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Predicting Inheritance of Breeding Herds

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How much of their advantage for a particular trait do superior animals transmit to their offspring? Heritability estimates help us answer this important question. This Guide explains the meaning of heritability estimates, how they are calculated, and how they may be used for the improvement of livestock through breeding.

What Are Heritability Estimates?

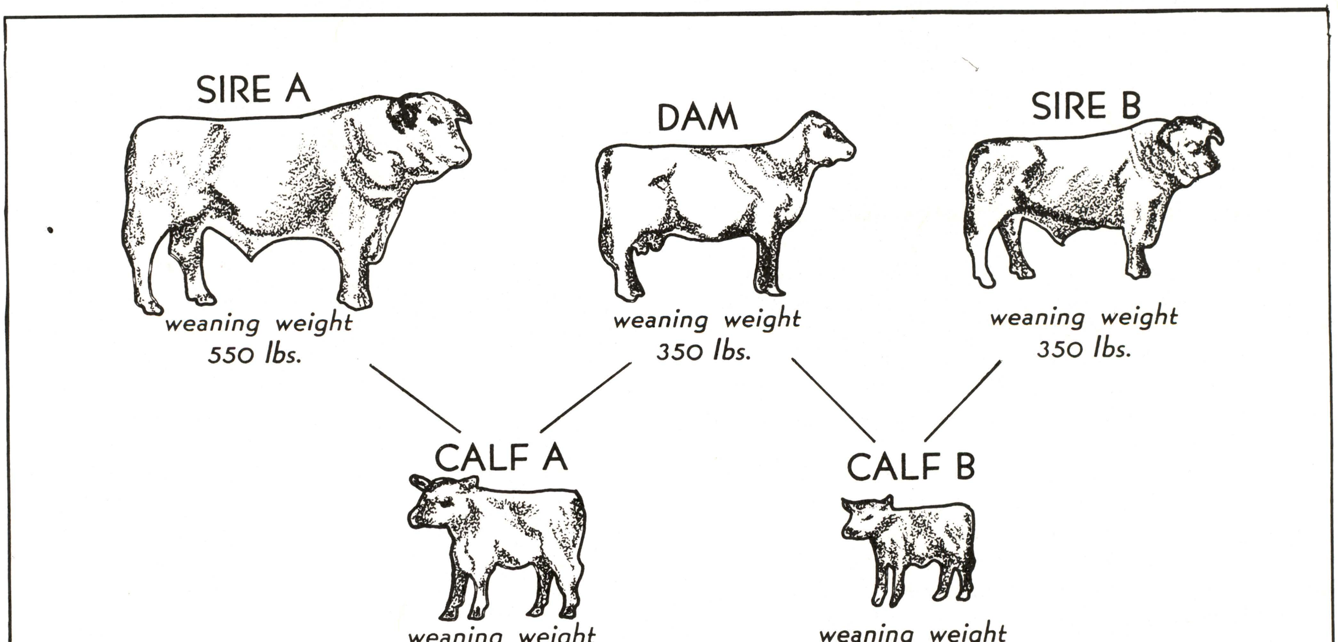
A heritability estimate is a figure showing the amount of variation in a trait, such as weaning weight, that is due to heredity. This figure is usually a percentage. Heritability percentages for cattle traits are given in Table 2. These are shown for hogs in Table 4.

If you subtract the heritability percentage estimate from 100, the remainder is the percentage due to environment (feed, climate, disease, etc.). The heritable portion of the variation is transmitted by parents to their offspring, the environmental portion is not.

To figure the amount of improvement in a trait that the parents will transmit to their offspring, figure the herd or group average for that trait and the amount that the parents vary from the average. For example, average daily gains in a test of 13 bull calves fed for 154 days are given in Table 1.

TABLE 1. DAILY RATE OF GAIN IN BULLS FULL FED FOR 154 DAYS

Number of Bull		Average Daily Gain
808		2.10
819		2.75
822		2.25
823		1.79
826		2.35
829		2.58
845		2.72
852		2.59
858		2.42
864		2.38
891		2.38
892		2.73
898		2.34
	Average	2.41



TABEL 2. HERITABILITY ESTIMATES FOR ECONOMIC TRAITS IN BEEF CATTLE.

Trait	Percent Heritable
Fertility	10
Birth weight	40
Weaning weight	30
Cow maternal ability	40
Feedlot gain	55
Pasture gain	30
Efficiency of gain in feedlot	40
Yearling weight (365-day)	60
Conformation score:	
Weaning	30
Slaughter	40
Carcass traits:	
Carcass grade	50
Dressing percent	45
Rib eye area	70
Fat thickness	45
Tenderness	60
Retail product, percent	30
Retail product, pounds	60
Height	55

The average rate of gain for the 13 bulls was 2.41 pounds. Bull 819 gained 2.75 pounds per day, 0.34 pounds above the average.

The question is: **How much of this 0.34 pound daily rate of gain advantage can bull 819 transmit to his offspring?** Heritability estimates help answer this question.

Note in Table 2 that rate of gain in the feedlot is about 55 percent heritable. This means that approximately 55 percent of this 0.34 pound advantage, or 0.19 pound per day, should be transmitted due to superior genes of bull 819.

This does not mean that this bull's calves will average 0.19 pound per day over the average for calves of the 13 bulls. Half of the inheritance also comes from the mother. This leaves about 0.10 pound advantage of inheritance from the sire. Thus, if the dams used were all average in rate of gain, we would expect the calves of bull 819 to gain 0.10 pound per day faster than the average of the calves sired by the 13 bulls.

How Are Heritability Estimates Calculated?

Estimates given in the tables used here are averages of numerous studies in college experiment stations of many states. The stations calculate their estimates by determining the resemblance between relatives for a particular trait. The resemblance between half brothers and sisters, full brothers and sisters, identical twins, or parents and their offspring may be used for this purpose.

Experiment stations try to equalize environmental factors as much as possible and adjust for other nongenetic factors that might cause variation in animal performance. For instance, if they are determining the correlation between the weaning weights of cows and their calves, they adjust for age of calf at weaning, age of dam of each calf, sex of calf, and possibly the season when the calf was born. All of these conditions are noninheritance factors which make a difference in weaning weights and tend to mask the influence of heredity.

$$\sigma_H^2 + \sigma_E^2 = \sigma_O^2 \text{ and Heritability } = \frac{\sigma_H^2}{\sigma_H^2 + \sigma_E^2} = \frac{\sigma_H^2}{\sigma_O^2}$$

σ_O^2 = Actual observed variance

σ_H^2 = That part of variance caused by heredity of different individuals.

σ_E^2 = That part of variance caused by environment under which different individuals develop.

When the fraction of $\frac{\sigma_H^2}{\sigma_O^2}$ is large, we say the trait is highly heritable, like yearling weight; while a low fraction would result in a lowly heritable trait such as fertility as shown in Table 2.

How to Use Heritability Estimates

Heritability estimates can be used to estimate the progress and set-backs in different traits that can be expected from different matings. For example, a particular mating may bring improvement in rate of gain if the parents are superior. If they are inferior, however, they may cause a decline in rate of gain in their offspring.

To illustrate how to figure expected progress from a particular mating, assume that from a herd in which the average daily gain in the feedlot is 2.40 pounds per day, bulls which gained 3.20 pounds and heifers which gained 2.80 pounds per day were kept for breeding purposes.

How much gain in genetic improvement would be expected in the progeny of these selected parents?

To answer this question, first calculate just how superior these parents were to the average in the herd, and something should be known about the inheritability to estimate for rate of gain in the feedlot.

The superiority of the breeding animals may be calculated as follows:

Superiority of dams = 2.80 - 2.40 or 0.40 lb. per day.
Superiority of sires = 3.20 - 2.40 or 0.80 lb. per day.
Superiority of parents = $\frac{0.40 + 0.80}{2}$ **= 0.60 lb. per day.**

The next question is how much of this 0.60 pound advantage of the parents is transmitted to the offspring. The heritability of rate of gain of beef cattle in the feedlot is about 55 percent (See Table 2 of heritability estimates).

Expected genetic gain = 0.60 x 55% or 0.33 lb./day

The advantage of the parents (0.60 pound) times the heritability estimate (55 percent) gives the genetic gain (0.33) expected in the offspring.

The herd average was 2.40 pounds feedlot gain per day. With all other things being equal, we would expect the offspring of the selected parents mentioned to gain an average of:

2.40 + 0.33 = 2.73 pounds per day

This is the average of the herd from which the parents were selected plus the genetic advantage transmitted by the parents.

When to Use Heritability Estimates

The calculations made above illustrate two important points. First, if the selected parents had not been superior in rate of gain over the average of the herd, there would have been no genetic improvement in the rate of gain of their offspring, regardless of the degree of heritability of the trait.

Second, the amount of genetic progress is also dependent on how highly heritable the trait in question is. Though the parents had an advantage over the average of the herd from which they came of 0.60 pound per day in gain, they would not have transmitted any of this advantage to their offspring if the trait had been of zero heritability.

The general conclusion, then, is that the greater the superiority of the individuals selected for breeding purposes and the higher the heritability of the trait, the more progress will be made in selection.

The size of the heritability estimates also gives some indication of the kind of selection that should be practiced for genetic improvement.

When the trait is highly heritable, find the best and mate the best to the best. On the other hand, when the trait is very low in heritability, little progress will be made by this kind of selection. More improvement in such a trait will be made by forming inbred lines and selecting between them to find those that combine or "nick" to the greatest advantage.

In other words, when traits are very lowly heritable, they seem to be more subject to hybrid vigor, which is obtained only by crossing lines with good combining ability. When they are highly heritable, this is less likely to be true and emphasis should be placed on selection of individuals with superior performance for the breeding herd.

How Many Traits in Selection?

The livestock industry, whether it be beef cattle or swine, is currently made up of high grade female herds in which purebred sires are used. There is an increased effort to exploit genetic variation by crossbreeding in both beef cattle and swine, especially for reproductive performance. The breeds that are our traditional germ plasma resource are involved in rapid changes from purely subjective, to objective evaluation for growth rate and carcass merit.

There is an increased objective in the livestock industry, dictated by current economics, to improve growth rate and meatiness in the animal. Those breeds that ultimately become the genetic resources and breeders who propagate them will depend a lot on the willingness of the breeder to change and the speed at which a specification product is developed within the industry species. This means there will be a great need for within-herd and within-breed record evaluation programs for highly heritable economic traits in order to remain competitive.

The economic traits for beef cattle and swine can be divided into three specific classes: **reproduction, production, and product.** Examples of these traits in the three classes would be calf crop percentage, yearling weight, and percent retail yield respectively. The relative net return in dollars for a unit change under average commercial condition for beef cattle can be measured in Table 3.

TABLE 3. AVERAGE ECONOMIC VALUE, HERITABILITY, AND PERCENTAGE OF HETEROSIS OF THREE CLASSES OF TRAITS IN BEEF CATTLE

Class of trait	Relative Economic Value	Heritability	Heterosis
Reproduction	20	10	10
Production	2	40	5
Product	1	50	0

When considering economic value, the reproduction traits are about ten times more important than production traits. And the production traits are two times more important than the product trait. As heritability increases, heterosis effects decrease. Or it might be stated that there is a negative association between heterosis and heritability.

The number of traits to select for depends entirely on the economic input to the commercial industry for maximum progress with a species. The rate of progress for a given trait in a multiple trait selection program is reduced by one over the square root of the number of traits being selected. The selection intensity is not only governed by the number of traits but also affected by the percent of progeny allowed to reproduce. Selections should be from the top performing animals. Percent of replacement governs the length of generation interval. This is figured by taking the average age of sire and dams used and dividing their average age into the expected change in a trait for rate of annual progress. The formula then would be:

Progress = ½ x the percent heritability x reach or selected parental difference x $\frac{1}{\sqrt{\text{number of traits selected}}}$ **divided by the generation interval.**

The method for figuring the rate of annual progress must consider heritability, selection differential, number of traits, and generation interval.

TABLE 4. HERITABILITY ESTIMATES FOR ECONOMIC TRAITS IN SWINE

Trait	Percent Heritable
Number of pigs farrowed	15
Number of pigs weaned	20
Litter weight at weaning	15
Weight of pig at five months	20
Growth rate (weaning to 200 lbs.)	30
Efficiency of gain	40
Carcass items:	
Carcass length	60
Thickness of backfat	45
Area of loin eye	50
Percent of ham	60
Percent of shoulder	50
Percent of fat cuts	60
Percent of lean cuts	35
Length of leg	65
Conformation	25

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