Breeding briefs

Contents

The information in this booklet was compiled by AHDB with assistance from Ann Hardy.

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Introduction

High quality cattle are at the heart of profitable dairy farming. This requires good quality genetics, as without this – however good your management – there is a ceiling to your herd's performance and profitability.

This isn't just about genetics for milk production. It's also about health, welfare, management and type traits, each one of which can make an important contribution to profitability and all can be improved through breeding.

A series of poor breeding decisions can mean the difference between profit and loss; even between a business's survival and failure. Yet the time, cost and effort needed for a good breeding decision to be made is much the same as those needed for a bad one.

Even more important is the fact that breeding decisions are cumulative. Their effects build up over the generations, such that a problem can be introduced or cured over just a few years through the breeding choices made.

This booklet aims to identify some of the tools of genetic improvement so that better breeding decisions can be made. It concentrates on the theory and adds comments on using breeding tools in practice and, for those confronted with an overload of information, it helps identify the figures to seek out and prioritise.

Marco Winters
Head of Animal Genetics

AHDB Breeding improves your herd's profitability through better genetics

1. **Set your own breeding goals.**
2. **Understand your herd's strengths and weaknesses.**
3. **Understand how to use all the tools available to you, including:**
   - **£PLI**
   - **£SCI**
   - **£ACI**
   - **Genomics**

Genetic indexes: the theory

What are they?

A genetic index provides a measure of an animal's ability to pass its genes on to the next generation. These could be genes for production, health, lifespan, conformation or for any trait that is inherited and can be measured. Although we are most familiar with genetic indexes for milk, fat and protein, it is a common misconception that indexes only relate to production. Genetic indexes are far more than this and their application for non-production traits is becoming increasingly important in today's health and welfare conscious society.

Why are they needed?

In measuring an animal's genetic merit and assigning it a genetic index, every effort is made to disregard the effects of its environment and to strip its performance down to the bare genetics. This means that a 12,000-litre cow from a high-input system can be compared with one in an extensive herd averaging 6,000 litres. Equally, bulls whose daughters are milking in different production systems can also be fairly compared. Before genetic indexes, there was no way of fairly making such comparisons.

Every herd has strengths they wish to maintain and weaknesses they are looking to address and by using genetic indexes, accurate breeding decisions based on the predicted performance of a bull's daughters can be made.

How are they calculated?

In the calculation of a genetic index (often colloquially known as a proof), information is drawn from a variety of sources to produce the best possible estimate of an animal's genetic worth. This includes information on the animal's own performance, where appropriate, and information on the performance of other family members. Since an animal's performance is a combination of genetics and environment, we need to make certain allowances for these environmental effects. In doing so, considerations such as age, lactation number, stage of lactation, herd performance and season are all taken into account.

For a bull, the most important component of his proof is his daughters' performance. For a cow, the most important component, initially, is her own performance.

However, if a bull or cow is too young to have any daughter or performance information of its own, its genetic index, in most instances, will be calculated from its own genotype (or gene set), measured from codes along each strand of its DNA (see 'Genomic indexes').

Traditionally an estimated genetic index for young animals has been called a Pedigree Index (or Parent Average), since information was based on the animal's family or pedigree. However, since the advent of genomic indexes, these terms are less used.

In all young animal indexes, as the animal accumulates performance information of its own (or from its progeny), its family and genomic information become progressively less important.

Information included in genetic indexes originates with both milk records organisations (for example, production and cell count information) and breed societies (for example, type and locomotion information), or a combination of the two (for example, fertility and longevity). It is then used by AHDB in the calculation of genetic indexes.

When calculating genetic indexes for production or production-related traits, information from five lactations is usually used. When calculating genetic indexes for type or type-related traits, information on heifer classifications is usually used.

AHDB provides independent and impartial genetic evaluations to the UK dairy industry.

The Test Day Model

The accuracy with which genetic indexes are calculated is continually improving and, over recent years, the Test Day Model (TDM) has played a part in this improvement. In the calculation of a genetic index, TDM uses production information from every milk recording test day, up to and including the fifth lactation. It takes better account of management and environmental conditions affecting performance than before; it provides earlier genetic information for bulls and cows and allows a smoother transition to be made from the animal's Pedigree Index, or genomic index, to its performance-based proof.

How are genetic indexes expressed and what do they mean?

In the UK, most genetic indexes are expressed as Predicted Transmitting Abilities (PTA). PTAs predict the extent to which a given trait will be passed on to an animal's offspring. They do not predict the offspring's actual performance, which will vary widely depending on management, but instead they predict the amount of a trait the offspring will, on average, receive from its parents, compared with 'average' parents whose PTA is zero. This principle applies to both male and female PTAs and to both indexes based on actual and progeny performance and to those based on family and genomic information.

A genetic index provides a measure of an animal's ability to pass its genes on to the next generation.

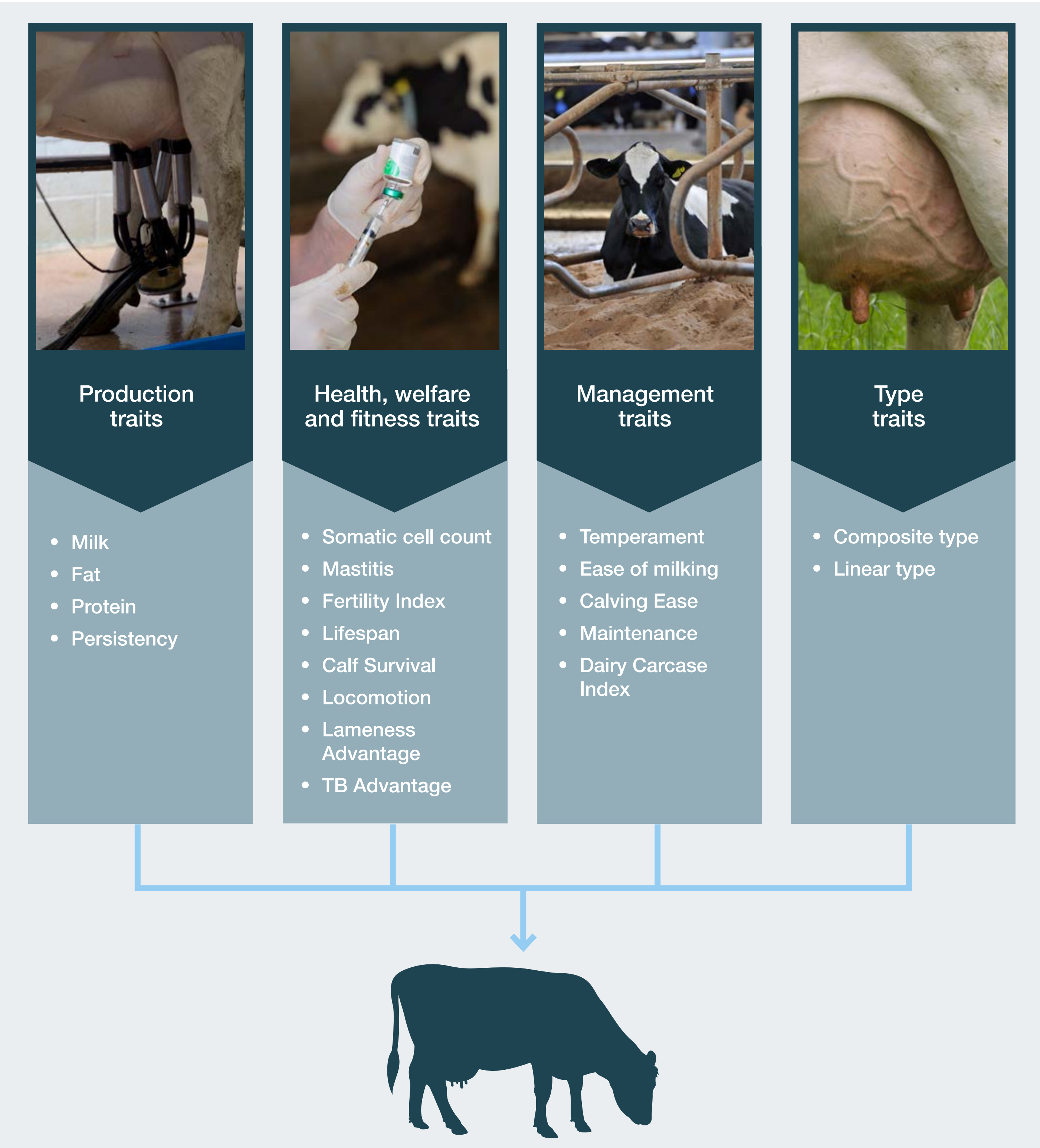


Figure 1. PTA categories and their associated traits

Production PTAs

Genetic indexes for production were the first to be introduced and have played an essential part in the increases in milk production achieved in recent decades.

Milk, fat and protein

The production traits for which all male and female dairy cattle are assigned a genetic index are as follows:

- Milk (kg)
- Fat (kg)
- Fat (%)
- Protein (kg)
- Protein (%)

The range of values for a PTA will vary from trait to trait; for example, a milk (kg) PTA may exceed 1,000 kg, whereas a fat (kg) PTA is unlikely to be more than 50 kg.

Persistency

Bulls' persistency PTAs provide an indication of their daughters' ability to maintain production throughout lactation. On AHDB factsheets, this information can be found in the same section as the production PTAs. They are derived from yield at 280 days as a percentage of yield at 60 days. Persistency PTAs will vary depending on breed, but for Holstein bulls, they commonly fall within the range of 57% (low persistency) to 67% (high persistency).

A higher persistency PTA generally reflects a flatter lactation curve, which is believed to result in fewer metabolic problems. Therefore, this may result in better health and fertility. However, research is yet to be carried out in the UK to confirm the genetic link between lactation shape and health traits. AHDB recommends that persistency PTAs are used only for a secondary screening of bulls.

Table 1. Breed averages, minimum and maximum persistency PTAs

Breed	Persistency PTAs (%)		
	Minimum	Average	Maximum
Ayrshire	51	57	63
Brown Swiss	55	61	67
Friesian	60	64	68
Guernsey	55	60	65
Holstein	57	64	71
Jersey	56	61	66
Montbeliarde	54	60	66
Shorthorn	52	57	62

Production PTAs for milk, fat and protein allow selection to produce cows that best suit the available milking contract.

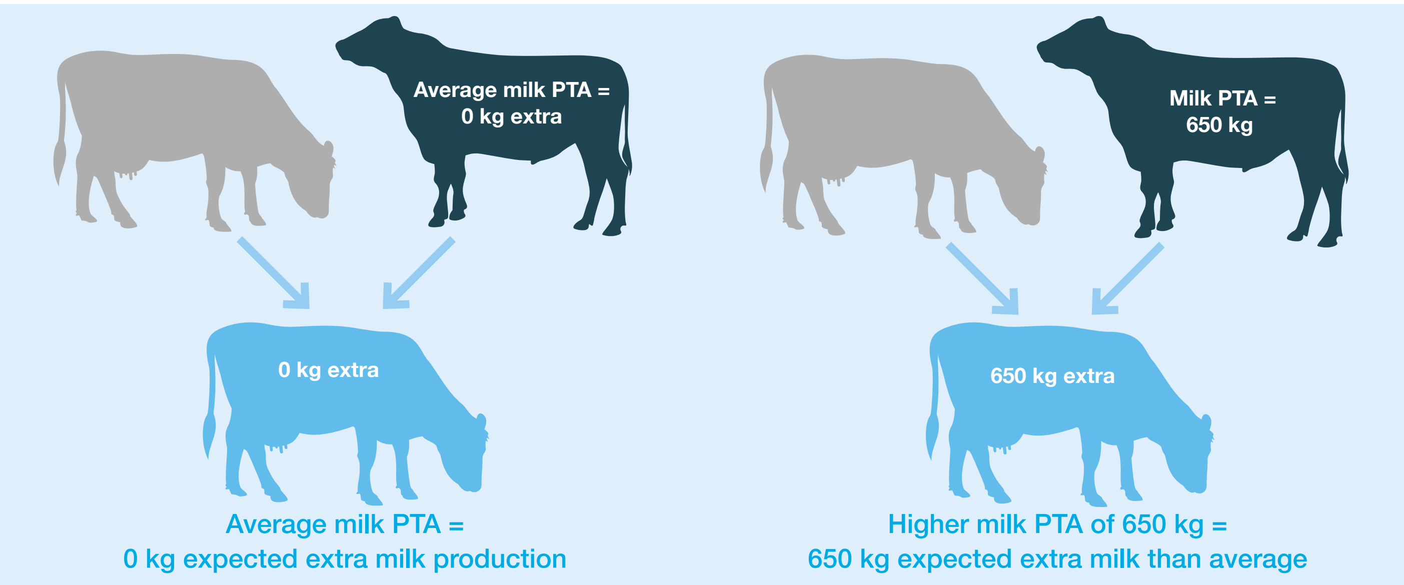


Figure 2. An example of a bull with an average milk PTA index (0 kg) compared with a bull with a higher milk PTA, indicating the difference in their resulting daughter expected performance

Health, welfare and fitness PTAs

In recent years, a growing significance has been attached to health, welfare and fitness traits, not simply because these traits are needed to sustain milk production over several lactations but also due to the growing demand from consumers for high health and welfare produce.

Somatic cell count

Somatic cell count (SCC) PTAs are expressed as a percentage and generally fall within the range +40% to -40%. For every 1% in a bull's SCC PTA, a change of 1% in his daughters' SCC is predicted.

> ***Negative PTAs***
>
> **For traits such as somatic cell count, mastitis and maintenance, negative PTAs are desirable.**
>
> **For example, daughters of a bull with a -10% SCC are expected to have cell counts that are 10% lower than daughters of a bull with a SCC PTA of zero. So, negative figures for SCC PTAs are desirable as these indicate a reduction in cell counts.**

Mastitis

Mastitis PTAs are calculated from actual cases of mastitis. Data about these cases comes directly from on-farm records, via the milk recording organisations National Milk Records (NMR) and the Cattle Information Service (CIS). The index gives an indication of a bull's ability to transmit mastitis resistance to his daughters.

It is expressed as a percentage, on a scale of about -5% to +5%. As with SCC PTAs, negative figures are desirable. This means that for every 1% decrease in a bull's Mastitis PTA, there will be a corresponding 1% decrease in the proportion of his daughters expected to get mastitis.

Although there is a strong link between SCC Index and a reduction in mastitis cases, a small number of bulls will reduce SCC but will not necessarily reduce cases of mastitis. The Mastitis Index helps to identify these bulls.

Figure 3. Testing quarters for somatic cell count

Fertility

The PTA for fertility (Fertility Index – FI) predicts female fertility. It is based predominantly on a combination of calving interval and non-return rates.

A bull with an above average FI will breed cows with improved calving intervals and better non-return rates. As a rough guide, every point increase in FI, for example from +4 to +5, will decrease the calving interval by 0.6 days and improve non-return rates by 0.25%. For example, the daughters of a +15 bull are expected to have about a nine-day shorter calving interval than daughters of an average bull whose FI is zero. Fertility Index scores generally fall within the range of -15 to +15.

Information included in the FI calculation is as follows:

- Calving interval
- Non-return rate at 56 days
- Body condition score
- Milk yield at around the time of insemination (110 days)
- Days from calving to first insemination
- Number of inseminations needed to get a cow in calf

The first two of these components are by far the most important, although early in a bull's life it is necessary to use more of the others as predictors of fertility, as well as genomic and parent information.

> **An average herd can reduce calving interval by around seven days in one generation by using bulls with the best Fertility Index. These benefits accumulate over generations.**

Lifespan

PTAs for Lifespan (LS) predict reduced or increased daughter survival and are expressed as extra days of life. They generally fall within the range of -305 days to +305 days, with an average of zero and positive indexes being desirable. Daughters of a +305 Lifespan Index bull are predicted to live, on average, 305 days longer than daughters of a sire whose index is zero. As with all UK genetic indexes, zero represents the breed average.

The Lifespan Index is calculated from actual daughter survival, when that information is available. When it is not, it is either calculated from the animal's own genotype (if it has a genomic index) or from predictive traits, such as type traits (Feet and Legs and Udders) and Somatic Cell Count Index, all of which are correlated with lifespan. Where necessary, information on ancestors' lifespan is also included in the calculation of the index. This – and all other predictors – will diminish in their importance as the animal acquires progeny lifespan information of its own.

An important feature of Lifespan PTAs is that they predict involuntary rather than voluntary culling. As there is such a strong relationship between milk production and survival (because low producers are generally culled earlier from the herd), Lifespan PTAs are corrected for milk production. This correction ensures the PTA is more a measure of daughters' ability to survive than of their failure to produce milk (which, of course, would be apparent from their PTA for production).

Calf Survival

The Calf Survival (CS) PTA shows that calves of some sires are more likely to survive between tagging and 10 months of age than those sired by other bulls. This PTA was developed using records from the British Cattle Movement Service (BCMS). The typical range for CS PTAs is from -5% (bad) to +5% (excellent), which indicates a 10% difference in the probability of survival between the progeny of the worst and best bulls.

Calves by a bull with a +5% CS PTA are 5% more likely to survive than those by a bull with a CS PTA of zero. They are 10% more likely to survive than those by a bull with a CS PTA of -5%.

Locomotion

The genetic index for Locomotion is expressed as standard deviations from the mean, on a -3 to +3 scale, with zero representing the average (mean). The best locomotion scores of +3 or higher predict the transmission of an 'excellent' gait: a perfectly parallel movement of the legs, in which the back feet are placed in the same spot left by the front feet.

The UK was the first country in the world to adopt and measure this important welfare trait when it was introduced by Holstein UK in 1995.

Figure 4. Breeding for enhanced locomotion scores in your future herd can aid reduced incidence of lameness

Lameness Advantage

Lameness Advantage (LA) is calculated using information about actual lameness incidents which come directly from on-farm lameness records via NMR and CIS. This information is combined with existing data for Locomotion and Feet and Legs, together with bone quality scores and digital dermatitis records from breed society type classification services, as recorded at the National Bovine Data Centre (NBDC).

Lameness Advantage PTAs are expressed as a percentage and range from -5% (bad) to +5% (excellent). Every 1% change in a bull's LA predicts a change of 1% of daughters becoming lame per lactation. For example, a bull with a +5% LA is expected to have 5% fewer cases of lameness in his daughters per lactation than a bull with an LA of zero.

Digital dermatitis

Digital dermatitis has been collected as part of the dairy breed society classification process for many years and has been used as part of the Lameness Advantage calculation since 2018. However, many producers are keen to know which bulls specifically transmit better resistance to digital dermatitis to their daughters, so it was also made available as a standalone index in 2020. The Digital Dermatitis Index (DD) is expressed on a scale of about -2% to +2%, with positive figures being desirable. Daughters of a bull with a +2% DD Index are expected to have 2% fewer cases of digital dermatitis than daughters of a bull whose DD Index is zero.

Figure 5. Selecting a bull with a positive Digital Dermatitis Index should aid daughters to have reduced cases of digital dermatitis

TB Advantage

TB Advantage (TB Adv) helps dairy farmers to breed cattle with improved resistance to bovine tuberculosis (bTB). Expressed on a scale that typically runs from -3% to +3%, positive scores are desirable. For every +1 point in the index, 1% fewer daughters are expected to become infected during a TB breakdown.

The index is available for bulls that have sufficient daughters milking in the UK, or Holsteins and Friesians with a genomic index. Its reliability, on average, is lower than that of other genetic traits because a smaller population has been used in its calculation. However, ongoing research is bringing far more cattle into the database from which the index is calculated, which will improve the reliability of young genomic indexes for TB Adv.

Table 2. Range of values for genetic indexes currently available for health, welfare and fitness traits

Trait	Range of values	
	Good	Bad
Somatic cell count (%)	-40	+40
Mastitis (%)	-5	+5
Fertility Index	+15	-15
Lifespan (days)	+305	-305
Locomotion (standard deviations)	+3	-3
Digital Dermatitis (%)	+2	-2
Lameness Advantage (%)	+5	-5
Calf Survival (%)	+5	-5
TB Advantage (%)	+3	-3

Breeding for health, fitness and welfare traits means that it is possible to breed cows with an inherently higher chance of experiencing better health and welfare or that can better fight off infection.

Management PTAs

The importance of management traits, which allow a streamlined and undisrupted milking routine, has increased as farm dynamics have changed over time.

Temperament

Although rearing and handling are key to shaping a cow's temperament, the clear genetic component to this trait has led to the calculation of genetic indexes for temperament in the parlour. Expressed on a standardised scale of -3 to +3, the highest indexes indicate the predicted transmission of a placid temperament.

Ease of milking

Genetic indexes for ease of milking are also expressed on a -3 to +3 scale. Low minus figures represent hard-milking cows, while high positive figures predict very fast milking and daughters potentially running milk.

Calving Ease

Calving Ease (CE) indexes are expressed as 'per cent easy calvings' on a scale of -4% to +4% and are centred around a breed average of zero. Positive figures predict easier than average calvings and negative figures predict more difficult calvings.

There are two CE indexes that together give a complete picture of a bull's 'calving performance':

- **Direct Calving Ease (dCE%)** predicts the ease with which a calf by that sire will be born
- **Maternal Calving Ease (mCE%)** predicts the ease with which a daughter of that sire will give birth

Negative dCE% should be avoided when breeding maiden heifers, as these are predicted to give a higher proportion of difficult calvings. However, long-term selection for dCE% without any regard to mCE% could set up problems for the future, so maternal Calving Ease should also be considered.

Figure 6. Consider both direct and maternal calving ease when choosing the sire to make sure you are selecting for long term benefits

Maintenance

The cost of maintaining a cow is related to its weight, such that a cow weighing 600 kg will have a lower feed requirement for its maintenance than a cow which weighs 700 kg, even if they give the same amount of milk. As we don't routinely weigh dairy cattle, we have studied the traits most closely related to the cow's weight. These traits are stature, chest width, body depth and angularity, and they are used as indicators of the costs of maintenance in the calculation of a Maintenance Index.

Figures for Maintenance Index are expressed on a scale of roughly +50 kg to -50 kg, giving an indication of the average difference in weight expected in a bull's daughters. Negative figures are desirable because they will help producers to breed cattle with lower feed costs, with all else being equal.

Dairy Carcase Index

A Dairy Carcase Index (DCI) has been developed primarily for producers sending dairy youngstock to the beef supply chain or rearing their own beef. It is calculated from weight, age and carcase information from most major abattoirs in the UK and is primarily based on average daily carcase gain and carcase conformation.

Expressed on a scale of about -5% (bad) to +5% (excellent), an increase in the index predicts an improvement in both carcase conformation and average daily carcase gain in a bull's progeny.

The DCI is jointly funded by AHDB Beef & Lamb and AHDB Dairy. The data collected is also used to enhance pure beef genetic evaluations.

Selection for Maintenance can aid increased herd feed efficiency.

Animals that calve easily and milk calmly will help reduce labour time.

Trait	PTA	Rel%		Min	Max	
SCC	-19	99	Non-improver	+40	-40	Improver
Mastitis	0	99	Non-improver	+5	-5	Improver
Lameness Advantage	-1.5	99	Non-improver	-5	+5	Improver
Calf Survival	1.7	99	Non-improver	-5	+5	Improver
Lifespan	115	99	Non-improver	-250	+250	Improver
Fertility Index	-2.7	99	Non-improver	-20	+20	Improver
direct Calving Ease	-1.2	99	Difficult	-4	+4	Easy
maternal Calv.Ease	-0.2	99	Difficult	-3	+3	Easy
TB Advantage	1.0	99	Undesirable	-4	+4	Desirable
Dairy Carcase Index	-0.4	99	Non-improver	-5	+5	Improver
Maintenance	15		Undesirable	+60	-60	Desirable

Figure 7. An example of a bull's genetic indexes for health and management traits, available from AHDB Bull Search

Type PTAs

Type traits can play an important role in determining a cow's suitability for sustained milk production. Many of the 17 traits assessed have an effect on cow durability. Type traits can be split into three groups:

- **Linear type traits** – 17 traits measured on a linear scale, which describe the physical attributes contributing to how a cow looks
- **Composite type traits** – there are two composite traits, Feet and Legs and Udder, which are described in terms of desirability on a scale of -3 to +3
- **Type Merit** – prediction of a bull's ability to transmit overall type, which is based on a combination of his daughters' scores for Udder, Feet and Legs and body conformation, on a scale of -3 to +3

Type evaluations are undertaken on first lactation cows by the breed societies, each of which determines its own breed standards. The data collected is used to calculate genetic evaluations for males and females. As with individual production and health indexes, type indexes should not be compared across breeds.

Linear type traits

Linear type traits are generally expressed on a bar chart, which provides a useful at-a-glance assessment of a bull's predicted breeding pattern. However, while it is generally considered desirable for bars to be on the right-hand side of the chart, they do not necessarily need to be on the extreme right-hand side, depending on breeding priorities. For example, extreme stature improvement is no longer desirable for most producers. Two very obvious exceptions are rear legs viewed from the side and teat length, each with approximately mid-score optimums. Once again, the intermediate score of zero represents the breed average for all linear traits.

Table 3. Description of the two extremes for genetic indexes for linear type traits

Trait	-3	+3
Stature	Small	Tall
Chest Width	Narrow	Wide
Body Depth	Shallow	Deep
Angularity	Coarse	Sharp
Rump Angle	High pins	Low pins
Rump Width	Narrow	Wide
Rear Leg Side View	Straight	Sickled
Foot Angle	Low	Steep
Fore Udder Attachment	Loose	Tight
Rear Udder Height	Very low	Very high
Udder Support	Broken	Strong
Udder Depth	Below hock	Above hock
Front Teat Placement Rear View	Outside of quarter	Inside of quarter
Teat Length	Short	Long
Teat Placement Side View	Close	Apart
Rear Teat Placement	Apart	Close
Condition Score	Low	High

Composite type traits

The two composite traits – Feet and Legs, and Udder – also appear on a bull's bar chart, but unlike the 17 linear traits above, these are described in terms of desirability rather than degree. Based on the type evaluator's observations, they are also expressed on a -3 to +3 scale, with the highest scores indicating the best overall quality.

Type Merit

Type Merit predicts a bull's ability to transmit overall type and is based on a combination of his daughters' scores for Udder, Feet and Legs, and body conformation, in order of importance. Again, it is expressed on a scale of -3 to +3.

For a fuller explanation of genetic indexes for type, readers are referred to the breed societies or the AHDB website.

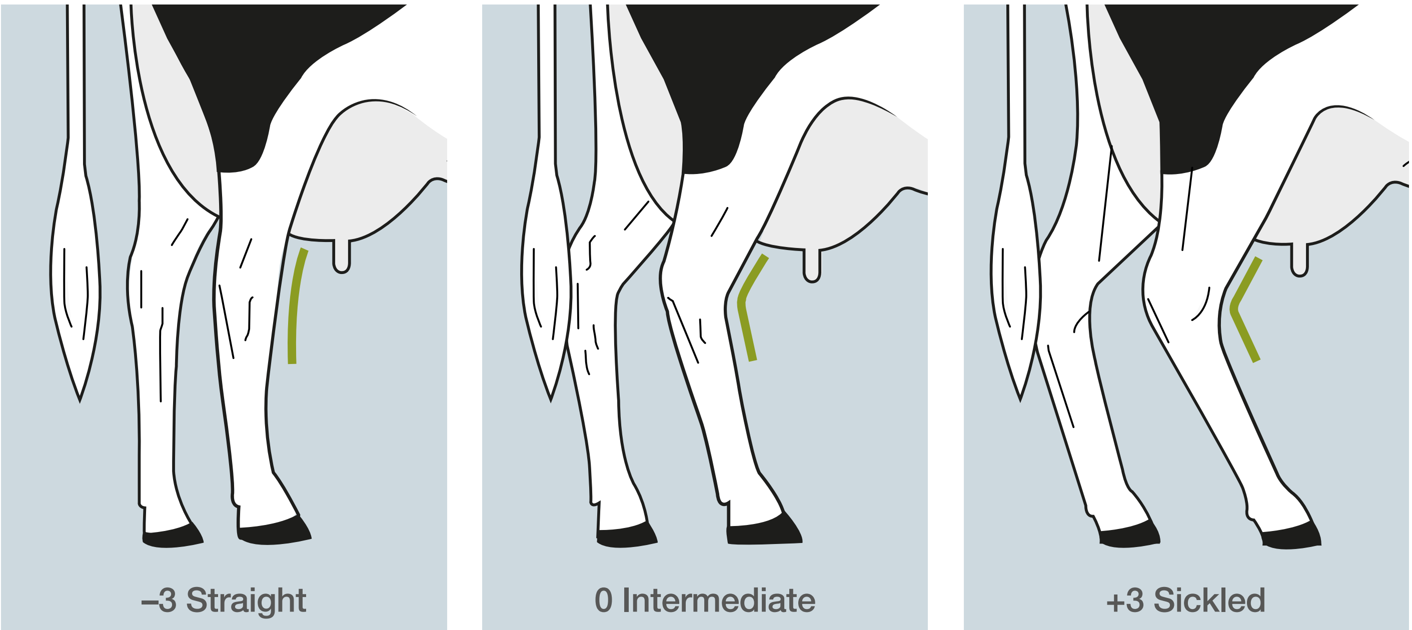


Figure 8. An example of rear leg side view scoring

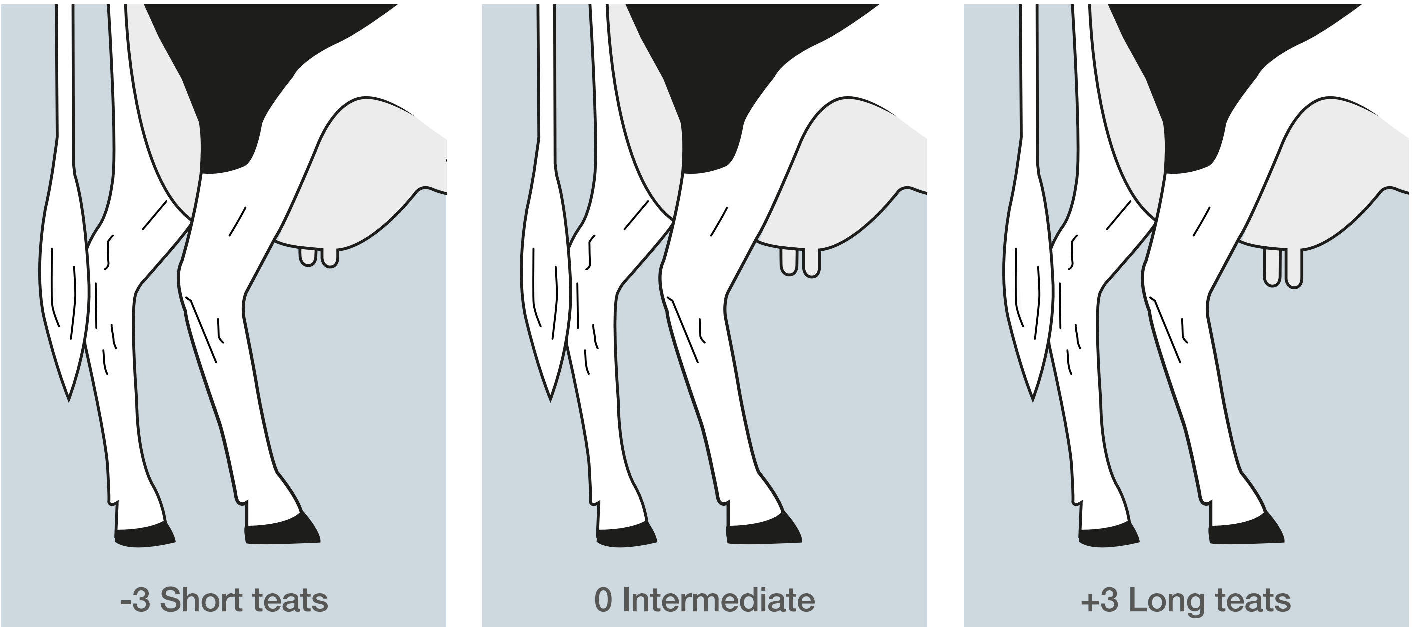


Figure 9. An example of front teat length scoring

Genomic indexes

Genomic indexes are calculated using a young animal's own DNA or genetic material, rather than being estimated from the performance of its parents and ancestors.

In the process of the indexes' calculation, the animal's DNA is expressed as a genotype, which is compared with the actual performance and genotype of thousands of animals in a 'reference population'. This allows relationships between the two to be established and a key of single nucleotide polymorphisms (SNP-key) to be calculated (see Figure 10). The UK collaborates with the USA, Canada and Italy to pool reference populations and increase the reliability of genomic indexes.

Reliabilities achieved for genomic evaluations on young bulls are currently around 65–75% for Holsteins and 55% for other genomically evaluated dairy breeds. As an animal accumulates progeny information, so the genomic (and parent average) component contributing to its index gradually diminishes. Studies undertaken by AHDB have repeatedly shown that genomic evaluations are a very reliable predictor of actual daughter performance.

The reliability of genomic evaluations is greater than the parent average alone (which is generally around 35% reliable), but less than an evaluation based on progeny performance (which can be up to 99%).

The process of genomic testing

Step 1
A sample of the calf's hair or ear notch is sent to a laboratory.

Step 2
Scientists at the laboratory extract the DNA from the hair.

Step 3
The DNA is converted onto a 'SNP-chip', showing the sequence of bases that make up this DNA. This can then be read at various locations along its length.

Step 4
A computer file showing this sequence is sent to geneticists working at Edinburgh Genetic Evaluation Services (EGENES) on behalf of AHDB.

Step 5
Geneticists develop a SNP-key, which unlocks or translates the sequence to turn it into a genetic index which can be understood by the farming and cattle breeding industries.

Step 6
In the UK, genomic indexes are expressed as Predicted Transmitting Abilities. All official PTAs are branded with the AHDB logo.

Figure 10. The process of genomic testing

Next steps

- Carefully study the bull's index, just as though he were a conventionally tested sire
- Remember that the lower the reliability of the index, the greater the chance the index will change as more information becomes available
- Check that your artificial insemination (AI) company clearly states that the bull is a young genomic bull – if not, ask them to confirm

Think about

- Avoiding overestimating the reliability of genomic indexes, which will be lower than those of most progeny tested bulls
- Trying to avoid the overuse of a young, low reliability bull with or without a genomic index

Remember

There's nothing mystical about genomic evaluations in themselves. A young bull marketed as a 'genomic young sire' may be no better or worse than any other bull.

Genetic indexes for selection

Although genetic indexes for the many individual traits now measured can reveal a great deal about an animal's breeding expectations, their detailed study can be time consuming and is often impractical on many farms. This is where selection indexes such as £PLI (Profitable Lifetime Index), £SCI (Spring Calving Index) and £ACI (Autumn Calving Index) can come into play. Selection indexes represent the additional monetary profit that a bull is expected to transmit to his average daughter, over her lifetime, compared with a bull with an index of zero.

The £PLI, £SCI and £ACI show the additional profit a bull is expected to pass onto his daughters compared to a bull with an index of zero in a year-round, spring block and autumn block calving system, respectively.

£PLI (Profitable Lifetime Index)

£PLI is a genetic ranking index made up of numerous traits, each of which is weighted by its relative economic importance. £PLI is suited for use in year-round-calving herds. Only animals of the same breed can be compared with each other using £PLI. The resulting figure represents the additional profit that a daughter of a high £PLI bull is expected to earn over her lifetime, compared with a daughter sired by an average bull with a £PLI of zero.

Although over one-third of the £PLI is accounted for by milk production, the remaining two-thirds comprise of health, fertility, survival and efficiency traits. This reflects demand from both the farming industry and consumers to strive for higher animal welfare standards and production efficiencies through better conversion of feed into milk.

For further information, please see £PLI – ***Profitable Lifetime Index*** factsheet.

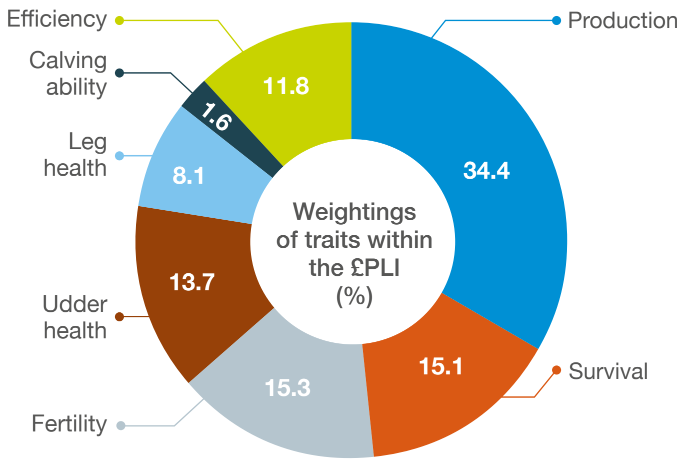


Figure 11. A breakdown of the individual weighting of traits in the £PLI

£SCI (Spring Calving Index)

The Spring Calving Index (£SCI) is an across-breed genetic ranking index developed specifically for spring block-calving herds and expressed as a financial value.

The index has been developed to breed a cow that produces lower volumes of milk of a higher quality. It places large emphasis on fertility and calving ease to achieve tight block calving. The index also favours bulls that will produce a smaller cow with lower maintenance requirements.

The £SCI has been specifically created for spring block-calving systems, which rely heavily on grazed grass and calve in a tight (12 week or less) block. As an across-breed index, it enables bulls of different breeds to be compared with one another.

For further information, please see £SCI – ***Spring Calving Index*** factsheet.

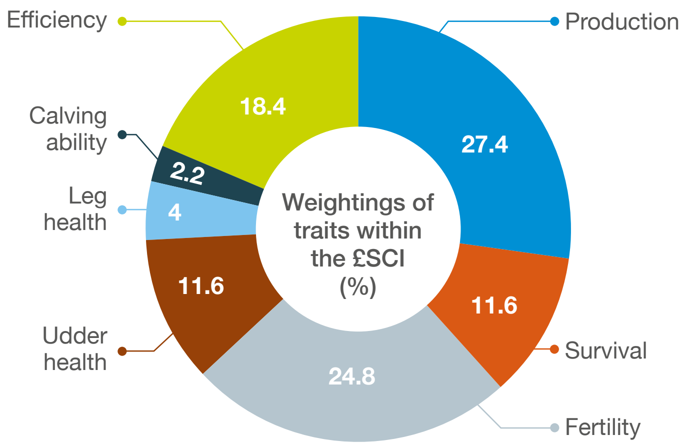


Figure 12. A breakdown of the individual weighting of traits in the £SCI

£ACI (Autumn Calving Index)

£ACI is suited for autumn block-calving herds. It differs from £PLI and £SCI by reflecting the costs of feeding for winter milk production and the higher milk price per litre received at that time of year. As such, it favours a greater weight of milk than £SCI but has less emphasis on fat and protein percentages. £ACI has a slightly greater emphasis on female fertility than £PLI, which is for year-round-calving herds.

£ACI is an across-breed index, which allows producers to compare the genetic merit of service sires from different dairy breeds on a level platform. It is for use in herds that calve in a tight block (12 weeks or less) in autumn.

For further information, please see £ACI – ***Autumn Calving Index*** factsheet.

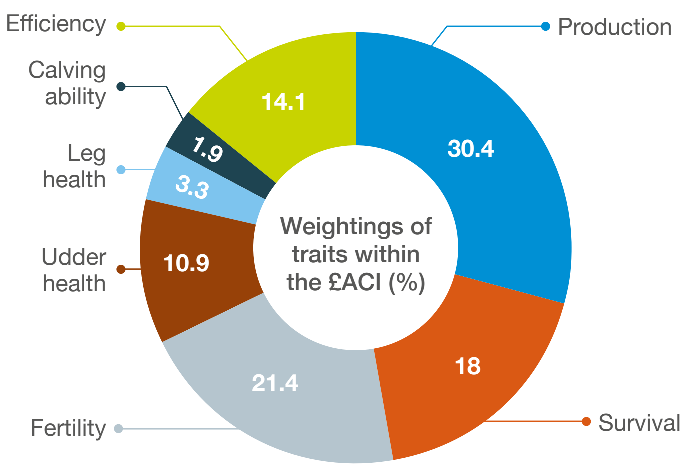


Figure 13. A breakdown of the individual weighting of traits in the £ACI

Table 4. Traits, by group, as part of the £PLI, £ACI and £SCI

Trait	Trait group
Milk Fat kg Protein kg Fat% Protein%	Production
Lifespan Calf survival	Survival
Fertility index	Fertility
SCC Mastitis Udder	Udder health
Feet & legs Lameness advantage	Leg health
Direct calving ease Maternal calving ease	Calving ability
Maintenance Body condition score	Efficiency

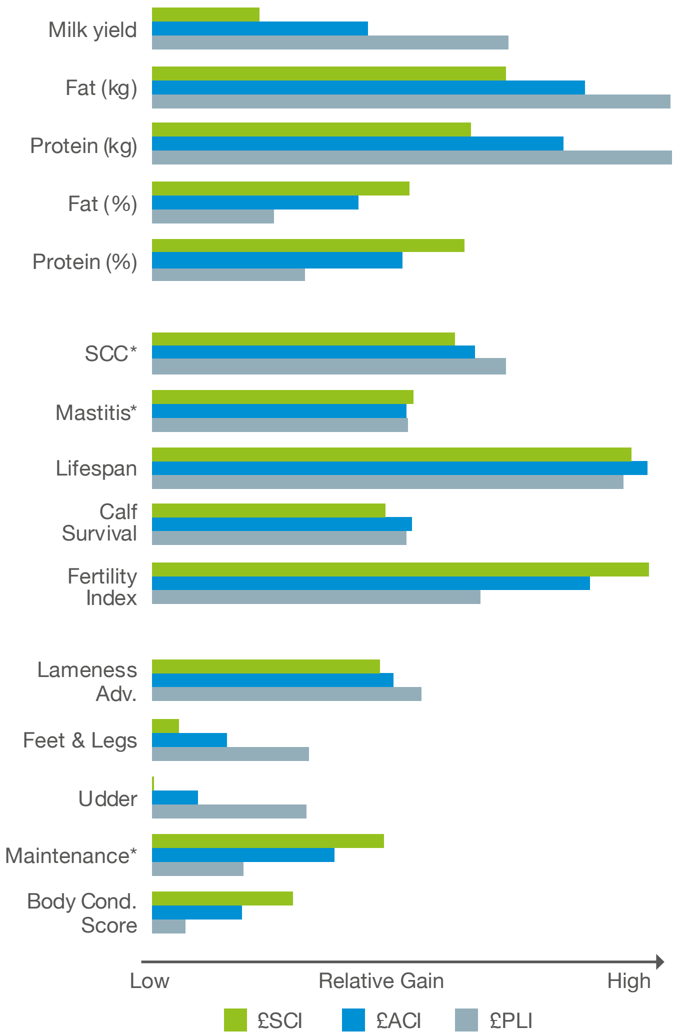


Figure 14. Relative genetic gain for a range of traits, based on the average of all available Holstein bulls; July 2018

*Trait reversed for presentation purposes

AHDB's Genetics Advisory Forum (GAF) reviews the UK's three economic indexes annually. The GAF is made up of breeding industry stakeholders, including farmers and processors, together with representation from breed societies, milk recording organisations, the Royal Society for the Prevention of Cruelty to Animals (RSPCA), AI companies and veterinarians. The GAF considers the genetic progress that dairy breeds are making and the long-term market outlook for inputs and output, fine-tuning the indexes as the need arises. The main differences between trait improvement between the UK's three economic indexes are shown in Figure 14.

Base changes

All discussion about PTAs has focused on the figures providing a comparison with an average animal. This average animal has a PTA of zero for every trait. But, as the national herd makes genetic progress, that average also goes up. It is for this reason that we have base changes – in effect an occasional recalculation of the average. If we didn't – because of genetic progress – almost every animal would eventually be better than the 'average' determined many years before.

So, every five years, the national average for every trait is recalculated and reset to zero. For example, in 2020 the genetic base was recalculated for all breeds. That is why PTA is occasionally referred to as PTA2020. However, for simplicity's sake, the suffix is generally dropped, even though every PTA calculated in the ensuing period will technically be a PTA2020.

Whenever there is a base change, there will be a noticeable reduction in PTA values across the board, although the base change itself causes no change in ranking.

The important point to remember is to compare like with like. A PTA2020 should never be compared with an earlier or later PTA and, equally, only PTAs from the same proof run should be compared. Be particularly cautious of published bull catalogues, which are generally out of date within four months of publication.

Genetic index reliability

The reliability of genetic indexes varies widely depending on the amount and source of information used in their calculation. For production traits, for example, a Pedigree Index based on a parent average typically has a reliability of around 30–40%. However, a widespread proof for a bull based on the performance of daughters in several hundred herds could have a reliability of up to 99%.

Genomic indexes have reliabilities somewhere between these two extremes, at around 65–75% for Holsteins and 55% for other genomically evaluated dairy breeds. When more information goes into the calculation of the genomic index and when the heritability of the trait is high (for example, production traits), the reliability will be improved. The lower the reliability of the index, the more likely it is to change as more daughters are added, so it is important to use such bulls with caution.

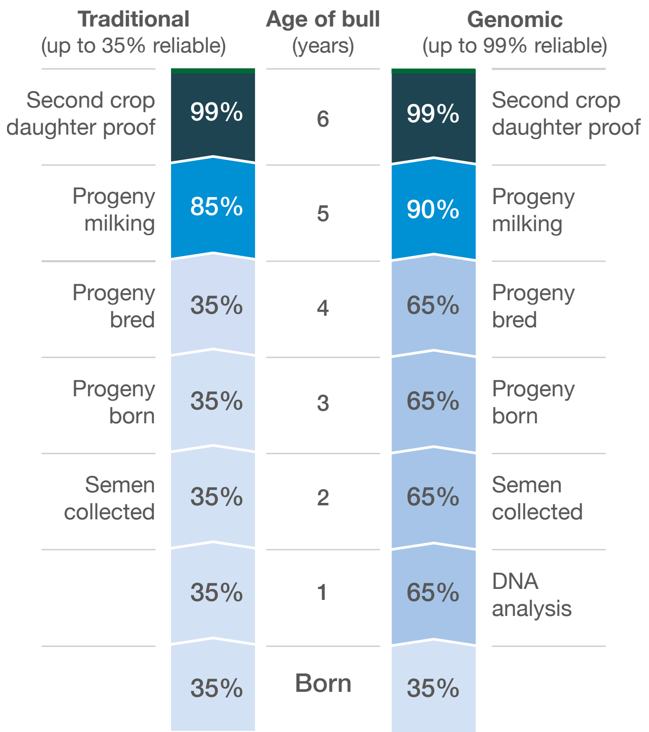


Figure 15. £PLI reliabilities over time for traditional (progeny-tested) and genomic evaluations for Holstein and Friesian bulls

When bull proofs are published, the number of daughters contributing to the figures and the number of herds in which they are found is generally also specified. Where there is a high proportion in just one or two herds, there are, again, greater chances of instability.

Remember

- When proofs of foreign bulls are converted to UK-equivalent figures (see 'Genetic indexes from other countries'), their reliability figure is reduced as part of the conversion process. A 99% reliable foreign bull will never reach 99% reliability in his UK-equivalent proof
- When a trait has a lower heritability (see Heritability), more information is needed to reach the same reliability as more highly heritable traits. For example, the reliability of the Fertility Index is likely to be lower than that of a production PTA

Table 5. Typical PTA reliabilities for bulls

Reliability (%)	Comment	Information contributing to PTA
10–29	Extremely low	Some Pedigree Indexes involving estimates from relatives
30–40	Very low	Most Pedigree Indexes involving estimates from parents with reasonable reliabilities
41–55	Low	Some Pedigree Indexes. Usually the sire is well proven and the dam has very high reliability Genomically evaluated non-Holsteins without progeny milking
56–65	Low to moderate	Bulls with officially published PTAs (minimum 50%) Genomically evaluated Holsteins without progeny milking
66–75	Moderate	Bulls with early progeny test data and typically foreign bulls
76–90	Moderate to high	Proven bulls with a first crop proof
91–98	High	Proven bulls with a large number of daughters from a wide cross section of herds
99	Very high	Widely proven and used AI bulls

The graph below advises how much semen should be used from each bull, depending upon its reliability figures.

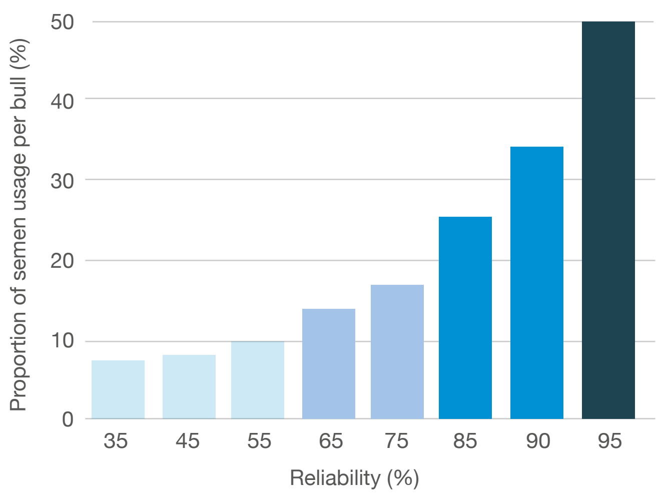


Figure 16. Guide to the proportion of semen usage for a single bull at different levels of reliability

Table 6. Current UK dairy trait heritability estimates

Trait	Heritability
Production	
Milk yield	55% (0.55)
Fat yield	47% (0.47)
Protein yield	51% (0.51)
Fat percentage	68% (0.68)
Protein percentage	68% (0.68)
Fitness	
Somatic Cell Count	11% (0.11)
Mastitis	4% (0.04)
Locomotion	10% (0.10)
Lameness Advantage	4% (0.04)
Digital Dermatitis	2% (0.02)
Lifespan	6% (0.06)
Calf Survival	5% (0.05)
Fertility	3% (0.03)
Temperament	11% (0.11)
Ease of milking	21% (0.21)
Body condition score	27% (0.27)
Direct Calving Ease	7% (0.07)
Maternal Calving Ease	4% (0.04)
TB Advantage	8% (0.08)
Dairy Carcase Index	40% (0.40)
Linear type	
Stature (ST)	41% (0.41)
Chest Width (CW)	25% (0.25)
Body Depth (BD)	33% (0.33)
Angularity (ANG)	34% (0.34)
Rump Angle (RA)	30% (0.30)
Rump Width (RW)	26% (0.26)
Rear Leg Side (RLS)	20% (0.20)
Foot Angle (FA)	10% (0.10)
Fore Udder Attachment (FUA)	22% (0.22)
Rear Udder Height (RUH)	23% (0.23)
Udder Support (US)	19% (0.19)
Udder Depth (UD)	35% (0.35)
Front Teat Placement (FTP)	29% (0.29)
Rear Teat Placement (RTP)	29% (0.29)
Teat Length (TL)	29% (0.29)
Composite type	
Feet and Legs	16% (0.16)
Udder	27% (0.27)
Type merit/Type score	32% (0.32)

Heritability

Genetic improvement depends on traits being inherited down the generations. Some traits are far more heritable than others. Heritability is defined as the degree to which a trait is observed as being passed down the generations.

- The more heritable a trait, the easier it is to improve through breeding. Examples of highly heritable traits include fat or protein percentage of milk
- Although breeding for highly heritable traits makes quick genetic progress, traits of low heritability can still be improved through breeding. Many such traits (for example, fertility or cell counts) tend to get worse as milk production goes up, which adds importance to selecting for these health and fitness traits
- As our understanding of environmental interactions improves, it is possible to improve the heritability of traits. Thus, although they will still continue to be passed down the generations to exactly the same extent, our observation of this process can improve

What genetic progress has been made?

Selection for increased milk production has been happening for many decades and the resulting genetic improvement has positively impacted milk yields across the UK dairy herd. Average production in the Holstein has increased by 4,500 kg since the 1980s to 9,500 kg in milk recorded herds today. Although much of this increase is attributable to improved management, better genetics have played an important part.

At the same time, improvement has been made in cow conformation, with many functional traits, including Feet and Legs and Udder, now vastly improved compared with those traits in the past.

For many producers, the focus has since moved to include health and fitness traits as well as production and type. This has been monitored closely for at least 30 years.

Highlights

- Throughout the 1990s, when the industry selected heavily for production, lifespan declined. However, in the past two decades, genetic selection has led to considerable improvement in lifespan
- Fertility has similarly improved, having also declined through selection for production in the 1990s. Since being included in £PLI (2007), it has started to rapidly recover and AHDB predicts that by 2024 the UK's average calving interval will be back to the levels of the mid-1990s
- SCC has shown a similar pattern of improvement since it was included in £PLI in the early 2000s. It also suffered as an unintended consequence of selection for milk production

How to continue improving herd genetics

Step 1
Identify the right economic index for your calving pattern – £PLI, £SCI, £ACI.

↓

Step 2
Shortlist the top 50% of bulls in the economic index you have selected in step 1.

↓

Step 3
Select bulls with individual traits that complement the improvement you would like to achieve – Lifespan and Fertility Index should be part of this.

↓

Step 4
Use a reasonable spread of bulls on the herd, based on their reliability.

Figure 17. How to continue improving herd genetics

Genetic indexes from other countries

Most dairying countries in the world produce their own genetic evaluations, but they are each calculated within a different population of animals and are expressed in a manner unique to that country. For these reasons, it is not possible to directly compare UK and foreign figures.

However, a technique called MACE (Multiple-trait Across Country Evaluation) has been developed to provide foreign-proven bulls with UK-equivalent figures.

An international organisation called Interbull carries out the MACE process. Interbull compares the performance of bulls in all the countries in which the bull has a proof. Where the information is limited, it might compare the performance of other family members, such as his sire, in each participating country. This process has improved the accuracy and stability of proofs and allows bulls with little or no UK information to be used with more confidence.

The UK and Interbull coordinate their work so that all the genetic indexes, from the UK and from Interbull, are combined and published in unison with all participating countries, three times a year.

Almost all traits (production, type, health and welfare and management PTAs) are now evaluated by Interbull and all known genetic defects or positive test results are published (see ‘Genetic defects’).

Selection indexes from other countries

Most other dairying countries also publish selection indexes similar to our own £PLI, £SCI and £ACI. Since they are based on different economic conditions and breeding priorities and are designed for use in different cattle populations, they have limited relevance in the UK. Therefore, they should not be used to select bulls for UK farming conditions.

Genetic defects

Several genetic defects can cause problems in dairy breeding. Many of these have been known and understood for several years, but some of the so-called haplotypes (DNA sequences at specific locations on a chromosome that are transmitted together as a group) have only been discovered since the advent of genomic evaluations.

Such discoveries have helped solve some problems that have perplexed dairy farmers, vets and scientists for many years.

Common genetic defects

- **Complex vertebral malformation (CVM)** – causing stillbirths or, more commonly, abortion or foetal reabsorption before 260 days of gestation
- **Brachyspina (BY)** – causes abortion and stillbirth, shortened spinal cord, long legs and abnormal organs
- **Fertility haplotypes (e.g. HH1, HH2, HH3, HH4, HH5 and HH6)** – causing lower fertility associated with early embryonic death or abortions. Fertility haplotypes exist in the Holstein, Jersey, Ayrshire and Brown Swiss breeds
- **Holstein cholesterol deficiency (HCD)** – causes a lack of cholesterol in the animal's cells, usually leading to death within months. Heterozygous animals (those that inherit only one copy of HCD) also have reduced levels of cholesterol and compromised health

These conditions are mostly caused by recessive genes, so they tend to be expressed only when two carriers of the defective gene are mated together (i.e. when the resultant animal is homozygous). The genetic defect occurs in about one in four of the offspring.

Most AI sires are tested and any found to be carrying the defective gene are identified by suffixes, for example: *CVC, *BYC, *HH1C and *CDC. Matings between carrier parents should be avoided to prevent any risk of expressing a genetic defect.

Only a tested free coding (*CVF, *BYF, *HH1T and *CDF) indicates that the animal is definitely not a carrier. No coding simply means that no notification of a test result has been received, so the animal may or may not be carrying the defect.

Table 7. International coding for main genetic breed defects

Defect	Carrier code	Tested-free code
CVM	*CVC	*CVF
Brachyspina	*BYC	*BYF
Fertility haplotypes found in Holstein (HH), Jersey (JH), Ayrshire (AH) and Brown Swiss (BH)	*HH1C *HH2C *HH3C *HH4C *HH5C *HH6C	*HH1T *HH2T *HH3T *HH4T *HH5T *HH6T
Holstein cholesterol deficiency (HCD)	*CDC (Heterozygous) *CDS (Homozygous)	*CDF
Bovine leukocyte adhesion deficiency (BLAD)	*BLC	*BLF
Mule foot	*MFC	*MFF
Deficiency of uridine monophosphate synthase (DUMPS)	*DPC	*DPF
Factor X1	*XIC	*XIF
Citrullinemia (CIT)	*CNC	*CNF
Polled	*POC (Heterozygous Pp) *POS (Homozygous PP)	*POF *POR (not tested)

Genetic indexes in practice

Breeding priorities

The most profitable cows of any herd will be its most efficient production cows. The breeding priorities of commercial dairy farmers must be driven by profitability, with milk, fat and protein production at its foundation regardless of the farming system, although the balance of these will vary according to milk contract. However, it is generally considered that breeding for total milk solids is the best long-term policy for most UK herds.

Breeding solely for production is both unsustainable and unethical, and should therefore be accompanied by breeding for traits associated with animal health, fertility, welfare, lifespan and efficiency.

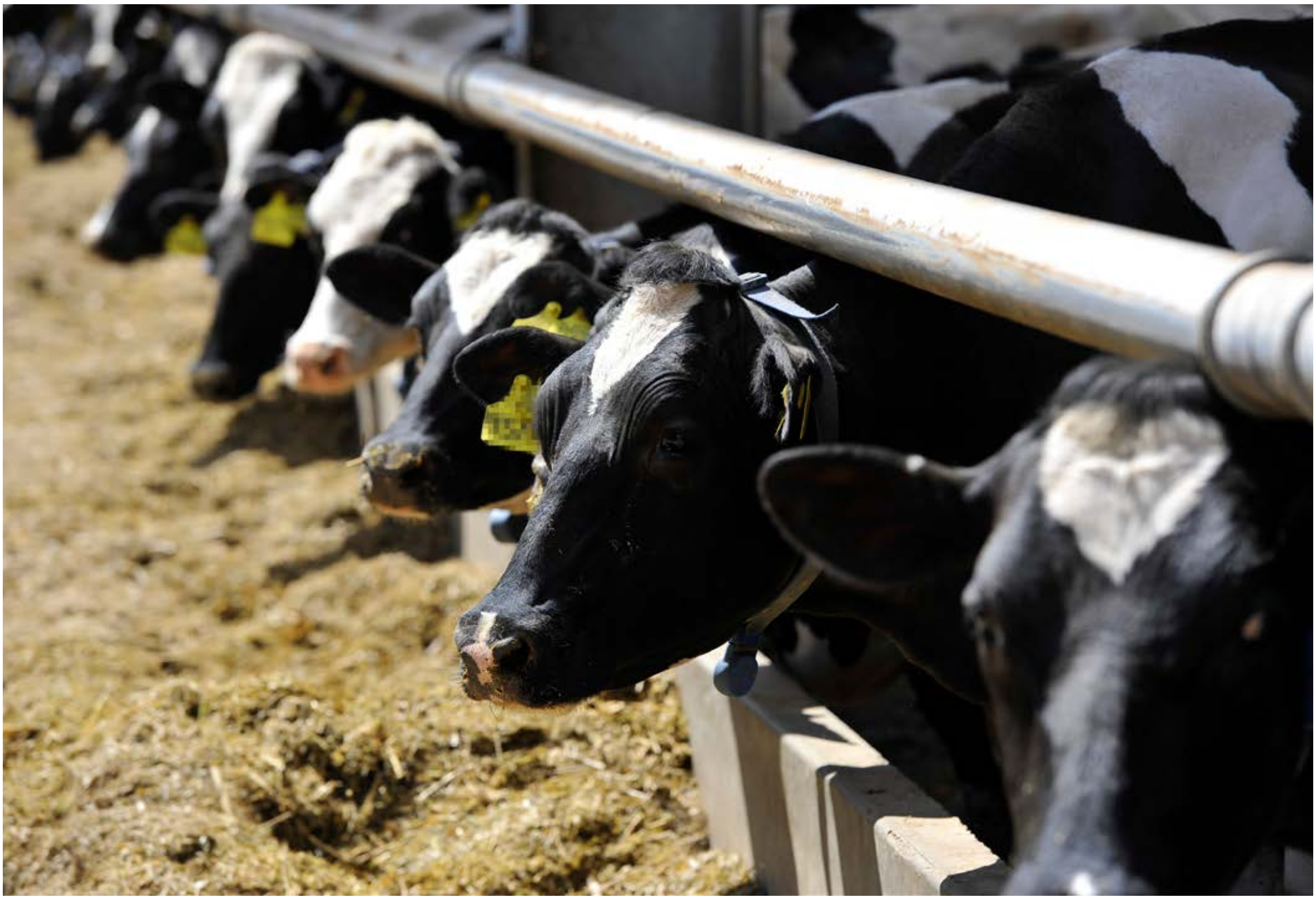
Creating the right balance of selection traits in a breeding programme leads to greater sustainability, consumer acceptance and long-term profitability. By breeding for a cross-section of traits, milk production can be sustained over many lactations and at low cost.

Selection indexes (see £PLI, £SCI and £ACI) have therefore been developed to encompass all of the traits that will help the dairy producer to reach this goal. In fact, non-production traits account for roughly two-thirds of each of these economic indexes, with only one-third accounted for by production. This highlights the importance of breeding for animal longevity.

Within the two-thirds of £PLI, £SCI and £ACI are the following sub-indexes:

- **Survival** (comprising cow Lifespan Index and Calf Survival Index)
- **Fertility** (comprising Fertility Index – see components in Fertility section)
- **Udder health** (comprising Somatic Cell Count Index, Mastitis Index and Udder composite)
- **Leg health** (comprising Lameness Advantage and Feet and Legs composite)
- **Calving ability** (comprising both direct and maternal Calving Ease Indexes)
- **Efficiency** (comprising maintenance costs based on body weight and Body Condition Score; soon to include feed efficiency data)

Using one of these economic indexes as a primary selection tool is therefore recommended. For year-round-calving herds, producers are advised to use £PLI; for spring block-calving herds, the £SCI has been developed; and for herds block-calving in the autumn, there is the £ACI (see 'Genetic indexes for selection').



Once sires have been shortlisted based on one of these economic indexes, the advice is to identify and study those individual traits that are particularly important to that herd. For example, the Lifespan and Fertility Index are likely to be a high priority for most herds, or a herd with a high somatic cell count might choose to focus on the bulls that transmit the greatest reduction in SCC. All of these traits are also included to a degree in the £PLI, £SCI and £ACI, but looking at individual components of each bull's index will assist with fine-tuning cattle for a particular herd.

Equally, some farming systems will demand a specific type of cow, such as medium sized, less angular animals for extensive farming systems. In others, beef from the dairy herd may be an important source of income, so they may include Dairy Carcase Index in their selection criteria. Other herds may derive a high income from pedigree livestock sales and will find specific type traits are in keen demand.

In reality, most herds' breeding programmes should involve improving a combination of traits to produce animals that are more productive and functionally sound and that have the potential to enjoy high standards of health and welfare. Many bulls within the top 100 £PLI list (or £SCI/£ACI) should achieve this balance and it is not necessary to only focus on the fashionable top 10. However, it is also not advisable to use bulls that rank low on the economic index of choice for the reasons given above. For any herd, using a reasonable spread of bulls is the safest policy, rather than using one bull across the herd.

Prioritising selection indexes will maximise lifetime profitability.

- Only use bulls ranking in the top 50% of available sires on your chosen ranking (£PLI, £SCI or £ACI)
- Focus on the three or four key traits for which you want to make most gains (e.g. lifespan, fertility, mastitis, lameness)
- Select bulls best suited to your milk contract needs
- Select easy-calving sires for maiden heifers (direct Calving Ease >0.5)
- Look for the type traits your herd most needs to improve
- Use a mix of sires to reduce risk (either three proven sires or eight genomic young sires)

Computerised mating programs

There are many computerised or web-based mating programs available from commercial companies involved in selling bull semen or from independent organisations offering this service. Such services will usually take account of your own breeding priorities and make recommendations based on the principles of complementary breeding.

They can also prevent the continuation or introduction of known genetic defects and avoid excessive inbreeding (see 'Inbreeding, outcrossing and hybrid vigour'). While such packages can play a useful part in making breeding decisions, it is important to establish whether the program bases its recommendations on both type and production data and to ensure they are based on the established scientific principles of genetic improvement. Bulls from multiple companies should be included in the recommendations, rather than those from just one stud.

Inbreeding, outcrossing and hybrid vigour

Inbreeding occurs when animals that are related to each other are mated, resulting in the concentration of genes. Although, historically, a certain level of concentration may have been considered desirable so as to 'fix' a trait to help ensure it is consistently expressed down the generations, too much inbreeding is not recommended as it can lead to losses in production, fertility, longevity and general vigour. Figure 18 displays a relationship diagram, showing possible inbreeding potential.

The level of inbreeding increases when the relationship between the animals is closer. For example, a father bred to his daughter or a brother bred to his full sister would lead to 25% inbreeding. This is considered excessive. Commercial producers are advised to carefully consider matings that lead to an inbreeding level greater than 6.25%.

In this example, the bull is inbred to ancestor B and the cow is inbred to both H and J. However, since ancestors B, H and J are not common to the potential progeny of this mating, they do not affect its level of inbreeding.

Ancestors D and G are common to both the bull and cow so are the only ancestors to contribute to the inbreeding from this possible mating.

- Too much inbreeding can be addressed by outcrossing to an unrelated animal. Assuming high genetic merit sires are used, improvements in production, fertility, longevity and general vigour are likely to result
- Improvement is attributed to hybrid vigour (or heterosis) rather than actual genetic gain and this benefit therefore does not transmit on to progeny
- Good hybrid vigour gives the outcrossed animal better performance than the average of its parents (but rarely better than the best parent). In the extreme, it is exploited by crossing two entirely different breeds

Remember!

Crossbreeding can lead to loss of uniformity. Improvements attributed to hybrid vigour are not passed down the generations; it raises questions for breeding subsequent generations and it should be taken as an option with thought to defined breeding goals and subsequent generations. Just as with purebreeding, the continued evaluation and use of high genetic merit purebred bulls of the main breeds involved remains essential to ensure long-term progress in any crossbreeding regime.

Monitoring inbreeding

AHDB Dairy now routinely publishes inbreeding percentages for all cows included in the Herd Genetic Report. It has also produced an Inbreeding Checker, which identifies how closely related any sire is to any heifer or cow in a herd. This allows dairy producers to check the inbreeding level of any proposed mating from the entire database of dairy sires listed on the AHDB website.

Both the Herd Genetic Report and Inbreeding Checker are available free of charge from AHDB to any herd that is fully milk recording in the UK. To request your login details, please contact **dairy.breeding.evaluations@ahdb.org.uk** with your trading name, address and milk recording number.

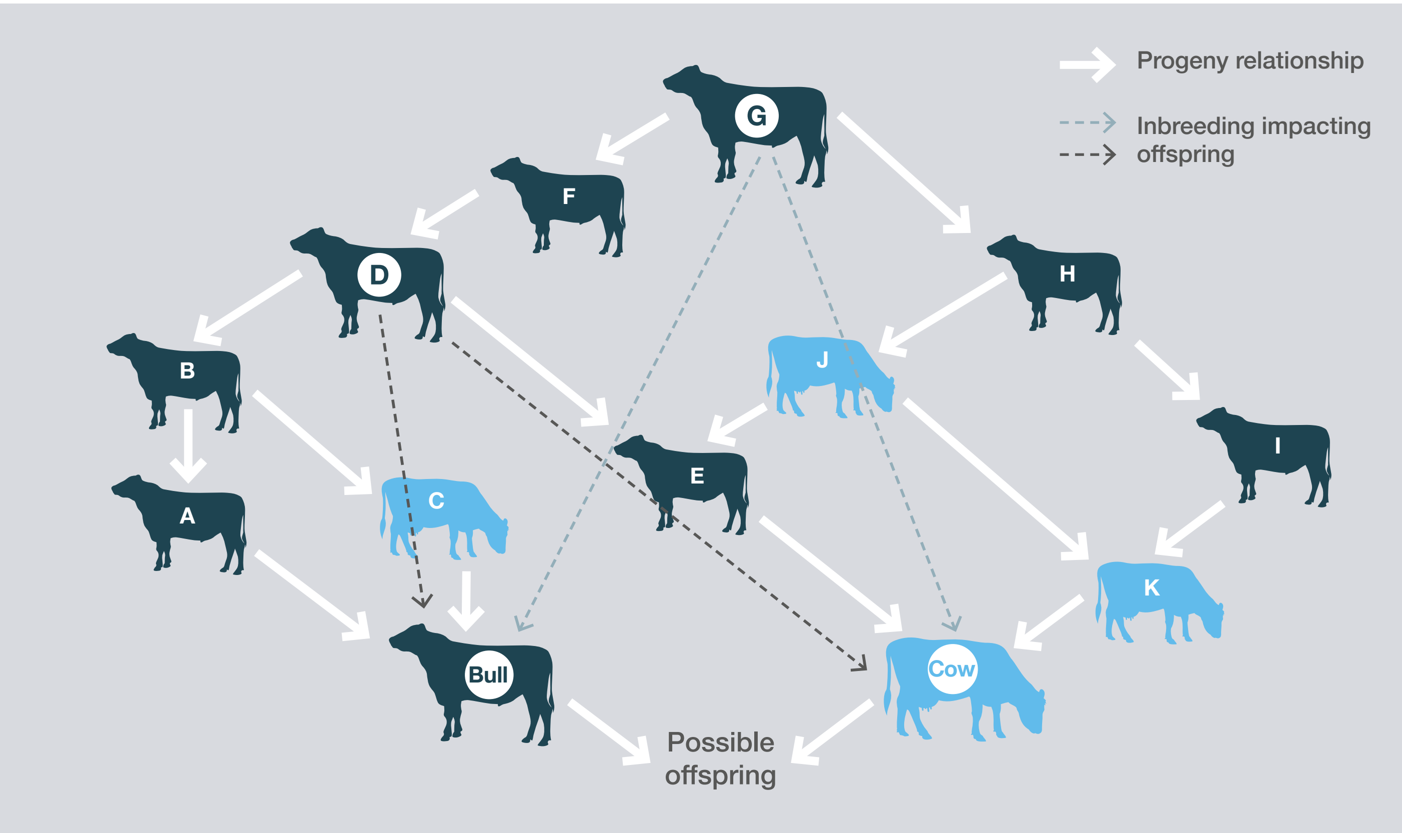


Figure 18. Relationship diagram describing inbreeding of potential offspring

Frequently asked questions

Q. Can male and female PTAs be compared with each other?

A. Yes. In the UK, we publish male and female PTAs on the same scale.

Q. Can I compare a Friesian with Holstein proof or a Jersey with a Guernsey?

A. On the £PLI rankings, each breed is expressed against its own genetic base or average and with its own breed variation. Since these are not the same, they cannot be compared. However, the £SCI and £ACI rankings are expressed on the same across-breed base so that figures for either of these indexes are comparable across the breeds. The £SCI and £ACI are different indexes so are not comparable with each other.

Q. Why can't I compare an April proof with one from August if they're compared with the same average?

A. Although averages are only recalculated every five years, every bull proof is updated in every proof run (three times per year). Comparing across runs would mean you are comparing old against new data. This should be avoided.

Q. Why is a maintenance cost included in the three economic indexes – £PLI, £SCI and £ACI?

A. Farmer experience and research indicate the greater cost of feeding a larger cow than a smaller one. If two cows are identical in every other way (production, health, fertility, etc.), then the smaller cow, which costs less to feed, will be more profitable and have a higher economic index. Many producers grazing their cows – in spring calving systems, in particular – also prefer a smaller cow for practical reasons.

Q. Can the £PLI, £SCI and £ACI be compared?

A. No. The indexes have been designed for different farming situations. The £PLI is a 'within-breed' index, while the £SCI and £ACI are calculated across breeds, which gives them a completely different average or base.

Q. Functional type is important in grazing systems. Why isn't there more emphasis on this in the £SCI?

A. Functional type forms part of £SCI, just as it does with £PLI. Udder, health and conformation and Feet and Legs are included, but it is important to note that these traits also strongly correlate with some of the other components of the index, including lifespan. This means they are more important than they might seem at first glance.

Q. Why have the £SCI and £ACI been developed as across-breed indexes?

A. £SCI and £ACI are presented as across-breed indexes because this is considered to be the most useful format for block-calving herds. Many of these herds use more than one breed, either as purebred or crossbred animals, so it is important to be able to compare the genetic potential of bulls from different breeds against one another.

Q. Which index should I use if I have a split block-calving system that calves in both spring and autumn?

A. £SCI and £ACI have been formulated specifically for herds which block-calve in spring and autumn respectively, both within a tight block of 12 weeks or less. Herds which have two such calving blocks – one in spring and the other in autumn – are advised to use the £SCI and £ACI for each defined block, respectively. Herds calving over a more protracted period or all year round are advised to use £PLI as their primary selection index. Each of these indexes has been formulated to reflect different feed costs and milk prices for the respective systems.

Q. Why should I worry? All bulls are pre-screened!

A. It is true that AI companies only market their best bulls and bulls that are poor in every area would not be brought to the market. However, all bulls have strengths and weaknesses, just like all herds. It is important to find those that are suited to your particular needs. There are over 1,200 daughter-proven bulls and nearly 900 young genomic bulls available to choose from, with many different qualities, so an ability to understand their proofs allows more informed breeding decisions to be made.

Q. Will a computerised breeding package make suitable choices for me?

A. Different packages do different things. The best will include both production and type and take account of health and fertility traits, genetic defects and inbreeding. Make sure that all bulls are included and not just those from a particular company. If these criteria can be met, then these programs can be good management tools.

Q. I don't have time to study the figures; what shortcuts can I take?

A. If you have time for nothing else, select bulls on £PLI/£SCI/£ACI and consider complementary breeding through the use of a computerised mating program.

Q. Will crossbreeding speed up the genetic progress of my herd?

A. The beneficial effects of crossbreeding are not brought about through genetic improvement but as a result of hybrid vigour. This is not passed down the generations and therefore does not result in long-term genetic progress.

Q. Can I compare proofs from another country with UK proofs?

A. No. Always use UK proofs. Each country's proofs are published on a different scale, so make sure you only use those published on the UK scale.

Q. My cows already have enough production. Shouldn't I just focus on type?

A. Production efficiency is still important and should remain an essential part of your breeding decisions. However, use the opportunity to select other traits you want to improve, such as lifespan, fertility, somatic cell count or specific type traits.

Glossary

Autumn Calving Index (£ACI) – An across-breed genetic ranking index that represents the additional profit a high £ACI bull is expected to return from each of its milking daughters over her lifetime compared with an average bull of £0 ACI. The £ACI is specifically designed for herds calving in a block in autumn, which experience different costs of production and milk prices from spring- or year-round- calving herds.

Allele – A form or version of a gene. For example, on its coat colour gene, an animal could have the allele for red or black or one of each allele. If it has two of the same alleles, it is homozygous. If it has two different alleles, it is heterozygous.

CRISPR-Cas9 – A specific genome editing system that enables the insertion or deletion of a precise section of an animal's genome. The advent of CRISPR-Cas allowed genome editing to be carried out with far greater precision and efficiency than ever before. At the time of going to press, it cannot be undertaken commercially in the EU.

DNA – Deoxyribonucleic acid is a genetic 'blueprint' containing the instructions for life, including instructions for growth, development, function and reproduction. It is a molecule comprising two chains that coil around each other to form a double helix.

Dominant allele – An allele that masks the expression of a recessive allele on the same gene. A classic example in cattle breeding is the polled allele, which is genetically dominant to that for horns.

Estimated breeding value (EBV) – A genetic index equivalent to double the PTA value.

Gene – The basic unit of heredity within animals' cells, which codes for a particular trait to take a particular form. It comprises a sequence of DNA. Each animal has two copies of each gene: these can either be the same (homozygous) or different (heterozygous). See also 'Allele'.

Gene editing – Technologies that allow genetic material to be added, removed, or altered at particular locations in the genome. Also called genome editing. At the time of going to press, it cannot be undertaken commercially in the EU.

Genetic base – The average genetic merit of animals born in a given period, which is used as a reference point for the expression of PTAs. The current UK genetic base is the average genetic merit of cows born in 2015. Because it was reset in 2020, we sometimes use the expression PTA2020.

Genetic index – Generic term for a PTA.

Genetic merit – Generic term for a genetic index.

Genetic modification – The process of altering an organism's genetic make-up. This has been done indirectly for thousands of years by controlled, or selective, breeding. However, it has more recently been associated with the insertion of foreign genetic material into an organism. At the time of going to press, such genetic modification cannot be undertaken commercially in the EU.

Genetics – The study of the mechanisms of hereditary transmission and the variation of inherited characteristics. Also used to describe the complete genetic make-up of an animal, which determines its characteristics and performance.

Genome – The entire complement of the animal's genetic material.

Genomic selection – The selection of animals through PTAs derived from DNA profiles based on genotype.

Genomics – The study of gene structure, arrangement, regulation and expression.

Genotype – The genetic make-up, as distinguished from the physical appearance/performance (phenotype), of an animal.

Heritability – An estimate of the degree to which a trait is passed down the generations. Expressed on a scale of 0 to 1 (or 0% to 100%).

Heterosis – Increased performance arising from the crossbreeding of genetically different animals, as measured by the extra improvement over the average performance of the parents. Also called hybrid vigour.

Heterozygous – See 'Allele'.

Homozygous – See 'Allele'.

Hybrid vigour – See 'Heterosis'.

Inbreeding – Inbreeding arises when individuals that are related are bred together. The level of inbreeding increases the more closely related the individuals are.

Interbull – International Bull Evaluation Service, responsible for the international comparison of dairy genetics.

Linear traits – Traits measured on a scale from one biological extreme to the other. The resulting numerical description indicates the degree and not the desirability of the trait. Examples are stature, foot angle and teat length.

MACE – Multiple-trait Across Country Evaluation is the method used by Interbull to calculate international genetic evaluations. See also 'Interbull'.

Pedigree Index – Genetic index calculated from half the sire and half the dam index. Also widely called Parent Average.

Phenotype – The observable physical traits of an animal (such as stature or milk yield), as determined by both its genetic make-up and environmental influences.

Predicted Transmitting Ability (PTA) – A measure used to express the genetic potential of an animal as a parent. The value indicates the superiority (or inferiority) of an animal compared with an average genetic base. See also 'Genetic base'.

Profitable Lifetime Index (£PLI) – The UK's main national breeding index, which is expressed as a financial index designed to maximise farm profitability from a combination of traits. This index is expressed as profit per lifetime.

Progeny testing – Traditionally, the primary way of establishing the genetic value of bulls through structured comparison of the performance and appearance of their daughters in a variety of herds.

Proof – Colloquial term for a genetic evaluation.

Recessive allele – A gene, the expression of which is masked by the presence of a dominant partner. Only when two copies of the recessive gene are present will the trait be expressed.

Reference population – A population (also called a 'training population' or 'predictor population') of several thousand animals, whose actual performance and genotype are compared in order to establish relationships between the two. From these relationships, a SNP-key can be devised, leading to the calculation of a genomic index.

Reliability – An indication of the likelihood of a PTA being a true estimate of an animal's genetic value. Values fall between 10% and 99%.

Selection index – An overall score of genetic merit combining information from several measured traits. Often used as a ranking index. Examples are £PLI, £SCI and £ACI.

Single Nucleotide Polymorphism (SNP) – A measure of genetic variation at one position on a strand of DNA, which can be used to describe an animal's genotype.

SNP-chip – A simultaneous measure of many different SNPs.

SNP-key – An equation that translates an animal's genotype (as measured by the SNP-chip) into a genetic index, such as a PTA. SNP-keys are specific to a cattle population and trait.

Spring Calving Index (£SCI) – The £SCI is an across-breed genetic ranking index and represents the additional profit a high £SCI bull is expected to return from each of its milking daughters over her lifetime compared with an average bull of £0 SCI. The £SCI is specifically designed for spring block-calving herds, making extensive use of grazed grass.

Test Day Model – The method used to calculate production PTAs from individual milk test day records.

Where to find the information

Bull proofs

Bull proofs are published three times a year in April, August and December. They are always available in the breeding and genetics section of the AHDB website (ahdb.org.uk/dairy) and are printed widely in the national press.

The AHDB website allows you to rank bulls on many different criteria; select your breed and then the type of report that you wish to view.

Herd Genetic Report and other online tools

All milk recording farms can obtain a genetic report for their herd. These reports give PTAs for all animals in the herd after each proof run. In addition to individual reports, this tool also contains a herd summary, herd standards table and herd sire list.

The herd summary gives average PTAs by lactation number and age group for youngstock, providing a snapshot of genetic progress on production as well as lifespan, udder health, fertility and maintenance. The herd standards table allows herds to be benchmarked against the national herd for each trait listed above, and a drop-down menu allows selection of which animals to compare: milking herd, youngstock or specific lactations. Finally, the herd sire list gathers the genetic proofs of bulls with daughters milking in the herd, easily identifying daughters who may require corrective mating to address poor traits or identify genetics which have thrived in the herd. Inbreeding coefficients for each animal in the herd are also included.

Herd Genetic Reports can be requested from the AHDB website or by contacting the Dairy.Breeding.Evaluations@ahdb.org.uk with your trading name, address and milk recording number.

The Breeding Trait Selector can be used to narrow down and prioritise traits for your breeding goal based on your current herd performance and herd aspirations.

The Breeding Season Semen Calculator can be used to estimate the quantity of semen required (dairy, beef or sexed) for your upcoming breeding season.

National averages

You can compare your own herd's performance with national figures through the AHDB website and Herd Genetic Report. Within the Herd Genetic Report, the Breed Standards section indicates where your herd sits for specific genetic indexes compared with the national herd.

Industry contact details

GB industry contact details can be found on the AHDB website where they are kept up to date.

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