Managing inbreeding and genetic diversity

There are a number of ways in which breeders can help preserve genetic diversity and minimise inbreeding, some of which are outlined below. Each breed is different and some of the topics discussed may not be applicable to all breeds.

Reduce the use of popular sires

Popular sires, or male dogs, that are used to produce large numbers of puppies, are one of the biggest contributors to a reduction in genetic diversity, an increase in inbreeding and elevated levels of genetic diseases within a breed. These dogs are often chosen because they have good characteristics, such as traits associated with good health. Breeders will use these dogs because they wish to improve the breed, but excessive use of any males can be detrimental to the over-all population.

Popular sires and autosomal recessive conditions

A popular sire, let's call him Charlie, will pass on both good and bad genes to each of his offspring. Every organism is a carrier for many autosomal-recessive conditions. These are health conditions that can only affect a dog when it has two copies of a faulty gene (inherited from both its mother **and** father). Dogs with only one copy of the mutant gene are said to be carriers and are unlikely to show any sign of the disease, but can pass the gene on to their offspring. The mutant genes for autosomal-recessive conditions can be the most difficult to predict, because they can be passed on from generation to generation without being noticed or identified. As long as a dog also has a healthy copy of the gene to do its normal job, then the mutant gene may never be noticed. Often, there is no way to know that these mutant genes exist, or what they cause, until they are expressed in a dog with two copies.

Distributing both good and bad genes through the breed

The more puppies that Charlie helps to produce, the more his genes will be spread throughout the breed, especially if his own offspring also go on to breed, or even become popular sires themselves.

This means that there will be more dogs in the breed with the genes associated with Charlie's positive traits, but there will also be more dogs that have copies of his "silent" autosomal-recessive genes too. Remember that a dog must inherit a copy of a faulty autosomal recessive gene from both its mother and father to be affected by one of these conditions. Dogs with only one copy of a mutant gene will appear completely normal.

Many of Charlie's faulty genes may initially be rare in the breed, but as the number of his descendants increase, his genes become more and more common. Within several generations, Charlie's genes could be distributed widely throughout the breed and at this point mating two dogs that are unrelated to Charlie becomes more difficult. If two dogs related to Charlie mate, then there is a chance that they both carry the same faulty autosomal-recessive genes and could produce affected puppies. This is how such diseases may appear to ‘suddenly’ emerge in a breed. The more descendants that Charlie has, the higher the proportion of carriers and affected dogs there will be in the breed. It may take several years for the effects of Charlie, as a popular sire, to become apparent, but by this time his genes may already be widely distributed throughout the breed.

Impact on the gene pool

In addition to increasing the risk of autosomal-recessive conditions, the over use of popular sires can also impact on the size of the gene pool. A breed's gene pool is the total amount of genetic variation within a breed, and unless new dogs are introduced into a breed, it is likely to become smaller over time. Every litter produced by Charlie means one less opportunity for another male to reproduce. The genes from the other dogs which were not chosen for mating will become rarer and may even disappear from the gene pool entirely. The smaller the gene pool becomes, the more difficult it can be to find unrelated individuals for mating. Smaller gene pools may be more difficult to manage and may result in further increasing levels of inbreeding, like a vicious cycle.

Breeding advice

To prevent the popular sire effect, stud dog owners should restrict the number of times their dog is used for stud.

The number of times a dog should be used will be dependent on the actual population size and size of the gene pool, so providing guidelines on how many puppies a stud can safely produce will be breed dependant and is difficult to estimate. We also need to consider that the popular sire effect will only occur if his puppies go on to produce litters themselves. So monitoring the level of contributions (whether sires are having breeding pups) is more effective than simply monitoring the number of pups a dog sires.

However, owners of bitches looking to use a stud dog should enquire how many times a dog has been used and should avoid using known popular sires. Using a wider variety of dogs will help maintain genetic diversity.

Use COIs before making breeding decisions

Taking proactive preventative steps to avoid inbreeding is much easier than trying to counteract the health complications that inbreeding can cause. One such proactive method is to look at how related two individuals are to help decide whether they are suitable mates. Inbreeding can be measured using a Coefficient of Inbreeding (COI). This is the probability that two copies of a gene have been inherited from an ancestor common to both the mother and the father. The lower the degree of inbreeding, the lower the inbreeding coefficient.

Every dog will be a carrier for many unknown autosomal recessive conditions and there is currently often no way to know that they exist, or what they cause, until they are expressed in a dog with two copies of the mutant gene. Dogs that share similar genes (i.e., are closely related) are more likely to be carriers for the same autosomal recessive conditions.

Inbreeding and health risk

If two related dogs mate, then their puppies have a higher risk of inheriting two copies of the mutant gene, and therefore being affected. These effects could be significant, or they can be small. If a dog is affected for a large number of these small conditions then the effects can be accumulative and can impact on the overall health of the dog. As the inbreeding coefficient increases, so too does the chances of the dog having poor health.

Using the COI calculator enables breeders to minimise the degree of inbreeding in future litters and reduce the risk of puppies developing inherited health problems. It is important to note that the inbreeding coefficient is a measure of risk, rather than a direct measure of

health. It is possible that two closely related dogs do not have the same autosomal recessive genes, while two seemingly unrelated dogs do - it's all down to chance. Although the COI is not a guarantee of health, it is a measure of risk with a higher COI suggesting a higher risk.

If a breeder DNA tests their dogs, they are taking steps to avoid a known risk. By using COI calculators when selecting potential mates, they are reducing the risk of unknown conditions.

Breeding advice

When choosing a potential mate for your dog, the Kennel Club recommends that breeders use Mate Select to calculate the inbreeding coefficient of the puppies that could be produced from a hypothetical mating.

The current Kennel Club breeding guidelines are that, where possible, breeders should produce puppies with an inbreeding coefficient which is at, or below, the annual breed average and ideally as low as possible. The annual breed average is recalculated each year and is shown to you each time you use the COI calculators.

There are other equally important factors to consider when deciding whether two dogs should be mated together, such as temperament, available health test results, the general health of the dogs, etc. Your decision should be well balanced between the inbreeding coefficient and the good qualities of the sire/dam that you are considering.

Use health test results cautiously

Choosing which dogs to breed from can be a difficult decision to make, especially as there are many different factors to consider. One of these is the health of the dogs, and while it is important to appropriately health test a dog prior to mating, it is equally important to carefully consider the implications of these results, as well as the implications of excluding it from a breeding programme, especially in breeds with a small gene pool.

DNA testing

With simple autosomal recessive disorders, remember that a carrier will not be affected by the condition you have tested for, but that they could pass on a copy of the faulty gene if they themselves are bred from. Only when a dog inherits two copies of a faulty gene (one from its mother and one from its father) will it be affected. When used responsibly, carriers are an important part of any breeding plan and should not be overlooked. By breeding from carriers, you can keep good, healthy dogs in the breeding population, helping to maintain genetic diversity.

Similarly, an affected dog could still be used in a breeding programme, but this will very much be dependent on the condition and whether the dog's welfare would be affected by the mating process. If only clear dogs are used for breeding, they are only known to be clear for the condition that they have been tested for, and may carry other unknown mutations which can be passed on to their offspring. These unknown mutations may then increase in frequency in the breed and a new inherited disease could emerge. In other words, no dog is completely risk-free, but there are ways a breeder can reduce the risk of known and unknown inherited disease.

If you are considering a mating that may produce carrier puppies then there are several precautions that it is strongly recommended you take.

1. It is important that carriers and affected dogs should never be used to produce affected dogs and so should never knowingly be mated to another dog that has one or more copies of the faulty gene. This means that carriers should never be bred to other carriers of the same condition or to affected dogs. Affected dogs should only ever be mated to a dog that is either tested clear or is hereditarily clear for the condition (i.e. both its parents are DNA tested clear). Sticking to these rules will mean that you can still use these dogs for breeding, while maintaining genetic diversity within the breed.
2. Never over use a carrier or affected dog for mating. If a dog has one or two copies of a known faulty gene it should never be over used for breeding. Over using these dogs increase the frequency of the faulty gene within the population, making it more difficult for future generations to breed without increasing the risk of producing affected dogs.
3. Do your research. If all breeders decided to use carriers or affected dogs for mating, then there is a possibility that as the frequency of mutant genes increases, then the proportion of 'clear' dogs would decline. You can use carriers & affected, but you always want to make sure you have a big enough supply of clear dogs. You may wish to talk to health representatives at your local breed club who will have access to summary information on the results of dogs that have been DNA tested and can advise you appropriately on the current situation in your breed.
4. Any possible carrier puppies that go on to be bred from should be DNA tested prior to mating. If you do decide to produce puppies that are potentially carriers, but are concerned that they may be used by their new owners for breeding, then you may wish to consider placing an endorsement on the puppy, or include a statement in your puppy contract that that any puppies used for breeding must be tested prior to mating and if the puppy is a carrier, it must only be mated to a clear dog.

Many people are concerned about breeding from a carrier or an affected dog because they are worried about making carriers more prevalent in the breed. Remember that every organism is already a carrier for many autosomal recessive conditions. Often, there is no way to know that these faulty genes are present until they are expressed in a dog with two copies of the gene or unless a DNA test is available. DNA tests are available for only some of the known mutations in dogs, but there are likely to be many more recessive mutations that we know nothing about. Every time you breed any dog you are already most likely breeding a dog that is a carrier for an autosomal recessive condition (this will be the same for all organisms). The only difference with breeding a dog that has tested positive for a carrier is that you know what disease the autosomal recessive gene can cause.

Use dogs from the same breed, but different sub-populations

Many species of animals have populations that are geographically separated, known as a sub-population. It is possible that your breed has sub-populations abroad, and imported dogs from these groups could be used to increase the genetic diversity. Similarly it is possible that your breed is separated into further groups by dog activities, or purpose, such as show populations, pet populations or working populations. Using imported dogs or dogs from other sub-populations can allow you to reintroduce genes that may have declined or have been previously lost, allowing a breed to maintain genetic diversity. Management of breeding schemes between these groups could be used to help manage and effectively reduce inbreeding in the population as a whole.

It is just as important to continue to choose the dogs you intend to breed from carefully to prevent the introduction of potentially harmful genes. Make sure that you do not assume that a dog from a sub-group is less related. It is still important to check the inbreeding co-efficient of a hypothetical mating between any two potential mates. Ensure that there are several generations of data available to calculate this, otherwise this may be misleading. It is also important that well-meaning widespread use of any dog does not occur. This popular sire effect can still have a detrimental impact on a breed, even if it is an import.

Use dogs from a different breed

A gene pool (the total genetic variation in a breed) is based on the genetic material that was first available from the founder dogs. If no new dogs are introduced into a breed, then no new genes can be added and the gene pool is likely to reduce in size. This loss of genetic information is inevitable and breeds with a high rate of inbreeding (rapid loss of genetic diversity) may consider using dogs from a different breed to add new genes into their gene pool, thereby increasing diversity in the breed and reducing the risk of further inbreeding.

This type of mating must be very carefully considered and must be carried out cautiously. If you are introducing new genes to a breed, you will want them to be as good as possible. Dogs selected for outcrossing must be (and must have been) in excellent health and should be clear of all known and testable genetic disorders. Any of its close relatives should also ideally be in excellent health and all must have other good traits, such as excellent temperament, etc.

All organisms are carriers for autosomal recessive conditions and although we can't know what recessive mutations these dogs may have, it is important to try to keep their frequency in the breed rare. A common objection against using dogs from a different breed to invigorate another breed is that it is impossible to know what harmful genes they may introduce. For this reason, it is important to consider how best to use the outcross and its descendants to improve the breed, rather than over using them and creating a popular sire effect.

It's advisable that anyone wishing to use a dog from a different breed do so with the advice of geneticists. Previous applications for Dalmatians, Miniature Bull Terriers and Belgian Shepherd Dogs to use dogs from other breeds have been accepted by the Kennel Club and this should be your first port of call for further advice on how best to proceed.

Making balanced breeding decisions

As well as considering the implications of a breed's genetic diversity, there are other equally important factors to consider when deciding whether two dogs should be mated together, such as temperament, conformation, available health test results, the general health of the dogs etc. Your breeding decisions should always be well balanced and take into consideration the qualities and compatibility of both the sire and dam that you are considering.

The complete article can be found at:

https://www.thekennelclub.org.uk/health/for-breeders/inbreeding-and-genetic-diversity/managing-inbreeding-and-genetic-diversity/