
DNA
PROVEN

LIC

DNA Proven
Changing dairy farming **FOREVER**

Foreword

Colin Holmes

Recently retired Professor of Dairy Production Systems, Massey University

Genetic improvements in NZ dairy cattle over the past 70 years have made enormous contributions to the ability of NZ dairy farmers to maintain their competitiveness and profitability. LIC, and its predecessor Herd Improvement, have been centrally instrumental to these improvements, and have remained focused on the goals of NZ dairy farmers.

DNA Proven is yet another important development in the long list of these important developments [which include sire proofs, herd testing, AB and semen processing, and genetic indexes]. As explained in this booklet, DNA Proven will enable more potential sires to be screened more quickly, so increasing the probability that exceptional individual sires will be discovered, and also reducing the number of years in which they are tested before being made available for widespread use in NZ dairy herds. These have the potential to significantly increase the rates of gain in genetic merit and farm profit.

I am delighted to express my congratulations and admiration for LIC, and especially to all those who have contributed directly to the development of DNA Proven, and I am confident that all of the dairy industry will join me in this.

However, we must keep our feet firmly on the ground, and

there are some important points to acknowledge. (The following comments are not intended to detract anything from my expressions of congratulation and admiration).

- DNA Proven has the potential to bring about faster improvements in genetic traits. But there is also a risk that a crucial trait will deteriorate if it is not included in the monitored traits. It is absolutely essential that we prevent any unexpected adverse genetic changes in the future. The performance of NZ dairy cows on NZ farms must continue to be monitored robustly and intensively into the future.

- The booklet holds up the fascinating prospect that BW will be 350 in 2030, compared with "only" about 150 now. What will the 350 BW cow look like, and what will she require? For example, she will need approximately an extra one tonne DM annually. Will she be able to obtain this from grazing, or will she require extra feeds, even concentrates? Will she be showing any unexpected problem traits? Her actual performance must continue to be monitored closely in grazing systems.

I want to finish by again expressing my congratulations to, and my admiration for LIC in their success in developing, testing and now launching this very important and exciting new genetic improvement tool for NZ dairy farmers. I wish you all every success with it.

Professor Colin Holmes

DNA Proven – Introduction

DNA Proven genetics is the most significant development in farm productivity improvement since artificial breeding (AB) began in New Zealand more than 50 years ago.

LIC has been investigating the possibilities of using DNA to add value to dairying since 1994, but the introduction of DNA Proven semen has been rapid – the concept was first mooted only as recently as 2001.

And what was that concept? To select bulls for widespread use based on their DNA profile rather than waiting for information on the performance of their daughters. This process, generally known as genomic selection, results in a generation interval that's shorter by about three years.

As all farmers who mate their yearlings to AB or use Forward Pack bulls or the Spring Pack know, sooner means faster! And that is why LIC has put huge resources into researching genomic selection and developing our product, called DNA Proven, so quickly – to increase the rate of genetic gain in your herd and the national herd more rapidly.

LIC, the company that led the world in developing AB and leads the world in semen technology, once again leads the world in developing DNA Proven technology.

LIC is doing this in two ways: by changing the way we select our bulls for Daughter Proven progeny testing, and by offering DNA Proven bulls to farmers NOW, in 2008.

Your decision whether or not to use DNA Proven bulls will probably be based on how confident you feel about the DNA Proven concept and technology. This booklet aims to give you the information you need to make an informed decision.

With DNA Proven technology, the concept is simple, but the science is sophisticated!

The material in this booklet is arranged from the basics to the complicated details, that is, from the minimum you need to know, to other information you may want to know.

So no matter where you stop reading – as long as you get as far as page 18 – you should know enough to make an informed decision on whether or not to use DNA Proven genetics, to appreciate its features and benefits, and to understand the basic principles.

New Zealand farmers, who led the world in the adoption of AB are once again poised to take advantage of cutting edge technology.

What is DNA Proven?

Everything we want to know about a bull's genetic merit is contained in its DNA, which can be collected from anywhere on the body, including semen.

We can look at the DNA patterns of known (proven) superior bulls for a particular trait, and determine the patterns they have in common. Then we can look at the DNA of any unproven bull, and see whether it displays those favourable patterns. **The more patterns they have in common, the better the unproven bull will be for that trait.**

Bulls can be screened (or profiled), using their DNA, for any traits that we have measured in a sample of superior bulls, including production, cow fertility, somatic cell, longevity and each of the individual traits other than production (TOP).

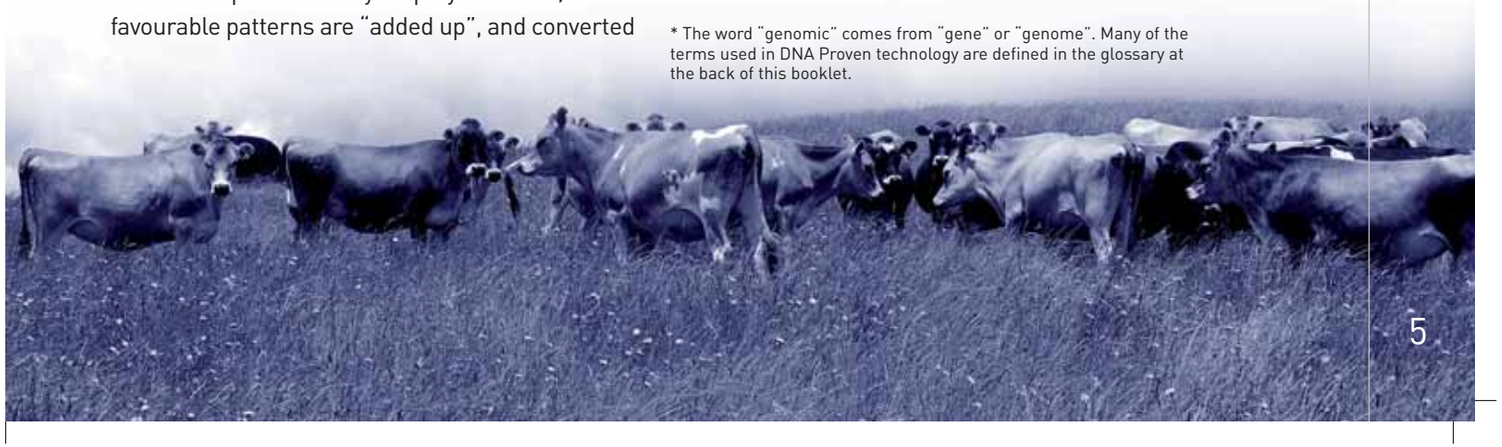
By analysing their DNA profile, we can even rank bulls for each trait, according to how many of the favourable patterns they display. In effect, the favourable patterns are "added up", and converted into an index or breeding value. **The more patterns that are considered, the better the reliability of the index.**

We often use the terms ancestry BVs and ancestry BW for Breeding Values and Breeding Worth calculated on ancestry information alone. "Ancestry" distinguishes them from the "proven" (ie, Daughter Proven) BVs and BW. The new DNA indexes will be referred to as "Genomic"* indexes to distinguish them from the traditional (Daughter Proven) BVs and BW.

So bulls will initially be given "Genomic Breeding Values" (GBVs) for each trait and an overall "Genomic Worth" (GW).

The Genomic Worth or GW, like the BW, will change as more information becomes available. Changes will come about as a result of ongoing improvements to statistical methods for using the DNA information or because more animals have been DNA profiled for that trait.

* The word "genomic" comes from "gene" or "genome". Many of the terms used in DNA Proven technology are defined in the glossary at the back of this booklet.



A bull will continue to have a GW until his daughters are milking, ie. until he is Daughter Proven.

Thus DNA profiling allows us to see what traits a bull can pass on to his daughters and calculate breeding values for those traits – even before he has any daughters!

Currently, when a bull is (daughter) proven, his BW includes ancestry and daughter performance information. In future, when a bull is Daughter Proven, his BW will include ancestry, daughter performance **and** genomic information.

And as yet, NZAEL (New Zealand Animal Evaluation Limited) is still working on how the genomic information will be included in the industry's animal evaluation index, the BW.

Faster...

Under the conventional Sire Proving Scheme it takes seven years to breed a bull and prove it for widespread use as a five-year-old. DNA Proven semen will be available for limited use when bulls are yearlings, and for widespread use as two-year-olds.

DNA Proven technology reduces the time taken to breed a bull and DNA prove it for wide-spread use to just four years. This is shown in the diagram opposite.

The increase in the rate of genetic gain comes about mainly because of the much shorter generation interval, but also because DNA can be used to select bulls from a much wider genetic pool. Under the traditional system, hundreds of bulls were considered for possible selection by daughter proving, whereas DNA screening enables us to consider thousands of young bulls.

Chart showing why DNA Proven technology increases the rate of genetic gain

DNA PROVEN – 4 years

Thousands of bull calves

YEAR –1	YEAR 0	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
Cows selected for contract mating	Thousands of bull calves DNA screened. Best bulls selected	Semen from 100 elite bulls despatched into Sire Proving Scheme herds	Elite bulls available for widespread use in Premier Sires and Alpha	3 years advanced genetic gain		

DAUGHTER PROVEN – 7 years

Hundreds of bull calves

YEAR –1	YEAR 0	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
Cows selected for contract mating	Bull calves purchased	300 bulls used in Sire Proving Scheme herds	Daughters born	Daughters mated	Daughter calves	25 elite proven bulls available for widespread use in Premier Sires and Alpha

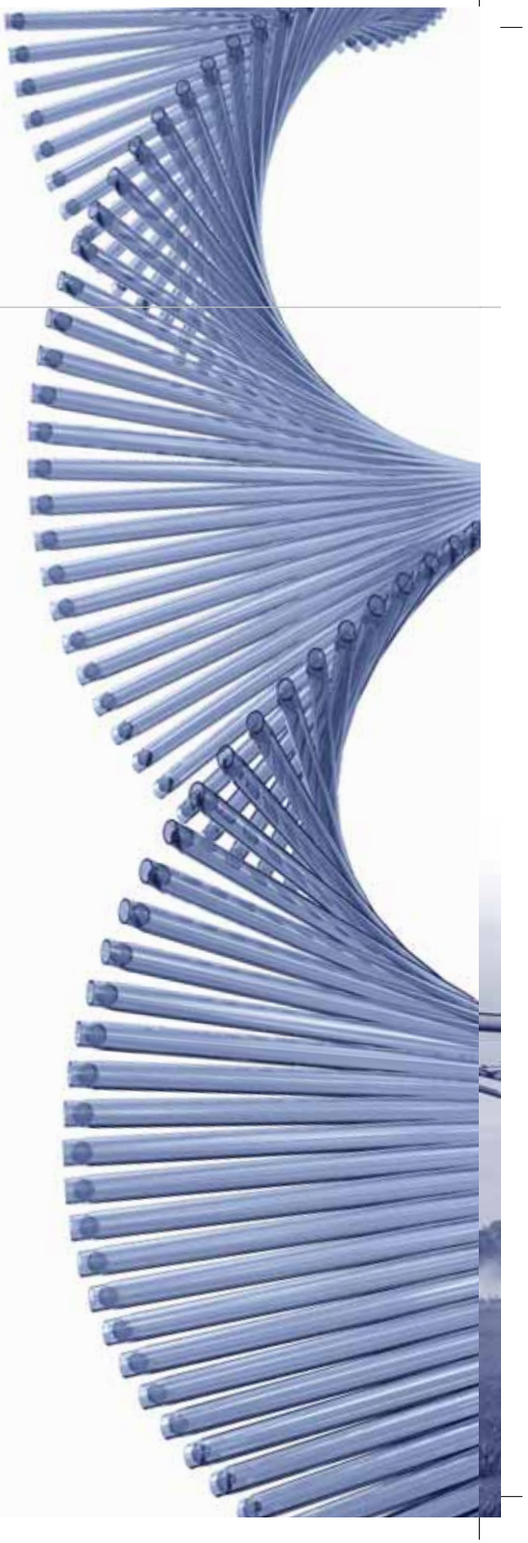
More profitable...

The potential for genomic selection (DNA Proven technology) to increase the rate of genetic gain in the dairy industry is huge.

It's expected to be worth **between $1.9 and $3.9 billion** in extra profit to the dairy farmers of New Zealand over the next 20 years.

> **To put that figure into perspective, most farm productivity improvements are measured as worth millions of dollars to the industry – never billions!**

No wonder it is being heralded as the biggest advance in genetics since artificial breeding was developed more than 50 years ago.



DNA Proven – In brief

- **Choosing to use DNA Proven bulls will not mean farmers have to make major changes to their farming practices. It's business as usual for you, except for your increased profitability further down the track.**
- Farmers can choose whether or not to use DNA Proven bulls. Daughter Proven bulls will always be available, now and in the future.
- There will be two Premier Sires teams, a DNA Proven and a Daughter Proven team – and Alpha will be offering DNA Proven from 2009 onwards as well as Daughter Proven individual bulls and Paks.
- DNA Proven bulls will, in general, cost more than Daughter Proven bulls – but remember, you will be getting so much more. Instead of a genetic gain of 10 BW units a year, you can expect a gain of 17 BW units per year. That's a 70% increase. This gain is permanent and cumulative.
- The indexes of individual DNA Proven bulls have lower reliabilities than the indexes of Daughter Proven bulls, but LIC will adjust the size of Premier Sires Teams to keep the average team reliability about the same as it's always been. You can still use the Premier Sires team with confidence.

Lower individual reliabilities are overcome by using a team of bulls. In particular, the Premier Sires DNA Proven bull team will be larger than the traditional Daughter Proven team. If you are using DNA Proven semen as Alpha Nominated, we recommend that you also use a larger team of bulls. (You can read more about reliability on pages 29-34).

- 2008 and 2009 will be transitional years.

  In those two years you will be able to buy bulls **proven by** their DNA, but not **selected for** their DNA. DNA Proven bulls will be sourced at first from the bulls-in-waiting – ie. bulls that were originally selected using the traditional criteria and systems of ancestry, dam inspections, contract mating, etc. for the 2006 and 2007 Sire Proving Schemes.

  From 2010 onwards, the DNA Proven bulls on offer will have come from a much wider pool of animals and selected using their DNA.

Also, because BW will not be available from New Zealand Animal Evaluation Ltd for DNA Proven bulls until 2009 at the earliest, LIC will be using a **temporary** term, GW to use as a guide until then. This index will be calculated using the same traits, with the same weightings and the same economic values, as the BW.

- **LIC has every confidence in the DNA Proven technology. We know it works, because we have tested it. So you can have confidence in it, too.**

  (You can read more about this on pages 26-27).

DNA Proven – Contribution to the NATIONAL herd

DNA Proven technology will generate huge incremental value for all dairy farmers.

Until now, the current rate of genetic gain in the national herd has been around 10 BW units per year. With DNA Proven technology, we expect the rate of genetic gain to increase to approximately 17 BW units per year.

The following graph (page 12) shows the difference in progress, leading up to 2030, between using DNA Proven technology and the status quo (no use of DNA Proven technology).

The bottom (**red**) line, the **status quo**, shows genetic progress if DNA Proven technology were not used at all, by farmers or by breeding companies, and genetic gain in the national herd continued to increase at 10 BW units per year.

The top (**blue**) line, **total adoption**, shows genetic progress if all farmers used DNA Proven technology for 100% of their herds.

Look closely at the blue line: while the herd BW gains are initially small and slow to impact on farmer bottom line profits, like compound interest, they are cumulative and permanent and, over a 20 year timeframe, become substantial.

Looking ahead to the years leading up to 2030, and comparing progress with the status quo (red line), the accumulated **additional** farmer profit for the national herd from total uptake (blue line) would be $3.9 billion.

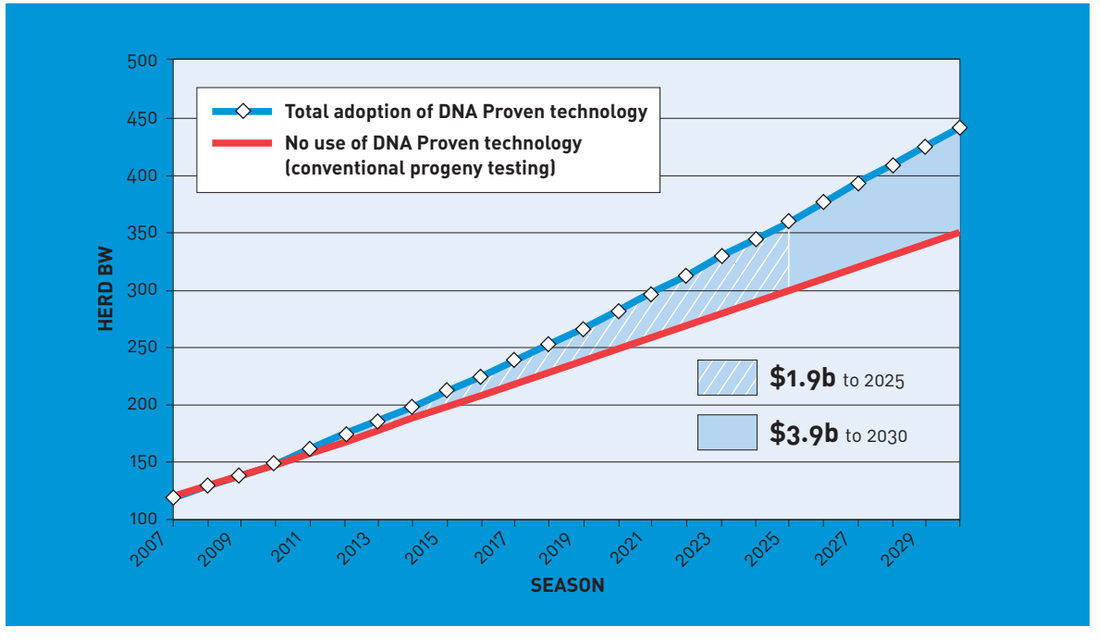
You can forget about the red line already, because LIC intends to use the DNA Proven technology for bull breeding and to select bulls for progeny testing – and indeed, has already begun doing so! So the industry has already started on a path towards the blue line.

How much progress?

The exact path depends on farmer (your!) uptake. This in turn depends on whether the value proposition seems to stack up in your circumstances, how convinced you are by the science or how comfortable you are with the technology, and – the ultimate test – your opinion of the herd replacements it produces.

Rest assured, LIC will be doing everything we can to make all those factors positive!

Increased progress and profitability in the national herd leading up to 2030



DNA Proven – Contribution to YOUR herd

DNA Proven does not complicate your farming life in any way. The simplicity of Premier Sires is retained, DataMATE™ still manages inbreeding – everything ticks along as before (but faster!).

Your herd

Let's translate the progress and profitability (shown on the graph opposite) into your herd of (say) 450 cows:

Good

At the current rate of genetic progress, your herd would have a BW of 350* by 2030.

Best possible

In a total adoption of DNA Proven technology scenario, your herd BW would be 440* by 2030.

Your bottom line

And translating that profitability into your bottom line:

Much better

With LIC and farmer-use of DNA Proven technology, you could get about $196,000* additional profit over the first 15 years.

Even better

Remember, increased genetic gains are cumulative and permanent. A mere five years further on, your total additional profit for the same herd would be about $382,000* for the 20 years (ie. another $186, 000* over a further five years).

* April 2008 equivalent

Keeps on forever!

The lines on the graph continue onwards and upwards, so within an even shorter time, say a further three to four years, your total additional profit would have amounted to about half a million* over the 23-24 years.

(Remember, that's profit – ie. with the modest premium cost of the DNA Proven semen already taken into account).

DNA Proven technology offers you more than just increased rate of genetic gain and more income.

The main feature of DNA Proven technology is that it shortens the generation interval. New bulls are in the pipeline for three fewer years than in traditional progeny test schemes. Apart from speeding up the rate of genetic gain, this shorter generation interval enables the industry to respond quickly to changing market requirements – for example, a change of emphasis in the composition of milk.

DNA Proven technology brings other advantages:

- DNA Proven bulls have higher reliabilities than progeny testing for some low heritability or late expressed traits such as fertility and longevity.
- As a shareholder of LIC, you are now starting to see a return on LIC's investment into biotechnology research.
- The implementation of the DNA Proven technology will also result in:
  - a larger team of widespread use bulls with less emphasis on any individual bull
  - a representation of a wider range of bull and dam families
  - bulls being under less pressure to provide semen because more bulls are required for a DNA Proven team
  - and therefore, fewer cases of "short supply" bulls
- The next logical step after DNA Proven bulls is DNA Proven cows and heifers. Indeed, LIC is already DNA screening potential bull mothers. It may not be long before you can have all your cows and heifers screened for favourable genes.
- If you like being at the forefront of latest dairying practices, DNA Proven technology is probably the most exciting development you could ever be part of – unless you were farming 50 years ago when AB began.

DNA Proven – and your breeding decisions

Essentially, all you need to do is decide whether or not you will use DNA Proven bulls – and this booklet should help you make that decision.

Whether you are an Alpha or Premier Sires client, you are able to use either Daughter Proven or DNA Proven, or a mixture of both. (DNA Proven for Alpha clients will be available from 2009 onwards).

We realise that while many clients will want to avail themselves of this new technology and enjoy the improved genetic gain as soon as possible, others will take a more cautious approach and want to "see how it goes." The decision is yours.

If you do decide to use DNA Proven bulls, LIC's service to you will remain the same – there won't be any changes to how semen is delivered to you, the number of bulls in a despatch, how your LIC AB Technician inseminates, etc.

Premier Sires clients

Your District Manager will have visited you, as usual, early in the year to discuss your service needs.

If you expressed interest in using DNA Proven, your District Manager will make further contact with you as information becomes available. Some of you may have decided you want to use DNA Proven there and then. Others may have decided to wait until they know the composition of the team, the team weighted GW, and the price.

Whatever your plans, please note there will be some limitations to the use of DNA Proven in this first season of use:

- Because of tight timeframes that don't enable large supplies of deep-frozen semen to be collected, DNA Proven can only be supplied as Long-Last Liquid semen for Premier Sires in 2008. This means DNA Proven semen will not be available for synchro herds or yearlings.
- For the same reason, your LIC AB Technician will not have DNA Proven as back-up. If insufficient supplies of DNA Proven semen are available on a day, the usual Daughter Proven semen will be used as back-up, and charged at the lower price.

DNA Proven bull teams, team averages, individual bulls, rankings and genomic BVs will be announced each year from February, along with pricing, and this information will be available from your District Manager and in the Premier Sires wallchart distributed to all farmers in August.

KiwiCross™, Holstein-Friesian and Jersey bulls will be available in two Premier Sires teams – a DNA Proven team and a Daughter Proven team.

You can choose to use the Daughter Proven team or the DNA Proven team, or a mixture of both. Your District Manager will help you finalise your mating plans.

If you choose to use the DNA Proven Premier Sires team, your part in the process will be just as easy as in the past – you simply sign up, say when you want to start, and draft your cows out for the LIC AB Technician when the time comes.

Your LIC AB Technician will still make a pre-mating run, and your preferred options regarding back-up semen can be recorded in your Matings Book, as usual. DataMATE™ will keep track of whether you have used DNA Proven semen or not (by the bull code, not by your mating plans) for charging purposes.

To achieve team reliability levels similar to Daughter Proven teams, the DNA Proven team will be larger than the Daughter Proven team. The larger team will ensure the team has a reliability of about 97%, which is similar to the reliability of the Daughter Proven team.

You can read more about reliability on pages 29-34.

Winter mating clients

No DNA Proven bulls will be available in time for winter mating in 2008, however it will be an option for 2009.

Please read the section above for Premier Sires clients.

Alpha clients

DNA Proven bulls will be available as frozen semen for Alpha clients from 2009 onwards.

DNA Proven bulls, rankings and Genomic BVs will be incorporated from 2009 in the Alpha Sires Catalogue, which all farmers will receive.

You will have the option of choosing individual bulls or DNA Proven Paks of ten or five bulls. The Ten-bull DNA Proven Pak will have a team reliability similar to a Five-bull Pak of Daughter Proven bulls.

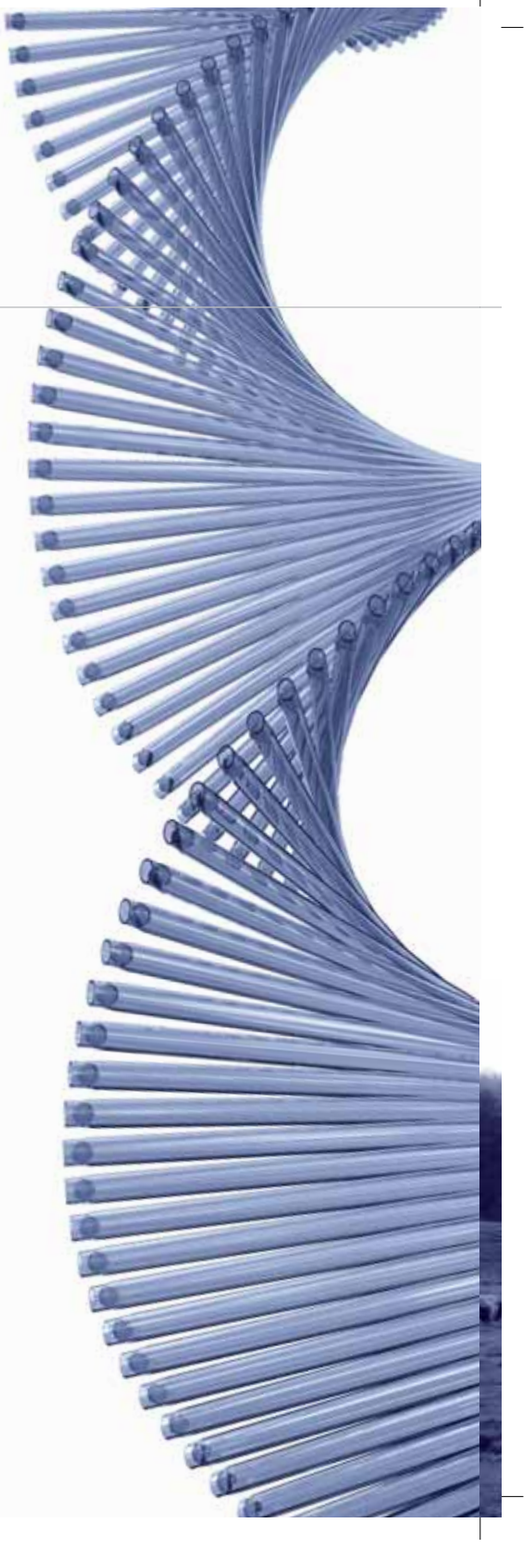
DNA Proven bulls will cost more than Daughter Proven bulls.

If you're choosing individual bulls, remember to choose a larger number of bulls to allow for the lower reliability of their indexes.

DIY clients

See the information for Premier Sires clients or Alpha clients above.

Straws of DNA Proven semen will be marked to differentiate them from Daughter Proven semen.



DNA Proven – and Daughter Proven

The timely and accurate information supplied by Sire Proving Scheme (SPS) farmers is as valuable as it has always been.

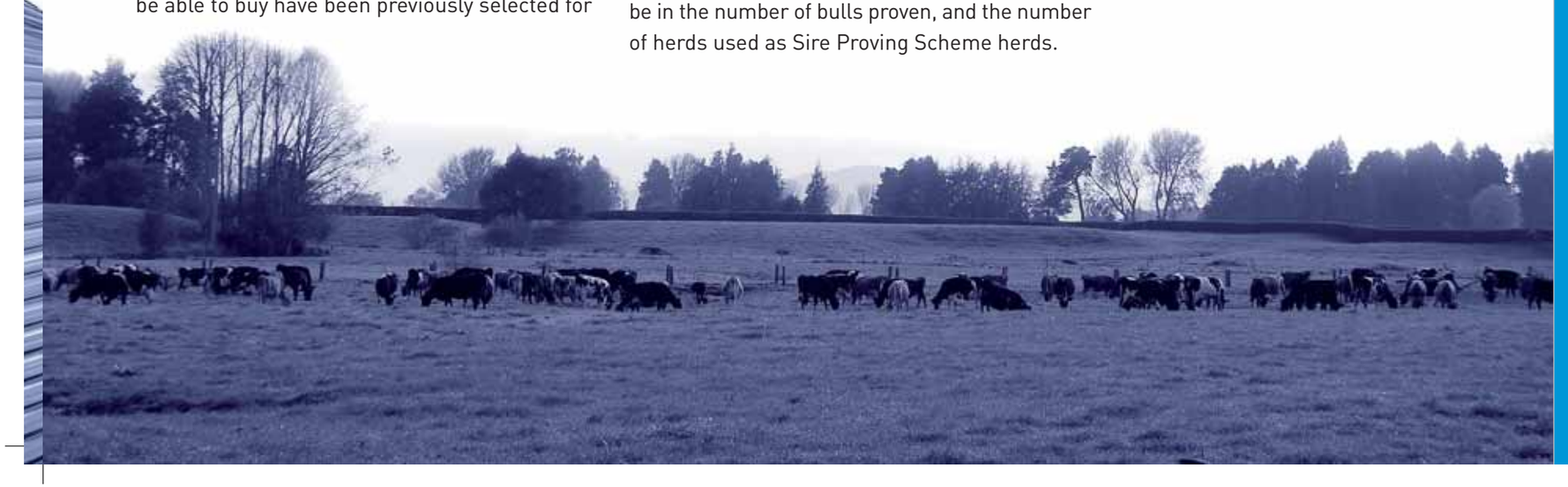
However, because DNA Proven technology will require the adoption of a new breeding scheme from 2008, it's inevitable that there will be some changes to the way the Sire Proving Scheme (SPS) will operate. Many of these operational changes are still to be developed.

The plans for 2008 are in place, but schemes beyond that are still to be finalised, depending on the results of research and the adoption of the DNA Proven technology by farmer clients.

We've described 2008 and 2009 as transitional years, because the DNA Proven bulls farmers will be able to buy have been previously selected for the Sire Proving Scheme on the traditional critera (ie. although they will have DNA Proven indexes, they have not been selected for their DNA). This means that 2008 and 2009 are transitional years for the breeding scheme and progeny testing too, as we work the young SPS bulls-in-waiting (originally chosen on ancestry) through the system, and introduce young bulls (from 2008 chosen on their DNA) into the new system.

DNA Proven technology will affect the breeding scheme and the Sire Proving Scheme

A Sire Proving Scheme (SPS) will still operate, but slightly differently than in the past, as there will always be – at least for the foreseeable future – a need for the collection of daughter performance information. The main changes will be in the number of bulls proven, and the number of herds used as Sire Proving Scheme herds.



From 2008 onwards, SPS farmers will be proving DNA selected bulls.

The two main changes in the scheme will be in the number of bulls proven in SPS herds, and the number of SPS herds. The traditional Daughter Proven scheme progeny tested 300 bulls in 400 herds. The revised breeding scheme will progeny test about 100 bulls – the bulls already having been DNA screened for suitability – in approximately 130 SPS herds. The number of daughters generated per bull will remain about the same.

SPS and Contract Mating farmers have been kept fully informed. Briefly, for the information of other farmers, semen charges and rebates for SPS farmers will reflect the significantly different value proposition, and the contract with breeders of bulls will include a commitment by LIC to **DNA test**, not necessarily **purchase**, the resultant bull.

The new breeding scheme has already started! 2008 SPS bulls will be the first batch of bulls to enter the DNA Proven **selected** on their DNA. They will graduate in 2010.

In 2008 we are DNA screening 3000-5000 potential bull dams, and contract mating the best 1000 or so of them. About 1000 bull calves (about half from contracts, and the rest from matings of interest) will be given an initial DNA screen. The best 500 of those will be given a second, much more detailed, DNA screen.

We will process and store the results, convert them into Genomic Breeding Values (GBVs), then provide those BVs to NZAEL for subsequent use for the calculation of the industry BW.

In 2009, a year before they will be made available for widespread use as DNA Proven two-year-olds, the best 100 of those yearlings will be used in SPS herds to generate about 80 daughters each, and in Contract Matings to generate potential future sires.

> **This use in SPS herds gives us the opportunity to collect essential information on semen quality and non-return-rates, to check for dominant genetic defects that don't show up in the current DNA tests and, of course, to generate daughters for conventional daughter proofs.**

Those that come through without any problems will be offered as DNA Proven bulls in the following year.

DNA Proven – and Animal Evaluation

New Zealand Animal Evaluation Ltd (NZAEL) has been kept informed about the development of breeding companies' intentions to select and market bulls on the basis of their DNA, and endorses the benefits that genomic selection (the scientific term given to the process of choosing bulls on their DNA) will bring to the New Zealand dairy industry.

At the request of the NZAEL directors, manager Bill Montgomerie looked at the potential annual benefit of genomic selection. This is a summary of his report (in December 2007):

- The annual benefit in 2020 from genomic selection compared to conventional progeny testing could be $175 million, growing to over $330 million by 2025.
- The annual benefits could accumulate to over $2 billion as early as 2025, if farmer uptake of the new technology is 100% (less for less than 100% uptake).
- The industry will be noticeably better off by 2020 from early adoption of this technology, even if some of the assumptions are substantially over-optimistic.

Indexes

New Zealand Animal Evaluation Ltd (NZAEL) is working to establish systems for incorporating DNA information into the BW, so that the BW will continue to accurately represent advances in the science of animal evaluation. This is not as straightforward as one might think.

They need to establish a system for converting/incorporating not one lot of DNA information but different types of DNA information into the BW. This is because LIC is not the only AB company supplying bulls to the New Zealand dairy farmer and using the Animal Evaluation system. It is possible that other companies may wish to include their particular DNA screening results into the BW as well – and, of course, they should be able to, as it's their Animal Evaluation system, too.

Not all "DNA screenings" are the same. Although LIC is screening our bulls using 50,000 comparisons of the DNA, another company might make only 30,000 DNA comparisons or make different comparisons altogether.

Bill Montgomerie has described the task facing the NZAEL as being similar to the one the international bull evaluation organisation Interbull faces to incorporate into the Interbull system the different measuring systems used and the different traits measured by evaluation centres in different countries.

All information has to be "audited" before being accepted, and then weightings and calculations developed to ensure conversions are valid. All this, of course, takes a lot of research, genetic and statistical know-how, work and time.

Consequently, the NZAEL does not expect to have DNA information included in the BW before 2009.

This means that DNA Proven bulls will not, initially, have a BW that includes DNA information (although they will have the traditional ancestry BW).

LIC wholeheartedly supports the industry principle of having one Breeding Worth for an individual sire or cow. However, we recognise that – in the absence of a BW for DNA Proven bulls this year – our clients would have great difficulty deciding whether or not to use the new DNA Proven bulls. And the pity of this is that clients would miss one year of faster genetic progress.

So, as an interim measure, LIC is producing a temporary index, the Genomic Worth (GW). This index is not for use **instead** of an AE index, but **until** an enhanced BW index is available.

We look forward to farmers having the BW index to use for selection of sires – both Daughter Proven and DNA Proven – for their herds, and are giving NZAEL every assistance we can to hasten the process.

In future years, the BW of a young bull will reflect both his DNA information and the performance records available for his parents.

DNA Proven and the RAS List

To be ranked on the Ranking of Active Sires List (RAS List), bulls need not only a BW but a high reliability of that BW.

The current criteria for selection to the RAS List is a reliability threshold of 75% so, as it stands, DNA Proven bulls would not be eligible for the RAS List (even though they do have a BW based on ancestry) until they are Daughter Proven.

However, because genomic selection will be the sire selection process of the future, breeding companies and NZAEL are talking about the changes that will be needed to accurately identify the quality of all artificial breeding bulls.

DNA Proven
– The science, its development, and how we know it works

For nearly 50 years the route to becoming an LIC bull (Premier Sires or Alpha) has been the Sire Proving Scheme, where LIC purchases the best bulls based on ancestry information and, when they are just over one-year-old, carries out enough inseminations in New Zealand to generate 80 daughters for each bull. When each daughter comes into milk, her performance data (on both production and traits other than production) is compared with her herdmates and other herds. This data is used to calculate her breeding values.

The data also flows back to her parents and alters their breeding values as well – up, if their progeny are performing better than herdmates, down, if their progeny are performing worse. This is how a bull gets a proof based on daughter performance.

This system has served the New Zealand dairy industry well, achieving high rates of genetic gain – an average of 2.8kg milksolids per cow per year over the last 15 years.

We have always known that a young bull inherits half his genes from his sire and half from his dam, but there has been no way of knowing which actual genes the bull has inherited. So progeny testing has been used in the past to identify (on the evidence of his daughters' performance records) which individual bulls from high genetic merit parents must have received a superior set of genes from his two parents, and which bulls received a lower than average set.

Since the first years of this 21st century, DNA has been emerging as a technology that could offer a significant step-up in the rate of genetic gain.

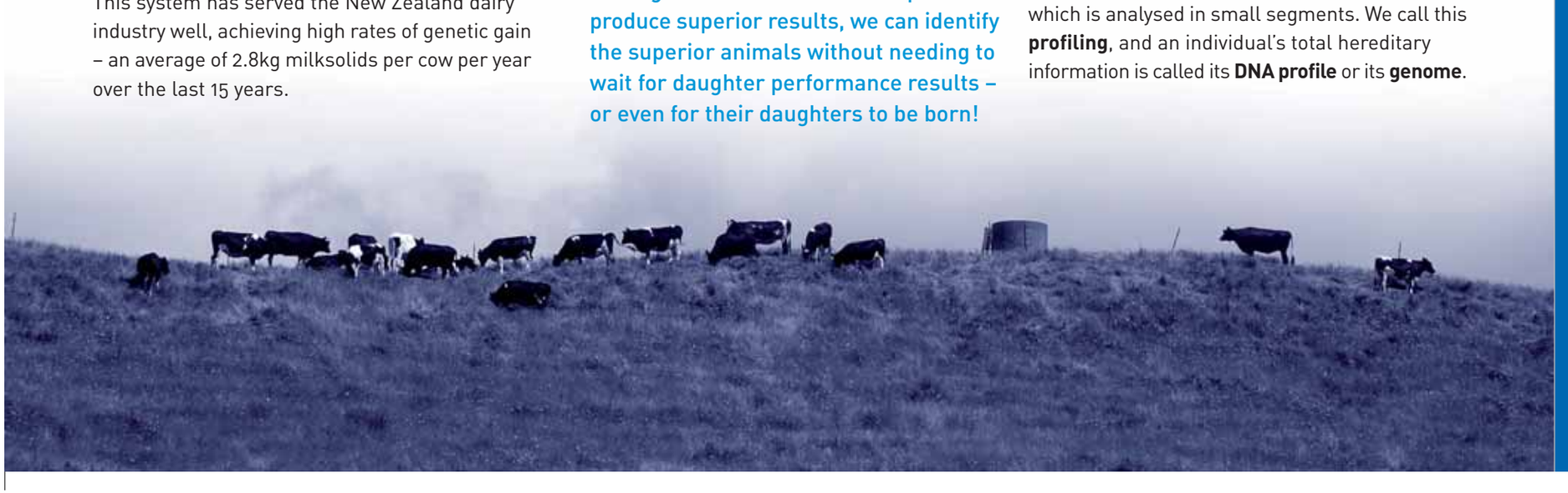
With DNA Proven technology, we can now look at the actual DNA of an animal and, as long as we know which DNA patterns produce superior results, we can identify the superior animals without needing to wait for daughter performance results – or even for their daughters to be born!

Before we go further with our explanations, you need some scientific vocabulary (which we've carefully avoided using until now!).

The body of any animal is made up of **cells**, and the nucleus of every cell contains the animal's genetic material (generally called **DNA**). The same genetic material is in every cell (except sperm and ovum which only have half the DNA, and red blood cells) of the same body.

DNA is in the form of a strand (or **sequence**) that when uncoiled would be more than two metres long. Parts of the DNA sequence are coded (called **genes**) and parts uncoded. The coded parts store the biological information.

The strand of DNA is divided into smaller bits called **chromosomes** (30 chromosomes for cows), which is analysed in small segments. We call this **profiling**, and an individual's total hereditary information is called its **DNA profile** or its **genome**.



The goal is to learn what effect the genes in those segments have on economically important traits.

Unfortunately, genes don't come conveniently labelled, telling us what they affect! To learn what variations in DNA underlie particular traits or diseases requires comparisons across individuals.

We make these comparisons by looking at markers. A marker is a difference in the DNA sequence at the same point in the DNA sequence between two animals. These markers have a technical name – single nucleotide polymorphisms, or SNPs for short. They're pronounced "snips", and you can think of them as little snips or snapshots of different places on the DNA sequence which are worthy of notice.

It wasn't long ago that only a few thousand markers had been identified; now hundreds of thousands of markers are available for research and commercial applications.

In line with this progress, the cost of profiling has come down to less than one-hundredth of the original price – which is part of the reason why genomic selection has become a viable option.

The science of genomic selection involves three major steps:

1. Identifying which SNPs are the favourable ones, using a test sample of proven bulls.
2. Establishing a way of measuring results so that bulls can be ranked (and therefore compared).
3. Identifying genomically selected bulls that rank highest for the traits measured.

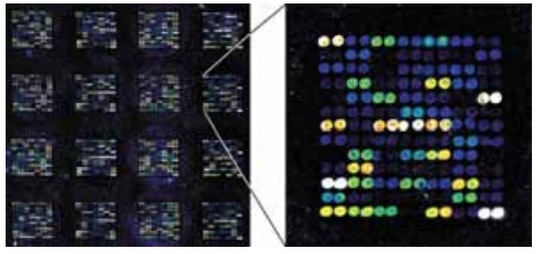
1. Identifying the favourable SNPs

This is done by looking at SNPs on thousands of widely-used bulls with well-established proofs for economically important traits.

How do we get the DNA of bulls used in the past? Fortunately, LIC visionaries like Harvey Tempero insisted that 80 straws of semen from every bull progeny tested were put into long term storage. This priceless store of semen has now given up its genetic secrets!

Few bulls make it into Premier Sires: of those we progeny test, only around one in 12 are selected. This gives us a large pool of bulls that didn't make it, and a large sample that did. The test results from the Premier Sires is compared with the test results from the 'also-rans' so we can determine a DNA pattern that leads to success.

To compare the superior sires and the also-rans we need not only DNA samples but also computer power. Consider the enormity of the computer job for a moment:



Each DNA sample provides around 50,000 individual test results for each bull. The image above left shows 2912 results, each "light" representing a result for a tiny fragment of DNA. In an enlargement of part of that picture, the image above right shows 182 results. Imagine what 50,000 results look like! And now imagine trying to compare all 50,000 results for many thousands of bulls for all traits.

It's about now that you will start to see the enormity of genomic selection. We look at 50,000 markers for **each** bull. And we look at **each** of those markers for **each** of the seven traits in the BW, total longevity, and the 16 TOP traits. And we compare the results for every individual with the results for **each** of the rest of the group of bulls.

LIC is uniquely placed to do this too. Since 1960 LIC has progeny tested over 4,000 bulls, generated over 300,000 Sire Proving Scheme daughters and collected around 65 pieces of production, TOP and other data from each daughter. All this wealth of information is stored on the database at LIC and is the raw material for New Zealand's Animal Evaluation system.

The computer power required to compare all these results is mind bogglingly large, and it has not been available up until now. This is another factor that has made genomic selection possible.

Some very sophisticated statistics identify the SNPs of the bulls whose daughters are superior for a trait, and contrast these with the SNPs of bulls whose daughters are not so good. This technique tells which SNPs on the DNA influence that trait, and what DNA code is required for a bull's daughters to be superior for that trait.

2. Measuring what we've found

Using the breeding values of all the daughter proven bulls we have worked out relationships between SNPS and BVs. With these relationships we now have two sources of genetic information about a young bull. There is the conventional

parent average information. And there is the extra information from his own SNPs. Combining these information sources we calculate Genomic Breeding Values (GBV) for each bull.

3. Identifying the best new bulls

We combine the Genomic Breeding Values into the GW index using the same economic values for traits that are used in BW.

Testing the research

The science sounds great in theory, and makes sense, but the important question is, does it work? Before implementation, our scientists wanted to have solid evidence that the theory was sound and that the application of it yielded accurate results – and we're sure you want to know that evidence, too.

It is possible to test the theory before implementation, and LIC has done this using a system called "back validating".

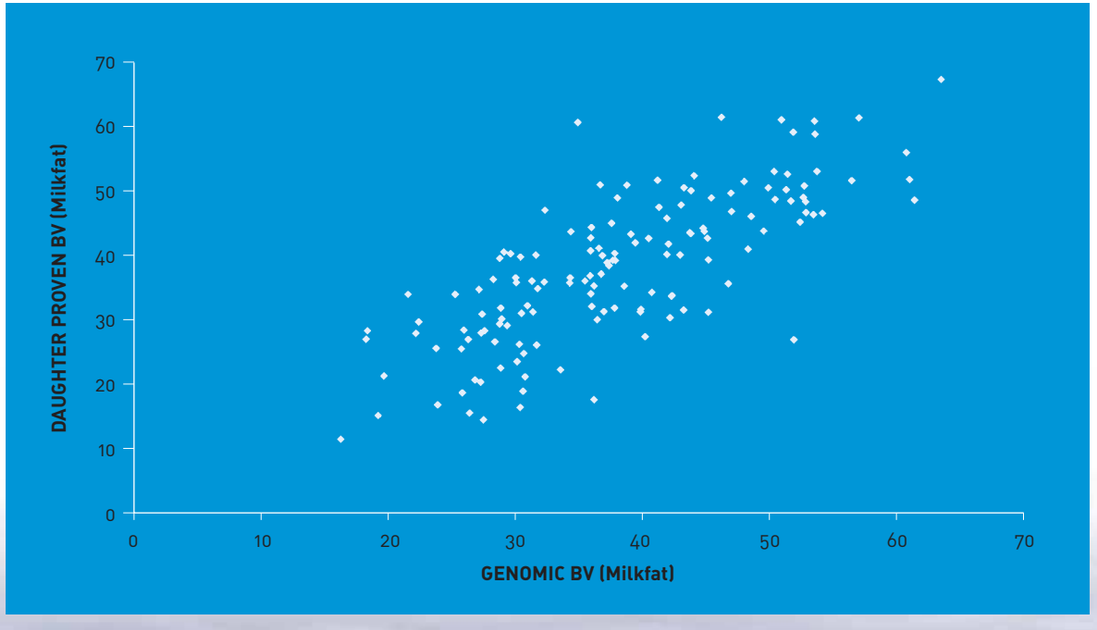
The historical bulls we have used for the science described so far included bulls used from the 1960s onwards, but only up to and including the bulls used in the year 2000. **It excluded the bulls used from 2001-2003.**

This group of bulls (about 900 of them) has become a different test group to be used for back validating, whereby our scientists DNA screen these bulls, calculate their genomic BVs on the strength of that screening, and then compare the resultant Genomic BVs with their BVs calculated from their daughter performance.

The way of comparing the two is shown on a "scatter graph", where each bull used in the back validation is plotted as a dot on a graph according to its Daughter Proven (BW) and DNA Proven (GW) indexes.

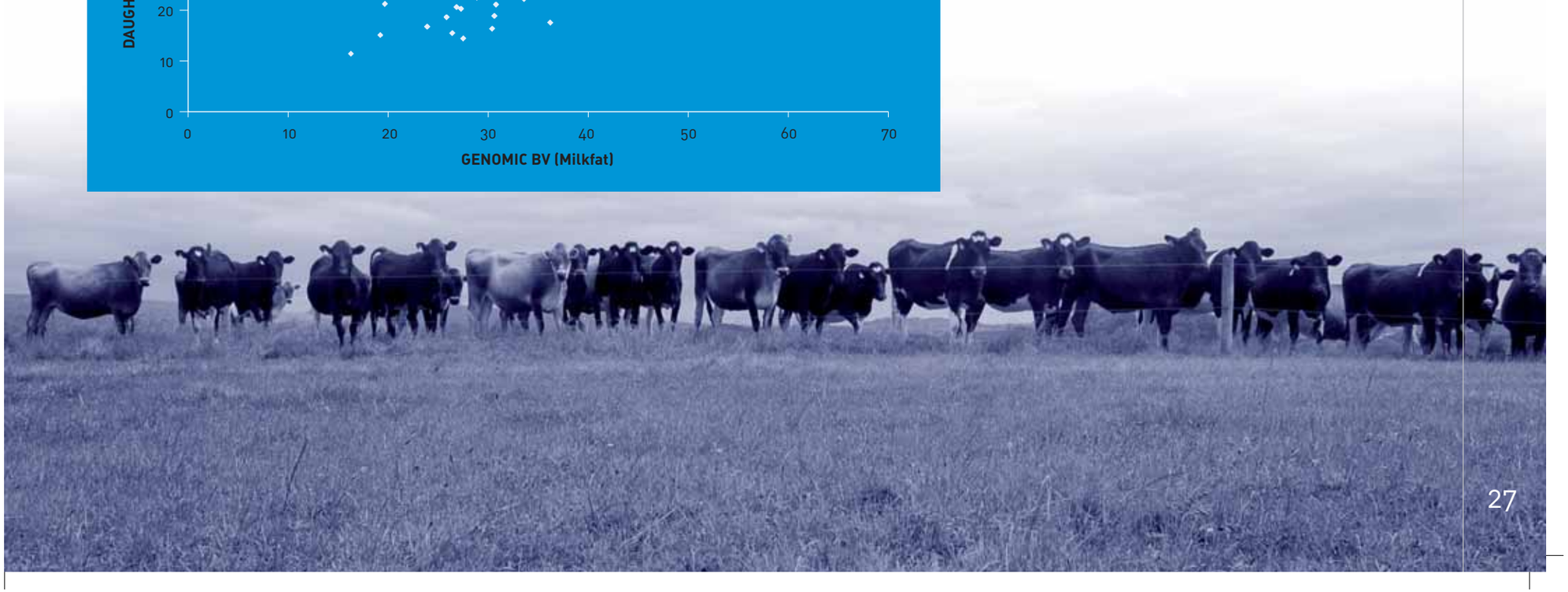
If the correlation between the two is high, the dots would form a cluster around a straight line. The actual scatter graph (opposite), which compares the GV and BV for milk fat of 143 bulls used in the back validation, shows a moderate to high correlation of about 0.77.

Scatter graph showing the correlation between Genomic Breeding Values and Daughter Proven Breeding Values for Milkfat of 143 Holstein-Friesian Bulls



The theory (expressed in various published scientific papers) said that approximately 30,000 SNPs would be required to calculate genomic BVs with accuracy... LIC uses 50,000. The theory said the chromosome segment effects should be estimated from at least 2000 phenotypic records... LIC used more than 4000. The theory also said it would be possible to get reliabilities of 55-60%... LIC achieved that. (See next section).

In brief, the theory said it could be done... and LIC's done it!



Summary

These are the essential ingredients for genomic selection:

- a large database of progeny tested bulls with accurate breeding values
- a genetic archive with DNA available for the progeny tested bulls
- the genome scan test with at least 30,000 DNA markers
- the computer power to handle the job
- scientists, statisticians and software developers to interpret raw test results and relate the genotypes to the breeding values

The LIC situation at April, 2008:

- the original statistical theory has been verified
- historical sires have been used for genotyping
- Genomic BVs and GW have been developed
- Genomic BVs and GW have been tested using a different group of historical sires
- the reliabilities of the indexes have been calculated and are statistically acceptable
- the future breeding scheme is being studied and redesigned
- contracts to breed sons for genotyping are being negotiated
- all bulls in the 2006 and 2007 Sire Proving Scheme intakes have been genotyped, and have had their GWs calculated
- those bulls are being offered to farmers in 2008 as DNA Proven sires

DNA Proven – Reliability

A huge step forward

One of the best features of DNA Proven technology is that, though it's a huge change and a huge step forward for the dairy industry, it's not a huge change for farmers.

This is one time when you improve your herd's performance, the value of your herd, your profitability, and your future income, without having to do anything except decide to make the most of the opportunity.

Once you've decided to use DNA Proven bulls, it's almost just a matter of sitting back and letting the changes happen.

But make no mistake – DNA Proven technology does mean huge changes, most of which affect LIC and occur behind the scenes at the animal evaluation, bull breeding and operational levels. But farmers won't see much of that.

You will see a bigger offering of bulls, additional Premier Sires teams (which are also bigger), changes to the BW in due course, and a new interim index for DNA Proven bulls. One of the differences you will notice immediately is that the DNA Proven bulls have a lower reliability for their index than you are used to seeing in the bulls you use in your herd.

This section of the book discusses reliability fully, showing you what reliability levels you can expect and what they mean, and explaining how LIC will implement the new technology so that farmers achieve the increased genetic progress at the same low risk/high reliability levels you're used to.

LIC is very aware that reliability is critical to achieving genetic gain. You do not need to worry about reliability if you use Premier Sires – LIC will, as always, ensure the teams contain enough bulls to ensure team reliability is very high.

Alpha Nominated Paks will also contain appropriate numbers of bulls.

The reliability figures themselves

Reliabilities are calculated using standard statistical methods. The following table (page 30) shows the reliabilities achieved with DNA Proven technology by breed for all seven traits in the BW, plus total longevity, plus the five main TOP traits.

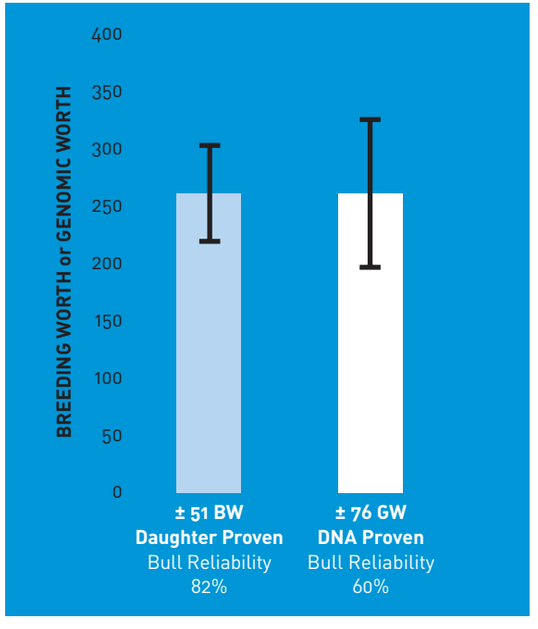
This table shows that individual DNA Proven bulls currently have a GW reliability of about 51-60%. You're used to seeing individual Daughter Proven bulls entering the market with an individual BW reliability of about 85% and, while it's possible that the reliability of individual DNA Proven bulls could increase as the technology proves itself, for now you will want to consider what effect the lower individual reliabilities could have in your herd.

Reliability of Genomic Worth (GW) and Genomic BVs

	Holstein-Friesian	KiwiCross™	Jersey	Parent average reliability without DNA
Genomic Worth (GW)	56	60	51	34
Protein BV	57	63	49	34
Milkfat BV	47	50	47	35
Milk BV	60	67	58	35
Liveweight BV	51	66	52	33
Fertility BV	59	47	47	29
Somatic Cell score	54	54	55	33
Total longevity	60	44	44	30
Shed temperament	47	43	42	31
Overall opinion	45	40	40	31
Udder overall	45	41	44	31
Dairy conformation	51	41	50	32

The lower individual reliability figure means that the GWs of individual DNA Proven bulls are more likely to change on re-ranking (when daughter information becomes available) than Daughter Proven bulls are (when their additional daughter

Possible re-ranking of bulls with the same level of indexes both with different reliabilities



information becomes available). The extent of the possible re-ranking is illustrated in the two parts of the graph above:

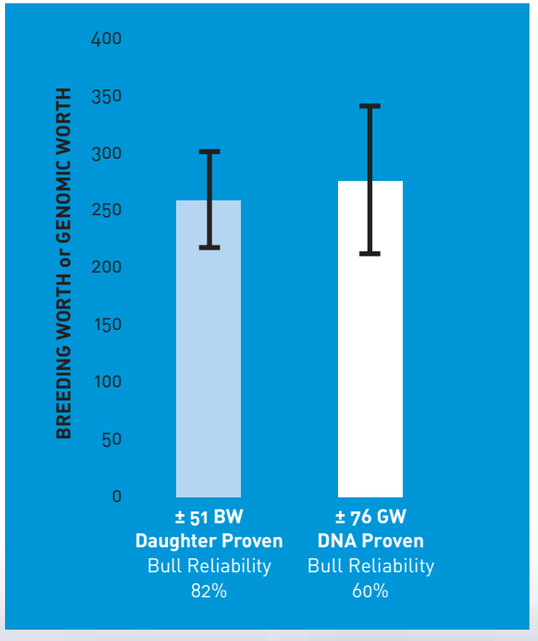
The black line shows the extent of possible variation on reproof. Individual DNA Proven bulls

are expected to deviate more once the bulls' progeny are milking. Variations at the extreme end will be rare – only about 5% of animals will vary more than 76 BW, most (67%) will vary less than 38 BW.

This graph shows the difference possible in reproof between a DNA Proven and a Daughter Proven bull with the same level of index. However, genomic selection allows us to find much higher GW bulls to start with. In general, DNA Proven bulls offered in 2008 are about 10-30 units higher than the Daughter Proven bulls.

Because the selection method identifies the better bulls earlier, DNA Proven bulls will have a higher index than bulls that are entering a daughter progeny test scheme have.

Possible re-ranking of bulls with different levels of indexes and with different reliabilities



Let's look again at the more likely situation, by comparing the likely change in a DNA Proven bull with an index of 275, and a Daughter Proven bull of 255 illustrated in the two parts of the graph (left).

You will see that, although DNA Proven bulls could drop more, the ones with the greatest negative movement could still be as high as the corresponding Daughter Proven ones.

(Remember we're looking at worst case scenarios. Allow yourself to consider the opposite end of the spectrum for a moment, and look at what the best ones could do!)

Using a team of bulls minimises the risk to you as a result of changes in the bulls' rankings. It doesn't stop them changing, but it lessens the impact that any one bull can have on your herd. New Zealand farmers are very familiar with the team concept, whereby if you use a team of bulls:

- the team reliability is considerably higher than the individual reliabilities of the bulls in the team
- your team BW is less likely to change on reproof (because the "swings and roundabouts" principle kicks in, where the "ups" compensate for the "downs" and the average result in the daughters is pretty much as predicted)

If you use Premier Sires, LIC looks after the reliability aspect for you by supplying the appropriate number of bulls in the team. If you wish to nominate your own bulls, you will need to use more bulls than you have in the past. (For example, five bulls with individual reliabilities of 80% will have a team reliability of 96%; but you will need to use a team of 10 bulls to achieve the same level of team reliability if their individual reliabilities are 60%).

Size of team required for high team reliability

(Teams used as)	Individual bull reliabilities	Team reliability	Size of team required
SPS bulls	35%	98%	35
Premier Sires DNA Proven bulls	60%	98%	18
Premier Sires Daughter Proven bulls	82%	99%	16

The Alpha Nominated DNA Proven Paks (available from 2009) will stipulate the appropriate number of bulls for reasonable reliability. Alpha Nominated staff or your District Manager can help you with your decision.

Lower individual bull reliabilities can be managed – using a larger team will ensure reliability in your herd.

The science of genetics includes the study of reliability, and the team sizes to achieve particular levels of reliability are well established and accepted.

For example, if team members have individual reliabilities of 82%, the team needs to have 16 members for a team reliability of 99%; for individual reliabilities of 60%, the team needs 18 members for 98% reliability, and for individual reliabilities of 35%, the team needs 35 members for 98% reliability. These examples are demonstrated by familiar breeding programmes. See table below left.

To protect your rate of genetic progress, the Premier Sires DNA Proven bull team will be considerably larger (considering the number of inseminations performed) than the traditional Daughter Proven team.

Reliability is lower in some contexts, but higher in others

It's worth noting that, although DNA Proven bulls have less reliable indexes than Daughter Proven bulls when they are offered to farmers for widespread use, their indexes are **considerably more reliable** than young bulls whose BWs include ancestry information only – young bulls in the past have had reliabilities of 35% when they entered SPS herds to be Daughter Proven. This is why we don't need to progeny test so many bulls if they are selected on DNA.

For fertility and longevity, DNA Proven is more reliable than Daughter Proven when bulls are being selected for the first time into those teams. For Daughter Proven, they have reliabilities of approximately 35-40% at first selection, and that increases to 60% for the second year. In DNA Proven it is 47% for Jersey and KiwiCross™ bulls and 59% for Holstein-Friesian bulls.

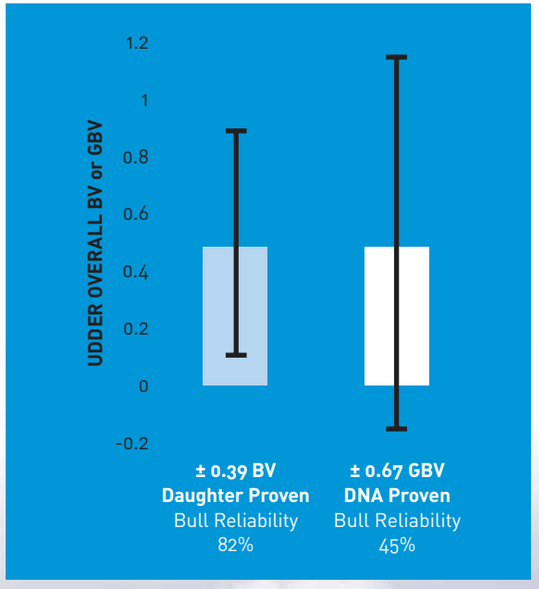
TOP Genomic BVs and their reliability

The TOP Genomic BVs are calculated using the same principles used to calculate production traits.

Again, the reliabilities of TOP Genomic BVs for DNA Proven bulls are likely to be a little lower than the reliabilities of BW for Daughter Proven bulls.

The example on the right for Udder Overall shows that the BVs of DNA Proven bulls could vary more on reproof than the Genomic BVs of Daughter Proven bulls, once progeny are milking and have been inspected for TOP traits. The black line shows the deviation possible on reproof. Again, most changes will be around the middle of the range.

Possible re-ranking of bulls with the same level of indexes but with different reliabilities



The differences between Genomic BVs and Daughter Proven BVs will not be as markedly high for TOP traits as they are for production traits. (TOPs generally show much less variation than BW does).

However, once again, protection will be achieved by using the appropriate number of sires in a team.

In addition, LIC will probably raise the TOP threshold for bulls entering the Premier Sires team, to help counteract the greater possible movement in BVs on reproof.

LIC has placed extra emphasis on TOP of Premier Sires daughters in the last ten years – it's a fact that all the important TOP traits have improved markedly in recent years. Daughters of LIC bulls have better conformation, better temperament and better udders overall than ever before. Rest assured, we're not about to undermine that!

What you can expect in your herd

- Expect your herd's genetic merit to increase at the increased rate of genetic gain.
- **Expect to have a greater range of sires represented in your herd, since sire teams used in your breeding plans will be larger. (This should make inbreeding easier to manage).**
- Expect to see bigger Premier Sires teams, and to use a larger team of bulls if you use Alpha Nominated DNA Proven bulls (available from 2009).
- Expect to enjoy better profitability in the future, as your herd gets more and more replacements sired by DNA Proven bulls.
- Expect to find the next few years very interesting!

DNA Proven – Frequently asked questions (FAQ)

Q 1 **Is genomic selection (or as LIC calls it, DNA Proven technology) just GE or Genetic Engineering using a different name? Is it an example of GE?**

A 1 Absolutely not! And no!

Genetic engineering (GE), recombinant DNA technology, genetic modification/manipulation (GM) and gene splicing are terms applied to the **direct manipulation** of an organism's genes.

By contrast, traditional breeding aims to manipulate an animal's genes **indirectly** by controlling which sire is mated to which dam, based on what is known about the animals and their relatives. Genomic selection also aims to manipulate the genes **indirectly** by using all knowledge about the animals, including information obtained from examining DNA.

Genomic selection merely involves **looking** at the DNA and using extensive scientific knowledge and historic information to draw sophisticated conclusions from what it shows. DNA Proven technology does **not engineer, manipulate or interfere** with the DNA.

Q 2 **Genomic selection seems to have arrived with a hiss and a roar! Why the rush?**

A 2 You're right, it has arrived quickly. We at LIC have hardly had time to catch our breath!

Genomic selection wasn't even a twinkle in somebody's eye before 2000, but recent developments in biotechnology, statistical techniques and computing power have all culminated in making genomic selection possible.

It's been gathering momentum – from 1882 with the discovery of chromosomes, to 1952 when DNA alone was found to be responsible for heredity, to 1966 when the genetic code was discovered, to 1988 when an international team of scientists began the project to map the human genome, to 2001 when the concept of genomic selection was first proposed, to 2004 when the bovine genome was first mapped, to now when LIC is making the benefits of DNA Proven genetics available to NZ farmers. (Notice the increasingly shorter time between significant developments). Genomic selection is another big step in a long history of genetic discovery.

SNP technology has developed extremely rapidly. Only three or four years ago we could cut DNA into only a few hundred pieces to estimate effects, at considerable expense. Now we have access to scores of thousands of SNPs, at a few cents each, sufficient to estimate breeding values with usable accuracy, years in advance of obtaining an estimate through progeny testing. Exciting, isn't it?

When we did the sums, we realised how big the benefits were going to be for the New Zealand dairy industry. And we knew that the sooner we got started, the sooner you would reap the benefits!

It's been fast, but a huge amount of work has gone on behind the scenes at LIC – and all science and other work has been tested, tested, tested before launching DNA Proven bulls to the market.

Q 3 **Will DNA Proven technology change the type of bulls bred?**

A 3 No. We are still wanting, and still looking for, and still breeding for animals which are the most efficient converters of feed (pasture) into profit.

LIC's breeding objectives are still:

- Moderate size Holstein-Friesian cows, and larger Jerseys
- Aggressive grazers/forage eaters/capacity
- High milksolids (protein)
- High fertility
- Good temperament and milking speed
- Sound udders
- Easy calving

With those objectives, LIC will continue to deliver sires that breed the kind of easy care cows desired on most large pastoral dairy farms. We will still produce a range of genetics and AB products, proven under New Zealand conditions.

Q 4 **What breeds will be available as DNA Proven semen?**

A 4 DNA Proven Premier Sires teams for Holstein-Friesian, KiwiCross™ and Jersey. Holstein-Friesian, KiwiCross™ and Jersey as Alpha Nominated semen (available from 2009).

No DNA Proven Ayrshire bulls will be available at first.

Q 5 **Will genomic selection replace proofs based on daughter performance?**

A 5 No, farmers will be able to choose whether to get the benefits of genetics three years earlier than has ever been possible before (ie use DNA Proven bulls), or wait for those genetics to gain daughter performance data on farm, much as they do now.

Q 6 **Will Daughter Proven bulls continue to be available? Or is LIC planning to phase them out?**

A 6 Daughter Proven bulls will continue to be available because bulls that have been used on the basis of their DNA will always eventually receive a traditional daughter proof.

However, in time, it's possible that the demand for Daughter Proven bulls will diminish considerably as the DNA Proven technology proves itself.

Q 7 **How does the dairy industry, and therefore individual farmers, reap the benefits of faster genetic progress, whether or not individual farmers choose to use DNA Proven bulls?**

A 7 Genetic improvement, as we have found in the past, "rubs off". Farmers today who have not wholly embraced AB still get some of the benefits of historic genetic improvement in the national herd.

The selection of bulls using DNA technology can be used in two key parts of the industry:

- by LIC (or any supplier of bulls to the industry) selecting which bulls to progeny test, and which cows and bulls to use to generate sons to progeny test.
- by individual farmers choosing which bulls to use over their cows.

LIC is committed to selecting future bulls using DNA Proven technology. These progeny test bulls will be ahead of (and therefore better than) bulls chosen using the traditional Daughter Proven progeny test systems. Their use in the national herd, even as Daughter Proven bulls, will lift the rate of genetic gain.

Of course, the more farmers who do use DNA Proven bulls, the faster the progress for everyone. The graph on page 12 shows the expected national herd advantage if all farmers use DNA Proven bulls will be $3.9 billion by 2030.

Q 8 **At the end of the day, no matter how high the bulls' genetic merit may be, they're no good if they don't get our cows in calf! How can we be sure DNA Proven bulls will do the job?**

A 8 All bulls marketed will have been tested in SPS herds the season before they are offered to the wider dairy industry. This use allows us to check a bull's fertility and screen for rare dominant genetic defects.

The bulls will be used for the same number of inseminations as they were under the traditional progeny test scheme (to generate approximately

80 daughters), so their fertility will be just as well tested.

LIC has extensive quality checks in place in the semen production laboratory, and continually monitors non-return rates throughout the spring to identify potential problems arising with bull fertility. These quality checks will continue.

Q 9 **How does DNA Proven technology deliver the predicted increased genetic gain? Can it be shown in a diagram?**

A 9 Faster genetic gain is delivered to you in two main ways:

i. through using cost effective (and quick!) DNA screening enables LIC to select from a much larger population of young bull calves than the cost structures of the Sire Proving Scheme have previously allowed

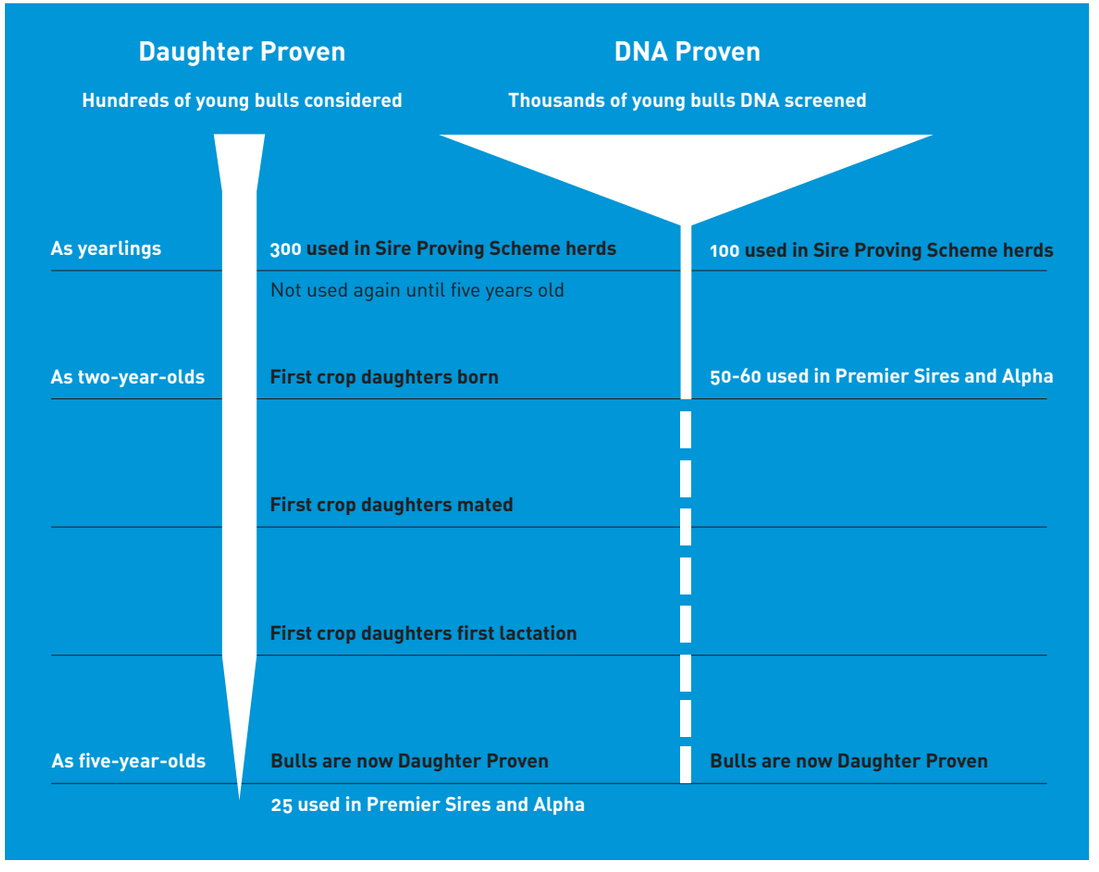
ii. through the much shorter generation interval

These are shown graphically in the diagram (right), which has been drawn to scale.

i. Around 500 young bulls are considered each year for the Sire Proving Scheme, whereas in a genomic selection environment we expect to screen the DNA of up to 10,000 young bulls annually. The genomic selection funnel has a much wider mouth.

ii. The generation interval for genomic selection is around two years compared to five years for the Sire Proving Scheme, represented as the vertical solid white lines.

Diagram showing why DNA Proven results in faster genetic progress



Q 10 **What are the advantages of DNA Proven semen over traditional progeny testing?**

A 10 The advantages can be summarised as follows:

- the ability to screen a larger number of animals, and therefore the opportunity to source bulls from a wider pool – who knows what we might find!
- reduced time involved in developing a bull's proof (by three years – see the chart on page 7 and the diagram on page 37)
- increased genetic gain through a reduced generation interval
- increased flexibility, allowing the industry to respond more rapidly to meet new breeding objectives should/as they arise
- larger team of widespread use bulls with less emphasis on any one individual
- semen collected from younger bulls with fewer health problems
- higher reliability of late-expressed traits such as fertility and longevity

Q 11 **Why do DNA Proven bulls cost more than Daughter Proven bulls?**

A 11 DNA Proven bulls cost more, quite simply, because they are worth more! They are higher merit bulls, and therefore their daughters will be more profitable in your herd.

In effect, you are paying the premium for a DNA Proven bull to get his extra genetic worth three years earlier than the farmers who will pay less for him later as a Daughter Proven bull.

Q 12 **Why won't a bull ever be available as a DNA Proven bull and as a Daughter Proven bull at the same time?**

A 12 To start with, he will be DNA Proven (and that's when you'll pay the premium to use him sooner), and then, three years later, he will be Daughter Proven (at which stage you will no longer be charged a premium, because you're not getting him as advanced genetics).

Q 13 **How can genomic information provide breeding values for TOP traits – surely you have to wait until a crop of daughters is in milk?**

A 13 DNA Proven technology incorporates TOP information just as it does the production traits. Historical TOP data has been analysed to generate genomic profiles on non-production as well as production traits.

If we have measured the trait in the Sire Proving Scheme, we can provide a breeding value for it in the DNA Proven process.

Q 14 **How much and what sort of data goes into calculating a Genomic BV?**

A 14 Let's take udder support for our example. The Genomic BV has been developed by testing the DNA of around 4,000 bulls that have been through the Sire Proving Scheme over the years. The DNA of each bull is analysed at 50,000 separate points across the genome. These results are then compared against the udder support BVs on the national database for hundreds of thousands of daughters.

Taking into account the number of bulls, the 50,000 DNA points for each, the number of daughters (from 80 to many thousands per bull), and all the data that is known about each daughter, there are literally billions of separate pieces of data.

Q 15 **In 2008 LIC is contracting about 1000 dams and proving about 100 bulls in SPS herds, whereas it used to place around 700 contracts and prove about 300 bulls before. Why the different numbers?**

A 15 First of all, please note that these are the figures for 2008 only. The breeding scheme study might indicate that we should do something different in subsequent years.

We are generating more bulls through contracts because:

- We can! The contract with breeders of bulls will be a commitment by LIC to **DNA test**, not necessarily **purchase**, any resultant bull calf. LIC will not be spending money to buy bulls that are not worth it, so this allows us to redirect that money to buying more bulls that are! The resulting bulls will be better than ever before. With DNA Proven technology we know the breeding values of the dams and the young bulls with greater reliability than we did in the past. That's a better deal for the bull breeders and the industry.

We are not testing as many bulls in SPS herds because:

- We don't need to! Only the best 5-10% of the 300 bulls – about 15-30 – ever made the Premier Sires team under the Daughter Proven system. With DNA Proven, we **already** know the best 100 bulls **before** we put them into SPS herds. Their use in SPS herds is

not to find the best bulls, but to identify any with problems.

Q 16 **Why can't all farmers (not just SPS farmers and breeders) use the bulls as yearlings. The bulls already have their DNA proof!**

A 16 At one year of age, bulls are only sexually mature enough to be used for about 1000 inseminations. Five hundred of those inseminations are used in SPS herds to generate about 80 daughters each, and the other 500 inseminations are used in high genetic merit breeder herds to breed future sires.

Even if a bull could supply more inseminations, he would not be used widely until he has been checked out in SPS herds. This is a safeguard before the bulls are offered for widespread use, checking for bull fertility (ie. semen quality), and also for the rare event of a bull carrying a dominant genetic defect.

Q 17 **In the traditional (Daughter Proven) Premier Sires team, the top 10 bulls usually performed 80% of the inseminations. What will the corresponding figures be for the larger DNA Proven team?**

A 17 You can expect a more even spread of the workload across the team. Our distribution systems are targeting 50% of semen to come from the top third of the team, 30% from the mid third, 20% from the lower third.

Q 18 **How do the reliabilities of Genomic BVs for bulls compare to the reliabilities for BVs?**

A 18 The reliabilities of indexes for DNA Proven bulls are lower than the reliabilities of the indexes for Daughter Proven bulls, but higher than the reliabilities of ancestry indexes for young bulls with no daughter information.

High reliabilities can be achieved by using an appropriately sized team of bulls. If you're using Premier Sires, LIC takes care of this for you. If you're using nominated bulls, you will need to increase the number of bulls you use. (See next question).

Reliability is fully discussed on pages 29-34.

Q 19 **Why does LIC recommend using a team of bulls if I'm using individual DNA Proven bulls?**

A 19 Actually, LIC recommends that you use a team of bulls, **whether you are using DNA Proven or not.**

By now, dairy farmers are familiar and comfortable with the "swings and roundabouts" principle of using a team of bulls. By using a team, you will end up with heifers with the BW you expected from the team average BW, because the bulls whose indexes drop on reproof are compensated for by the bulls whose indexes rise.

If you're using nominated DNA Proven bulls, you should use a larger team than you would if you were using a Daughter Proven team. Some examples are given in the table:

Individual bull reliabilities	Number of bulls used	Team reliability
35%	35	98%
60%	10	96%
60%	18	98%
80%	5	96%
82%	18	99%

Farmers will vary in the level of reliability they think is acceptable.

Q 20 **Why don't the GWs for all DNA Proven bulls have the same reliability? Surely they have all gone through the same DNA screening? (It's not as if they have different numbers of daughters in their proofs like the Daughter Proven bulls have).**

A 20 (Good thinking!) They do vary a little. That's because the ancestry component of the GW may vary for different bulls.

You will notice when studying the table for different breeds on page 30 that the reliability of BVs for different traits can differ, too. This is because, although the bulls are all screened using the same 50,000 SNPs, the reliability of the Genomic BV depends on how many of the 50,000 markers reveal information about that particular trait.

Q 21 **How many patterns are used for the calculations of LIC's Genomic BVs?**

A 21 Scientists have calculated that approximately 30,000 patterns (SNPs) must be screened to calculate an index with satisfactory accuracy. However, to increase the accuracy and reliability of the indexes of our DNA Proven bulls, LIC uses a chip of 50,000 SNPs.

Q 22 **Will DNA Proven technology dispense with the need for TOP scoring?**

A 22 No – TOP inspections provide valuable information for the selection of sires and will still be needed in a DNA Proven system.

Q 23 **Does DNA Proven technology spell the end of the Sire Proving Scheme?**

A 23 A progeny test scheme is still needed to collect daughter information, particularly the all-important information on bull fertility. The timely and accurate information supplied by Sire Proving Scheme (SPS) farmers is as valuable as it has always been.

See pages 19-20 for the role of the SPS herd now.

Q 24 **Will DNA Proven technology do away with the need to herd test?**

A 24 We don't believe it ever will. DNA reveals the genetics, whereas herd testing measures the performance (which is a combination of genetics and environment).

Q 25 **Is it possible that, at sometime in the future, LIC might use DNA Proven technology to identify the best cows – in other words, to enable farmers to profile their herds?**

A 25 Yes – we've started using it to screen cows already identified as potential bull mothers, and plan to use it as a selection tool to identify bull mothers from a wider range of cows in the future.

Q 26 **So we now won't use daughter proofs any more?**

A 26 Conventional Daughter Proven and DNA Proven systems are not mutually exclusive. Daughter proofs will provide useful confirmation of selection decisions made earlier on DNA evidence.

Q 27 **Will there be less emphasis on pedigrees in the future?**

A 27 There may well be slightly less emphasis on paper pedigrees in the long run, for two reasons:

- Improved accuracy – paper pedigrees are only as accurate as the accuracy of the recording they depend on. DNA profiles are a more accurate identifier of parentage and inherited traits.
- To enlarge the pool of genetics – GWs can be applied without pedigree information, thereby giving breeding companies the opportunity to source bulls and dams from a larger population of animals.

However, traits are inherited, so there will never be less emphasis on breeding the best bulls and the best cows.

Q 28 **What impact will DNA Proven semen have on the New Zealand Test Day Model?**

A 28 LIC is working with New Zealand Animal Evaluation Ltd and breeding companies to develop a new prototype of the New Zealand Test Day Model, which will deliver enhanced BVs and take into account the new information that DNA Proven technology will provide.

Q 29 **It seems logical that GWs for bulls will change in much the same way and for the same reasons that BWs do. How often will they be updated?**

A 29 You're right. More information (and this now includes DNA as well as production information) is continually becoming available about the bull's relations, so the GW, which incorporates ancestry **and** DNA information, will be an ongoing estimation.

Another factor contributing to a changing GW is statistical methods. These continue to improve at a very rapid rate, along with scientific knowledge and experience.

It's very likely that the initial GWs (calculated in April 2008) will be updated, or re-estimated, in

August/September 2008. At this stage, we don't know how often or at what intervals the GWs will be updated, but there will be regular updates.

Premier Sires DNA Proven will contain the best bulls available at the time of use.

Q 30 Where is the rest of the world in terms of genomic selection?

A 30 A small number of breeding companies around the world are working to bring genomic selection technology to their customers, and LIC is at the forefront. We have all that's required for success: the DNA and the database information for comparing bulls, the computer power to compare DNA profiles, the scientists to make it all happen, and the systems in place to provide a quality service to our farmers.

The accuracy of the whole genomic selection process depends on the number of unique chromosome segments that are examined and the number of historic bull records per unique chromosome segment. The number of SNPs examined is fairly standard, ranging from 30,000 to 60,000; LIC is using 50,000.

The number of historic bull records being used around the world varies greatly.

LIC used the records of around 4000 historic bulls for each trait.

In New Zealand, no other company can base their SNP technology on such a large historic base without using overseas bulls in their sample. Using overseas bulls for this purpose would involve converting indexes and using bulls not specifically bred for New Zealand conditions.Our relevant, accurate data ensures the optimal accuracy of LIC's predictions (genomic BVs and GW) for the performance of young bulls in New Zealand conditions.

Q 31 Where will DNA Proven technology lead the dairy industry?

A 31 Certainly, DNA Proven technology makes LIC better positioned to deliver new technologies such as sexed semen. The following could also be possible:

- **Even greater genetic gain than the graph on page 12 indicates?**

  At the moment, estimates of the benefits to the dairy industry are based on the same traits as are available with initial progeny test results. Additional gains could be made by incorporating information on traits such as longevity and fertility that would not normally be available until after selection of bulls for widespread usage. Currently the majority of information for both of these traits is not available until after the sire has had one or two years of widespread usage and thus the majority of the direct genetic contribution is completed before accurate estimates are available.

- **DNA Prove your own cows? Use DNA screening to generate and/or select your replacements?**

  The same DNA technology could in the future be used by GeneMark to offer screening tests for cows.

Major benefits in using this DNA Proven technology for the New Zealand dairy industry include:

1. selection of young bulls to progeny test
2. selection of heifers as bull dams based on their DNA profile
3. selection of young bulls for widespread use without progeny testing
4. selection of young bulls as bull sires
5. selection of replacement heifers

LIC is already doing the first four. The use of DNA screening to choose replacement heifers is still in the future, but certainly not in the distant future – you can look forward to being able to use this GeneMark service in due course.

- **Selecting for other traits?**

  What health traits would you like to see? This could read like an industry wish-list.

  DNA Proven technology is expected to be most useful in genetic evaluations for traits with low heritabilities, eg. for health and fertility traits that don't respond quickly to selection, and where we don't see any real improvement for some traits for 15 years or so. This technology means we may be able to see improvements in a much shorter timeframe than that.

  DNA technology may reveal major genes for traits that are expensive or hard to measure, like feed efficiency or resistance to disease. With existing technology it's really hard and slow to change those traits through direct selection.

▲ **Extending the technology to other species?**

Genotyping costs have fallen dramatically, and could continue to fall, so DNA screening will become more widespread in sheep, beef and deer, and will probably be utilised by the industries in that order.

The dairy industry is perfect for the introduction of DNA Proven technology because it has:

- widespread use of AB
- a huge database of information on animals and their performance
- a structure that allows a return to investors
- the opportunity to reduce the generation interval
- financial benefits to farmers to breed for improved traits

DNA Proven technology would not have the same impact on generation intervals in the beef, sheep and deer industries, but could be used to select for traits that are measured following slaughter. It would need to be accompanied by an increased use of AB.

Q 32 **What's possible with genetic gain?**

A 32 Who knows?

Over the last few years we have been achieving a rate of genetic gain of about 10 BW units per year. This was considered close to the economic optimum genetic gain that could be expected from an industry of four million cows using daughter proofs.

When considering the gains from genomic selection, researchers both in New Zealand and overseas have come up with figures of between 1.5 to 2 times that rate.

So up to 20 BW units per year may be possible with genomic selection.

Q 33 **It seems that LIC is asking farmers to just "trust" us. Where can I get more information?**

A 33 Well, you can trust us, or you can check out every bit of information that's available, and then trust your own judgement.

Start with this booklet, go to our website, read the scientific papers, ask experts whose opinion you value, talk to other farmers and your district manager.

There's always trust involved in any commercial transaction, so do also consider LIC's past record in contributing to the genetic gain of the dairy industry. We stand on it.

Finally, just to give you one expert opinion that you may value:

At a conference in February 2008, one of LIC's District Managers asked Bill Montgomerie of the New Zealand Animal Evaluation Ltd (knowing Bill is a dairy farmer himself): "Bill, would you use bulls chosen solely on DNA in your own herd?"

"Yes."

"On 100% of the herd?"

"Yes – I've done a lot of number crunching."

(Bill has given us permission to report this exchange).

Glossary

Cells cells make up the body of any animals or organism. The nucleus of every cell of the same body (except sperm and ovum which only have half the DNA, and red blood cells) contains the animal's DNA.

Chromosome one of the threadlike groups of genes and other DNA in the nucleus of a cell. Different kinds of organisms have different numbers of chromosomes.

DNA stands for Deoxyribonucleic Acid, the main constituent of the chromosomes of nearly all organisms (excluding some viruses) in the form of a double helix. DNA is self-replicating and is responsible for the transmission or hereditary characteristics.

Gene the functional and physical unit of heredity passed from parent to offspring. Genes are pieces of DNA, and most genes contain the information for making a specific protein.

Genome all the DNA contained in an organism or a cell.

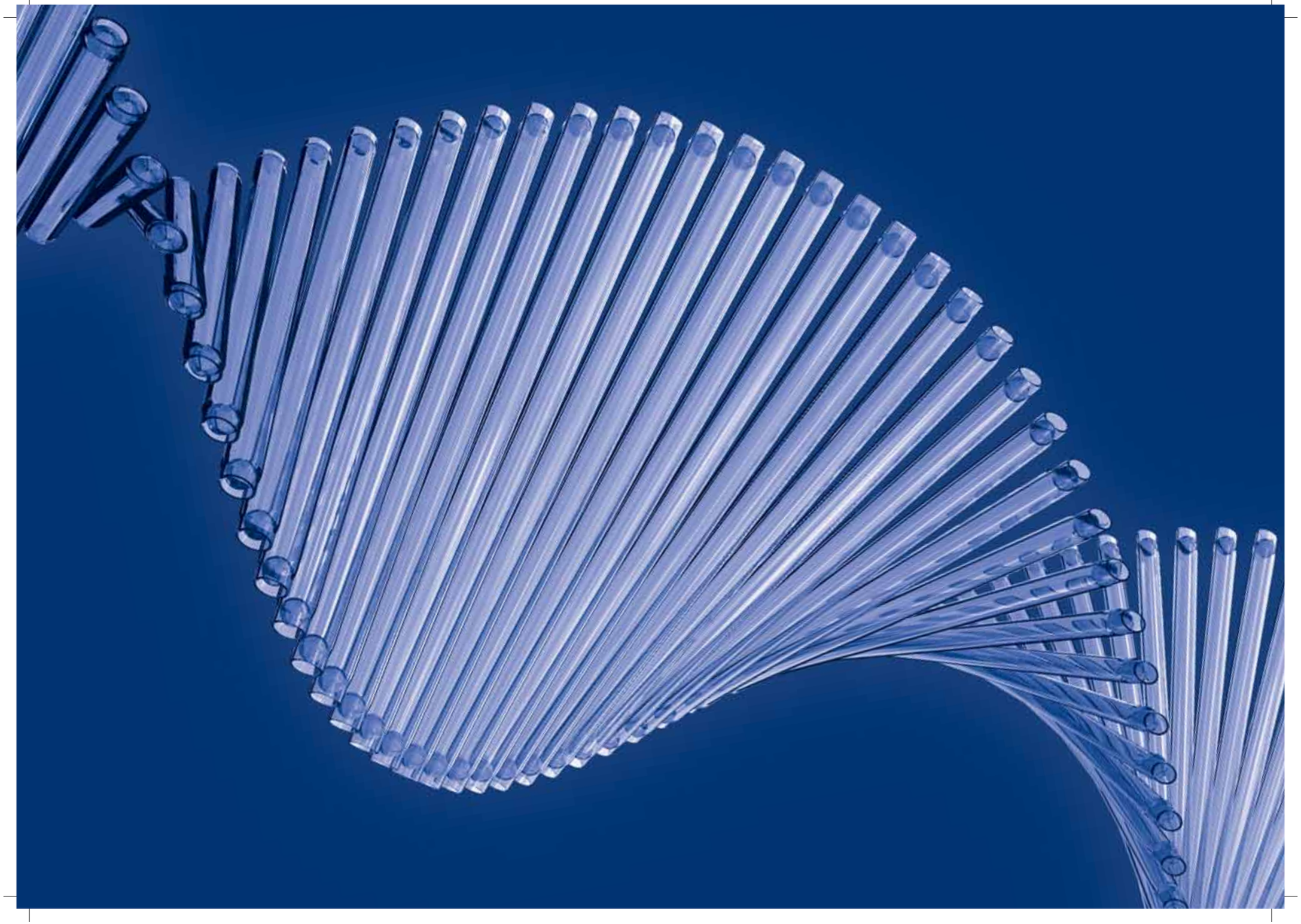
Genotype the genetic makeup of an organism consisting of the entire complex of genes inherited from dam and sire. The genotype determines the hereditary potentials and limitations of an individual. Sexual reproduction guarantees that every animal has a unique genotype, except for identical twins, which come from the same fertilised egg.

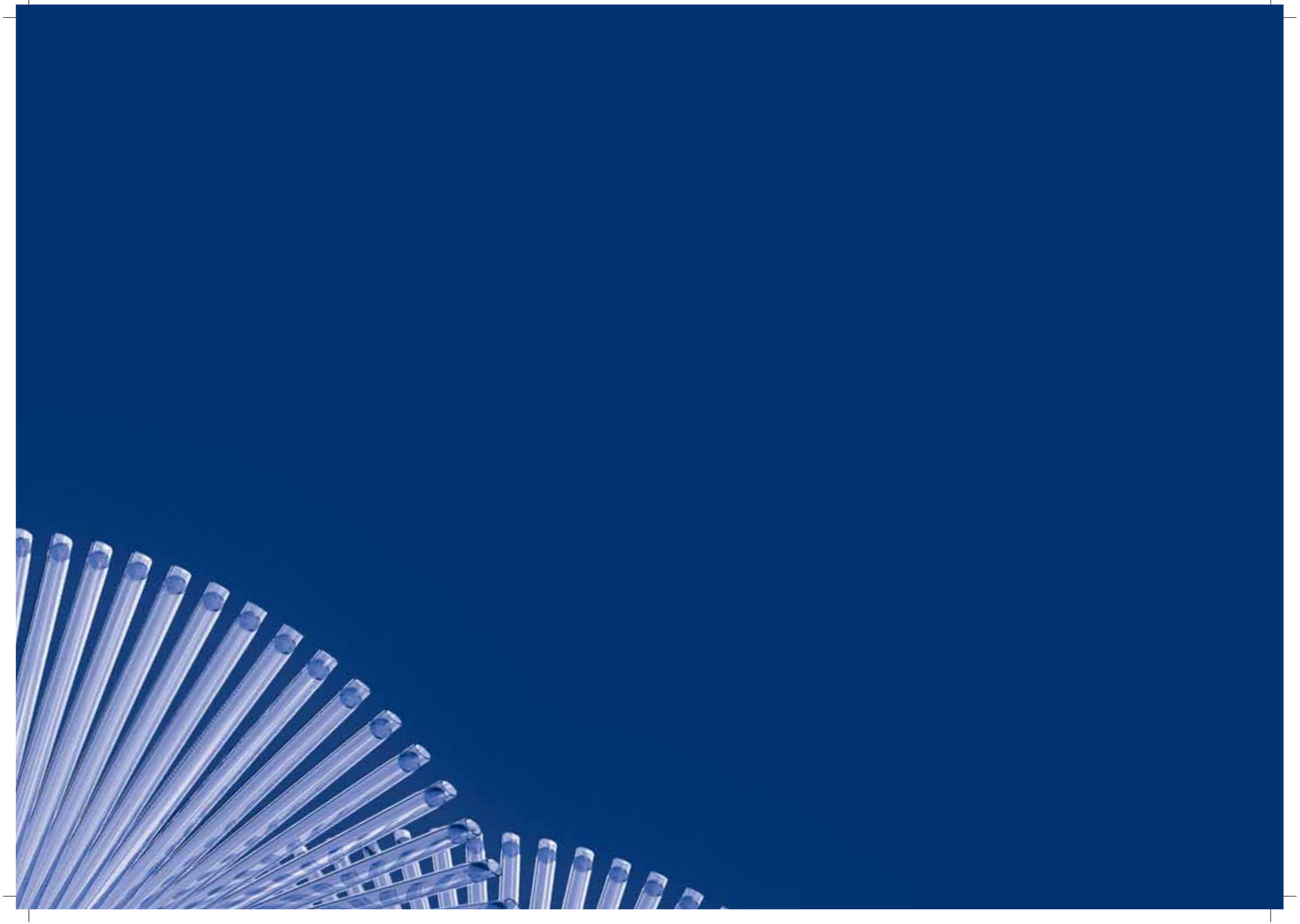
Marker assisted selection the forerunner of genomic selection. Marker assisted selection used DNA to enhance conventional selection methodologies.

Phenotype includes all the observable characteristics of an animal, such as shape, size, colour and behaviour that result from the interaction of its genotype (total genetic makeup) with the environment. The phenotype may change throughout the life of an individual because of environmental changes and the changes associated with aging. Different environments can influence the development of inherited traits (eg. size is affected by available food supply). Not all inherited possibilities in the genotype are expressed in the phenotype, because some are the result of inactive, recessive, or inhibited genes.

Protein a large complex molecule made up of one or more chains of amino acids. Proteins perform a wide variety of activities in the cell.

SNP (pronounced as "snip") stands for "single nucleotide polymorphism". A SNP is a single unit of DNA at the point where its sequence can vary from animal to animal.





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