Are you afraid of inbreeding?

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There are advantages and disadvantages in the use of inbreeding and outbreeding in domestic animal reproduction. Both approaches complement each other and, when used rationally, can help breeders progress in their genetic gain.

A quick reminder

What is inbreeding?

Inbreeding is the **mating of relatives**. This means that any inbred animal has at least one **common ancestor** on its dam's side and on its sire's side.

Homozygosity & heterozygosity

In superior animals, such as Mammals, and therefore alpacas, half of the genetic material is inherited from the sire and the other half from the dam. When a given gene inherited from the sire is the same as the one inherited from the dam, the animal is said to be **homozygous** for that gene. If the two genes are different, the animal is **heterozygous** for the gene.
The chief effect of inbreeding is to increase homozygosity in the progeny. The proportion of genes found in homozygous combination is higher in inbred than in non-inbred animals.

Consequences of inbreeding

There are interesting positive consequences with an increase in homozygosity, as it produces more homogenous animals, which "breed true". In particular, **prepotent** sires are highly homozygous animals, with many dominant genes. Inbreeding, at least to a certain degree, is the only way to create and fix a breed.
However, inbreeding has a bad name because it also increases **inbreeding depression** (which is the same as saying it decreases **hybrid vigour**).

Inbreeding depression & Hybrid vigor

Inbreeding depression is the expression of unfavourable recessive genes in homozygous combinations. This leads to what we commonly refer to as genetic faults, for example polydactyly or choanal atresia. However the effect can be

more subtle but still quite undesirable: for example infertility or subfertility, failure to grow properly, or lack of resistance to infection.
Hybrid vigor is the opposite. It is the masking of unfavourable recessive alleles in heterozygous combinations. Hybrids are quite robust and usually very fertile.
The reason why unfavourable genes are usually recessive has to do with evolution (natural selection), which eliminates unfavourable dominant genes rather quickly.

What is outbreeding?

Outbreeding (also called outcrossing) is the exact opposite to inbreeding. Its chief effect is to increase heterozygosity. The progeny exhibits hybrid vigor, however there is a lot of variability in these animals: The outcome of outbreeding is less predictable, compared to the results you can expect from inbreeding.

A few important points

Outbreeding does not eliminate the unfavourable recessive genes but only masks them. It allows these genes to persist in a population, where they can reappear at any time down the track.
Note also that inbreeding does not create these unfavourable recessive genes either but only brings them to the fore. It may be useful to a breeder to know what kind of recessive genes are present in his/her herd.
Finally, it is important to understand that neither inbreeding depression nor hybrid vigour are heritable. They can be “undone” at any time. The two following examples will illustrate this very point:
Two inbred animals can produce a vigorous hybrid. For example, an inbred Peruvian mated to a totally unrelated inbred Chilean will give a cria exhibiting strong hybrid vigour. Conversely, two vigorous hybrids can give an inbred animal. For example, 2 F1’s (vigorous hybrids) from the same two parents, mated together, give an inbred F2.

What should you choose?

If your aim is to develop animals that breed true, with highly prepotent sires, and predictable progeny – in other word, to develop a line – you will have to inbreed. However, you should also be prepared to cull ruthlessly as inbreeding may bring to the fore some unwanted recessive genes.
If your aim is to breed show champions, it may be a good idea to outcross. Hybrid vigour is a definite plus in the show ring. Similarly, if you wish to breed large herds of commercial animals, outbreeding is also the path to follow. Hybrids need very little medical attention and often can fend for themselves remarkably well.

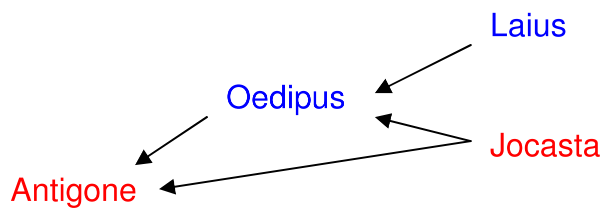
In practice, many breeders will use both techniques. For example, if an inbred animal is not perfect on a conformation point of view, breeders would often choose to join this kind of animal to a totally unrelated mate, in an attempt to correct inbreeding depression by outbreeding.

A bit of mathematics may help make a decision

The inbreeding coefficient

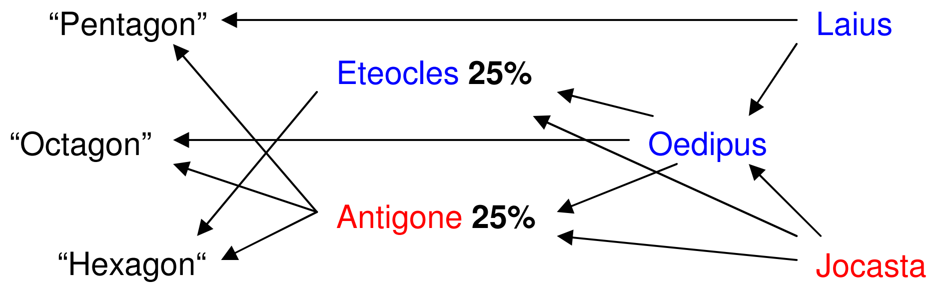
Inbreeding can be measured. The immediate advantage is that you can plan your mating so that inbreeding remains below a certain limit. For example, a stud may decide not to breed animals more than 25% inbred. This is actually quite high as this corresponds to the product of a daughter mated to her sire (or a son to her dam).
The **inbreeding coefficient** is defined as the probability that both genes of a pair in a given animal are identical (homozygous) **by descent**. This is the same as saying that it is the probable proportion of a given animal's genes to be identical **by descent**. Being identical by descent means that the two genes on the maternal and paternal chromosome are copies of the same ancestral gene.
It is beyond the scope of this article to explain how this coefficient is calculated; however a few examples will illustrate the usefulness of such a coefficient.

The stud Laius mated to the dam Jocasta produced a male cria, Oedipus. Oedipus was then mated back to his mother and produced a female cria, Antigone. Antigone is inbred and her inbreeding coefficient is 25%. This is often written as follows: F(Antigone) = 25%. The arrow diagram below illustrates the relationship (males in blue, females in red).



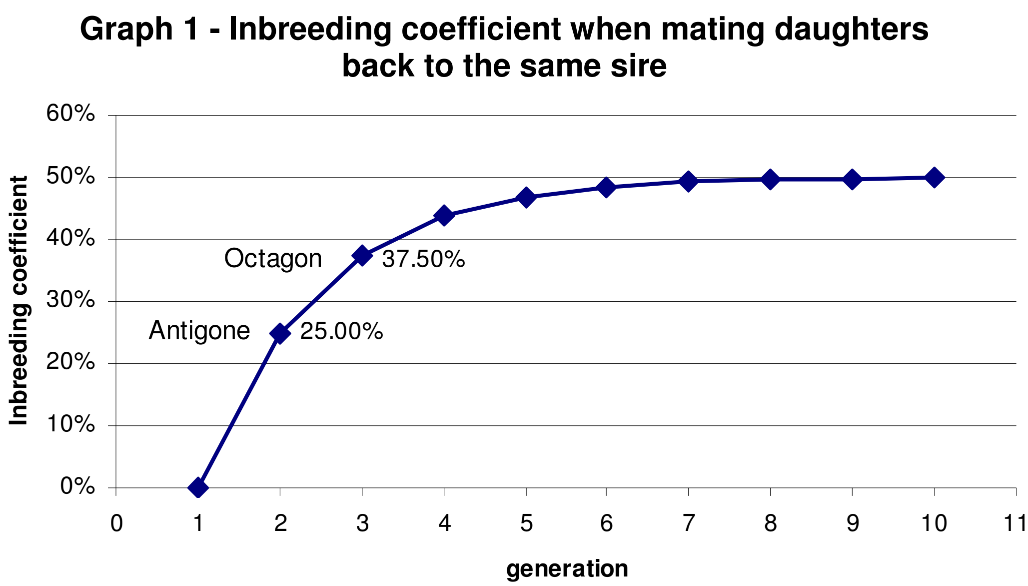
Antigone is likely to have inherited some genes, in homozygous combination, from Jocasta. The inbreeding coefficient measures this likelihood. One member of the pair came directly from Jocasta; the other one was transmitted from Jocasta through Oedipus. Note that the original gene, present in Jocasta, may or may not necessarily be present in a homozygous combination within Jocasta. Twenty five percent (25%) of Antigone's genes are probably identical by descent i.e. are copies of a given gene in Jocasta.

Oedipus was mated to Jocasta another time and produced a male, Eteocles. Of course, Eteocles is also 25% inbred like his full sister Antigone.

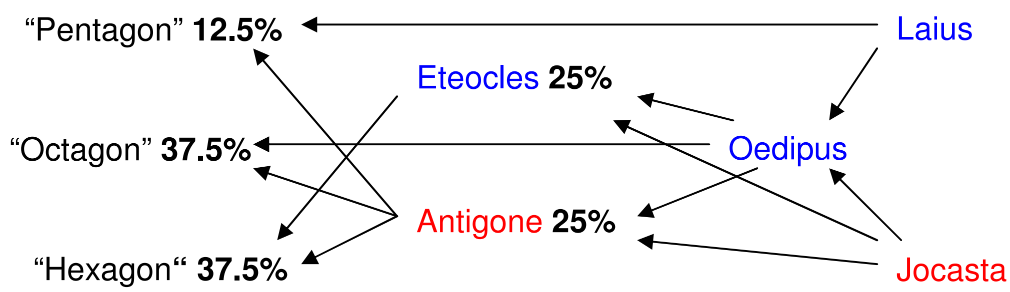


What happens now if we mate Antigone back to her sire Oedipus (to produce "Octagon") or to her brother Eteocles (to produce "Hexagon") or to her grand-sire Laius (to produce "Pentagon")? Will the products be more inbred or less inbred than Antigone?

Mating Antigone back to her sire will result in a cria, Octagon, with an even higher inbreeding coefficient than herself: 37.5%. If this cria is a female and is mated to Oedipus again, the resulting cria will be 43.75% inbred… etc. These intuitive results are better explained on graph 1 below.

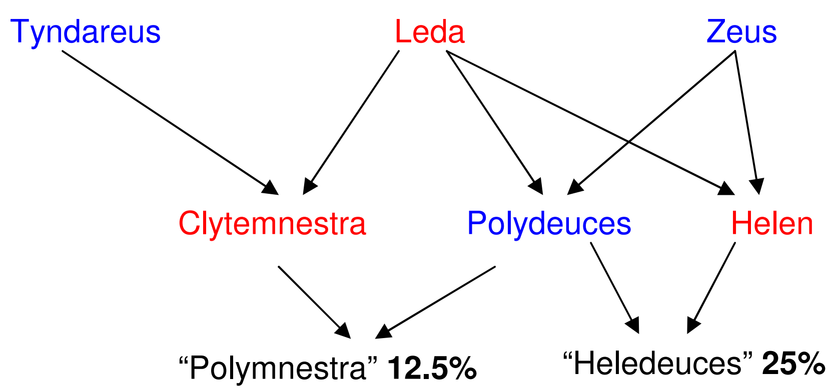


On the other hand Antigone mated to her grand-father Laius will only result in 12.5% inbreeding for Pentagon, whereas Antigone mated to her brother Eteocles will result in 37.5% inbreeding for Hexagon.



Who could have predicted that Hexagon and Octagon would have the same degree of inbreeding, without the use of the inbreeding coefficient? The reason is that Antigone and Eteocles are already inbred **to the same ancestor, Jocasta**. When mating a "normal" brother to his "normal" sister, it results in 25% inbreeding only.

Let's go to another alpaca stud, Olympus alpacas. The arrow diagram below illustrates the relationships:



As you can see, a half-sib mating results in 12.5% inbreeding ("Polymnestra") and a full-sib mating results in 25% inbreeding ("Heledeuces"). Compare this latter result with the mating of Antigone and Eteocles described above. They are full brother and sister but, because they are already inbred **to the same ancestor Jocasta**, their product will be more inbred (37.5%) than the product of "normal" brother and sister (25%).

Practical consequences

The use of the inbreeding coefficient helps you measure and therefore limit inbreeding in your herd.
The more you know about the ancestry of the animals you are using, the more accurate your calculations will be.
The example presented above in graph 1, where all daughters are mated back to the same sire is an extreme one, only presented to make a point. In practice, breeders are more likely to use at least two or three males.

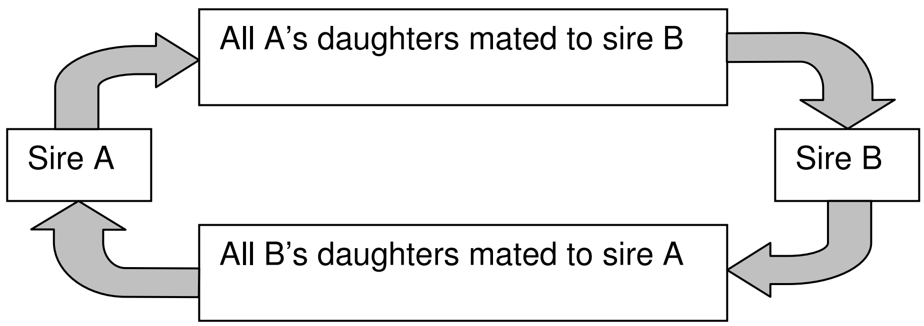
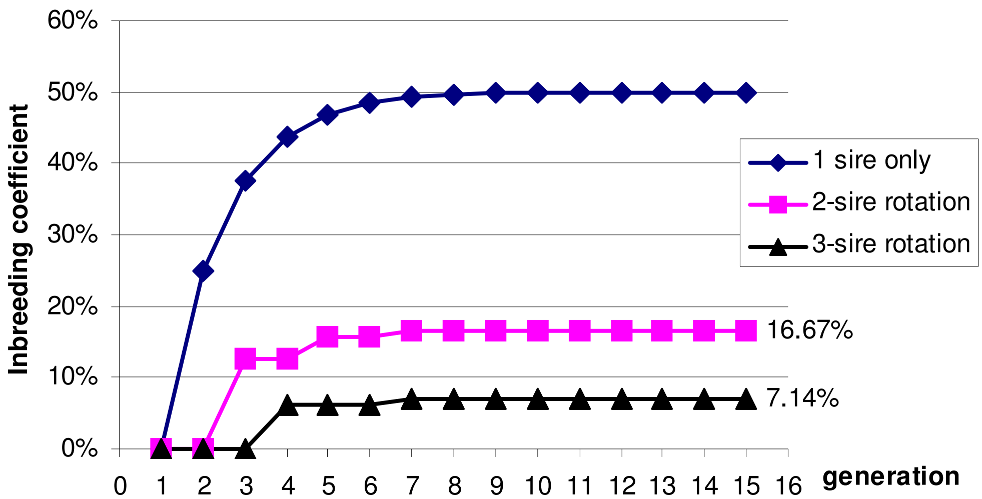


Figure 1 - Schematic representation of a two-sire rotation system

Using a two-sire rotation system as illustrated in Figure 1 would limit inbreeding dramatically, compared to using only one sire, as expected. The graph below gives the inbreeding coefficient of the progeny resulting from such a system. A three-sire system is also presented for comparison.

Graph 2 - Inbreeding coefficient in the progeny resulting from three different mating systems



Again, a two-sire rotation, or even a three-sire rotation, can be regarded as extreme cases, as it would not be expected in practice that such stringent systems would be adhered to blindly (some of A's daughters will not be mated to B and some of B's daughters will not be mated to C). They are however useful examples, showing that the use of three sires in a stud can limit inbreeding to about 7% (negligible) and still achieve a reasonable degree of homogeneity in the progeny. This of course only works if the two or three sires used are not already related.

Concluding remarks

All the figures presented above are theoretical calculations and are only probabilities. Reality can sometimes vary substantially from prediction but these calculations can help you make decisions with a certain level of confidence.
Keep in mind that outbreeding is not an insurance against genetic faults and that inbreeding does not always lead to catastrophe. The outcome actually depends a lot on the genetic health of the base population.

References

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