

Inbreeding in Sheep

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Inbreeding is broadly defined as the mating of individuals that are related. Strictly speaking, however, all animals within a breed are related. So, in a sense, every purebred sheep producer practices some degree of inbreeding. In most cases this relationship is very slight. Therefore, inbreeding is more practically defined as *the mating of individuals more closely related than the average of the breed*. This practice includes mating brother to sister, sire to daughter and son to dam.

Effects of Inbreeding on a Flock

Inbreeding can have dramatic effects on a flock. These effects are the result of an increase in the pairing of identical genes. When an individual receives an identical gene (**A** or **a**, for example) from each parent, it is said to be **homozygous** (**AA** or **aa**) for that pair of genes. If the parents are related, it is more likely they have genes that are identical. So, inbreeding results in an increased number of

homozygous gene pairs and a decreased number of **heterozygous** (**Aa**) gene pairs.

This increase in homozygosity is desirable, and inbreeding is good, *if* the gene the individual receives from each parent leads to superior performance. Unfortunately, however, most individuals carry undesirable recessive genes that remain hidden unless he or she has a pair of them. Inbreeding brings to light these undesirable recessive genes. An inbred individual is more likely to have gene pairs with identical members (in other words, to be homozygous for any gene) and, as a result, is more likely to express undesirable genes. *If* this expression occurs, inbreeding is bad because it results in the expression of undesirable traits.

On the average, animal performance for traits such as fertility, prolificacy, disease resistance, vigor and survivability declines with inbreeding. This decline is called **inbreeding depression**. This phenomenon is well-documented in all major livestock species. It is essentially the opposite of heterosis, or hybrid

The inbreeding process itself is not responsible for undesirable genes; it merely permits the recessive genes to be expressed as a result of the increased homozygosity.

vigor, which is the advantage gained from crossing lines or breeds. Inbreeding also increases the frequency of abnormalities. For example, the spread of spider lamb syndrome in black-faced sheep is believed to be the consequence of inbreeding.

Measurement of Inbreeding

Inbreeding in an individual is measured with the **inbreeding coefficient**. The inbreeding coefficient measures *the percent increase in homozygous gene pairs in an individual relative to the average of the breed*. If an individual animal has an inbreeding coefficient of 0.25, it is expected to have 25 percent more homozygous gene pairs than a non-inbred individual from the same breed. As explained earlier, this increase in homozygosity is what leads to inbreeding depression if the recessive alleles are detrimental.

Theoretically, the inbreeding coefficient can have any value between 0 and 1.0, although it is unlikely for it to have a value much above 0.5 in most flocks of sheep or herds of cattle, goats or pigs. On the other hand, it is fairly easy to have it approach 1.0 in some plant species, where self-fertilization is possible. Also, there are some lines of laboratory animals with very high levels of inbreeding. It is unlikely that farm animals will have extremely high inbreeding coefficients because it takes several generations of full-sib or parent-offspring matings to have an inbreeding coefficient greater than 0.5.

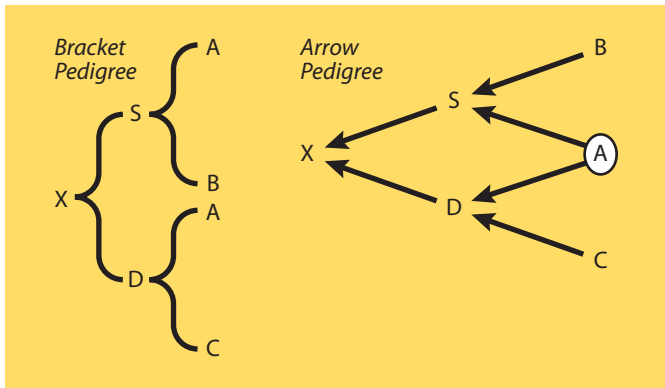


Figure 1. Half-sib mating scheme

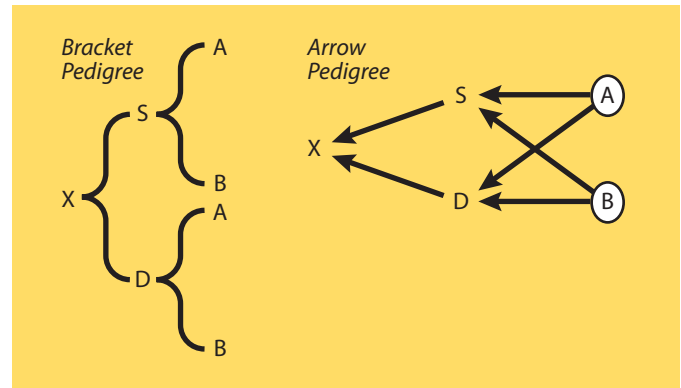


Figure 2. Full-sib mating scheme

The inbreeding coefficient is expressed as follows:

$$F_X = \varphi \left[\left(\frac{1}{2} \right)^{n+1} (1 + F_A) \right]$$

Where

F_X = Inbreeding coefficient of individual X

Σ = Summation sign (means values in the brackets are to be added together)

n = Number of segregations (arrows) between the sire and dam in each separate path through the common ancestor

F_A = Inbreeding coefficient of the common ancestor in each separate path. A common ancestor is one that appears on both the sire and dam side of the pedigree. Whenever a common ancestor is inbred, his or her inbreeding coefficient will have to be calculated before the inbreeding coefficient of individual X can be determined.

Inbreeding Systems

Some of the more common forms of inbreeding can be used to illustrate calculation and interpretation of the inbreeding coefficient.

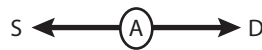
Mating between Half-Sibs

The first inbreeding system involves mating between half-sibs. This mating scheme is presented in Figure 1 in both *bracket* (traditional way to depict a pedigree) and *arrow* forms.

In this pedigree (Figure 1), **S** is the sire of **X** and **D** is the dam of **X**, and these two individuals are half-sibs (that is, half brother and sister because they have one parent in common). Also, **A** is the common ancestor (appears in both the

top [sire] and bottom [dam] sides of the bracket pedigree and is indicated by a circle in the arrow pedigree).

When calculating the inbreeding coefficient of individual **X**, it is necessary to consider all possible paths by which the sire and dam of individual **X** are connected. In the pedigree illustrated in Figure 1, there is only one path by which the sire (**S**) and dam (**D**) are connected:



Using the equation presented earlier, the inbreeding coefficient (F_X) is calculated as:

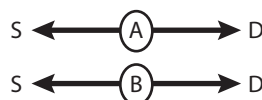
$$F_X = \left(\frac{1}{2} \right)^{n+1} (1 + F_A) \\ = \left(\frac{1}{2} \right)^3 (1 + 0) \\ = 0.125$$

Because no pedigree information is available on **A**, the common ancestor, F_A is assumed to be zero. This inbreeding coefficient tells us that individual **X** is expected to have 12.5 percent more homozygous gene pairs than a non-inbred individual from the same breed.

Mating between Full Sibs

This system can be depicted as shown in Figure 2. In this case **S** and **D**, the sire and dam of **X**, are full-sibs (that is, full brother and sister) because they have the same sire (**A**) and dam (**B**).

Here is how the inbreeding coefficient is determined. First, the two paths connecting the sire and dam of **X** are drawn:



Then, using the equation presented earlier, the inbreeding coefficient is calculated as:

$$F_X = \left(\frac{1}{2} \right)^{n+1} (1 + F_A) + \left(\frac{1}{2} \right)^{n+1} (1 + F_B) \\ = \left(\frac{1}{2} \right)^3 (1 + 0) + \left(\frac{1}{2} \right)^3 (1 + 0) \\ = 0.25$$

Again, because no pedigree information is available on the two common ancestors (**A** and **B**), their inbreeding coefficients, F_A and F_B , are assumed to be zero. The inbreeding coefficient reveals a much higher level of inbreeding when **X** results from the mating of full-sibs (Figure 2), as compared to the situation where **X** results from the mating of half-sibs (Figure 1).

Parent-Offspring Mating

Another form of inbreeding involves parent-offspring mating. One type, for example sire-daughter, is illustrated with the pedigree in Figure 3. This example also includes an inbred ($F_S = 0.25$) parent, because the sire (**S**) resulted from a mating between full-sibs.

In the pedigree illustrated in Figure 3, there is only one path by which the sire (**S**) and dam (**D**) are connected:



Using the equation presented earlier, the inbreeding coefficient is calculated as:

$$F_X = \left(\frac{1}{2} \right)^{n+1} (1 + F_A) \\ = \left(\frac{1}{2} \right)^2 (1 + 0.25) \\ = 0.3125$$

If **S** had been non-inbred ($F_S = 0$), then F_X would be 0.25. Consequently, the inbreeding of **S** has contributed to the inbreeding of **X**.

Uses of Inbreeding

Inbreeding can sometimes benefit a purebred sheep producer. Inbreeding tends to subdivide a breed into families, which can be identified and crossed with some small benefit. It also promotes an increase in **prepotency**, which refers to the ability of an individual, usually a sire, to transmit the same inheritance to different offspring, or, on other words, to uniformly “stamp” his characteristics on his progeny. This prepotency is a result of the increase in homozygosity, as was described earlier. Because an inbred individual will have more homozygous gene pairs than a non-inbred individual, there are fewer possible combinations for the gametes (sperm in sires, eggs in dams). The genetic makeup of gametes from the inbred individual will be less variable so the offspring will be more similar.

One of the most common uses of inbreeding is **linebreeding**, which is *a mating system designed to maintain a high degree of relationship to a genetically superior ancestor without causing high levels of inbreeding*. Linebreeding is a mild form of inbreeding. An example of linebreeding is represented with an arrow pedigree in Figure 4, where individual **X** is linebred to individual **5**. Individual **5** shows up so often in the pedigree of individual **X** that the relationship between the two is 47 percent, practically the same as the

relationship between a parent and its offspring. However, because very close matings were avoided—no mates shown in the arrow pedigree are more closely related than half sibs—individual **X** is only mildly inbred ($F_X = 12.5\%$). The linebreeding depicted in Figure 4 illustrates a very deliberate strategy. The goal was to concentrate the genetic material of individual **5** in individual **X** while keeping the level of inbreeding low.

Linebreeding has the advantage of maintaining genes from outstanding individuals, usually sires, that are no longer available for breeding purposes. It also enables a certain amount of family name recognition, which can be useful when advertising breeding stock. At the same time, at least two dangers may be associated with linebreeding: it is difficult to follow a linebreeding program for any period of time without increasing the amount of inbreeding in a flock, and there is the possibility of linebreeding to rams that are not genetically superior.

A linebreeding program should only be started by a sheep breeder with a superior purebred flock and a fundamental understanding of the benefits and dangers of such a program. It should not be considered unless the flock is so high in quality and performance that it is difficult to find outbred animals that will improve the genetic merit of the flock. The animal, usually a sire, at the center of the

linebreeding program should be an individual that was superior in performance and type but is no longer in service. If such an individual cannot be identified clearly, the purebred sheep producer should continue to avoid inbreeding.

Summary

Although inbreeding does not create undesirable recessive genes, it does bring them to light. This approach can result in the expression of undesirable traits, genetic deformities and, ultimately, inbreeding depression. Therefore, the disadvantages of inbreeding outweigh the advantages for all but a small number of top purebred sheep breeders. Inbreeding limits flock improvement by reducing reproductive performance, vigor and survivability, and it restricts selection opportunities by placing a disproportionate emphasis on pedigree information.

Generally, the recommendation is that inbreeding should be avoided as much as possible by any purebred producer who does not have a clear understanding of its use. Linebreeding can be an effective tool for perpetuating the genes of an *outstanding* ancestor, but it should only be used in superior flocks and only with *truly outstanding* rams. Finally, mating of close relatives, such as parents with offspring or brothers with sisters, should be avoided in all flocks.

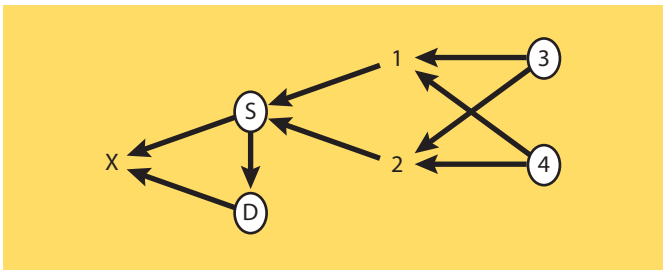


Figure 3. Sire-daughter mating with an inbred parent

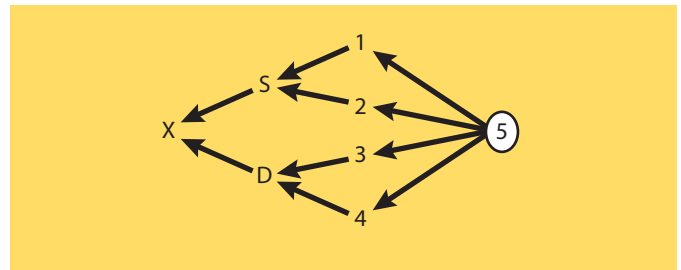


Figure 4. A form of linebreeding where individual **X** is linebred to individual **5**