Acronyms Galore: What do they all mean?

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Genetic improvement in your flock depends on your ability to select breeding sheep that are genetically superior for traits of economic importance. Unfortunately, visual appraisal alone may not identify those sheep that have the greatest potential as parents. That is why records are a necessary part of your breeding program. In this *Genetically Speaking*, we take selection and genetic improvement a step further and answer some questions about heritability, estimation of genetic merit, and genetic evaluation programs. In the process, we will define some of the acronyms you will encounter as you use those genetic evaluation programs for flock improvement.

Is What You See Always What You Get?

An animal's performance (**Phenotype**, **P**) for a trait is the result of its genes (**Genotype**, **G**) and the effect of the **Environment** (**E**) in which it is raised (i.e., nutrition, health program, housing, temperature, humidity, parasite exposure, etc.). Thus, the phenotype of an animal is often expressed as:

$$P = G + E$$

An animal's genotype is the set of genes that affects a particular trait. Those genes that act independently, or additively, make up the animal's **Breeding Value** (**BV**). This is the portion of the animal's phenotype that can be passed on to its offspring. As a result, we express the phenotype as:

$$P = BV + E$$

This is a slight oversimplification, but it will work for our discussion here.

In real life, we observe an animal's phenotype, but we want to know its breeding value (e.g., its genetic merit as a future parent). Unfortunately, it is not possible to know the ***true*** genetic merit of an animal for a particular trait. Therefore, in order to make selection decisions, we must ***estimate*** its breeding value. The animal's own performance is one indicator of its breeding value. The usefulness of this individual information depends on the proportion of the differences in performance between animals that is due to differences in breeding values. This is called the **heritability** (represented by the symbol, h^2) of the trait.

$$h^2 = \frac{\text{BV Variation}}{\text{Phenotypic Variation}}$$

Heritability measures the relative importance of genetics and environment in developing an animal's phenotype, for a trait.

Traits are not equally heritable; that is, traits are not equally affected by an animal's genetics. Theoretically, heritability can range from 0 to 100%. A heritability of zero indicates that all of the phenotypic differences between animals are due to environmental effects. A heritability of 100% indicates that all phenotypic differences between animals are due to differences in breeding values. Heritabilities for most economically important traits in sheep range from 5 to 55% (Table 1). This tells us that most of the phenotypic differences we observe between sheep are due to non-genetic, or environmental,effects. This is the reason ***what you see is not always what you get.*** For highly heritable traits (35% or higher), the animal's own performance is a good indicator of its breeding value. For lowly heritable traits (below 15%), the animal's phenotype is much less useful. In these cases, having performance information on the animal's relatives (progeny, pedigree) will be important in estimating its breeding value.

Table 1. Heritabilities for Different Types of Traits in Sheep.

Type of Trait	Level of Heritability
Reproductive	Low (5 to 15%)
Growth	Moderate (20 to 25%)
Carcass	High (30 to 45%)
Fleece	High (35 to 55%)
Dairy	High (30 to 40%)

What are EBVs?

An animal receives one-half of its genetic make-up from each parent so we expect the breeding value of an individual to be equal to the average of the breeding values of its parents:

Expected BV = ½ (Sire's BV) + ½ (Dam's BV)

This is only an expectation. An animal's ***true*** breeding value for a trait is never known. We must estimate it using the animal's own performance and/or performance of its relatives. This is called the **Estimated Breeding Value** (**EBV**); it is the ***predicted*** value of an animal as a parent compared with other potential parents. Because selection is about picking the parents of the next generation, this measurement is important to a breeding program.

The simplest form of EBV is based on an animal's own performance:

EBV = h^2 x Selection Differential

where Selection Differential is the difference between the individual's performance and the average performance of its contemporaries.

For example, suppose a ram has a weaning weight of 40 kg (or 88 lb) and his contemporary group (other rams of the same breed and approximate age raised under the same conditions) has an average weaning weight of 28 kg (or 62 lb). His selection differential for weaning weight is 40 - 28 = 12 kg. Assuming a heritability of 10%, his EBV is 0.10 x 12 kg = +1.2 kg (or +2.6 lb).

What are EPDs?

A sire (or dam) passes on a random half of his (or her) independent gene effects to his (or her) offspring. Because the breeding value is the sum of the independent effects of all of an individual's genes affecting a trait, a parent transmits, *on the average*, half its breeding value to its offspring. Half of the parent's breeding value for a trait is our expectation of what is inherited from the parent and is called the **Progeny Difference** (**PD**).

PD = ½ BV

Recall, the previous equation:

Expected BV = ½ (Sire's BV) + ½ (Dam's BV).

We can rewrite this as equation as:

Expected BV = Sire's PD + Dam's PD.

In other words, the expected merit of progeny from a particular mating is equal to the average of the parents' breeding values *or* the sum of their progeny differences.

Progeny difference is a very practical concept. Think of it as the expected difference between the average performance of an individual's progeny and the average performance of all progeny (assuming randomly chosen mates). For example, if a particular ram has a PD = +0.5 kg for weaning weight, and we mate him to an average set of ewes (their average PD = 0), we can expect the weaning weights of his lambs to average 0.5 kg heavier than average lambs.

Like breeding values, progeny differences are not directly measurable, but can be predicted from performance data. Such predictions are called **Expected Progeny Differences** (**EPDs**) and are commonly used to make genetic comparisons among animals. Just as the predicted difference is equal to half the breeding value, an EPD = ½ EBV.

What is the NSIP?

Purebred producers can have EBVs calculated on their sheep by enrolling their flocks in the **National Sheep Improvement Program** (**NSIP**, www.NSIP.org). Producers submit on-farm performance data and NSIP returns genetic evaluations. Currently, genetic evaluations are limited to purebred sheep. However, commercial producers can use EBVs to improve traits in their flocks by selecting purebred rams with strong EBVs for the traits that are economically important to them.

NSIP was established in 1986. Initially, it was limited to within-flock evaluations. As the program grew and more flocks with linkages (common genetics) joined, across flock (within pure breed) evaluations were generated and NSIP became a breed-centered program.

Predictions of genetic merit were originally reported as EPDs. Through 2009, yearly genetic evaluations were conducted by Virginia Tech under the direction of Dr. Dave Notter. In 2010, NSIP finalized a partnership with Meat and Livestock Australia that transferred data processing from Virginia Tech to LambPlan, the national sheep performance program of Australia. This partnership allows the U.S. sheep industry to generate genetic evaluations, now reported as EBVs, every two weeks.

Currently, NSIP provides genetic evaluations for 20 breeds:

Black Welsh Mountain	**Meat Merino**
Border Leicester	**Oxford**
Columbia	**Polypay**
Dorper/White Dorper	**Rambouillet**
Dorset	**Royal White**
Finnsheep	**Shropshire**
Hampshire	**Suffolk**
Katahdin	**Targhee**
Icelandic	**Texel**
Lincoln	**White Suffolk**

What Traits Have EBVs?

Specific traits for which EBVs are calculated vary among breeds. EBVs for some of the more economically important traits are described below (Dr. Dave Notter, NSIP EBV Notebook, September 1, 2011): Please refer to the blue tables shown here to the right.

How are EBVs reported?

An EBV is reported, in the normal units of a trait (kg for weight traits), as a deviation (+ or -) from the average population value, which is considered to be zero. Therefore, EBVs always have a positive (+) or negative (-) sign in front of them. The positive and negative symbols don't always mean better or worse; it depends on the trait. For example a WWT EBV of +0.5 kg is good (i.e., heavier lambs at weaning) but a FD EBV of -0.3 microns is also good (i.e., smaller diameter fiber).

EBVs for Weight Traits Reported for all breeds, expressed in kg; 1 kg = 2.2 lb.	
Birth Weight (BWT)	The BWT EBV estimates direct genetic effects on weight at birth. Positive selection on BWT EBV is expected to increase birth weight; negative selection is expected to decrease birth weights.
Weaning Weight (WWT)	The WWT EBV provides an estimate of preweaning growth potential. Selection for high WW EBV is expected to increase weaning weights.
Maternal Weaning Weight (MWWT)	The MWWT EBV estimates genetic merit for mothering ability. It reflects genetic differences in ewe milk production as realized her lambs. It is derived by evaluating whether individual ewes produce lambs that are heavier or lighter than expected based on EBVs of the parents. Ewes whose lambs grow faster than expected are assumed to be better milk producers. Ewes whose lambs grow slower than expected are assumed to produce less milk. Selection for high MWWT EBVs is expected to improve milk production.
Total Maternal Weaning Weight	The Total Maternal Weaning Weight EBV combines information on weaning weight and maternal milk. Previously, this was provided by NSIP as the **Milk plus Growth EBV**. Total Maternal Weaning Weight EBVs are not directly provided by LambPlan, but can be calculated from maternal weaning weight and weaning weight EBVs as: **MWWT EBV + ½ WWT EBV** The Maternal Weaning Weight EBV recognizes the genetic contribution of a ewe to the weaning weight of her lambs is the combined effect of her milk production (measured by the MWWT EBV) and a random one-half of her genes for preweaning growth potential (measured by the WWT EBV).

EBVs for Wool Traits Reported for Western Range Breeds and Maternal Wool Breeds.	
Fleece Weight (GFW)	The GFW EBV is expressed as a percentage (%). It is based on grease fleece weight and estimates the animal's genetic potential for wool production.
Fiber Diameter (FD)	The FD EBV is expressed in microns. It estimates genetic merit for fleece quality. Animals with finer, more desirable fleeces have negative FD EBV, so negative EBVs are favored for this trait.
Staple Length (SL)	The SL EBV is expressed in millimeters. It estimates genetic potential for length of the wool fiber.

EBVs for Reproductive Traits Reported for all breeds.	
Number of Lambs Born (NLB)	The NLB EBV (%) evaluates genetic potential for prolificacy. For example, ewes with NLB EBVs of +10.0 are expected to have an average of 0.10 more lambs at each lambing than average ewes, and their daughters are expected to have an average of 0.05 more lambs at each lambing compared to daughters of average ewes. Selection on NLB EBV is expected to increase prolificacy in the flock.
Number of Lambs Weaned (NLW)	The NLW EBV (%) evaluates combined ewe effects on prolificacy and lamb survival to weaning. For example, ewes with NLW EBVs of +10.0 are expected to wean an average of 0.10 more lambs at each lambing than average ewes. Their daughters are expected to wean an average of 0.05 more lambs at each lambing compared to daughters of average ewes. Selection on NLW EBV is expected to increase weaning rates in the flock.

EBVs for Parasite Resistance Reported for all breeds.	
Worm Egg Count (WEC)	The WEC EBV (%) evaluates genetic merit for parasite resistance based on worm egg counts recorded at weaning or at early or late postweaning ages. Animals with low WEC EBVs are expected to have greater parasite resistance

How Can Sheep Producers Use EBVs?

Consider the NSIP genetic evaluation for a sample set of five rams presented in Table 2. We can use these data to rank rams based on their expected contribution as sires and to choose sires for different flock situations.

Ranking Rams. Consider weaning weight. Ram #5 ranks highest for this trait. He has a WWT EBV of +2.4 kg. This means that Ram #5 is estimated to have genes that result in lambs that are 2.4 kg heavier at weaning than a ram of average genetic value from the same population (i.e., a ram with a WWT EBV of 0.0). Ram #5's WWT EPD is 1.2 kg (EPD = ½ EBV). This means that if Ram #5 is mated to a group of ewes of average genetic merit (WWT EBV = WWT EPD = 0.0), his progeny are expected to weigh 1.2 kg more at weaning than lambs sired by a ram of average value (WWT EBV = WWT EPD = 0.0).

Ram #1 is on the other end of the rankings for weaning weight. He ranks last with a WWT EBV of -1.2 kg and, therefore, a WWT EPD of -0.6. If Ram #5 and Ram #1 are both mated to a group of ewes of average genetic merit, Ram #5's progeny are expected to weigh 1.8 kg more at weaning than Ram #1's progeny.

Expected Difference in Performance of Progeny of Ram #5 and Ram #1 = **Ram #5's WWT EPD - Ram #1's WWT EPD** = **1.2 - (0.6)** = **1.8 kg**

Table 2. Sample EBVs for Growth, Maternal and Reproductive Traits.

			EBV			
ID	Sex	Birth Year	Weaning Weight (WWT, kg)	Maternal Weaning Weight (MWWT, kg)	Total Maternal Weaning Weight (kg)	Number of Lambs Born (NLB, %)
1	Ram	2015	-1.2	+0.1	-0.5	+10.1
2	Ram	2015	+0.3	-0.6	-0.5	+2.8
3	Ram	2006	+2.2	+0.7	+3.3	-4.4
4	Ram	2017	+0.4	+0.2	+0.4	+17.2
5	Ram	2017	+2.4	+1.0	+2.2	+0.8

Selecting Sires for Specific Flocks

Consider the flock situations presented below. Given the breeding objectives of the respective producers, which of the five rams (**Table 2**) would be the best choice?

Situation 1: ***Producer is satisfied with lambing percentage (already 220%) but wants to improve milk production and growth rate.***

Choose Ram #5 for high EBV for weaning weight, maternal weaning and total maternal weaning weight. We would expect Ram #5 to sire fast-gaining lambs that grow well to weaning, relative to the breed average, and to sire daughters that will produce above average weaning weights for their lambs.

Situation 2: ***Producer is satisfied with lamb weaning weight and growth rate but wants to improve lambing percentage.***

Ram #4 is the choice for this flock because he ranks highest for number of lambs born. His EBV for weaning weight, maternal weaning weight and total maternal weaning weight are all positive, so no progress should be lost for those traits. We would expect Ram #4 to sire daughters to have an average of 0.086 [(½)(0.172)] more lambs at each lambing compared to daughters of average rams.

Situation 3: ***Producer knows the flock has serious production problems and needs a general improvement in total productivity.***

This situation is different from the other two. The producer is not satisfied with overall production in the flock and wants to improve production in both growth and maternal traits. The goal here is to select a ram with high EBVs for all traits. Most of the time, rams will not be rank high in *all* traits, so trade-offs are often required. In this example, it is a hard decision. Ram #5 is positive for all traits, but ranks next to last for number of lambs born. Ram #4 ranks highest for number of lambs born, but ranks in the middle for the other traits. Ram #3 ranks higher for weaning traits but has a negative EBV for number of lambs born. Neither Ram #1 nor Ram #2 are considered because of their overall rankings for the traits shown. Thus, it boils down to either Ram #4 or Ram #5. Either way, the producer has to make a trade-off. Because the primary determinant of profit in a flock is number of lambs sold, we may choose to give up a little with regard to weaning performance in order to make a big improvement in number of lambs born. In that case, Ram #4 is our choice.

Remember, EBVs (and EPDs) do not predict absolute performance. EBVs (and EPDs) are used for ranking and for ranking.

Finally, What Does It All Mean?

Estimated breeding values are the best available estimates of genetic merit. They allow animals to be compared fairly and directly with other animals from the same breed. They do not necessarily reflect the animal's observed performance (phenotype), which is a combination of both genetic and environmental influences. Rather, they are an estimate of the genetic component of that performance. Estimated breeding values are tools to create and manage genetic change. The optimal use of estimated breeding values requires a clearly stated breeding objective. The breeding objective is a statement of the genetic characteristics that need to be changed in your flock, that need to be maintained at the current level or that can be ignored. Ultimately, your breeding objective depends on your role in the sheep industry.

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