Understanding Genetics
and the Sire Summaries

HF
HOLSTEIN FOUNDATION

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"Developing Future Leaders for a Vibrant Dairy Community"

Understanding Genetics and the Sire Summaries

The goal of this workbook is to give young people a basic understanding of dairy cattle genetics and how it applies to their animals. It also includes a section about the genetic evaluation system and a guide to reading and understanding the Holstein Association USA Sire Summaries.

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Basic Biology of Genetics

What color eyes do you have? What is your hair color? How tall are you? How fast can you run? If you have siblings, you know that you are all different in many ways, but you can also probably notice some similarities in your appearance and abilities. It's also likely that some of those similarities can be seen in your parents. Many of those traits can be credited, at least in part, to your genetics. Through this workbook we will explain the science behind genetics and explore some real world, practical applications.

First, let's look at how genetic information is contained in our bodies. The components that make up genetic information are very similar, whether you're studying humans, cattle, or any other organism. Every living thing is made up of millions of cells. A **cell** is the smallest structural unit of an organism that is capable of independent function. Looking inside of a cell, you will find a structure known as the **nucleus**, which serves as the nerve center of cellular activity.

All of an animal's genetic information is housed within the nucleus of a cell, in the form of **chromosomes**. Each species of animal has a specific number of chromosomes. For example, humans have 23 pairs of chromosomes (for a total of 46), and cattle have 30 pairs (for a total of 60 chromosomes). Of those, 1 pair are the sex chromosomes (determine whether the calf is male or female, plus some other physical characteristics), and the other 29 pairs are "autosomal chromosomes" and determine the rest of the body's makeup.

Chromosomes are made up of many strands of **DNA (deoxyribonucleic acid).** DNA are "ladder-shaped" chains of information formed by complementary base pairs. This ladder appears "twisted," a shape known as a "double helix."**Genes**, the basic units of inheritance, are specific portions of a cell's DNA. Each gene on a chromosome has a corresponding gene in the same location, or **locus**, on a corresponding chromosome, and that corresponding gene is known as an **allele**. Each gene pair (or set of alleles) codes for a specific trait, such as whether or not a cow has horns, or what color hair they have.
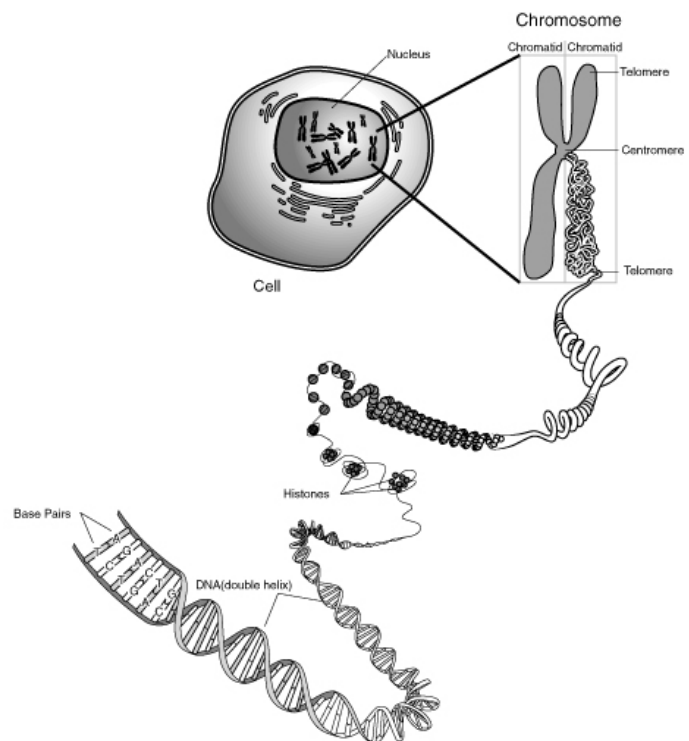
KEY GENETIC TERMS

Nucleus: Part of the cell (located in the center) that contains an organism's DNA.

Chromosome: A "packaged bundle" of genes that determine the physical characteristics of an organism. Dairy cattle have 30 pairs of chromosomes (for a total of 60).

DNA (and complimentary base pairs): Nucleic acid that is arranged in a double helical structure. DNA strands contain numerous genes, which are part of a larger element, the chromosome.

Gene: A distinct portion of a cell's DNA that determines a portion of an animal's appearance, performance, behavior and other characteristics.

Allele: One component of the gene pair, which is located at a given locus, or position, on the chromosome.

Locus: Region of the chromosome where a particular gene is located.

Expression of Genes

When discussing different traits of animals and how genes are expressed and measured, there are a few more terms to learn. First, understand the difference between an animal's genotype and phenotype. The **genotype** is the actual genes an organism, such as a dairy cow, possesses for a given trait. The **phenotype** of an organism is physical characteristics that you can observe or measure; an individual's actual performance, such as a 305-day milk production record or type classification score.

When looking at phenotype, there are two types of traits — qualitative and quantitative traits. **Qualitative traits** are generally those controlled by one pair of genes, where a given genotype will typically result in the same phenotype each time. Examples of qualitative traits include gender, hair color, and horns in cattle. **Quantitative traits** are controlled by many genes. Each gene generally has a relatively small influence on the expression of a trait, but collectively, these genes can have large effects. Examples of quantitative traits include milk production, milk component percentages, and physical traits such as stature and rump angle. Quantitative traits can be significantly influenced by an animal's environment.

While gene interactions can be very complex and may seem confusing, many traits, including most qualitative traits, are controlled by single genes. The alleles, or version of the gene, an animal inherits will determine its phenotype. At each locus of a chromosome, there are two alleles for a specific trait. In cases where a trait is controlled by a single gene, such as coat color or horns in dairy cattle, alleles are labeled as **dominant** or **recessive. Dominant traits** will be expressed when at least one version of the dominant allele is present; dominant alleles are typically symbolized by capital letters, such as an "AA" genotype. **Recessive traits** will only be expressed when two copies of the recessive allele are present; recessive alleles are typically symbolized by lowercase letters, such as an "aa" genotype.

Organisms inherit two versions of an allele from their parents (one allele from each parent). In simple cases of dominant/recessive genes, the pairing of alleles in a genotype can occur in three ways:

- **<u>Homozygous</u> dominant** means that both alleles were inherited in the dominant form, such as "AA." To help you remember, the prefix "homo-" means "same."

- **<u>Homozygous</u> recessive** means that both alleles were inherited in the recessive form, such as "aa."

- **<u>Heterozygous</u>** means that one dominant allele was inherited from one parent, and one recessive allele was inherited from the other parent, written as "Aa." To help you remember, the prefix "hetero-" means "different."

Sometimes an animal's genotype is not easily determined just by looking at its phenotype – animals that are expressing a dominant trait can either be homozygous for that trait (have two copies of the dominant allele), or heterozygous for the trait (one copy of the dominant allele and one copy of the recessive allele).

Animals that are heterozygous for recessive traits are commonly called "carriers" because, even though they don't express the recessive gene, they still carry it and may pass it on to their offspring. Looking at an animal's pedigree can sometimes help determine whether or not an animal is a carrier or homozygous. If a question exists after looking at the pedigree, consult with your breed organization to see if a genetic test could be performed to determine the animal's genotype for the trait.

Recessive traits can have a positive impact, negative impact, or be neutral, having neither a positive or negative impact on an animal. Neutral or positive traits would include traits such as coat color. Negative traits would be heritable defects that may cause poor health or death. Genetic ailments such as this are generally controlled by one gene.

MAKING SENSE OF THE GENETIC PUZZLE

A **Punnett Square** is a simple way to predict the possible genetic combinations from the mating of two individuals. To use a Punnett Square, draw a box with four squares inside of it. Across the top, list the gene combination of the sire (father), and down the left side, list the gene combination of the dam (mother). Then, bring one value from each parent into the corresponding box within the square. Looking at the results will give you the probability of offspring born expressing the trait you are looking at.

A Punnett square looks like this:

This example looks at mating two animals that are both heterozygous for trait "R", so their genotypes are both "Rr."

	R	r
R	RR	Rr
r	Rr	rr

1/4 (or 25%) Homozygous Dominant (RR)
2/4 (or 50%) Heterozygous (Rr)
1/4 (or 25%) Homozygous Recessive (rr)

There are many ways that dominant and recessive genes can impact an animal's phenotype, including simple dominance, which can explain many common traits in dairy cattle. Other types of dominance include incomplete dominance and codominance, and more clear-cut examples can be found in the plant kingdom than in dairy cattle. If you're interested in learning more about different types of inheritance, ask a parent or teacher to help you to do some research. Some example search topics could include Gregor Mendel, Laws of Mendelian Inheritance, incomplete dominance, codominance. Genetics is a very interesting topic and many resources are available online to help you learn more.

LEARN

What does this all mean and how is it useful? Turn to page 27 to complete the case study exercises on bovine coat color and the polled gene and learn more about using Punnett Squares to determine phenotype from genotype.

RECOGNIZED RECESSIVE & DOMINANT TRAITS & CONDITIONS IN HOLSTEIN CATTLE

All dairy breed associations recognize recessive and dominant traits and conditions for their breed, and label them with specific codes on animals' pedigrees and genetic evaluations so information is readily available to breeders. Few dominant traits are recognized in Holstein cattle. The polled trait is one example of a dominant trait; polled cattle naturally never grow horns, while non-polled cattle develop horns normally, as most dairy producers are familiar with.

More recessive than dominant traits are recognized and labeled in the Holstein breed. Most are known as undesirable recessives, being defects that, if inherited in a homozygous form, may cause poor health and/or death. These qualitative traits are generally controlled by only one gene, so if the animal is homozygous for that recessive allele, the undesirable condition is expressed.

Not all recessive traits are negative. For example, red coat color in Holsteins is a recessive trait and is sometimes selected for by breeders desiring red and white Holsteins. The following table lists some common gene codes found on Holstein pedigrees. Seeing this code for a recessive trait on an animal's pedigree would mean that they are a carrier for the trait (do not express the actual trait). Seeing the code for a dominant trait would mean that the animal expresses the trait, as they only need one allele to express it.

Holstein Gene Codes			
BL	Bovine Leukocyte Adhesion Deficiency (BLAD)*	PO	Observed Polled**
BY	Brachyspina*	PC	Tested Heterozygous Polled**
CD	Cholesterol Deficiency*	PP	Tested Homozygous Polled**
CV	Complex Vertebral Malformation (CVM)*	RC	Carrier of Recessive Red Coat Color*
DP	Deficiency of Uridine Monophosphate Synthase (DUMPS)*	B/R	Black/Red Coat Color*
MF	Mulefoot (Syndactyly)*	DR1	Tested Heterozygous for Dominant Red**
		DR2	Tested Homozygous for Dominant Red**

Note: This is not an exhaustive list.   ** denotes a recessive trait*   ***denotes a dominant trait*

If an animal is tested free of a trait (meaning they do not carry any alleles for the trait), that result is also recorded and published on pedigrees and genetic evaluations. If the animal is not a carrier, they cannot pass those genes down to the next generation.

Tested-Free Codes			
TL	Tested free of BLAD	TD	Tested free of DUMPS
TY	Tested free of Brachyspina	TM	Tested free of Mulefoot
TC	Tested free of Cholesterol Deficiency	TP	Tested free of the Polled Condition (horned)
TV	Tested free of CVM	TR	Tested free of Recessive Red Coat Color

Making Genetic Progress

Now that you understand the basic biology of how genetics work, the next important concept to understand is genetic change and the factors which influence it. The primary goal of most dairy producers is to maximize the profitability of their herd. One way to achieve this goal is to have genetically superior cattle. As an important foundation of a profitable herd, genetic change is permanent and accumulates over time.

Genetic change is dependent on four major factors:

1. **Accuracy of Selection** refers to a breeder's ability to select animals that truly are genetically superior for a given trait, and is dependent on evaluation techniques, phenotypes and heritability.

2. **Selection Intensity** is dependent on the proportion and quality of animals kept as parents (breeding stock) for the next generation. The more intense the selection, the more superior a group of animals is compared to the overall population.

3. **Genetic Variation** indicates the relative differences among animals that are controlled by genetic factors. It is a function of the heritability of a trait. Genetic variation can be greatly influenced by things such as inbreeding, outcrossing, or crossbreeding, which we will discuss more later in this section.

4. **Generation interval** is the average age of a parent when offspring are born.

In general, genetic change can be predicted by the following equation, which clearly shows the relationship between factors.

$$\frac{\text{Accuracy of Selection } \times \text{ Selection Intensity } \times \text{ Genetic Variation}}{\text{Generation Interval}} = \text{Genetic Change}$$

Heritability is the proportion of variation in a trait due to genetic factors, and is measured in numbers ranging from 0 to 1.0. The higher the number, the more heritable the trait is, and the faster one can make genetic progress by selecting for that trait. Traits with very low heritability, those less than 0.1, do not offer much opportunity for rapid improvement.

Heritabilities of Holstein Association USA Type Traits

Trait	Heritability	Trait	Heritability	Trait	Heritability
Stature	0.42	Rear Legs-Rear View	0.11	Udder Depth	0.28
Strength	0.31	Foot Angle	0.15	Front Teat Placement	0.26
Body Depth	0.37	Feet & Legs Score	0.17	Rear Teat Placement	0.32
Dairy Form	0.29	Fore Attachment	0.29	Teat Length	0.26
Rump Angle	0.33	Rear Udder Height	0.28	Final Score	0.29
Thurl Width	0.26	Rear Udder Width	0.23		
Rear Legs-Side View	0.21	Udder Cleft	0.24		

For example, imagine a cow in your herd needs improvement in both foot angle and teat placement. With a heritability for foot angle of 0.15 and a heritability for front teat placement of 0.26, which trait could you expect to make more progress on through selection? The answer is front teat placement, because of the higher heritability. Both the heritability of a trait and the relative economic relationship of the trait to overall profitability should be considered when determining which traits to incorporate into a breeding program.

A final concept to understand with genetic progress is that correlations exist between some traits, meaning that selecting for one trait may result in genetic changes in other traits. This occurrence is known as **correlated response**, and the correlations may be positive or negative. Mathematically, correlations range from -1 to 1; the closer a correlation is to either -1 or 1, the more correlated the traits are, and more of the same genes likely control those traits. A value near 0 indicates that few of the same genes regulate the same traits.

Selection for an increase in one trait can result in an increase for another **positively correlated trait**. For example, a correlation of 0.4 exists between milk yield and dairy form. Selection only for increased milk yield will generally improve dairy form, even though no direct selection was made for dairy form.

On the other hand, selection for an increase in one trait can also result in a decrease in another **negatively correlated trait**. For example, a correlation of -0.35 exists between milk yield and fat percent. Selection for an increase in milk yield will generally result in a decreased fat percent. Correlations are important to look at in a breeding program to ensure you won't be sacrificing more than you are gaining if unfavorable correlations exist between traits.

LOOKING AT GENETIC VARIATION FROM TWO EXTREMES: INBREEDING & OUTCROSSING

As we discussed on the previous page, genetic variation is one of the factors that influence the rate of genetic change. Two breeding philosophies seen in dairy cattle breeding relate directly to genetic variation in a dairy cattle population – inbreeding and outcrossing.

Inbreeding is when two animals who are more closely related than the average population are mated. When related animals are intentionally mated to increase the frequency of the favorable genes found in a family, the practice is sometimes referred to as **linebreeding**.

While linebreeding is sometimes used to amplify the favorable genes in a family, the practice may also result in an increased concentration of any undesirable genes found in the bloodline, which may reduce health, vigor and growth and increase calf mortality.

Production and reproduction are also negatively impacted by inbreeding. For each one percent increase in inbreeding, a cow will, on average, lose 60 pounds of milk production annually. The table below shows average inbreeding levels for five major U.S. dairy breeds and how they have changed over time. Breeds with larger populations have lower inbreeding coefficients. However, as you can see, average inbreeding levels for all of the breeds have increased over the past decade, so inbreeding is something that today's breeders should be aware of and take into consideration when mating their cattle. It is important to remember inbreeding is on a mating-by-mating basis and can be corrected in one generation.

Breed	Average Inbreeding (%)		Change over the past decade
	2007	2017	
Ayrshire	5.76	6.80	+1.04
Brown Swiss	5.43	6.88	+1.45
Guernsey	6.24	7.63	+1.39
Holstein	5.32	7.16	+1.84
Jersey	6.77	7.78	+1.01

Source: Council on Dairy Cattle Breeding (CDCB), 2018

Outcrossing occurs when animals less related than the average population are mated. Outcrossing increases heterozygosity. A continuing challenge of any breed is to identify superior genetics from animals less related to the average breed population. **Crossbreeding** is a special form of outcrossing and occurs when two purebreds of different breeds are mated. The purpose of crossbreeding is to produce a generation that will have greater performance than expected, considering the genetic merit of the parents. The first generation of crossbred animals generally has increased health, vigor, and reproductive performance, a phenomenon known as **hybrid vigor**. However, crossbreeding is not a practice recommended by many breeders, because the offspring of crossbred cattle do not typically exhibit the same hybrid vigor as their parents. Crossbred dairy cattle are also unable to provide extra profit through marketing genetics.

LEARN Turn to page 31 to test your skills and see how well you understand how to influence genetic change!

The Impact of Environment

When someone clones an EX-95 point cow that has made 40,000 pounds of milk, they are guaranteed that her clones will also score EX-95 and make over 40,000 pounds of milk in a single lactation, right? They might, but it's not likely. When breeding cattle and working to make genetic progress, it's important to understand that an animal's performance isn't solely determined by their genetic makeup.

The environment where an animal is raised and lives has a large influence on things like milk production, stature, and other quantitative traits. In fact, environment contributes more to the difference among cows' milk production than genetics does; 75 percent of milk production performance is attributed to environment, while only 25 percent is based on genetic merit. **Environmental variance** is the term used to describe the difference in performance of animals that is caused by environmental effects. Genetic evaluations are designed to account for differences in production and type due to environmental variance.

Genetics & Technology

Genetics is an exciting field because it is ever changing. New discoveries and advancements are made each year that provide cattle breeders with additional tools to improve their herds and breed higher quality cattle. In this section we will cover some advanced technologies that have an impact on dairy cattle breeding today.

EMBRYO TRANSFER (ET)

Embryo transfer, commonly known as "**flushing**," is a tool that has been around for decades, and allows breeders to produce more offspring from their most superior animals in a shorter period of time.

Embryo transfer can be performed on any non-pregnant heifer (as long as she has reached sexual maturity) or cow, and is done by veterinarians or other trained professionals. The cow or heifer that is being flushed (known as the "**donor dam**") is given a series of hormone injections over a specific timeframe. This causes her to produce a higher than normal number of eggs, known as **superovulation**. Typically, five days after the first injection, the donor dam is bred. Six to eight days later, the embryos are recovered, by "flushing" them from the uterus. The ET technician examines the eggs under a microscope to determine the number and quality. The viable (fertilized) embryos are then either implanted into recipient animals (which will carry the calf and give birth to it, like a surrogate) that have been synchronized to be at the same reproductive phase as the donor dam, or they will be frozen and implanted at a later date.

Embryo transfer increases genetic progress as it increases selection intensity (using a smaller number of the most elite cows as dams of many offspring) and may decrease the generation interval (as heifers may be flushed sooner than they would normally be able to give birth to a calf).

IN VITRO FERTILIZATION (IVF)

In vitro fertilization is a process somewhat similar to ET, increasing in popularity as another option for breeders to get more offspring from their most valuable animals in a shorter period of time. "In vitro" is a Latin phrase, translating to "in the glass," meaning that with IVF, fertilization of the oocytes (eggs) literally occurs "in the glass" in the laboratory, in a petri dish or test tube, as opposed to embryo transfer, where fertilization of the eggs occurs inside the cow, and embryos are collected from the cow.

With IVF, unfertilized oocytes are harvested directly from the ovaries of the donor dam by a skilled veterinarian, a process called an aspiration. After being allowed to mature for 20-24 hours, the oocytes are then fertilized in a petri dish. Next, eggs are placed in an incubator to grow for a week, in a controlled environment designed to imitate the conditions of a cow's uterus. Finally, viable embryos are implanted into synchronized recipient animals, seven days following the recipient's standing heat, much like with embryo transfer. IVF embryos may be frozen, but the highest success rates are seen when they are implanted fresh.

While there are some similarities between IVF and ET, there are a few key differences. IVF may be performed on pregnant females (as well as open cows and heifers), typically in a window of the first 40 to 100 days of pregnancy. While the procedure is consider to be quite safe, there is a slight risk of pregnancy loss as the donor cow's reproductive tract is being handled. IVF can also be performed more frequently than ET work; oocytes may be collected as often as every other week (under a veterinarian's advisement), whereas most ET programs will collect embryos from the donor dams about every 60 days. Finally, since fertilization is taking place outside of the cow, one unit of semen may be used to fertilize eggs from several donor dams, or, semen from several different bulls can be used to fertilize eggs harvested from one elite cow.

GENOMICS

Genomic testing is the process of taking a DNA sample from an animal and analyzing it to determine which genes are present in the animal and may be expressed. It gives a much more accurate picture of an animal's genetic potential and increases the reliability of an animal's genetic evaluation over traditional methods.

Genomic testing became commercially available to the dairy industry in 2009 and has had a significant impact on the Holstein breed over the past decade, with hundreds of thousands of new Holsteins being tested each year. The most common types of DNA samples submitted for testing are hair (pulled from the switch) or tissue (punched from the ear with a special collection tube). The process of obtaining genomic results is very simple. First, take a DNA sample from the animal(s) you are interested in testing. Next, order your test from a genomic test provider, such as Holstein Association USA. Your test provider will send you information on how to send your DNA sample off to the laboratory, where the actual genotyping is performed. At the lab, the DNA is extracted and a genotype is compiled, which is then sent on to the Council on Dairy Cattle Breeding (CDCB) for analysis. The CDCB distributes genomic PTAs back to the test providers, who then delivers your results. The process typically takes three to five weeks from the time the DNA sample arrives at the lab until your results are returned.

Most bulls used for breeding purposes, including the vast majority of those used for artificial insemination, have been genomic tested and many breeders are testing their females so they can make more informed breeding and selection decisions. Here are some common uses for genomic information:

- For herds with extra replacement heifers – testing heifers in the group they are considering selling as a sorting tool to help ensure they are keeping the best group of females for their operation.
- For herds doing ET and IVF work, or looking to grow their herd internally – using genomic results to determine which females should be donor dams, or bred to sexed semen, and which are better suited to be bred with conventional semen or used as recipients. Genomic information can also be useful to screen potential recipients for fertility and calving traits, to be sure that those animals who will be implanted with high-value embryos are genetically predisposed to conceive and have a live calf.

Aside from the genomic PTAs which delivered back from the genomic test, there is a wealth of other information gleaned from that DNA sample. First, all animals being genomic tested have their parentage verified as the first step of the process – so if an animal is genomic tested, you can be sure that their parentage is correct. Animals are also screened for several of the genetic conditions that may affect the breed (see page 8 for more information on genetic conditions). Official genetic test results may be added on to a genomic test (sometimes for additional fees). In additional, several haplotype results will be delivered, for no additional fees.

A **haplotype** is a combination of alleles (DNA sequences) at different locations on a chromosome that are transmitted together as a group (linked). These can be used to give a good indication as to whether or not an animal is a carrier of a genetic condition, but they are not 100 percent accurate. For more information on haplotypes and other genetic conditions, visit www.holsteinusa.com.

Remembering back to the formula for genetic progress, technologies such as ET/IVF and genomic testing are influencing every piece of the equation, and we are seeing genetic progress in the Holstein breed increase at an increasing rate because of it. Additionally, we are seeing the negative trend observed in some of the health traits reversed due to the ability to make more intensive and accurate selection decisions to improve on those traits.

Holstein Genetic Progress for Net Merit
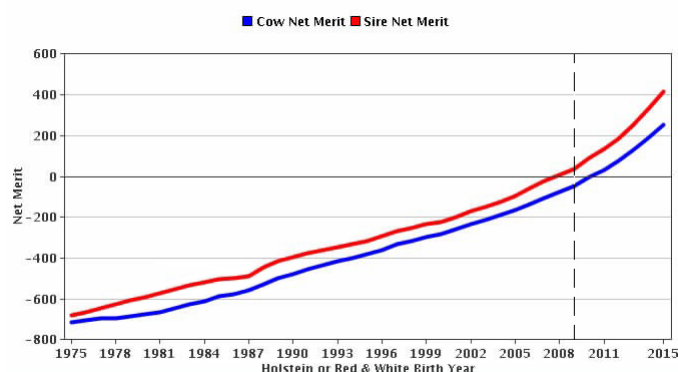
Source: CDCB, 2018

Holstein Genetic Progress for Daughter Pregnancy Rate

Source: CDCB, 2018

LEARN
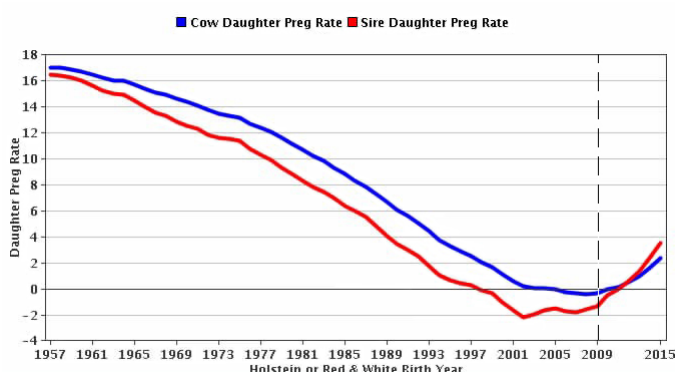
For the most up-to-date information about genomic testing in Holstein cattle, visit www.holsteinusa.com/programs_services/genomics.html.

The U.S. Dairy Genetic Evaluation System

The goal of any breeder should be to improve the quality of the next generation of his or her herd with each calf that is born, and genetic evaluations are a critical tool used to achieve that. The U.S. dairy genetic evaluation system is very important in providing accurate information about genetic merit of cattle to dairy producers. Official genetic evaluations are released three times annually, in April, August, and December. Genetic and performance data is supplied by organizations such as the dairy breed associations and Dairy Herd Information Associations (DHIAs) to the Council on Dairy Cattle Breeding (CDCB) to be incorporated into evaluation calculations.

Genetic evaluations for type and production in the United States are computed using Animal Model procedures for estimating Predicted Transmitting Abilities (PTAs). **PTAs** are an estimate of genetic superiority (or inferiority) that a bull or cow will transmit to their offspring for a given trait, and will be discussed in more detail in the next section. **Animal Model** evaluations are based on an animal and its relationship to other animals being evaluated. Information from the animal itself, its ancestors, and its progeny is all incorporated, with all known relationships among the animals being considered. In an Animal Model evaluation, all identified relatives of an animal affect that animal's evaluation. Additionally, each animal influences the evaluations of its relatives. Naturally, the amount of influence depends on how closely the animals are related; daughters, sons, and parents have greater impact on an animal's evaluation than do grandparents, cousins, or other more distantly related animals.

STANDARDIZING EVALUATIONS

Many factors affect production and type records. Management, environment and genetics all influence an animal's performance and must be accounted for when estimating genetic merit. The following factors are considered:

- Regional and seasonal effects
- Genetic merit of mates
- Genetic competition of herdmates
- Environmental correlation between daughters of a sire in the same herd
- Ancestor information

Accounting for these non-genetic factors allows us to obtain a meaningful estimate of an animal's genetic merit. A few additional considerations also play a part in both production and type information.

Production records are standardized to account for the effects of age, season at calving, lactation number and days open in the previous lactation. All records are standardized to a 2X (twice a day milking), 305-day mature equivalent basis. Records less than 305 days in length are extended to a 305-day basis. A cow's lactation record is included in the evaluation if she has been in milk at least 40 days. If a cow has died or sold for any reason other than dairy purposes, her record will be included if she was in milk at least 15 days. The effects of age and stage of lactation on **final score and linear traits** at the time of classification are also accounted for in the Animal Model evaluation system.

Finally, to help adjust for genetic progress and keep evaluations comparable over time, the evaluations use a **genetic base**, which is updated every five years, as a reference point. The base is defined by making the average PTA for all cows born in a certain year equal to zero (the base year). Evaluations are calculated and expressed relative to that base year. For example, in December 2014 (closest genetic evaluation to 2015), the genetic base was updated so the average PTAs of cows born in 2010 was zero for every trait except for somatic cell score, calving ease and stillbirth rate, which are centered at breed average.

HOW GENETIC VALUES ARE EXPRESSED

The next section will walk you through the Holstein Association USA Sire Summaries, but some basic terminology needs to be understood first that is applicable across all breeds of dairy cattle.

Predicted Transmitting Abilities, or PTAs, were mentioned briefly in the previous section. PTAs are an estimate of genetic superiority (or inferiority) that a bull or cow will transmit to their offspring for a given trait. PTAs are calculated for several traits, including milk, fat, protein, productive life, and final score, and the numbers can be used to rank bulls and cows by their genetic merit. PTAs for production traits, somatic cell score, productive life and Net Merit are calculated by CDCB. PTAs for Holstein type traits are calculated by Holstein Association USA.

Linear type trait genetic evaluations are first calculated as PTAs, the same as production traits and final score. PTAs for different traits that are expressed in the same units can be very difficult to display on the same graph, because they can vary so much. For example, it would be hard to display information for a bull that was +2000 for pounds of milk and +50 for pounds of fat on the same graph, because 2000 and 50 are so far apart. Trying to include other traits (like PTA type), that are expressed in different units (such as points), is nearly impossible. A practical solution for displaying several traits on the same graph is to standardize each of the traits, a practice that results in **Standard Transmitting**

Abilities, or STAs. Genetic evaluations for linear type traits are expressed as STAs; these STAs allow people to easily compare different traits of the same bull, and see which traits have the most extreme values. Again using the genetic base, the average STA for all traits is zero. The majority of animals will fall within three points (plus or minus) of zero.

The figure shown here is an example of the distribution of STA values for a linear trait, and is known as a bell curve. Many biologically important traits in dairy cattle will have this sort of distribution. At the average (STA=0), you will see the greatest number of bulls. A majority of bulls are within one STA point in each direction of the average. As the STA value moves further from the average, fewer and fewer bulls will be at that STA value; more bulls have low STA values (0 to 1) than large STAs (2 or higher).
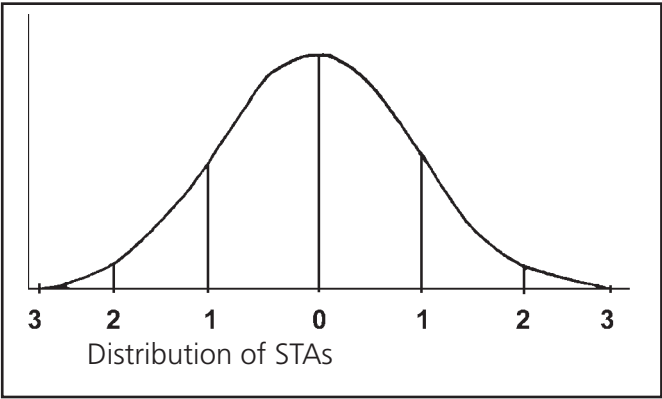
A final piece of information to look at when evaluating PTAs is the **reliability** number (often abbreviated as "%R" in the sire summaries). Reliability is a measure of the estimated

Distribution of STAs

accuracy of the PTA, based on the amount of information included in the evaluation. Information from the animal, parents and progeny is all included. When a calf is born, their PTAs are based on an average of their parent's PTAs for each trait, known as "parent average," as that calf would have no progeny of its own to include in the evaluation. An animal that has been genomic tested will have a higher reliability than an animal who only has parental information included in its evaluation (because the genomic information will be included in the evaluation), and a bull with genomic information plus daughter performance information will have a higher reliability than a bull with just genomic data, again because even more information is being included in his evaluation. As more daughters are included in a bull's evaluation, more emphasis is placed on progeny information, and less is placed on genomic and ancestor information. Reliabilities show how much confidence can be placed in an evaluation. The maximum reliability an animal can have is 99 percent, which can only be achieved when a bull has hundreds, if not thousands of daughters included in his evaluation. The example below demonstrates how reliability increases as more information is included in an evaluation.

Projected Reliabilities for PTA Milk	
Newborn Calf with parental information only	42% Reliability
Calf that has been genomic tested	65% Reliability
Bull that has been genomic tested and has information from over 300 daughters included in his evaluation	96% Reliability

Looking at the impact of adding daughters to an evaluation, we will use Stantons Main Event-ET as an example. In April 2017, he had 68 daughters in his production proof, and his reliability for PTA Milk was 91 percent. Fast forward to December 2017, he had 263 daughters included in his evaluation, giving him a reliability of 96 percent. Because of the actual daughter performance data, breeders can have more confidence in his evaluation.
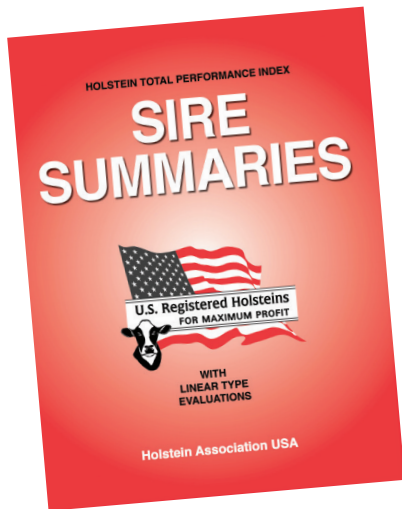
The Holstein Association USA Sire Summaries

The Holstein Association USA Sire Summaries, also known as the "Red Book," because of its color, are considered the comprehensive source for genetic information on Holstein bulls. The book is published three times each year, in April, August and December, immediately following the national genetic evaluations. The Red Book contains a great deal of information about bulls available from AI studs, including detailed genetic information on over 1,200 Registered Holstein bulls, along with several lists ranking bulls on genetic merit for a variety of traits. Holstein Association USA also releases an electronic version of the Sire Summaries, packaged with a mating program, called Red Book Plus/MultiMate. For more details on that program, visit www.holsteinusa.com and click on Software in the main menu.

The following sections will provide an overview of what you will find in the Holstein Red Book and how to interpret the information.

LINEAR COMPOSITE INDEXES

Holstein Association USA Linear Composite Indexes combine linear trait information on several related traits into one numerical value. Composite indexes can be used as a selection tool in breeding programs to identify those bulls which are predicted to transmit a desirable combination of the traits in the Composite Index.

UDDER COMPOSITE INDEX (UDC)

Udder Composite describes a well formed capacious udder with strong attachment. Using bulls with a high UDC results in a lowering of the somatic cell score and daughters whose udders are trouble-free and capable of holding more milk.

The UDC formula is as follows:

$$UDC = -0.03 + [(.16 \times FU) + (.23 \times UH) + (.19 \times UW) + (.08 \times UC) + (.20 \times UD) + (.04 \times TP) + (.05 \times RP^*) + (.05 \times TL^*) - (.2 \times ST)] \times 1.16$$

Note: Where RP* and TL* have an intermediate optimum. There is a penalty for rear teats that are placed too close to one another. The same goes for teat length. Teats that too long or too short are penalized. The values -0.03 and 1.16 are used to standardize the composite with the 2010 Base Population of cows.

Where:					
FU = Fore Udder Attachment		UH = Rear Udder Height		UW = Rear Udder Width	
UC = Udder Cleft		UD = Udder Depth		TP = Front Teat Placement	
RP* = Rear Teat Placement		TL** = Teat Length		ST = Stature	

If Rear Teat Position is less than or equal to 1, then RP = RP.
If Rear Teat Position is greater 1, then RP* = 1-(RP x 0.1).

**TL* = (-1 x ABS(TL)) – (ABS(TL) x ABS(TL) x 0.1)
where ABS(TL) is the absolute value of Teat Length

FEET & LEGS COMPOSITE INDEX (FLC)

The Feet & Legs Composite formula utilizes a combination of the major category Feet & Legs Score along with three linear traits. The FLC formula is as follows:

$$FLC = +0.02 + [(.09 \times FA) + (.21 \times RV) + (.70 \times FLS) - (.20 \times ST)] \times 1.09$$

The values +0.02 and 1.09 are used to standardize the composite with the 2010 Base Population of cows.

Where: FA = Foot Angle   RV = Rear Legs Rear View   FLS = Feet & Legs Score   ST = Stature

Feet and legs are a primary concern for dairy producers worldwide. Selecting animals that transmit superior mobility, steeper foot angle, wider rear leg stance with little or no hock-in and slightly straight rear legs (side view) will result in animals capable of longer productive lives. The Feet and Legs Composite was designed to maximize within-herd lifetime production of combined Fat and Protein.

BODY WEIGHT COMPOSITE INDEX

The Body Weight Composite includes a measure of both body size, i.e., the dimensions of the cow, and dairy form. By including dairy form, we take into consideration how hard the cow is milking, accounting for an excess or lack of body fat. The BWC formula is as follows:

BWC = (.23 x Stature) + (.72 x Strength) + (.08 x Body Depth) + (.17 X Rump Width) - (.47 x Dairy Form)

Every 1.0 STA increase in body size correlates with a 40 pound predicted increase in mature body weight. For example, daughters of bulls that sire large cows (large positive evaluations for body size, +3.00) are predicted to weigh 240 pounds more than those that sire small cows (large negative evaluations for body size, -3.00.)

TOTAL PERFORMANCE INDEX® (TPI®)

TPI® is the gold standard in ranking world-wide Holstein genetics, serving as a rudder for the genetic direction of the breed. TPI represents HAUSA's vision for feeding the world through the improvement of the domestic and international Holstein population, encompassing animals identified in the Herdbook as well as commercial Holsteins. TPI is not necessarily aimed at breeding individual cows, but rather to advance the entire genetic pool. HAUSA recognizes and encourages diversity in breeding philosophies to ensure the continual improvement of the Holstein breed.

The formula is evaluated periodically by Holstein Association USA's Genetic Advancement Committee to ensure it continues to meet the goals of Holstein breeders nationwide.

$$\left[\frac{19(PTAP)}{17} + \frac{19(PTAF)}{22} + \frac{8(FE)}{52} + \frac{8(PTAT)}{0.8} + \frac{11(UDC)}{0.8} + \frac{6(FLC)}{0.8} + \frac{5(PL)}{1.6} + \frac{2(HT)}{2.0} + \frac{3(LIV)}{1.4} - \frac{4(SCS)}{0.13} + \frac{13(FI)}{1.3} - \frac{0.5(DCE)}{0.5} - \frac{1.5(DSB)}{0.8} \right] 3.8 + 2363$$

The value 2187 adjusts for our periodic base change, allowing TPI® values to be comparable across time. Formula updated April 2021.

Where:

PTAP = PTA Protein	PL = PTA Productive Life	PTAT = PTA Type
PTAF = PTA Fat	LIV = PTA Cow Livability	UDC = Udder Composite
FE$ = Feed Efficiency $	FI = Fertility Index	FLC = Feet & Legs Composite
BWC = Body Weight Composite	DF = STA Dairy Form	DCE = PTA Daughter Calving Ease
	SCS = PTA Somatic Cell Score	DSB = PTA Daughter Stillbirth

Weighting of Major Categories

Production	46%	(Fat, Protein, Body Weight Composite, and Feed Efficiency)
Health & Fertility	28%	(SCS, PL, LIV, FI, DCE and DSE)
Conformation	26%	(PTAT, UDC, FLC and Dairy Form)

OTHER COMPOSITE INDEXES

FEED EFFICIENCY $

Feed Efficiency $ index reflects good feed utilization. It includes better utilization of the feed to produce extra pounds of milk, fat, and protein; feed saved from cows with a lower body weight and less maintenance costs; and feed saved from better feed conversion. This last part is known as residual feed intake (RFI), i.e., the difference in efficiency that we see between cows after accounting for the feed that goes into the maintenance of the cow and the production of milk.

Production $ + Body Weight Composite $ + Residual Feed Intake $

FE$ is calculated as follows:
FE$ = ($0.0008 x PTA Milk) + ($1.55 x PTA Fat) + ($1.73 x PTA Protein) + ($0.11 x Feed Saved)

The first three components of this formula reflect the extra profit coming from cows producing more pounds of milk, fat, and protein. That is the additional feed costs, required to produce an extra pound of milk, fat, and protein, have been subtracted from the income that farmers receive for their milk. Component prices, reflecting primarily a cheese market, were updated in 2021. The trait Feed Saved is calculated by CDCB as a combination of HAUSA's Body Weight Composite and CDCB's RFI data which is based upon dry matter intake. Every pound of feed saved returns a net profit of eleven cents per cow per lactation. Economic values are based upon research from USDA-AGIL and a multi-state research program for the improvement of feed efficiency.

FERTILITY INDEX (FI)

The Fertility Index combines several reproductive components into one overall index: ability to conceive as a maiden heifer, ability to conceive as a lactating cow, and a cow's overall ability to start cycling again, show heat, conceive, and maintain a pregnancy. The Fertility Index is derived from the formula:

FI = 18% Heifer Conception Rate (HCR) + 18% Cow Conception Rate (CCR) + 64% Daughter Pregnancy Rate (DPR)

SECTIONS IN THE RED BOOK

The Holstein Association USA Red Book is broken out into five easy to navigate sections, that help breeders find the information they're looking for quickly and efficiently. Each list and section has its own criteria for inclusion. For specific details on that information, reference the tab for each section in a hard copy of the Red Book.

Section 1: **High Ranking Bull Lists** has several lists ranking elite Holstein bulls by various criteria. Included in this section are:

- Top 100 TPI Bulls
- Top 50 Bull Lists
- Top 50 Red & Red Carrier Bulls, by TPI
- Top 100 International TPI Bulls
- Top 100 Inactive Bulls, with at least 95% Reliability for Production and Type

Section 2: **Available Proven Bulls** gives detailed pedigree and genetic information for individual bulls. It includes the popular "bull blocks" for the top 400 TPI bulls meeting the criteria. More on interpreting the information in this section will be covered under the "How to Interpret Sire Information" section.

Section 3: **Daughter Proven Plus Bulls** was designed for breeders who are most interested in bulls with a large amount of actual daughter performance information included in their evaluations. Bulls found in this section all have at least 75 U.S. daughters in 50 herds. Included in this section are:

- Top 100 Daughter Proven Plus TPI Bulls
- Top 50 Daughter Proven Plus Bull Lists
- Top 100 TPI Bulls with 97%+ U.S. Reliabilities for Milk and Type

Section 4: **Genomic Young Bulls** highlights the elite young bulls of the breed. Bulls in this section have no daughters included in their evaluations. Lists found here include:

- Top 200 TPI Genomic Young Bulls
- Alphabetical listing of the Top 500 TPI Genomic Bulls

Section 5: **Reference Information** includes several cross reference lists and additional information about genetic evaluations and how they are calculated, which may be interesting to breeders. Also contained in this section are lists of the haplotype status of available proven and genomic young bulls and cross references of names and NAAB codes for bulls found in the book.

How to Read and Interpret Holstein Sire Information

The information contained in the Holstein Association USA Sire Summaries is of little value if you don't know how to interpret it! Here we will focus on the data found in Section 2: Available Proven Bulls, commonly referred to as "bull blocks." These blocks offer answers to nearly every question a breeder may have about a bull.

			G	H	I	J

A
MR MOGUL DELTA 1427-ET			TPI +2849 G	Protein	3.00 High	
USA 72128216 100%RHA-NA TC TV TL TY	01-31-13 GM 08-17			Fat	4.31 High	
Sire: MOUNTFIELD SSI DCY MOGUL-ET		+2504 G		Final Score	2.67 High	
840003006972816 100%RHA-NA TR TP TC TV93	GM			Productive Life	5.30 High	
Dam: MISS OCD ROBST DELICIOUS-ET		+2798 G		Somatic Cell Score	2.58 Low	
840003006989479 100%RHA-NA	87 +EV+V	GMD DOM		Stature	0.11 Tall	

B
PRODUCTION	%	%R	SIRE	DAM	DAU	GRP		Strength	0.45 Frail
Milk	+1817		98	+1220	+2247	30610	28727	Body Depth	0.08 Deep
Fat	**+97**	+.10		+79	+76	1221	1121	Dairy Form	2.58 Open Rib
Pro	**+57**	+.01		+40	+73	949	892	Rump Angle	0.22 Sloped
08-2017	518 DAUS	113 HERDS			95 %RIP	100 %US		Rump Width	0.52 Wide

C
PL	**+8.0**		86	+4.1	+8.4	SCE	7%	99 %R	R Legs-Side View	0.30 Curved
SCS	**2.79**		94	2.98	2.81	DCE	5%	91 %R	R Legs-Rear View	1.33 Straight
FE +219	NM$ +951		CM$ +962			FI	3.8	85 %R	Foot Angle	1.07 Steep

D
TYPE		%R	SIRE	DAM	DAU SC	AASC		Feet & Legs Score	1.32 High
Type	+1.95	95	+2.22	+1.57	79.7	83.2		Fore Attachment	2.23 Strong
UDC	+2.51		+3.08	+2.12				Rear Udder Height	3.95 High
FLC	+1.41		+2.35	+.63	BD -1.42	D +1.25		Rear Udder Width	3.63 Wide
08-2017	159 DAUS	49 HERDS		EFT D/H 8.4				Udder Cleft	1.20 Strong

E | **F**
Breeder	Lookout Hols,R Pesce,Butz-Hill & F & D Borba, IL	ACTIVE		Udder Depth	0.83 Shallow
Owner	Lookout Hols,R Pesce,Butz-Hill & F & D Borba, IL	203HO1468		F Teat Placement	1.54 Close
Controller	Trans-World Genetics LTD.	DELTA		R Teat Placement	1.41 Close
				Teat Length	1.91 Short

BLOCK A: IDENTIFICATION & PEDIGREE INFORMATION

Line 1
- **Bull's Registered Name**
- **Total Performance Index (TPI)**
  You can see that Delta's TPI value is +2849. You may occasionally see different letters following a bull's TPI value. This indicates of the source(s) of information used to calculate the genetic evaluation.
  - No label = Domestic U.S. evaluation (no genomic data included)
  - G = Genomic information is included in this bull's evaluation
  - M = The bull has a MACE (Multiple-trait Across Country Evaluation) evaluation. MACE evaluations are released by Interbull to estimate how sires from other countries would compare to sires will domestic U.S. proofs. MACE evaluations assist U.S. breeders by expressing evaluation information from other countries in the same format as U.S. bulls are displayed. If a bull's evaluation contains information from both U.S. and foreign daughters (but no genomic information), it will be labeled with an M.

  ★ *In 2017, the top 100 proven bulls had TPIs ranging from +2421 to over +2800; the top 200 genomic young bulls ranged from +2711 to over +2900.*

Delta's TPI has a "G" after it, indicating the genomic information is included in his evaluation. This labeling after the TPI value is unique to the Sire Summaries and included lists. In conversation, a bull's TPI will be described different ways, depending on the information in his evaluation:

- **PTPI:** The bull has not been genomic tested and does not have any daughter information in his evaluation. His TPI value is based on parental average. The "P" stands for predicted.
- **TPI:** The bull has not been genomic tested, but has daughter information included in his evaluation.
- **GTPI:** The bull has been genomic tested and may or may not have daughter information included in his evaluation. The majority of bulls in AI today, both young and proven, will have GTPIs. The "G" stands for genomic.

Line 2: • **Nation Code:** The nation code indicates the country the bull is registered in, in this case, the United States
- **Registration Number:** The bull's registration number officially identifies him and is assigned by Holstein Association USA
- **% RHA:** stands for "Percent Registered Holstein Ancestry," and is an indicator of the animal's lineage. The %RHA will be followed by a suffix of either "-NA" (North American) or "-I" (International), which indicates the heritage of animals in their pedigrees. Delta has 100% Registered Holstein Ancestry-North American, meaning that all of the animals in his pedigree are registered in North America; if any ancestors are registered in herdbooks outside of North America, that animal will have the "-I" suffix after their %RHA. Animals may have less than 100% RHA if they have unidentified ancestors in their pedigree. If an animal has any unidentified ancestors, the highest %RHA they can ever attain is 99% RHA.
- **Genetic Codes:** These codes indicate the results of any genetic tests that have been done on the bull, so breeders can see if there are any traits or conditions they should be aware of. Refer to page 8 for a description of these codes. Looking at Delta's codes, you can see that he has been tested free of the gene for Cholesterol Deficiency, and is not a carrier of CVM, BLADS, or Brachyspina.
- **Classification Score:** Many bulls have official classification scores that have been assigned by Holstein Association USA classifiers, which is an evaluation of their physical conformation. Delta is not classified yet. If you are interested in learning more about Holstein Association USA's classification program, visit www.holsteinusa.com/programs_services/classification.html.
- **Birthdate:** Delta was born on January 31, 2013 (01-31-13)
- **Gold Medal Sire Recognition (if applicable):** Some bulls will be recognized as Gold Medal Sires, and that recognition will be labeled here, indicated as "GM" with the date the recognition was received. You can see that Delta received Gold Medal Sire recognition in August 2017. To be recognized as a Gold Medal Sire, bulls must meet a minimum TPI requirement (which is updated semi-annually to recognize approximately 25 new bulls each year), have a minimum 90% reliability for PTA Fat and PTA Type, and be free of undesirable recessive traits. All bulls 87% RHA and higher are automatically evaluated twice a year, and Gold Medal Sire is a permanent recognition.

Line 3: • **Sire's Name:** Delta is sired by Mountfield SSI DCY Mogul-ET
- **Sire's TPI Value:** Mogul's TPI is +2504. The "G" after the number indicates that genomic information is included in his evaluation

Line 4: • **Sire's Nation Code & Registration Number**
- **Sire's %RHA**
- **Genetic Codes:** Mogul has been tested and is not a carrier for CD, CVM, Red or Polled
- **Classification Score:** Mogul is classified Excellent 93
- **Gold Medal Sire Recognition (if applicable):** Mogul has been recognized as a Gold Medal Sire

Line 5: • **Dam's Name**: Delta's dam is Miss OCD ROBST Delicious-ET
- **Dam's TPI Value:** Delicious' TPI is +2798; the "G" after it indicates that she has been genomic tested. In conversation, females can be labeled with different kinds of TPIs, depending on the information that is included in their evaluation, like bulls:
  - **PTPI:** A heifer or cow that has not been genomic tested, and doesn't have a required classification score and/or is not enrolled in an official milk production records testing program.
  - **CTPI:** A cow that has not been genomic tested, but has a required classification score and a milk record completed under an official testing program.
  - **GTPI:** A heifer or cow that has been genomic tested; she may or may not have a required classification score and/or a milk record completed under an official testing program.

How to Read and Interpret Holstein Sire Information

A

MR MOGUL DELTA 1427-ET   **TPI +2849 G**
USA 72128216 100%RHA-NA TC TV TL TY   01-31-13 GM 08-17
Sire: MOUNTFIELD SSI DCY MOGUL-ET   +2504 G
840003006972816 100%RHA-NA TR TP TC TY93   GM
Dam: MISS OCD ROBST DELICIOUS-ET   +2798 G
840003006989479 100%RHA-NA   87 +EV+V   GMD DOM

B

PRODUCTION		%	%R	SIRE	DAM	DAU	GRP
Milk	+1817		98	+1220	+2247	30610	28727
Fat	+97	+.10		+79	+76	1221	1121
Pro	+57	+.01		+40	+73	949	892
08-2017	518 DAUS	113 HERDS				95 %RIP	100 %US

C

PL	+8.0		86	+4.1	+8.4	SCE	7%	99 %R
SCS	2.79		94	2.98	2.81	DCE	5%	91 %R
FE +219	NM$ +951		CM$ +962			FI	3.8	85 %R

D

TYPE		%R	SIRE	DAM	DAU SC	AASC
Type	+1.95	95	+2.22	+1.57	79.7	83.2
UDC	+2.51		+3.08	+2.12		
FLC	+1.41		+2.35	+.63	BD -1.42	D +1.25
08-2017	159 DAUS	49 HERDS		EFT D/H 8.4		

E

Breeder   Lookout Hols,R Pesce,Butz-Hill & F & D Borba, IL
Owner   Lookout Hols,R Pesce,Butz-Hill & F & D Borba, IL
Controller   Trans-World Genetics LTD.

F

ACTIVE
203HO1468
DELTA

G   H   I   J

Protein	3.00	High
Fat	4.31	High
Final Score	2.67	High
Productive Life	5.30	High
Somatic Cell Score	2.58	Low
Stature	0.11	Tall
Strength	0.45	Frail
Body Depth	0.08	Deep
Dairy Form	2.58	Open Rib
Rump Angle	0.22	Sloped
Rump Width	0.52	Wide
R Legs-Side View	0.30	Curved
R Legs-Rear View	1.33	Straight
Foot Angle	1.07	Steep
Feet & Legs Score	1.32	High
Fore Attachment	2.23	Strong
Rear Udder Height	3.95	High
Rear Udder Width	3.63	Wide
Udder Cleft	1.20	Strong
Udder Depth	0.83	Shallow
F Teat Placement	1.54	Close
R Teat Placement	1.41	Close
Teat Length	1.91	Short

Block A: Identification & Pedigree Information (continued)

Line 6:
- **Dam's Nation Code & Registration Number**
- **Dam's %RHA**
- **Genetic Codes:** Delicious does not have any Genetic Codes listed
- **Classification Score:** Delicious is classified Very Good-87 and of the five major breakdowns – Is Excellent in Dairy Strength, Very Good in Rump and Udder, and Good Plus in Front End &Capacity and Feet & Legs.
- **Recognitions (if applicable):** Holstein Association USA can designate cows with two major recognitions: Gold Medal Dam (GMD) and Dam of Merit (DOM). Delicious has been recognized with both of these honors.
  - ○ **Gold Medal Dam:** A cow must meet several strict criteria to be recognized as a GMD. She and at least three of her daughters must be classified. The cow herself must be milking in a herd participating in a Holstein TriStar service option (Custom, Deluxe or Premier). Equal emphasis is placed on both production and type, and on progeny and dam performance; the dam's age adjusted final and Mature Equivalent (ME) production records are evaluated, along with the average of the daughters' age adjusted classification scores and ME production records. Separate cutoffs are determined by the birth year of the dam. If the cow herself does not qualify on an ME production basis, she may qualify based on high lifetime production credits (200,000 pounds of milk OR 7,200 pounds of fat, OR 6,400 pounds of protein). Automatic evaluation is done twice a year for all cows 87% RHA or higher that were born in the past 25 years, and GMD is a permanent recognition.
  - ○ **Dam of Merit:** To be recognized as a DOM, a cow must have a GTPI or CTPI exceeding a cutoff based on their year of birth. The cow must have at least three offspring with a PTA for production and type, and the animal's GTPI or CTPI must be calculated using a required classification score. Automatic evaluation is done twice a year for all cows 87% RHA or higher that were born in the past 25 years and milking in a herd enrolled in a Holstein TriStar service option. Like the others, DOM is permanent recognition.

BLOCK B: PRODUCTION GENETIC VALUES

Information in this section gives you an estimate of a bull's ability to transmit production traits, such as pounds of milk, pounds and percentages of components. It also gives information about how a bull's PTAs compare to his sire and dam, and how his daughters are performing compared to herdmates, so you can evaluate his genetic superiority.

Line 1: PTA Milk Information
- **PTA Milk (PTAM):** Delta's PTAM is +1817.

  ★ *In 2017, the top 50 daughter proven bulls ranged from +1694 to over +3100 for PTA milk, with reliability ranging from 87% to 99%.*

- **%R:** Delta's reliability for his production evaluation is 98%
- **Sire's PTAM:** Delta's sire, Mogul, has a PTAM of +1220
- **Dam's PTAM:** Delta's dam, Delicious, has a PTAM of +2247
- **Daughter ME Averages:** This number tells you what daughters of a bull are actually averaging for a given trait, in this case, what they average for milk production. These values are based on twice a day milking, 305-day lactation, on a Mature Equivalent (ME) basis. If a bull has an official MACE evaluation, the daughter production averages will be based on the bull's domestic U.S. evaluation. Delta's daughters are averaging 30,610 pounds of milk.
- **Management Group ME Averages:** This number allows you to contrast how daughters of a bull perform compared to herdmates of the same age, so you can evaluate whether they are, on average, superior or inferior to herdmates. Herdmates of the same age as Delta's daughters are averaging 28,727 pounds of milk; on average, Delta daughters are producing 1,883 pounds of milk more in a 305-day lactation than their herdmates of the same age, on an ME basis.

Line 2:   PTA Fat Information
- **PTA Fat Pounds (PTAF):** Delta's PTAF is +97.

    ★ *In 2017, the top 50 daughter proven bulls ranged from about +75 to +107 for PTAF, with reliability ranging from 86% to 99%.*

- **PTA Percent Fat:** Delta's PTA for % Fat is +0.10
- **Sire's PTA Fat:** Delta's sire, Mogul, has a PTAF of +79
- **Dam's PTAF:** Delta's dam, Delicious, has a PTAF of +76
- **Daughter ME Averages:** Delta's daughters are averaging 1,221 pounds of fat, based on an ME, twice a day milking, 305-day lactation.
- **Management Group ME Averages:** Herdmates of the same age as Delta's daughters are averaging 1,121 pounds of fat; on average, Delta daughters are producing 100 pounds of fat more in a 305-day lactation than their herdmates of the same age, on an ME basis.

Line 3:   PTA Protein Information
- **PTA Protein Pounds (abbreviated PTAP):** Delta's PTAP is +57.

    ★ *In 2017, the top 50 daughter proven bulls ranged from +54 to +91 for PTAP, with reliability ranging from 91% to 99%.*

- **PTA Percent Protein:** Delta's PTA for % Protein is +0.01
- **Sire's PTA Protein:** Delta's sire, Mogul, has a PTAP of +40
- **Dam's PTAP:** Delta's dam, Delicious, has a PTAP of +73
- **Daughter ME Averages:** Delta's daughters are averaging 949 pounds of protein, based on an ME, twice a day milking, 305-day lactation.
- **Management Group ME Averages:** Herdmates of the same age as Delta's daughters are averaging 892 pounds of protein; on average, Delta daughters are producing 57 pounds of protein more in a 305-day lactation than their herdmates of the same age, on an ME basis.

Line 4:   Production Evaluation Information
- **Evaluation Date:** This tells you the date that the evaluation was calculated. This particular evaluation was calculated in August 2017 (08-2017)
- **Number of Daughters and Herds:** This tells you the number of daughters the bull has included in this evaluation, along with how many different herds those daughters come from. Delta has 518 daughters included in his production evaluation, and those daughters come from 113 different herds (an average of about four daughters per herd).
- **Percentage of Records in Progress (RIP):** A record in progress means that the daughters of the bull have not yet completed a lactation. 95% of Delta's daughters have records in progress (RIPs).
- **Percentage of Daughters in the U.S.:** 100% of the daughters included in Delta's evaluation are in the United States.

A
MR MOGUL DELTA 1427-ET   **TPI +2849 G**
USA 72128216 100%RHA-NA TC TV TL TY   01-31-13 GM 08-17
Sire: MOUNTFIELD SSI DCY MOGUL-ET   +2504 G
840003006972816 100%RHA-NA TR TP TC TY93   GM
Dam: MISS OCD ROBST DELICIOUS-ET   +2798 G
840003006989479 100%RHA-NA   87 +EV+V   GMD DOM

B

PRODUCTION		%	%R	SIRE	DAM	DAU	GRP
Milk	+1817		98	+1220	+2247	30610	28727
Fat	+97	.10		+79	+76	1221	1121
Pro	+57	.01		+40	+73	949	892
08-2017	518 DAUS	113 HERDS				95 %RIP	100 %US

C

			%R				
PL	+8.0		86	+4.1	+8.4	SCE 7%	99 %R
SCS	2.79		94	2.98	2.81	DCE 5%	91 %R
FE +219	NM$ +951	CM$ +962				FI 3.8	85 %R

D

TYPE			%R	SIRE	DAM	DAU SC	AASC
Type	+1.95		95	+2.22	+1.57	79.7	83.2
UDC	+2.51			+3.08	+2.12		
FLC	+1.41			+2.35	+.63	BD -1.42	D +1.25
08-2017	159 DAUS	49 HERDS		EFT D/H 8.4			

E
Breeder   Lookout Hols,R Pesce,Butz-Hill & F & D Borba, IL
Owner   Lookout Hols,R Pesce,Butz-Hill & F & D Borba, IL
Controller Trans-World Genetics LTD.

F
ACTIVE
203HO1468
DELTA

G   H   I   J

Protein	3.00	High
Fat	4.31	High
Final Score	2.67	High
Productive Life	5.30	High
Somatic Cell Score	2.58	Low
Stature	0.11	Tall
Strength	0.45	Frail
Body Depth	0.08	Deep
Dairy Form	2.58	Open Rib
Rump Angle	0.22	Sloped
Rump Width	0.52	Wide
R Legs-Side View	0.30	Curved
R Legs-Rear View	1.33	Straight
Foot Angle	1.07	Steep
Feet & Legs Score	1.32	High
Fore Attachment	2.23	Strong
Rear Udder Height	3.95	High
Rear Udder Width	3.63	Wide
Udder Cleft	1.20	Strong
Udder Depth	0.83	Shallow
F Teat Placement	1.54	Close
R Teat Placement	1.41	Close
Teat Length	1.91	Short

BLOCK C: HEALTH TRAIT INFORMATION & ADDITIONAL INDEXES

Line 1: Productive Life (PL) & Sire Calving Ease Information

- **PTA PL:** Productive life (PL) gives a measure of the amount of time a cow stays in the herd as a "productive" animal, and represents how many months of additional (or fewer, if a negative number) lifetime you can expect from a bull's daughters. Cows receive credit for each month of lactation, and the amount of credit corresponds to the shape of the lactation curve. The most credit is given to months at the peak of lactation, and credit diminishes as the cow moves to the end of her lactation. First lactations are given less credit than later lactations, in proportion to the difference in average production. PTAs for PL generally range from -7.0 to +7.0, with higher numbers being preferred. Delta's PTA for Productive Life is +8.0, meaning you can expect his daughters to stay in the herd eight months longer than average.

  ★ *In 2017, the top 50 daughter proven bulls ranged from +6.6 to +9.4 for PTA PL, with reliability ranging from 77% to 99%. Since health and fertility traits are influenced greatly by management, the traits, like PL, typically have lower reliabilities than other traits, like milk production and type.*

- **%R for PL:** Delta's PTA PL has a reliability of 86%
- **Sire's PTA PL:** Delta's sire, Mogul, has a PTA PL of +4.1
- **Dam's PTA PL:** Delta's dam, Delicious, has a PTA PL of +8.4
- **Sire Calving Ease (SCE):** Sire calving ease measures the tendency of calves from a particular sire to be born more or less easily. Calving ease evaluations are expressed as a percent of difficult births in first calf heifers; difficult births are those classified as requiring considerable force or being extreme (a 4 or 5 on a five-point scale, with a 1 classified as "no problem"). The percent difficult births among first-calf Holstein cows is approximately 8 percent. In general, bulls with an SCE of 8% or less are considered "calving ease" bulls that are fine to use on heifers and smaller cows. Bulls with a high SCE percentage should be used with caution on heifers and smaller cows, as they have a higher percent chance of siring larger calves that may pose more of a problem at delivery. Delta's SCE is 7%, putting him at less than the average for percent of difficult births in first-calf cows, which is desirable.
- **%R for SCE:** Delta's SCE evaluation is 99% reliable.

Line 2: **Somatic Cell Score & Daughter Calving Ease Information**

- **PTA Somatic Cell Score (SCS):** SCS evaluations are based on somatic cell count data from monthly DHIA tests. These evaluations provide an indicator of mastitis in a bull's daughters. PTAs typically range from 2.5 to 3.5, with higher values indicating that daughters tend to have higher somatic cell counts (SCC). Lower SCS values are more desirable. Delta's PTA SCS is 2.79.

  ★ *In 2017, the top 50 bulls for PTA SCS had values ranging from 2.65 to 2.44.*

- **%R for SCS:** Delta's PTA SCS has a reliability of 94%
- **Sire's PTA SCS:** Delta's sire, Mogul, has a PTA SCS of 2.98
- **Dam's PTA SCS:** Delta's dam, Delicious, has a PTA SCS of 2.81
- **Daughter Calving Ease (DCE):** Like Sire Calving Ease (SCE), Daughter Calving Ease (DCE) is a measurement of the tendency of calves from a particular animal to be born more or less easily. DCE measures the ability of a particular cow (a daughter of a bull) to calve easily; daughters of bull's with high DCE numbers would be expected to have a more difficult time giving birth than daughters of bulls with lower DCE numbers. DCE is evaluated on the same scale as SCE. Delta's DCE is 5%, which is breed average, meaning that one could expect daughters of Delta to calve more easily than daughters of bulls with higher DCE numbers.
- **%R for DCE:** Delta's DCE evaluation is 91% reliable.

Line 3:
- **Feed Efficiency (FE):** Predicts an animal's ability to produce large volumes of milk without having to consume a great deal of feed, taking into account the value of milk produced minus feed costs for producing extra milk and extra maintenance costs associated with a larger animal. Delta's FE value is +219.
- **Net Merit (NM$) Index:** The Net Merit Index (abbreviated as NM$) is a selection index calculated by USDA, which estimates lifetime profitability of an animal; it is defined as the difference in expected lifetime profit of an animal, compared with the average genetic merit of cows within the breed born in the year of the genetic base. Like the TPI (which is developed and calculated by Holstein Association USA), NM$ combines several production, type and health traits with weightings placed on their economic importance and the goals of the index. Delta's NM$ value is +951.

  ★ *In 2017, the top 50 daughter proven bulls had NM$ values ranging from +687 to over +951, with reliability ranging from 90% to 99%*

- **Cheese Merit (CM$) Index:** Like NM$, CM$ is another index calculated by USDA with different weightings on production traits, geared more towards producers who sell milk to cheese plants. Delta's CM$ value is +962.
- **Fertility Index (FI):** Combines several reproductive components into one overall index: ability to conceive as a virgin heifer, ability to conceive as a lactating cow, and a cow's overall ability to start cycling again, show heat, conceive, and maintain a pregnancy; the index is comprised of the traits Heifer Conception Rate (HCR), Cow Conception Rate (CCR) and Daughter Pregnancy Rate (DPR). Delta's FI value is +3.8
- **%R for FI:** Delta's reliability for FI is 85%.

BLOCK D: TYPE INFORMATION

Information in this section will give you a summary of the physical conformation traits that a bull transmits to his offspring, and how his daughters compare to herdmates of the same age in regards to phenotype.

Line 1: **PTA Type and Classification Information**

- **PTA Type (PTAT):** Delta's PTAT is +1.95. PTA's for Type and the Composite Indexes typically range from -3.0 to +3.0, with higher numbers correlating with more desirable physical conformation.

  ★ *As a frame of reference, in 2017, the top 50 daughter proven bulls ranged from about +2.42 to +3.75 for PTAT, with reliability ranging from 84% to 99%.*

- **%R for PTAT:** Delta's reliability for PTAT is 95%
- **Sire's PTA Type:** Delta's sire, Mogul, has a PTAT of +2.22
- **Dam's PTAT:** Delta's dam, Delicious, has a PTAT of +1.57
- **Daughter Averages for Final Score:** Daughters of Delta have an average actual final classification score of 79.7 points.
- **Daughters' Average Age Adjusted Final Score:** Like production records, classification scores on animals are standardized to account for the effects of age and stage of lactation in an evaluation. The age adjusted final score for Delta's daughters is 83.2 points.

How to Read and Interpret Holstein Sire Information

A

MR MOGUL DELTA 1427-ET   TPI +2849 G
USA 72128216 100%RHA-NA TC TV TL TY   01-31-13 GM 08-17
Sire: MOUNTFIELD SSI DCY MOGUL-ET   +2504 G
840003006972816 100%RHA-NA TR TP TC TV93   GM
Dam: MISS OCD ROBST DELICIOUS-ET   +2798 G
840003006989479 100%RHA-NA   87 +EV+V   GMD DOM

B

PRODUCTION		%	%R	SIRE	DAM	DAU	GRP
Milk	+1817		98	+1220	+2247	30610	28727
Fat	+97	+.10		+79	+76	1221	1121
Pro	+57	+.01		+40	+73	949	892
08-2017	518 DAUS	113 HERDS				95 %RIP	100 %US

C

PL	+8.0	86	+4.1	+8.4	SCE 7%	99 %R
SCS	2.79	94	2.98	2.81	DCE 5%	91 %R
FE +219	NM$ +951	CM$ +962		FI 3.8		85 %R

D

TYPE		%R	SIRE	DAM	DAU SC	AASC
Type	+1.95	95	+2.22	+1.57	79.7	83.2
UDC	+2.51		+3.08	+2.12		
FLC	+1.41		+2.35	+.63	BD -1.42	D +1.25
08-2017	159 DAUS	49 HERDS	EFT D/H 8.4			

E

Breeder   Lookout Hols,R Pesce,Butz-Hill & F & D Borba, IL
Owner   Lookout Hols,R Pesce,Butz-Hill & F & D Borba, IL
Controller Trans-World Genetics LTD.

F

ACTIVE
203HO1468
DELTA

G   H   I   **J**

	G/H	I
Protein	3.00	High
Fat	4.31	High
Final Score	2.67	High
Productive Life	5.30	High
Somatic Cell Score	2.58	Low
Stature	0.11	Tall
Strength	0.45	Frail
Body Depth	0.08	Deep
Dairy Form	2.58	Open Rib
Rump Angle	0.22	Sloped
Rump Width	0.52	Wide
R Legs-Side View	0.30	Curved
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Fore Attachment	2.23	Strong
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Rear Udder Width	3.63	Wide
Udder Cleft	1.20	Strong
Udder Depth	0.83	Shallow
F Teat Placement	1.54	Close
R Teat Placement	1.41	Close
Teat Length	1.91	Short

Block D: Type Information (continued)

Line 2:   Udder Composite (UDC) Information
- **Udder Composite (UDC):** Delta's UDC value is +2.51

    ★ *In 2017, the top 50 daughter proven bulls ranged from about +2.49 to +3.55 for UDC, with reliability ranging from 87% to 99%.*

- **Sire's UDC:** Delta's sire, Mogul, has a UDC value of +3.08
- **Dam's UDC:** Delta's dam, Delicious, has a UDC value of +2.12

Line 3:   • Feet & Legs Composite (FLC): Delta's FLC value is +1.41.

    ★ *In 2017, the top 50 daughter proven bulls ranged from about +1.99 to +3.39 for FLC, with reliability ranging from 87% to 99%.*

- **Sire's FLC:** Delta's sire, Mogul, has an FLC value of +2.35
- **Dam's FLC:** Delta's dam, Delicious, has FLC value of +0.63
- **Body Weight Composite:** Delta's Body Weight Composite is -1.42

    ★ *In 2017, the 50 highest bulls for Body Composite ranged from about +1.79 to +3.69, with reliability ranging from 86% to 99%.*

- **Dairy Capacity:** Dairy Capacity evaluates a combination of both Dairy Form and Strength. Delta's Dairy Capacity value is +1.25.

Line 4:   Type Evaluation Information
- **Evaluation Date:** Like in the Production section, this tells you the date the evaluation was calculated. This particular evaluation was calculated in August 2017 (08-2017)
- **Number of Daughters and Herds:** This tells you the number of daughters the bull has included in this evaluation, along with how many different herds those daughters come from. Delta has 159 daughters included in his type evaluation, and those daughters come from 49 different herds.
- **Effective Daughters per Herd (abbreviated EFT D/H):** The Effective Daughters per Herd is an indication of the distribution of daughters across herds. If each daughter were in a separate herd, the EFT D/H would be 1.0. The lower the value of the EFT D/H, the greater the reliability of the evaluation for a given number of progeny, because more daughters are being considered that were raised in a variety of different management conditions. Delta's EFT D/H is 18.4.

BLOCK E: OWNERSHIP INFORMATION
- **Breeder:** The breeder was the owner of the bull's dam at the time of conception. Delta's breeder is Lookout Hols,R Pesce,Butz-Hill & F & D Borba from Illinois.
- **Owner:** The owner is the person who currently owns a bull. Delta is owned by Lookout Hols,R Pesce,Butz-Hill & F & D Borba of Illinois.
- **Controller:** The controller is the marketer of the bull's semen and the entity responsible for submitting the bull's status to the National Association of Animal Breeders (NAAB). The owner and controller are usually the same entity, but not always. In this case, Delta's controller is Trans-World Genetics LTD.

BLOCK F: NAAB INFORMATION

Line 1: • **Semen Status:** A bull's semen status is an indication of his semen availability and the source of information included in his evaluation. In the Holstein Association USA Red Book, bulls listed in Section 2: Available Proven Bulls will be coded either Active, Limited, or Foreign. As you can see, Delta's status is Active. Following is a list of the most common NAAB semen status codes and their meanings.

- **A (Active AI Sire):** The bull has been sampled, has a USDA genetic evaluation and semen is routinely available and for sale.
- **F (Foreign):** The bull has been genomic or progeny tested outside of the U.S. and is actively being marketed in the U.S.
- **G (Genomic):** The bull has been genomic tested, is at least one year of age and has been assigned a NAAB code.
- **L (Limited):** The bull has a USDA evaluation and semen is available in limited amounts.
- **I (Inactive AI Sire):** The bull has been marketed in the past, but is now inactive and widely unavailable.

Line 2: • **NAAB Code:** Delta's NAAB code is 203HO1468. The NAAB code is a unique number that identifies a bull with the National Association of Animal Breeders (NAAB), and is comprised of three parts. The first part identifies the source of the semen (the organization that processes it); in Delta's case, the number is 203, which corresponds to Trans-World Genetics. This number is between one and three digits, and each entity has a unique identification number with NAAB. The second part of the NAAB code is the breed code, in this case, "HO" for Holstein. The third part is the bull's individual number, which is assigned by the semen collection center; in this case, Delta's individual number assigned by Trans-World Genetics is "1468."

Line 3: • **Short Name:** A bull is given a short name as more simple identification than his full official registered name. Like in Delta's case, a bull's short name is usually easily identifiable from his registered name, but not always. For example, O-Bee Manfred Justice-ET's short name is "O-Man." The Reference Section of the Red Book has a cross reference for Available Proven and Genomic Young Bulls, listing short name referenced with their registered name, to help avoid any confusion.

BLOCK G: TRAIT NAME BLOCK

This area lists the 23 traits that STAs are provided for, including protein, fat, final score, PL, SCS, and the 18 linear type traits.

BLOCK H: STANDARD TRANSMITTING ABILITIES (STAS)

STAs for the 23 traits are listed in this area. An STA is a bull's PTA value for a trait listed on a standardized scale, allowing the traits to be easily viewed with and compared to other traits. STAs usually fall within three units plus or minus of zero.

BLOCK I: BIOLOGICAL EXTREMES

This column contains descriptions of the biological extreme for the 23 traits. When a bull's STA value is above 0.85 or less than -0.85, the descriptor is highlighted, showing that the bull's STA is in the top 20 percent of the available bull population. Delta is in the top 20 percent of the available bull population for several traits, as shown by the highlighted values, including Protein, Fat, Final Score, Productive Life and Somatic Cell Score.

BLOCK J: TRAIT PROFILES

This section provides a visual representation of each STA and its confidence range. The length of the bar for each STA is the confidence range. As reliability increases, the confidence range (length of the bar) shortens. If the trait has a short bar, the bull has a higher reliability; longer bars indicate lower reliabilities.

STA values greater than +2.35 or less than -2.35 may not show entirely on this scale. These values are displayed with either some or none of the confidence range displaying (depending on the value), with a < or > sign at the appropriate end of the scale. Delta is "off the chart" for several traits, including Protein, Fat, Final Score and Productive Life, as indicated by the arrows pointing off the right side of the graphic for those traits.
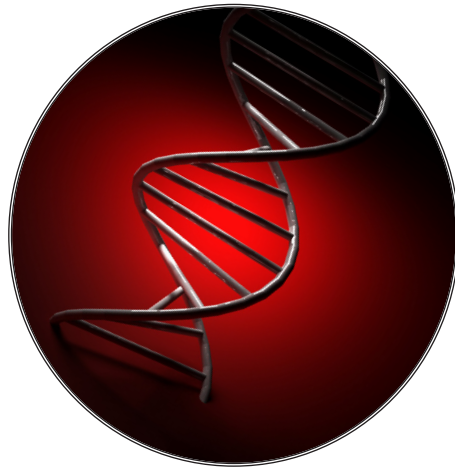
Practice Activities and Resources

Case Study Exercise #1 – Holstein Coat Color

Let's look at coat color in Holstein cattle as an example of simple dominance, which is responsible for many physical traits in Holsteins.

Each animal has two alleles for coat color.
- Black coat color is dominant (labeled "B")
- Red coat color is recessive (labeled "b")

Holstein cattle can possess one of three genotypes for coat color:
- Homozygous for black coat color
- Heterozygous (called "red carrier")
- Homozygous for red coat color

1. Write out what the genotype (which alleles they have) and phenotype (what coat color they have) would be for each combination.

    Homozygous for black coat color   Genotype   _____

    Phenotype   _____

    Heterozygous/Red Carrier   Genotype   _____

    Phenotype   _____

    Homozygous for red coat color   Genotype   _____

    Phenotype   _____

Scenario:

Your black and white Holstein cow, Holstein-Acres Daisy May, does not have any red and white cattle in her pedigree, so you know she is <u>homozygous for black coat color</u>. You are interested in red & white cattle though, and want to try to eventually get some red and white offspring from this cow family. Because of this you decide to breed her to a <u>red & white Holstein bull</u> to work towards this goal, and you choose Mighty-Fine Studly Brick-Red.

2. Start by writing out the genotypes for Daisy May and Brick.

    Daisy May's genotype   _____

    Brick-Red's genotype   _____

3. Now use a Punnett Square to see what type of offspring you could get if you bred Daisy May to Brick-Red.

    What are the results? First tally the **genotypes** of the resulting offspring:

    _____/4 calves would be **homozygous for black coat color**

    _____/4 calves would be **heterozygous (red carriers)**

    _____/4 calves would be **homozygous for red coat color**

    Now look at the **phenotypes:**

    _____/4 calves would be black and white

    _____/4 calves would be red and white

    Is it possible to get red and white daughters from Daisy May? Why or why not?

    _____

    _____

    _____

27

The Next Generation

4. You are lucky and Daisy May's first calf is a heifer, sired by Brick-Red. Because of the Punnett Square you know that this calf's genotype is _____.

5. When it comes time to breed this heifer, your parents give you the option of three bulls to pick from as a sire, all of about equal genetic merit. Because you would still like to try and get a red and white calf in your herd, which bull makes the most sense for you to pick? Draw a Punnett Square for each mating to justify your choice.

Option 1: Ladys-Manor Shamrock   (Homozygous for black hair color)

<table>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
</table>

Genotypes of the resulting offspring:

_____/4 calves would be homozygous for black coat color

_____/4 calves would be heterozygous (red carriers)

_____/4 calves would be homozygous for red coat color

Phenotypes:

_____/4 calves would be black and white

_____/4 calves would be red and white

Option 2: Ronelee SS Durable *RC   (Red Carrier)

<table>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
</table>

Genotypes of the resulting offspring:

_____/4 calves would be homozygous for black coat color

_____/4 calves would be heterozygous (red carriers)

_____/4 calves would be homozygous for red coat color

Phenotypes:

_____/4 calves would be black and white

_____/4 calves would be red and white

Option 3: Tiger-Lily Ladd-Red   (Homozygous for Red coat color)

<table>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
</table>

Genotypes of the resulting offspring:

_____/4 calves would be homozygous for black coat color

_____/4 calves would be heterozygous (red carriers)

_____/4 calves would be homozygous for red coat color

Phenotypes:

_____/4 calves would be black and white

_____/4 calves would be red and white

6. Your best chance at getting a red and white calf would be to breed your cow to _____.

7. By doing that you would have a _____% chance at getting a red and white calf.

8. Aside from the red gene, give an example of at least one other recessive trait that can be found in Holstein cattle.

_____

_____

_____

Case Study Exercise #2 – Polled Holstein Cattle

Animals that naturally do not grow horns are known as "polled." With the increasing emphasis on animal welfare, as well as practical on-farm management, interest in the polled gene is increasing, with naturally hornless animals becoming more popular.

Like coat color, each animal has two alleles for the polled gene.
   • Polled is dominant (labeled "P")
   • Horned is recessive (labeled "p")

1. It may come as a surprise that the polled gene is dominant over the horned gene, since most Holstein cattle are born with horns. How does this being a dominant trait help increase the number of polled animals more quickly than if it were a recessive trait?

   _____

   _____

   _____

2. Write out the three genotypes polled cattle can have, and the phenotypes that go with each. Remember, polled is dominant.

   Genotype 1   _____

   Phenotype 1   _____

   Genotype 2   _____

   Phenotype 2   _____

   Genotype 3   _____

   Phenotype 3   _____

What would happen in the following scenarios?
Use the Punnett Squares to justify your answers.

3. Horned Cow (genotype = _____) x Heterozygous Polled Bull (genotype = _____)

Genotypes of the resulting offspring:

   _____/4 calves would be homozygous for the polled gene

   _____/4 calves would be heterozygous for the polled gene

   _____/4 calves would be homozygous for the horned gene

Phenotypes:

   _____/4 calves would have horns

   _____/4 calves would be naturally polled

4   Heterozygous Polled Cow (genotype = _____) x Heterozygous Polled Bull (genotype = _____)

<table>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
</table>

Genotypes of the resulting offspring:

_____/4 calves would be homozygous for the polled gene

_____/4 calves would be heterozygous for the polled gene

_____/4 calves would be homozygous for the horned gene

Phenotypes:

_____/4 calves would have horns

_____/4 calves would be naturally polled

5   Homozygous Polled Cow (genotype = _____) x Horned Bull (genotype = _____)

<table>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
</table>

Genotypes of the resulting offspring:

_____/4 calves would be homozygous for the polled gene

_____/4 calves would be heterozygous for the polled gene

_____/4 calves would be homozygous for the horned gene

Phenotypes:

_____/4 calves would have horns

_____/4 calves would be naturally polled

6.   Based on what you now know about the polled gene, is it possible to have a horned calf born from two polled animals? Why or why not?

_____

_____

_____

_____

7.   How would you explain to a classmate the difference between dominant and recessive genes?

_____

_____

_____

_____

If you are still interested in learning more about genes and inheritance, ask a parent or teacher to help you research dominant and recessive traits in humans. Are there any traits that you can see expressed in yourself?

_____

_____

_____

Understanding Genetic Progress Worksheet

Answers can be found on page 37

Use the activities below to test your knowledge and understanding of the factors influencing genetic progress and heritability. Refer to the definitions on page 8 if you need a reminder of what each term means.

Matching Game!

Match the factor of genetic change with the example below that best describes fits it.

Accuracy of selection	Sorting your heifers based on their PTPI and deciding NOT to use the bottom 20% for breeding purposes
Selection Intensity	Trying to breed cows that produce a lot of milk to bulls with high fat and protein percentages, instead of other bulls that are high for milk production
Genetic Variation	Breeding all of your heifers to sexed semen from genomic young sires to be sure you get more heifers from your younger animals
Generation Interval	Studying the Sire Summaries and carefully reviewing all genetic information available to make sure you pick the best bulls to use on your farm

This or That - Which would lead to faster genetic progress?

In each pair, circle the phrase that would result in faster genetic progress in a dairy herd.

1. Selecting the bulls you want to use based on your neighbor's recommendation of which ones are the best right now

   OR

   Looking at genomic information on a group of bulls and using that to select the ones that you feel will work best in your herd

2. Breeding cows in heat to a random assortment of bulls

   OR

   Picking individual matings for cows before breeding them

3. Breeding all of your heifers to one of five bulls, all with different pedigrees

   OR

   Breeding all of your heifers to one of five sons of your favorite bull

4. Selling your extra bred heifers to free up some space in your barns

   OR

   Selling some third and fourth lactation cows to a local dairy to free up some space in your barns

ANSWER KEY

ANSWER KEY FOR:
Case Study Exercise #1 – Holstein Coat Color

Let's look at coat color in Holstein cattle as an example of simple dominance, which is responsible for many physical traits in Holsteins.

Each animal has two alleles for coat color.
- Black coat color is dominant (labeled "B")
- Red coat color is recessive (labeled "b")

Holstein cattle can possess one of three genotypes for coat color:
- Homozygous for black coat color
- Heterozygous (called "red carrier")
- Homozygous for red coat color

1. Write out what the genotype (which alleles they have) and phenotype (what hair color they have) would be for each combination.

Homozygous for black coat color	Genotype	*BB*
	Phenotype	*Black and White Coat*
Heterozygous/Red Carrier	Genotype	*Bb*
	Phenotype	*Black and White Coat*
Homozygous for red coat color	Genotype	*bb*
	Phenotype	*Red and White Coat*

Scenario:

Your black and white Holstein cow, Holstein-Acres Daisy May, does not have any red and white cattle in her pedigree, so you know she is <u>homozygous for black coat color</u>. You are interested in red & white cattle though, and want to try to eventually get some red and white offspring from this cow family. Because of this you decide to breed her to a <u>red & white Holstein bull</u> to work towards this goal, and you choose Mighty-Fine Studly Brick-Red.

2. Start by writing out the genotypes for Daisy May and Brick.

Daisy May's genotype   *BB*

Brick-Red's genotype   *bb*

3. Now use a Punnett Square to see what type of offspring you could get if you bred Daisy May to Brick-Red.

	b	*b*
B	*Bb*	*Bb*
B	*Bb*	*Bb*

What are the results? First tally the **genotypes** of the resulting offspring:

0 /4 calves would be **homozygous for black coat color**

4 /4 calves would be **heterozygous (red carriers)**

0 /4 calves would be **homozygous for red coat color**

Now look at the **phenotypes:**

4 /4 calves would be black and white

0 /4 calves would be red and white

Is it possible to get red and white daughters from Daisy May? Why or why not?

No, she is not a red carrier, so there is no chance that a calf from her would be homozygous for the red coat color gene. Since red coat color is recessive, an animal must have two copies of this gene (homozygous) is order for it to be expressed.

(Continued on next page)   33

The Next Generation

4. You are lucky and Daisy May's first calf is a heifer, sired by Brick-Red. Because of the Punnett Square above, you know that this calf's genotype is __Bb____.

5. When it comes time to breed this heifer, your parents give you the option of three bulls to pick from as a sire, all of about equal genetic merit. Because you would still like to try and get a red and white calf in your herd, which bull makes the most sense for you to pick? Draw a Punnett Square for each mating to justify your choice.

Option 1: Ladys-Manor Shamrock   (Homozygous for black coat color)

	B	B
B	BB	BB
b	Bb	Bb

Genotypes of the resulting offspring:

__2__/4 calves would be homozygous for black coat color

__2__/4 calves would be heterozygous (red carriers)

__0__/4 calves would be homozygous for red coat color

Phenotypes:

__4__/4 calves would be black and white

__0__/4 calves would be red and white

Option 2: Ronelee SS Durable *RC   (Red Carrier)

	B	b
B	BB	Bb
b	Bb	bb

Genotypes of the resulting offspring:

__1__/4 calves would be homozygous for black coat color

__2__/4 calves would be heterozygous (red carriers)

__1__/4 calves would be homozygous for red coat color

Phenotypes:

__3__/4 calves would be black and white

__1__/4 calves would be red and white

Option 3: Tiger-Lily Ladd-Red   (Homozygous for red coat color)

	b	b
B	Bb	Bb
b	bb	bb

Genotypes of the resulting offspring:

__0__/4 calves would be homozygous for black coat color

__2__/4 calves would be heterozygous (red carriers)

__2__/4 calves would be homozygous for red coat color

Phenotypes:

__2__/4 calves would be black and white

__2__/4 calves would be red and white

6. Your best chance at getting a red and white calf would be to breed your cow to __Ladd – Red_____.

7. By doing that you would have a __50__ % chance at getting a red and white calf.

8. Aside from the red gene, give an example of at least one other recessive trait that can be found in Holstein cattle.
   _BLAD, CVM, DUMPs, many health-related problems_____

   _____

   _____

ANSWER KEY FOR:
Case Study Exercise #2 – Polled Holstein Cattle

Animals that naturally do not grow horns are known as "polled." With the increasing emphasis on animal welfare, as well as practical on-farm management, interest in the polled gene is increasing, with naturally hornless animals becoming more popular.

Like coat color, each animal has two alleles for the polled gene.
- Polled is dominant (labeled "P")
- Horned is recessive (labeled "p")

1. It may come as a surprise that the polled gene is dominant over the horned gene, since most Holstein cattle are born with horns. How does this being a dominant trait help increase the number of polled animals more quickly than if it were a recessive trait?

    An animal only needs to inherit one copy of the gene to express it.
    _____

    _____

2. Write out the three genotypes polled cattle can have, and the phenotypes that go with each. Remember, polled is dominant.

    Genotype 1   *PP*

    Phenotype 1   *Polled*   *(homozygous polled)*

    Genotype 2   *Pp*

    Phenotype 2   *Polled*   *(heterozygous polled)*

    Genotype 3   *pp*

    Phenotype 3   *Horned*   *(homozygous polled)*

What would happen in the following scenarios?
Use the Punnett Squares to justify your answers.

3. Horned Cow (genotype = ___*pp*___) x Heterozygous Polled Bull (genotype = ___*Pp*___)

	P	*p*
P	*Pp*	*pp*
p	*Pp*	*pp*

    Genotypes of the resulting offspring:

    __*0*__/4 calves would be homozygous for the polled gene

    __*2*__/4 calves would be heterozygous for the polled gene

    __*2*__/4 calves would be homozygous for the horned gene

    Phenotypes:

    __*2*__/4 calves would have horns

    __*2*__/4 calves would be naturally polled

4   Heterozygous Polled Cow (genotype = __*Pp*__) x Heterozygous Polled Bull (genotype = __*Pp*__)

	P	p
P	PP	Pp
p	Pp	pp

Genotypes of the resulting offspring:

__1__/4 calves would be homozygous for the polled gene

__2__/4 calves would be heterozygous for the polled gene

__1__/4 calves would be homozygous for the horned gene

Phenotypes:

__1__/4 calves would have horns

__3__/4 calves would be naturally polled

5   Homozygous Polled Cow (genotype = __*PP*__) x Horned Bull (genotype = __*pp*__)

	p	p
P	Pp	Pp
P	Pp	Pp

Genotypes of the resulting offspring:

__0__/4 calves would be homozygous for the polled gene

__4__/4 calves would be heterozygous for the polled gene

__0__/4 calves would be homozygous for the horned gene

Phenotypes:

__0__/4 calves would have horns

__4__/4 calves would be naturally polled

6. Based on what you now know about the polled gene, is it possible to have a horned calf born from two polled animals? Why or why not?

Only if both the sire and dam were heterozygous for polled (Pp), and the resulting calf inherited the horned gene from both parents (25% chance, genotype = pp).

7. How would you explain to a classmate the difference between dominant and recessive genes?

Dominant genes "dominate" other genes and only need one copy to be expressed in an animal's phenotype. Recessive genes can be passed along without being expressed, but an animal must inherit 2 copies of a recessive gene for it to be expressed in an animal's phenotype.
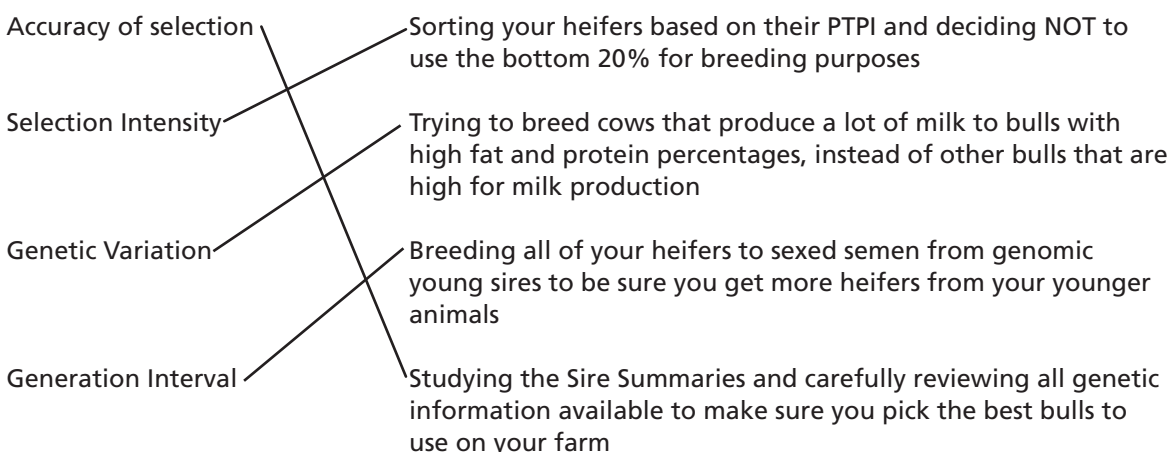
ANSWER KEY FOR:
Understanding Genetic Progress Worksheet

Use the activities below to test your knowledge and understanding of the factors influencing genetic progress and heritability. Refer to the definitions on page 8 if you need a reminder of what each term means.

Matching Game!

Match the factor of genetic change with the example below that best describes fits it.

Accuracy of selection — Sorting your heifers based on their PTPI and deciding NOT to use the bottom 20% for breeding purposes

Selection Intensity — Trying to breed cows that produce a lot of milk to bulls with high fat and protein percentages, instead of other bulls that are high for milk production

Genetic Variation — Breeding all of your heifers to sexed semen from genomic young sires to be sure you get more heifers from your younger animals

Generation Interval — Studying the Sire Summaries and carefully reviewing all genetic information available to make sure you pick the best bulls to use on your farm

This or That - Which would lead to faster genetic progress?

In each pair, circle the phrase that would result in faster genetic progress in a dairy herd.

1. Selecting the bulls you want to use based on your neighbor's recommendation of which ones are the best right now

   OR

   (Looking at genomic information on a group of bulls and using that to select the ones that you feel will work best in your herd)

2. Breeding cows in heat to a random assortment of bulls

   OR

   (Picking individual matings for cows before breeding them)

3. (Breeding all of your heifers to one of five bulls, all with different pedigrees)

   OR

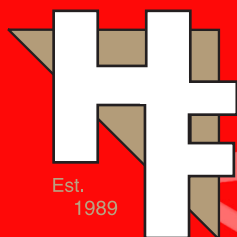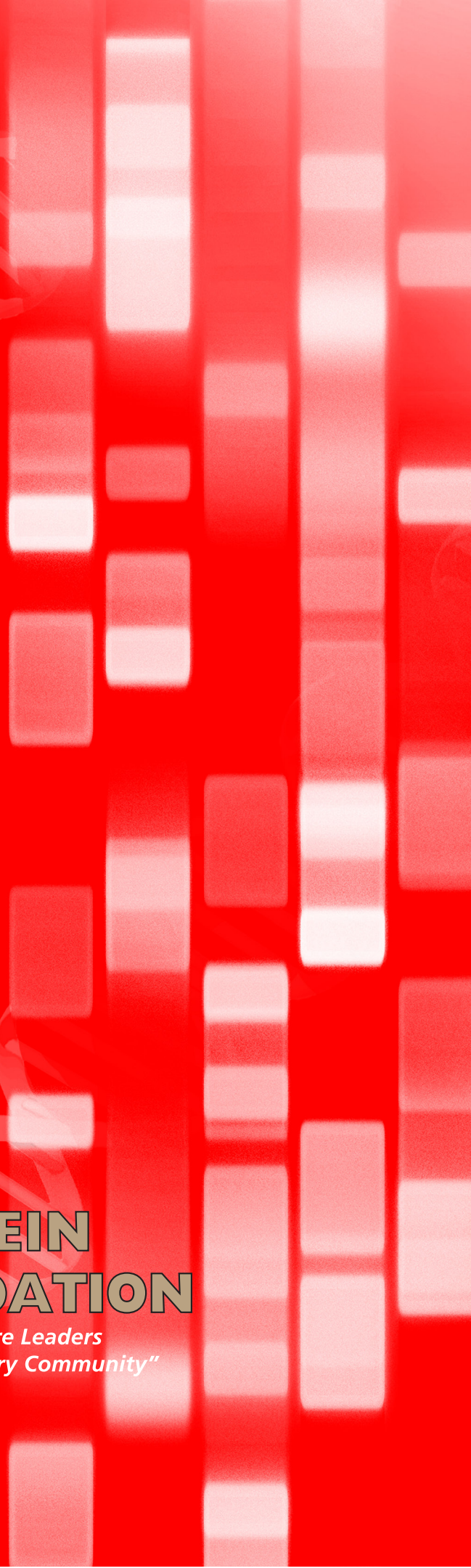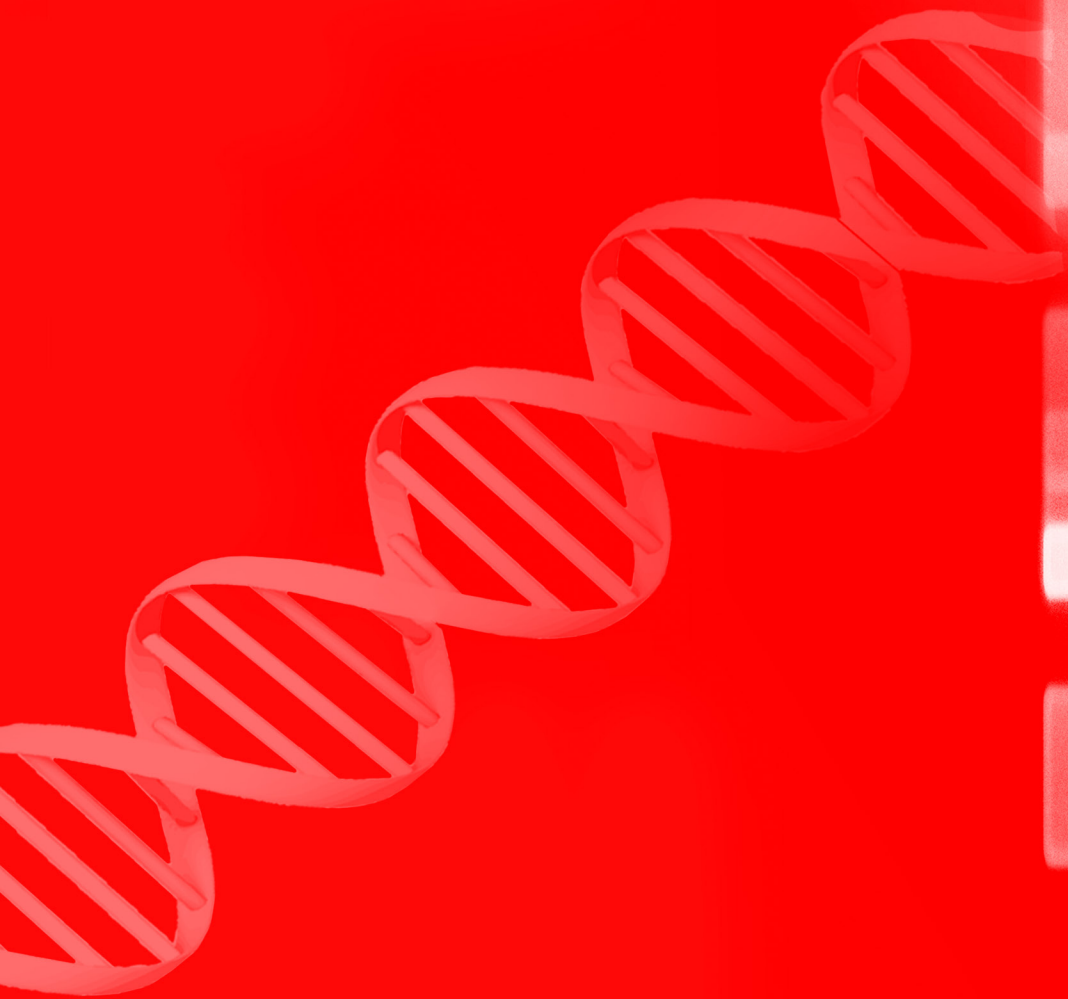   Breeding all of your heifers to one of five sons of your favorite bull

4. Selling your extra bred heifers to free up some space in your barns

   OR

   (Selling some third and fourth lactation cows to a local dairy to free up some space in your barns)

Notes:

Notes:

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