTMTs for genetic gain in seedstock operations to optimise profit in the seedstock herd and consequently in their clients operations. It is up to the seedstock producer to collaborate with the research projects.

Chapter 5: Case Studies

The following case studies are outstanding global examples, that are leading the way to select for genetic optimisation.

5.1 Case Study: The Germplasm Evaluation Program and Beef Genomic Research

US Meat Animal Research Centre (USMARC), Clay Centre, Nebraska, USA.

The Germplasm Evaluation Program is the longest running research program at USMARC. The program began in 1972 with genomic analysis introduced in 2007. The GPE identifies:

- Breed differences across 18 breeds
- Crossbreeding effects, such as hybrid vigour
- Genetic correlations among diverse traits
- Genomic effects on novel trait complexes

The research has collaborated with five feedlots, two abattoirs and five commercial cow/calf herds to learn more about industry traits that are hard to measure, while searching for genomic effects that can be utilised across breeds (Kuehn, 2019). The identification of breed differences enables the producer to select suitable bulls, by generating an across-breed EPD adjustment factor (Kuehn, 2019).

The genomic research results are:

- The development of genomic reference populations specific to breeds.
- The location of important regions in the genome, responsible for hard to measure traits such as feed efficiency, fertility and disease resistance.
- The transfer of high-density information to breed societies to initiate reference populations for BVs.
- The ongoing targeting of high impact genomic regions and new 'sequencing' technology to improve the reach of the genomic program (Kuehn, 2019)

Australia has research projects gathering data to make this possible, such as:

- The Repronomics I and Repronomics II Project (Johnson, 2019).
- Southern multi-breed beef cattle program, that will enable the direct comparison of bulls from different breeds. (Walmsley, 2019)

Other research projects gathering data for more robust genomic reference populations are:

- The northern beef genomics project, which uses a reference population to provide information on fertility and other traits to produce GBVs over 54 properties (Hayes, 2018).
- Breed-based BINs Projects.

Whilst USA have this long-standing project, Australia’s past and present research work is commendable. Australian scientists and researchers are working hard, gathering phenotypic measurements to build genomic reference populations aiming for similar outcomes to GPE.

5.2 Case Study: Gardiner Angus Ranch, Kansas, USA

The Gardiner Angus Ranch (GAR) is an inspiring example of animal breeding. Located in Kansas USA, in an 18-inch (450mm) rainfall area, natural mating has not been carried out for 56 years. Henry Gardiner pioneered Artificial Insemination (AI) use in Beef Cattle in the 1950s, to exclusively AI from 1964. However, it is interesting to note that they achieved reproduction but NO early genetic change occurred, when they were using raw measurements alone.

The introduction of genetic evaluation in 1980 provided improved selection. Mark Gardiner went on to say he had used high-accuracy EPD bulls for the economically important traits since 1980. In doing so he has seen weaner weights of from 237kg at 10mths prior to the use of genetic evaluation, increase to 362kg at 9months only eight years later. GAR has also improved eating quality achieving 90% or better choice grading on progeny. Nowadays genomic BVs have added higher accuracy to selection earlier in life to further accelerate genetic improvement.

Currently performing 2,500 embryo transfers (ET) per year, every animal on the ranch has been the result of either AI (since 1964) or ET more recently since 1987. The average female grazes 11 months per year. They are brought in to synchronize, breed and are scanned with

ultrasound for pregnancy. Heifers are given 30 days to conceive or be culled. Cows have been bred on a 60-day breeding season.

Figure 30: Gardiner Angus AI Barn Facility aerial view (Gardiner, 2019)

Figure 31: Gardiner Angus AI Barn Facility (Gardiner, 2019)

The Gardiner Ranch Grand Plan 2020, included a complete registered female dispersal sale. This would not be possible without advanced reproductive technologies and accurate genetic evaluation to select what genetics to multiply. It was observed that high selection pressure was applied by harvesting eggs from genetically superior females, using genotyping to ensure high selection accuracy and multiplying younger superior genetics to reduce the generation length.

These advancements in production have all been done with accurate measurement, genetic evaluation and by continually selecting using EPDs and Indexes what Mark calls the 'Michael Jordans of the Angus breed' (Gardiner, 2019).

5.3 Case Study: Beef Suckler Herd, Ireland

Irish Cattle Breeders Federation (ICBF) was an amazing example of what can be achieved through industry collaboration of storing data into one hub. When interviewed, no one said it was easy and compared it to marriage, explaining that compromise from all parties is involved, to not only begin, but to survive and thrive for 22 years to date (Cromie, 2019).

ICBF is a non-profit organisation, formed in 1998, which began providing cattle breeding information services to the Irish dairy and beef industries. The ICBF houses a cattle-breeding database, that benefits the farmers, wider industries and communities through collating measurements, then analysing and providing benchmarked information to improve genetic gain.

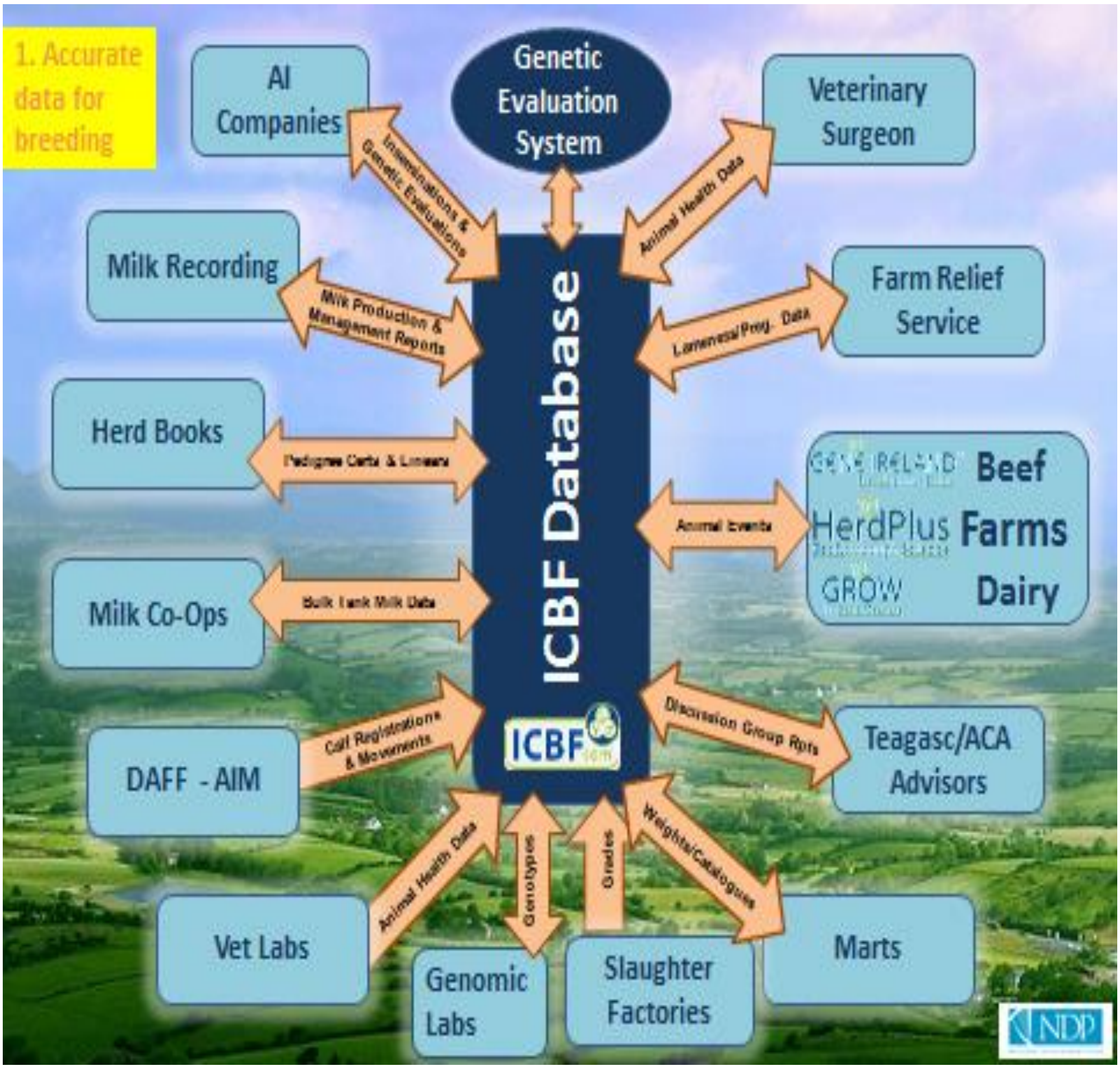

Figure 32: Data Sources for the ICBF (Cromie, 2019)

ICBF CEO, Andrew Cromie, has been involved since inception. This quote captured the Irish view on the importance of measurement to achieve national genetic progress.

Data is needed for genetic progress. Data collection costs.
So pay the farmer, it is cheaper (Cromie, 2019).

To ensure the provision of genetic evaluations, ICBF is funded by 'user pay' services at minimal cost. HerdPlus pictured below provides a genetic evaluation service for €60/year. The data is analysed into usable information for all producers. e.g. EuroStars (EBVs) and benchmarking reports etc.

Figure 33: Beef HerdPlus inputs and outputs (Cromie, 2019)

The Irish Beef Suckler herd was similar to northern Australia, initially experiencing poor adoption of animal measurement. As recently as 2015, this has changed as the Irish farmer has been encouraged to measure and submit data via several action-based payment schemes as explained below.

Beef Data and Genomics Programme (BDGP) 2015-2020, 2020-2025

The farmer receives €95/cow after the following six requirements are recorded and submitted to the ICBF:

1. Calving details
2. Surveys giving herd information
3. Genotyping (€22/head)
4. Replacement Strategy e.g. High EuroStar animals introduced 4-5 Star merit
5. Annual completion of 'Carbon Navigator'
6. Training costs; applicants are paid €166 to cover course costs

Beef Environmental Efficiency Pilot (BEEP) 2019-2024

The farmer receives a €40/calf in return for both cow and calf liveweight. Due to the average suckler herd being less than 20 cows, scales may be hired. The aim is to breed a more efficient cow which meets the necessary weight and fertility targets, significantly reducing the amount of greenhouse gases (GHG) generated per kg of beef produced in Ireland. With 24,000 farms involved and 1.9 million animals genotyped, the BDGP is delivering further carbon efficiencies with the ICBF estimating that by 2030 the genetic gain achieved through the programme will reduce greenhouse gas emissions by 14%/kg of beef produced (Cromie, 2019).

In addition to these voluntary, yet subsidised actions on farm, the following mandatory collection of data is required by Department of Agriculture Food and Marine. (DAFM)

Irish Bovine Animal Identification System

In 1996, Ireland introduced mandatory traceability of cattle from birth to factory with the Cattle Movement Monitoring System (CMMS). The aim of the Bovine Animal Identification System is to guarantee the safety of beef and beef products by the operation of an effective animal identification and tracking system. The system has four elements:

1. Tagging within 20 days, two yellow accreditation tags
2. Bovine passport, recorded within seven days of tagging. The passport accompanies the animal each time it is moved.
3. On-farm bovine herd registers
4. Animal Identification and Movement (AIM) System i.e. Used to check for eligibility for the Single Payment Scheme, under the EU Common Agricultural Policy. (DAFM, 2020)

The introduction of these subsidised schemes, and subsequent adoption of measurement, has seen significant genetic progress in the Irish Suckler Beef Herds. The below graph shows the genetic gain achieved in the Dairy Herd due to the early adoption of Dairy Estimated Breeding Indexes. Adoption of the equivalent tools in the Irish Suckler Beef Herd, the Eurostar Index, happened 15 years later, only after incentivised action-based payments were offered. Irish beef is now experiencing the same rate of genetic gain as dairy, just over 15 years later due to late adoption!

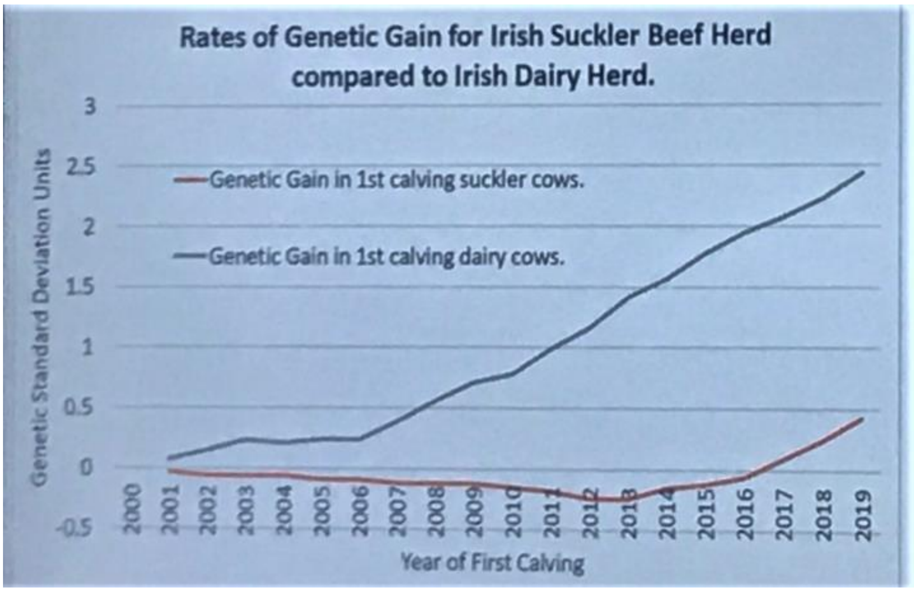

Figure 34: Rates of Genetic Gain for the Irish Suckler Beef Herd compared to the Dairy Herd (Cromie, 2019)

Currently in Australia there is data recorded on many separate databases, such as the National Livestock Identification Scheme (NLIS), Livestock Data Link (LDL), Meat Standards Australia (MSA) and beef cattle breed society databases. Many Australian producers are collecting weight and other measurements on individual animals, but the data flow often stops on farm, even though it is linked to an individual animal via an NLIS tag. ICBF must supply scales to its farmers to obtain data, whereas measurement is occurring voluntarily in Australia.

An Australian framework for a national livestock data hub is currently being developed by the National Livestock Genetics Consortium to hold and easily allow the sharing of genetic information (Crowley M. , 2019). The advantages observed at ICBF of sharing captured data for the Australian cattle industry would be the accumulation of all measurement, for a robust reference population to further support genotyping. Incentives could be offered in Australia to reward those who measure and contribute to the genomic reference population.

Shared measurement in a standard language could be converted into decision making information by the proposed national hub offering genetic benchmarks. Benchmarking a herd provides knowledge of what a herd is achieving. As Julius van der Werf (from Sheep Genetics in Armidale) explained, benchmarking provides motivation to adopt new management, technology or tools to improve last year’s performance (van der Werf, 2019) The possibilities of this type of collaboration provides more tools to optimise genetic gain in northern Australia.

5.4 Case Study: Special Certificate of Identification and Production (CEIP), Brazil

A point of difference was observed in Brazil with the Special Certificate of Identification and Production (CEIP). The CEIP is an official document, issued with the authorization of the Ministry of Agriculture, Livestock and Food Supply (MAPA), which attests to the genetic quality of an animal. Incentives offered by government such as reduced taxes on cattle sold as 'CEIP' has helped to accelerate genetic progress. After being genetically evaluated by one of the several services available in Brazil, (eg. Datagen, GeneSys) only the top 20% of progeny (young bulls and heifers) for each year are eligible to receive the CEIP certification. Only the top 1% young sires are semen collected. CEIP assessment is focussed on using performance recording and genetic evaluation of beef cattle to breed superior animals, generation on generation, ensuring high selection differential or faster genetic progress. (Embrapa, 2019) Eligible animals are physically branded with the CEIP brand on the front nearside shoulder.

Part of what makes the CEIP certification comprehensive is that the trait measurements combine an outside independent, visual assessment or CPMU evaluation. The four structural traits are included in the genetic evaluation and reported as EPDs. The CPMU occurs after 24hrs feed and water curfew, for unbiased information. In Colombia, it was also noted that a team of assessors measured seedstock structure for BV formulation. CEIP is currently trialling video recognition to reduce the subjectivity of human assessment of these structural traits (Nelore Prodacao, 2019).

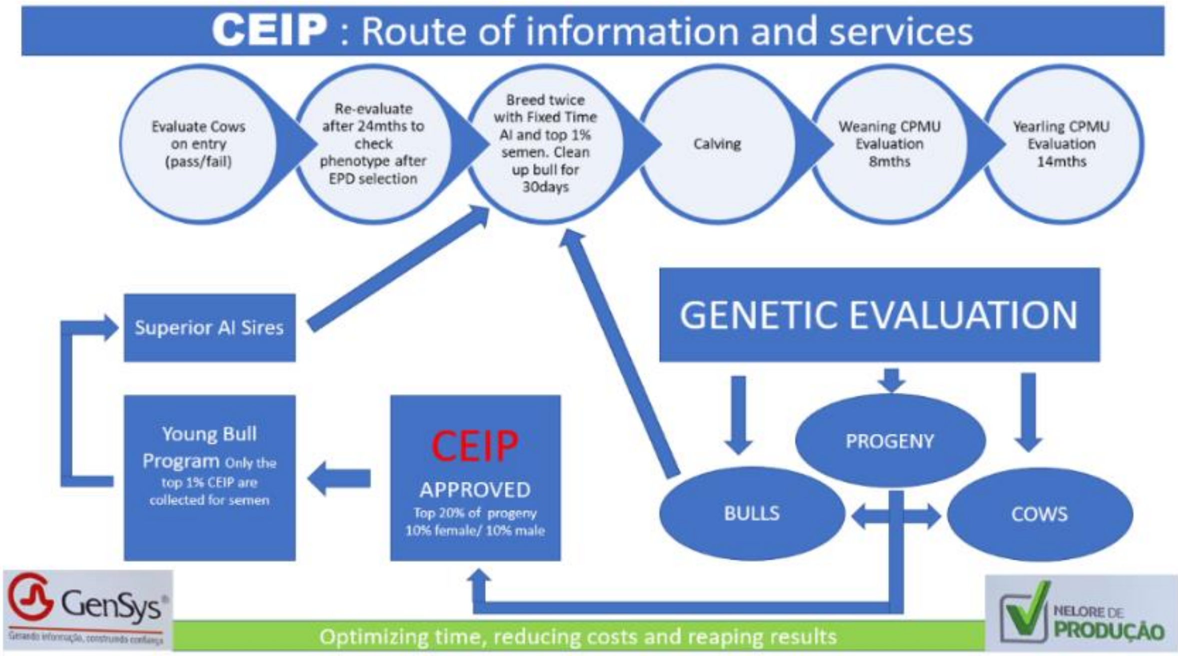

***Figure 35: CEIP overview - accelerating genetic progress in Brazilian beef** (Author, 2019)**.*

The author sees this model taking the complexity out of genetic evaluation selection as a beast is branded as being in the top 20% of the breed. The physical branding removes the need to interpret the EPDs, making it straightforward to identify the top genetic performers. A breeder does not have to understand the figures, but just identify with the brand.

Figure 36 : Brand instant recognition of CEIP approval or top 20% of genetic merit *(Author, 2019)*

5.5 Case Study: Gene Editing

Gene editing involves the artificial alteration of the genome. It is a technique that can be used to introduce useful genetic variations into breeding programs, similar to a pair of molecular scissors that go and cut the DNA at a very precise location in the genome, e.g. CRISPR. An alteration can be made to one particular gene, and deletions or insertions of useful genetic variations can be applied (Eenennaam A. V., 2020)

Alison Van Eenennaam at UC Davis, California USA, went onto explain what her team were working on as future possibilities for the Beef Industry:

- **Surrogate sires**. Adapted bulls in phenotype, that produce sperm carrying only the *genetic* traits of donor animals. This possibility requires less labour and time to implement than the alternative of AI programs or dealing with the reduced survival rate of a purebred Bos taurus in northern Australia. For example:
    - An outstanding EBV sire of the same breed could be multiplied
    - A *Bos taurus* bull to facilitate a crossing breeding program
    - Single sex progeny from an EBV top ranked sire eg. All bull calves
- **Eliminating dehorning**. Gene editing can permanently eliminate horns from cattle while potentially maintaining their hard-won production genetics (Mueller, M. L. et al., 2021) Dehorning accounts for 2.1% mortality in Northern Australia (Bunter, K. L. et al., 2013).
- **Gene editing to produce healthy animals**. Porcine Reproductive and Respiratory Syndrome (PRRS) virus-resistant pigs have been created. Genetic improvement could

provide a solution to animal disease rather than chemical treatments, e.g. antibiotics, tick resistance etc

Whether breeders will be able to employ genome editing in cattle breeding programs will very much depend upon global decisions around the regulatory framework and governance of genome editing for food animals (Eenennaam A. V., 2020).

Alison Van Eenennaam explained that gene editing could be the ultimate addition to the animal breeder's toolbox, or the 'Cherry on Top of the Breeding Sundae' shortening the generation interval that would normally take years of natural breeding to achieve change.

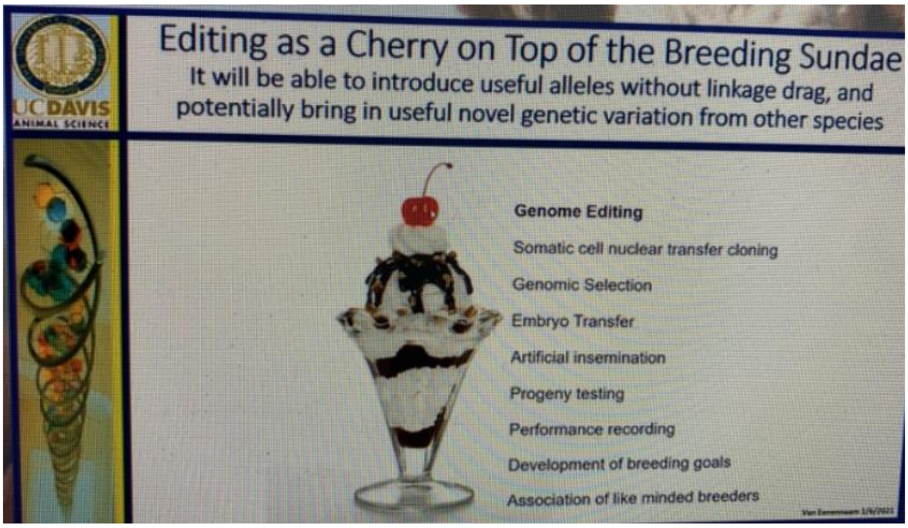

Figure 37 : Gene editing as a 'Cherry on Top of the Breeding Sundae' *(Eenennaam A. V., 2020)*

5.6 Case Study: Genotyping explained

Dr Matt Spangler shared his thoughts on buying a young bull. He explained that the bull's EBV data accuracy will remain low, until there are measurement records on the daughters of the that bull which takes up to five years. Genotyping of an individual animal can deliver genetic information quickly. At birth, or even embryo stage. This would speed up genetic gain, enabling optimal selection (Spangler, 2019).

Figure 38: Dr Matt Spangler, Beef Genetics Specialist. University of Nebraska Lincoln, USA with author** (Author, 2019)**.

What is DNA?

Deoxyribonucleic acid (DNA) is a complex, long chain molecule which is found in the cell nucleus and contains an animal's genes. DNA is bundled into chromosomes and beef cattle have 30 chromosomes. Half of each chromosome is inherited from the sire and half from the dam. They contain proteins that regulate everything that happens in that animal.

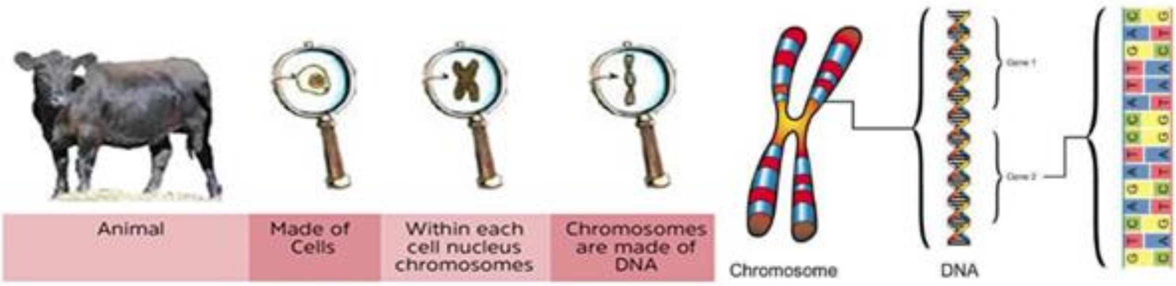

***Figure 39: Introduction to DNA** (Angus Australia, 2019) **and Bovine DNA contains 22000 genes** (Anime Science, 2020)*

What is DNA Testing?

Variation between animals is caused by variation in DNA. DNA is a string of paired molecules, called base pairs. A difference at one point is called a single nucleotide polymorphism (SNP), regularly referred to as "markers" or "snips". These SNPs largely dictate the physical differences we see among animals. In bovine genomics, a selected group of SNPs that have high frequency and are in coding regions are identified for routine measurement.

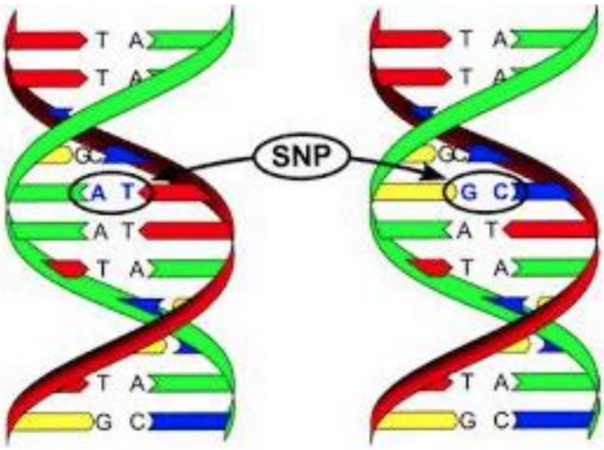

Figure 40: An example of a SNP between two individuals *(Crowley, 2019)*

To measure all SNPs would be very expensive. Therefore, laboratories select smaller groups or "panels" of these SNPs for 'chips' (a slide on which multiple animals can be tested for the same panel of SNPs), which makes genotyping affordable for animal breeding purposes, e.g. the current Neogen GGPTropBeef SNP chip tests 35 million SNPs. Panels can be sorted into five different categories based on density, as represented in the table below.

Table 6: Genotyping Panel Density *(Crowley, 2019)*

Genotyping Panel Density	Number of SNPs	Use	Cost
1. Small panel test	Few - 2000	Parent Verification	$
2. Low Density (LD)	5000-30000	Genomic Prediction	$$
3. Medium Density (50K)	50000-150 000	Density used for building of a reference population	$$$
4. High Density (HD)	500 000-1 000 000	Cost : benefit low, for increase in EBV accuracy	$$$$
5. Whole Genome Sequence	All 3 billion	Research only	$$$$$

The cost per SNP has reduced significantly in the 9 years that testing has been available in Australia, down from 40cents to approximately 0.1 cents/SNP (Author, 2019). The identification of SNPs has important applications for animal breeding, particularly to the beef seedstock producer.

What is Genomics?

Genomics is the study of an animal's genome, which includes approximately three billion base pairs, containing approximately 22,000 known genes. A statement that clarified the role of genomics in breeding, was made by Lee Leachman who stated *'I don't care who your parents are, but I care which genes you got from each parent'* allowing for more accurate genetic selection (Leachman, 2019).

In 2009, the world's first bovine Whole Genome Sequence (WGS) was for a Hereford cow named, L1 Dominette 01449 (Figure 40). The project was a six-year effort that involved more than 300 scientists from 25 countries and cost $53 million. This opened the door to using genotypes for enhanced selective beef cattle breeding (Spangler, 2019).

Figure 41: L1 Dominette 01449. The world's first bovine WGS *(ABC, 2009)*

Eight years later, in 2017 in Australia, saw the WGS of a Brahman cow, Elrose Naomi 3492, being mapped for $1million (Figure 41). The previous Bos taurus reference genome assembly was not as accurate as working with a Bos indicus genome for northern Australian cattle. This progress has been essential in helping to understand the underlying production traits in tropically adapted cattle (Jefferies, 2020).

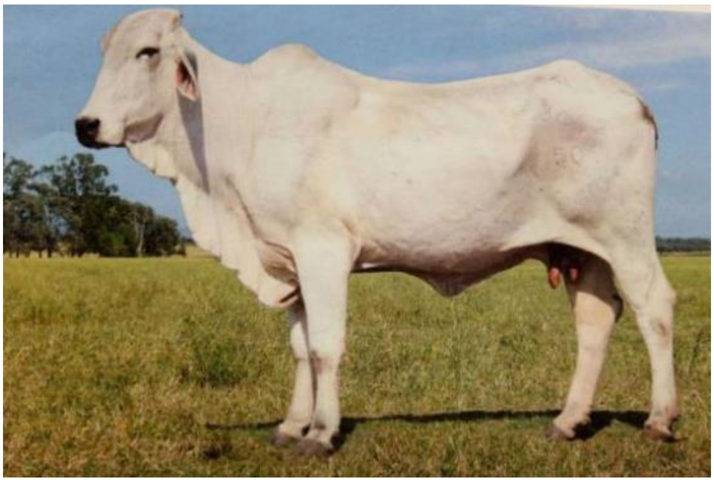

Figure 42: Elrose Naomi 3492. First WGS Brahman Cow in Australia *(ABC Rural, 2017)*

Genomic selection is based on an estimation of detailed associations between SNPs and phenotype measurements on a group of animals, called the **reference population** (Hayes, 2018).

The Future of DNA Technology

Genotyping is the current method of DNA testing, analysing around 50,000 SNP will soon be replaced by **Next Generation Sequencing** (NGS). NGS technology is more able to deal with crossbred cattle in a faster, cheaper and more detailed manner, analysing up to 3million SNPs (Snelling, 2019).

DNA Pooling was discussed as a future advantage for commercial producers wanting to obtain an estimated genetic value on a herd rather than on individuals, essentially combining hundreds of samples into one solution, to perform a single genomic evaluation (Kuehn, 2019).

A **crush side genotyping** device may be an additional decision-making tool for the beef producer in the future by pulling a tail hair and letting the USB machine genotype the animal and even generate an EBV in the yard (Hayes, 2018).

Figure 43: DNA Sequencer that is the size of a USB stick and it reads off the genome of the animals (Beef Central , 2018)

Conclusion

The beef animal of the future will be bred through focussed genetic selection based on the genetic evaluation of the increased collection of phenotypes and genotypes using modern technologies. Optimised selection will provide increased profit and sustainability for the Australian beef industry. This will also result in nurturing consumer trust by proactively addressing environmental and welfare matters through selection.

To achieve genetic gain, a clear breeding objective must be set. Australian producers can take advantage of the free technical consultancy and online training resources available to develop a breeding plan and commit to it for the long-term. The factors that influence the rate of genetic progress are selection intensity, accuracy of selection, genetic variation and generation length. Genetic optimisation can be achieved through increased measurement (phenotype and genotype) that is genetically evaluated to result in high accuracy selection tools. Globally, the use of selection indexes has optimised genetic gain in a cross section of livestock breeding, based on objective measurements.

Phenotype and genotype measurements can form a genetic baseline for a herd, breed or industry, providing information on performance improvement or decline. The results of internal genetic benchmarking, through the use of genetic evaluation platforms such as BREEDPLAN, can provide motivation to adopt new management to improve the individual and in turn the entire beef industry.

Currently northern Australia is benefiting from the important contributions being made by research and industry funded initiatives, but into the future the responsibility for maintaining the quality of the genomic genetic evaluation and measurements will be with the seedstock breeders. Although DNA is quick to collect, performance recording of an animal's physical traits or phenotype will remain vital in obtaining a good genetic evaluation. Without measurement, genomics will be meaningless (Hayes, 2018). Modern technology will play a role to assist northern seedstock producers to collect objective and accurate phenotypes.

Northern Australia has potential for optimising genetic selection, by increasing measurement of both phenotype and genotype, utilising emerging modern technologies that address current labour and time constraints. This will result in improved selection accuracies and hence genetic progress. The ability to select cattle to survive and thrive in Northern Australia's conditions, to return profit whilst also being responsive to social and environmental pressures from the market, are all compelling motives for beef producers to apply new knowledge to create more from less.

It is often believed today that successful breeders have some sort of mysterious methods, of which all others are ignorant. Instead, the principles of the successful breeder are exceedingly simple………the difficulty lies not so much in knowing the principles as applying them. (Wright, 1920)

Recommendations

Producers:

- Take advantage of the free technical consultancy and online training resources available to develop and achieve a clear breeding objective for the herd and commit to it long-term. See: https://genetics.mla.com.au/ http://tbts.une.edu.au/

- Utilise all the tools available in the cattle selection toolbox, including BREEDPLAN, seeking herds that measure when introducing new genetics to the herd, especially when employing biotechnologies.

- Consider partnerships to provide progeny testing in a commercial setting e.g., seedstock producers offer semen/bulls and the commercial producer captures measurement in return.

Seedstock Producers:

- As genotyping becomes routine for seedstock production, a responsibility is continuing the amount of quality physical measurements/ phenotyping for genetic evaluations. Modern technology offers options to reduce labour and time needs of measurement.

- Capitalise on the current opportunities to measure expensive and hard to measure profit traits (HTMTs) objectively through research projects.

Industry:

- Progress industry education on BVs, phenotyping and genotyping.

- Continue the development of the across-breed BVs to assist focussed beef selection using crossbreeding.

- Capitalise on the extensive commercial MSA carcase data set already collected for genetic analysis and continue to research an objective and reliable indicator of eating quality that is measurable on farm for all breeds.

- Explore the possibility of introducing a genetic model similar to the Brazilian CEIP for straightforward identification and reward for breeding top performing selection index bulls.

- To develop an Australian central data hub from paddock to processor for all cattle data, considering:
    - incentives for those who contribute phenotype data, e.g. financial; and
    - reward genetic progress, e.g. genetic benchmarking reports.

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Plain English Compendium Summary

Project Title:	Optimising Beef Genetic Selection in Northern Australia
Nuffield Australia Project No.:	1901
Scholar:	Rebecca Burnham
Organisation:	The Yulgilbar Foundation
Phone:	0419776249
Email:	REBgrazing@gmail.com
Objectives	"How to optimise Beef Genetic Selection in Northern Australia". Report objectives were: • Reporting on the tools that global livestock breeders used to breed profitable cattle. • Identifying modern technologies that are assisting objective livestock measurement (phenotyping and genotyping) for hard-to-measure, profit-driving traits.
Background	This report examines selection techniques and modern technologies that are assisting in gathering information to match or supersede prevailing genetic improvement methods. Particular focus was given to optimising genetic progress in profit-driving traits, not recognisable by eye. e.g. fertility, feed efficiency, carcass yield and eating quality.
Research	In the author's visits to production enterprises around the world, extraordinary genetic gains were observed in beef and other animal species. Commonalities identified were: (a) clearly defined 'long-term' breeding objectives (b) excellent herd and grazing management (c) animal measurement (collection of phenotypes) (d) genotyping (e) genetic evaluation (f) and the use of <u>all</u> the selection tools available Globally it was noted that leading livestock operations were focussed on breeding animals that were not only profitable yet fulfilled environmental goals and met consumer expectations.
Outcomes	Northern Australia has potential for optimising genetic selection, by increasing measurement of both phenotype and genotype, utilising emerging modern technologies that address current labour and time constraints. This will result in improved selection accuracies and hence genetic progress. The ability to select cattle to survive and thrive in Northern Australia's conditions, to return profit whilst also being responsive to social and environmental pressures from the market, are all compelling motives for beef producers to apply new knowledge to create more from less.
Publications	Nuffield Australia Webinar Series presentation, February 2021