

HERITABILITY

Its Meaning and Use in Animal Breeding

D. W. Vogt

Associate Animal Scientist
Department of Animal Sciences

Consider a trait that requires measurement to make an evaluation—a trait in which individual differences are of degree rather than kind. Examples are reproductive efficiency, body weight, feed efficiency, egg production, milk production, or loin-eye area. These are called quantitative traits or characteristics. Most of the economically important traits that characterize various animal species are quantitative. Heritability estimates describe the single most important genetic consideration of such traits.

To understand the meaning of heritability, it is necessary to think in terms of *variability*. Consider, for example, the individual differences in weaning weight observed among beef calves in a single herd. The *range* in individual weights might extend from 300 to 600 pounds at 7 months of age. This range is *one* measure of the variability of this trait. A more sophisticated and useful measure of this variability is called the *variance*. Variance, in this case, measures how the individual calf-weaning weights are dispersed or spread out around the average weaning weight of all calves in the herd; it measures the total observable variance.

Through statistical techniques, it is possible to determine *how much of this total variance*

is caused by genetic or inherited differences among the calves, and how much of it is due to environmental differences. An environmental difference would arise, for example, when calves receive different amounts of milk, or when some become ill and others do not. Obviously, factors such as these influence the individual calf-weaning weights and cause an increase in the total variance of weaning weights. There are many different sources of environmentally induced differences. In considering quantitative traits such as weaning weights, then, it is important to understand that there are both genetic and environmental differences among animals and these *many* differences produce the total variance that we see.

Heritability measures that part of the total variance which is caused by *genetic differences* among the individuals in the study. The numerical value of the heritability estimate is given either as a percentage or a decimal, and is calculated as the variance associated with genetic differences divided by the total variance.

A heritability estimate is a partial description of one trait in one group of animals at

some particular time. It may vary (for each trait) during one period of time from herd to herd, or it may vary in the same herd from one time to another. This is to be expected, since herds do differ with respect to genetic make-up and, more obviously, there are wide environmental differences from herd to herd. A heritability estimate, then, is not a constant. This is evident in Tables 1 and 2 which include high and low estimates of heritability for some economically important traits in beef cattle and swine.

Since a heritability estimate is a fraction, its numerical value can be increased or decreased by changes in any of its component parts. An increase will result from a reduction in the environmental variance or from an increase in genetic variance. Conversely, a decrease will result from an increase in environmental variance or from a reduction in genetic

variance. Genetic variance is affected by a number of factors. Introduction of new and unrelated animals into the herd may increase the genetic variance. *Effective* selection within a group of animals over a number of generations will decrease the genetic variance. The use of inbreeding as a system of mating will also reduce the genetic variance. Environmental variance is reduced by any management practice that assures *uniform treatment* to the animals concerned; for example, by insuring that each animal receives the same amount and quality of feed.

When adjustments are made for any of the many environmental differences that affect the trait under consideration, the objective is to remove differences that exist in performance of the animals because they were not "treated" uniformly.

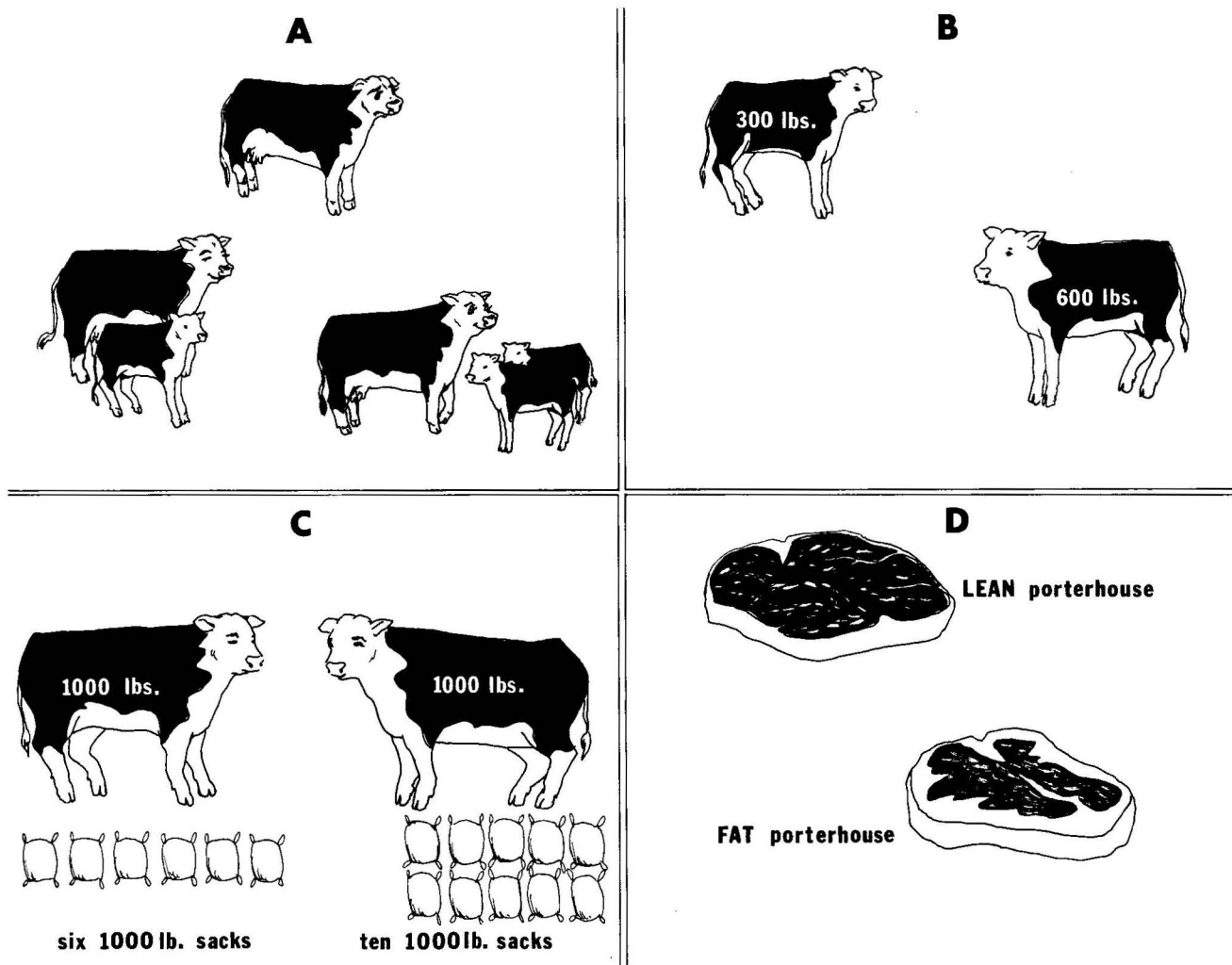


Figure 1. Reproductive efficiency (A), weaning weight (B), feed efficiency (C), and quality of meat (D) are examples of quantitative traits—traits that are influenced by the animals' genetic constitution and the many environmental factors that come into play during its development.

Table 1. Heritability estimates of some important traits in beef cattle.

Trait	Number of estimates	Range in estimates	Average estimate
Calving interval	3	.00 to .15	.08
Birth weight	15	.11 to .99	.40
Weaning weight	54	.00 to .81	.30
Weaning grade	33	.00 to .75	.30
Post weaning ADG (feedlot)	31	.07 to .88	.50
Postweaning ADG (pasture)	13	.18 to .57	.33
Postweaning grade (feedlot)	14	.00 to .92	.37
Postweaning grade (pasture)	15	.00 to .77	.32
Efficiency of feedlot gain	4	.03 to .75	.39
Slaughter grade	5	-.13 to .63	.39
Carcass grade	5	-.30 to .84	.34
Rib-eye area	3	.69 to .72	.70
Tenderness score	2	.41 to .81	.61
Cancer eye susceptibility	3	-.06 to .41	.19
Eyeball pigmentation	6	.27 to 1.37	.60
Eyelid pigmentation	3	.60 to 1.09	.79

Adjustment of calf-weaning weights for age of dam differences (a routine practice in the Hawaii BCIA program) is an attempt to remove this one source of environmental difference among calves. Effective adjustment also reduces total variance of weaning weights of calves within the individual herds. This reduction in total variance makes the job of recognizing genetic differences among calves in the herd easier. Adjustment of records and the uniform treatment of animals, then, are both done with the idea of reducing environmental variance so that genetic differences among animals are more easily recognized.

Theoretically, heritability estimates should fall within the range of 0.0 to 1.0. In some instances they fall outside this range. This is a chance occurrence and can happen due to the nature of the statistical manipulations.

A Common Misconception

A common misconception concerning the meaning of heritability is its association with absolute values. Heritability is not concerned with absolute or average values. It is concerned with a description of differences among animals in terms of variance. This misconception can be illustrated as follows: The heritability of feedlot average daily gain (ADG) in beef cattle is about 50 percent. Assume that the average feedlot ADG in the herd in question is 2.2 pounds per day. Given these two factors, it *does not* mean that 50 percent of this 2.2 pounds per day (or 1.1 pounds) is the result of genetic differences and that the remaining 1.1 pounds

the result of environmental differences that come into play during the animals' stay in the feedlot. Instead, it means that, on the average, 50 percent of the total variation among animals is due to genetic differences, and the remaining 50 percent is caused by differences in their environments.

Usefulness of Heritability Estimates

A heritability estimate is the most important single consideration in deciding which breeding plan should produce the fastest rate of genetic improvement. When heritability of the trait concerned is high (above about 30 percent), selection based upon the individual's own level of performance will allow a relatively rapid rate of improvement. When the trait concerned has a low heritability, other methods of identifying the genetically superior individuals must be used. These "other methods" involve various schemes for including in this judgement the level of performance of related individuals such as siblings (brothers and/or sisters) or progeny.

Heritability estimates are also used to determine the amount of improvement expected to occur in one generation, from applying a certain amount of selection pressure. This can best be illustrated with an example. Consider weaning weight in beef calves. The average heritability estimate for this trait is 30 percent (Table 1). The amount by which the average weaning weight would change in one generation can be estimated by multiplying the heritability estimate by the average superiority of the selected parents over the herd from which they

Table 2. Heritability estimates of some important traits in swine.

Traits	Number of estimates	Range in estimates	Average estimate
Litter size at birth	17	-.17 to .33	.12
Litter size at weaning	10	-.05 to .32	.15
Birth weight	6	.00 to .28	.15
Weaning weight	10	.01 to .37	.13
Slaughter weight	11	.14 to .81	.38
ADG, birth to weaning	3	.02 to .22	.12
ADG, weaning to slaughter	11	.14 to .58	.31
Feed efficiency, weaning to slaughter	5	.02 to .57	.28
Backfat thickness	32	.09 to .80	.40
Carcass length	5	.42 to .96	.65
Loin-eye area	4	.16 to .66	.52
Weight of lean cuts	1		.68

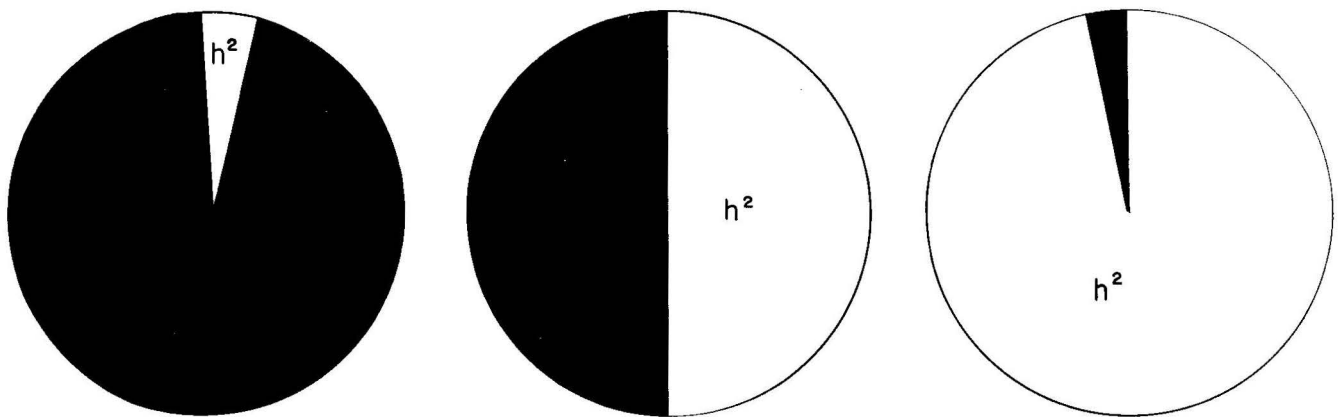


Figure 2. Heritability represents that part of the total variation which is due to genetic differences among the animals in the study. It can vary from nearly 0 to 100 percent, depending upon the trait and herd under study.

were selected. This average superiority is called the selection differential or the reach. Assuming, for example, that the average weaning weight in the herd (males and females) is 400 pounds, and that cows and bulls selected from this herd to produce the next calf crop had weaning weights of 425 and 525 pounds, respectively, the selection differential would be 75 pounds, i.e., $(425 + 525)/2 - 400 = 75$. Multiplying this selection differential of 75 pounds and the average heritability estimate of 30 percent gives a product of 22.5 pounds. This 22.5 pounds represents the *average expected increase* in weaning weight of the calves over the average of the herd from which their parents were selected. The *expected average weaning weight* of the calves is the sum of the expected increase (22.5 pounds) and the average weaning weight of the herd from which the parents were selected (400 pounds), which equals 422.5 pounds. This expected increase

is on a *per generation* basis. The average generation interval in beef cattle is about 5 years; the expected *annual increase*, then, would be $22.5 \div 5$ or 4.5 pounds per year.

Summary

A heritability estimate is a measure of the relative importance of heredity and environment in the conditioning of a particular trait. It is expressed either as a percentage or a decimal. It is not a constant as it is influenced by environmental and genetic factors specific to the group of animals upon which the observations used in its estimations were made. Its usefulness lies in helping to decide which of the various breeding plans will produce the fastest rate of genetic improvement, and in predicting the amount of improvement to be expected, as a result of selection, in the next generation of animals.