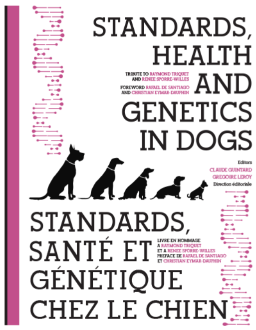

Standards, Health and Genetics in Dogs
CHAPTER II - Health and genetics

Relationships between genetics, breeding practices and health in dogs

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Abstract - In this chapter, we examine the specificities of dog breeding and selection in order to better understand how these practices impact breed health. Selection within the species is characterised by breeding in closed populations, selection objectives that are generally aimed at conformation, animals that receive substantial veterinary care, selection that is often empirical using a small number of breeding dogs and, more occasionally, the use of practices such as mating between close relatives.

These practices can have different direct or indirect consequences on breed health. We address in particular the potential health impacts of selection based on morphology (hypertypes, etc.), as well as genetic drift, linked to a limited basis of selection, resulting in particular in an increase in inherited diseases. Faced with these recurrent problems, it is important that clubs and breeders hoping to improve their breed health adapt their practices and use the appropriate tools, especially in terms of breeding strategies and diagnoses.

Keywords: Dog, Genetics, Inherited diseases, Inbreeding, Breeding.

INTRODUCTION

After a reminder of the linkages between the standard and the very notion of a breed, and before taking a closer look at some of the health problems affecting our canine populations, it seems important to address the issue of selection and how it is managed in dogs. More specifically, after a brief historical review of differentiation in canine populations over the centuries, we examine the practices that characterise dog breeding today. We will investigate how these practices impact breed health and discuss avenues for health improvements.

SOME HISTORICAL REMINDERS

Until the 18th century, selection practices were largely guided by empiricism. For example, in his hunting treaty, d'Yauville (1788) advised against breeding dogs affected by natural faults such as epilepsy, and noted that "if the sire or dam has been blinded by accident, there is nothing to fear for the offspring".

Nevertheless, it was not until the 19th century that the foundations of modern day cynology emerged, with the first dog shows, the development of standards and the creation of stud books, which went hand-in-hand with the concept of purebred dogs. **In most cases, breeds were formed based on a small number of founding individuals,** which increased the impact of genetic drift within those breeds (see below). In so doing, dog breeders took inspiration from the first selection experiments in livestock species, especially sheep and cattle (Russel, 1986). Consequently, the phenotypic differentiation of canine populations increased, with a growing number of new breeds.

Over the course of the 20th century, the selection of productive species was streamlined, with the implementation of programmes aimed at improving animal productivity, based on quantitative traits (milk production, growth, prolificacy). However, **for companion animals, selection objectives are still aimed at conformation or at behavioural traits,** which are difficult to select due to generally low heritability. The organisation of breeding has also remained largely in the hands of enthusiasts, in contrast to productive species. In this respect, modern day cynology has evolved little and has largely inherited from breeding practices established in the 19th century.

CHARACTERISTICS OF DOG BREEDING

At present, the laws of heredity are generally well known to dog breeders. The organisation, which is generally collective, and the principles remaining the same as for the other domestic species, there are many similarities particularly with mammal pets (especially cats and horses), and to a lesser extent with ruminants. Dog breeding remains characterised by a certain number of practices, which may or may not be specific to this activity, as we shall see.

Purebred breeding

More than in any other domestic species, purebred breeding is still a paradigm in dogs, which inherently impacts the genetic structure of the species (Leroy, 2015). In France, for example, waiting list registration (for the 21 breeds with closed books) or initial registration (for breeds with open books) accounted for only 0.3% of births in 2015 (Leroy, 2016). At FCI level (FCI, 2015), recent guidelines authorise crossbreeding only between varieties of colour, size, or coat length. Finally, it is worth noting a number of initiatives, such as those of the Finnish Kennel Club (FKK, 2014; Maki, 2015), which implement outcrossing generally with the goal of improving genetic variability within small population breeds.

By way of comparison, crossbreeding is a common practice in other domestic species, whether in cats (Leroy *et al.*, 2014), horses (Piraut, 2013) or cattle (Lauvie *et al.*, 2008). It is nevertheless worth noting that within these species, situations differ according to the breed in question, with some still managed in a closed manner, while others are subjected to recurrent crosses.

Selection objectives primarily linked to the standard

Although dogs have been bred over time for a wide range of uses, they are now used above all for the company they provide. Morphology and conformation to the standard are now the main selection objective for breeders: in 2007, a survey among 985 French producers showed that morphology was the main selection objective, ahead of behaviour, health and working abilities, with differences nevertheless seen according to breed groups (Leroy *et al.*, 2007).

At first sight, it could be thought that selection according to a breed standard would have little impact on the morphological evolution of the breed; experience, however, has shown that this is not the case. Over the decades, standards and their interpretation by breeders, judges and clubs have significantly evolved (Fondon *et al.*, 2004). Thus, the study by Drake *et al.* (2008) illustrated the continuous evolution of the skull in the Saint Bernard breed over the last 120 years with, in particular, an expansion of the skull and a reduction in muzzle size. And when, as a consequence of different fashions, breeders began to produce miniature phenotypes whose characteristics were outside the limits for the standard, new breeds and varieties were thus developed. These changes may, however, be harmful to breed health, as we will see later.

Highly medicalised animals

Due to the close relationship between humans and their pets, purebred dogs often receive substantial veterinary care, which may have consequences in terms of reproduction and selection. **The development of veterinary medicine enables individuals, which under other circumstances would have been incapable of surviving or reproducing, to produce offspring**, if breeders consider them to be interesting for selection. However, if the health problems affecting these animals have a genetic component, it is highly likely that these will be passed on accordingly.

Selection using a limited number of breeding animals

Any selection, whether artificial or natural, involves restricting the reproductive base, which is linked for domestic animals to breeders' choices of the animals to be bred. The smaller the number of males and females used to produce the next generation, the more intense the selection will be. In this respect, a common practice for domestic animals consists in using a small number of studs considered as superior, which may, over their career, produce a very large number of offspring in relation to dams.

By way of example, the development of artificial insemination in cattle has enabled some bulls to produce hundreds of thousands of offspring over their lifetime (Funk, 2006). Although this technique is less developed for dogs, due to the prolificacy of the species, **the number of offspring produced by some studs may exceed 2 000 puppies** (Calboli *et al.*, 2008; Taubert *et al.*, 2007). For Golden Retrievers, Calboli *et al.* (2008) estimated that 10% of English studs sired more than 100 puppies over their lifetime. In 2010, the FCI included in its recommendations that "no dog should have more offspring than equivalent to 5% of the number of puppies registered in the breed population during a five-year period" (FCI, 2010). It is, however, difficult to evaluate the practical implications of these recommendations.

Selection that remains largely empirical

As previously indicated, in contrast to productive species, there are no real quantitative selection objectives for dogs. Moreover, because breeding is traditionally seen as a passion, without financial consequences at the breed level, there are generally no streamlined breeding plans, and programmes are often non-restrictive for breeders. Depending on the country and the club, there may or may not be breeding restrictions based on morphological or health criteria (for example, the confirmation examination in France), and breeders are generally free to choose their breeding animals from a relatively large pool. To do so, the analysis of pedigrees, the examination of breeding animals and their offspring, the results of shows and the breeder's reputation will all influence the choice of animals (Leroy *et al.*, 2007). Selection by breeders therefore remains relatively free and largely empirical.

This situation is nevertheless changing with the development of an increasing number of clinical, molecular and even quantitative health tests. The growing problem of breed health is pushing breeders to make choices based on better health in their breeds. Clinical and molecular testing raise the issue of the integration of simple traits, (generally linked to the fact that dogs are carriers of or affected by an inherited disease) into breeders' choices and the constraints that may be imposed by clubs. **For more complex disorders (especially hip dysplasia), several kennel clubs (in England and Sweden, for example) have recently implemented quantitative genetic evaluations** to assess the genetic level of affliction in a dog (Fikse *et al.*, 2013; Asnaghi 2016), which is an important opportunity for objectivising selection.

The use of inbreeding

The final important practice for the canine species, which is also observed for other domestic species such as cats (Leroy *et al.*, 2014a), concerns the use of inbreeding, especially of close relatives, as a selection practice. In a study of seven breeds of dog bred in France (Leroy *et al.*, 2014b), it was estimated that in almost 5% of litters, the coefficient of inbreeding recorded was more than 12.5% (equivalent to a half-brother/ sister mating). The extent of this practice nevertheless varies according to the breed and the country (Wang *et al.*, 2016). Dog breeders probably use inbreeding in order to increase the influence of an ancestor considered to be an improver within the origins of an individual, with a view to attaining the ideal phenotype.

IMPACTS OF BREEDING PRACTICES ON BREED HEALTH

In recent years, breeders, owners and the media have expressed growing concern about the impacts of selection on health in purebred dogs, as shown by a BBC documentary entitled “Pedigree Dogs Exposed” (2008). Indeed, dogs are the species with the second highest number of identified genetic diseases after humans, with several hundred genetic disorders identified (OMIA, 2016). Although this result is not independent of the fact that this species is highly medicalised, as previously mentioned, many disorders are specific to certain breeds, and it has often been suggested that crossbred animals are more healthy than purebred dogs (Bellumori, 2013). It is therefore important to ask just how much selection impacts breed health.

In 2009, a double British study (Asher, 2009; Summers, 2009) identified 396 disorders specific to purebred dogs, 84 of which could be directly or indirectly linked to standards, and 312 of which did not seem to be linked to conformation in dogs. This classification according to two groups seems very appropriate, since it can be considered that dog breeding practices involve two different mechanisms that are likely to affect breed health: selection based on deleterious phenotypic characteristics, and genetic drift linked to selection intensity.

Selection based on deleterious phenotypes

Health in dogs is inextricably linked to their morphology. This is demonstrated by average life expectancy, which is generally lower for large breeds. But animal health can also be impacted by a whole range of morphological characteristics. Deafness, for example, is often associated with specific coat or eye colours, since melanocytes play an important role in the hearing process. As illustrated by the chapter on ophthalmology by Gilles Chaudieu (Chaudieu, 2017), some eye problems are linked to the general or exaggerated morphological traits of certain breeds. Another recent example (Packer *et al.*, 2015) is Brachycephalic Obstructive Airway Syndrome (BOAS), whose expression has been shown to be significantly correlated with the ratio of muzzle length to skull length in animals. Above a ratio of 0.5, none of the 700 individuals in the study appeared to be affected, but the risk increased dramatically below 0.2, with more than half of individuals of the study affected.

However, over the last 100 years, animal morphologies have significantly evolved to follow certain trends. Hypertype animals, in other words those that express extreme phenotypic characteristics specific to their breed, may have been considered by judges, clubs or breeders as improvers and bred repeatedly. In brachycephalic dogs, the trend for shortened muzzles, to produce animals that resemble comic illustrations, is thought to have considerably increased the scope of health problems such as BOAS. The relationships that may exist between health and the overriding importance given to phenotypes within selection objectives for dog breeds may therefore have largely impacted on the well-being of these breeds. This is compounded by the fact that the possibility of treating certain syndromes has enabled the reproduction of dogs whose health was compromised by their morphology.

Genetic drift

The loss of genetic variability and the increase in inbreeding levels are often seen as the second side of health problems in purebred dogs. For the most part, this problem is primarily linked to genetic drift, in other words to a random fluctuation in allele frequency, which is all the higher if the reproductive base (the number of breeding animals) is small within the population. In connection with this drift, a given allele, for example a recessive allele responsible for a disease, could suddenly increase in frequency within the population. In fact, this often occurs with the overuse of a given sire, which will massively disseminate the alleles he carries. In the case of a recessive disease, which is the most common determinism in dogs, the sire himself will not express the disease. It is only several generations later that his descendants, having inherited this allele in the homozygous state through inbreeding, will express the disease.

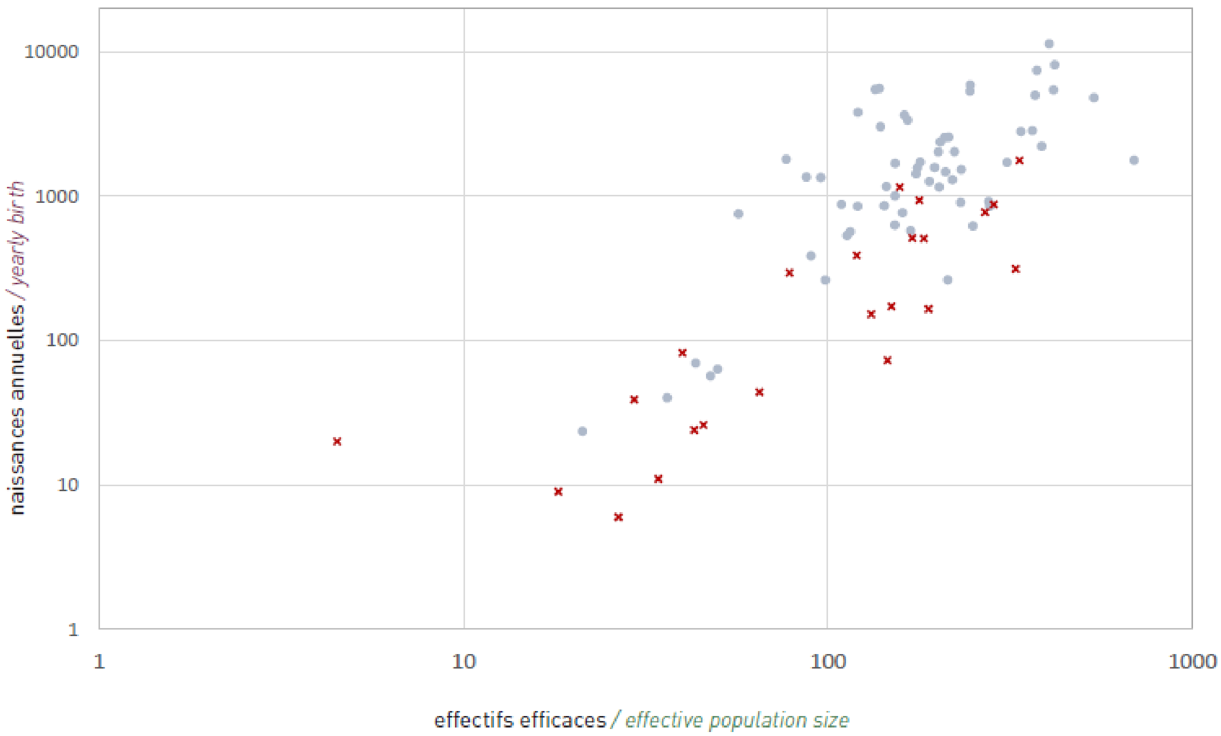

Fig a. Nombre de naissances annuelles et effectifs efficaces estimés sur 60 races françaises (•) et 21 races belges (x) (D'après Leroy *et al.*, 2013 et Wijnroxc *et al.*, 2016) */ Number of births per year and effective* population size estimated for 60 French breeds (•) and 21 Belgian breeds (x) *(from Leroy et al., 2013 and Wijnroxc et al., 2016)*

For dogs, the effect of small, closed populations and the intensive use of sires is clearly illustrated by the small effective population sizes that have been calculated within dog breeds. These effective population sizes – which correspond to an idealised population following the same trend in terms of genetic drift as the population studied – rarely exceed 100 to 200 individuals, even in breeds with more than 1 000 registered births per year, as illustrated in figure a. In some breeds, the effective population size is below 100 individuals, which demonstrates the limited genetic variability within these populations.

The limited gene pool and, to a lesser extent, the practice of inbreeding, have almost certainly contributed significantly to the spread of inherited diseases through genetic drift. The mechanisms for this dissemination work in the same way for more complex disorders. For alleles with limited deleterious effects, it is only through the accumulation of effects expressed by inbreeding that "inbreeding depression" can be measured. In dogs, it has been shown that for the Brittany Spaniel or the German Shepherd in particular, between dogs with an inbreeding coefficient of less than 6.25% and those with a coefficient of more than 12.5%, inbreeding depression results in an average reduction in longevity of more than a year (Leroy *et al.*, 2014b).

Discussion

Building on the analysis made in this chapter, it is important to look at possible solutions to the problems encountered by purebred dogs today. These could take different forms.

First, **it is essential that selection objectives be redirected in order to give greater importance to breed health**. It is fairly clear that the desire – whether conscious or unconscious – to produce increasingly hypertype dogs, in disregard of their well-being, has caused substantial and sometimes irreparable damage in many dog breeds. This will require political will from clubs and awareness raising among breeders concerning the problem of animal health.

Second, it seems important that dog breeders consider adapting their practices in order to limit the consequences these may have on breed health. This would imply opening selection bases to a larger number of breeding animals, considering, where necessary, the use of crossbreeding, and discouraging the use of inbreeding, as is already the case in most Scandinavian kennel clubs.

The adaptation of breeding practices depends on the implementation of breeding policies and selection plans that help to steer breeders' selection choices towards improvements in the health of their breed. This could result in the establishment of measures, which may restrict the choice of breeding animals. **In a context in which breeding is seen as a passion or a hobby, it is important to educate those concerned and to clearly explain the necessary choices so as to avoid discouraging a large number of enthusiasts who make dog breeding what it is.**

In order to help clubs and breeders to improve breed health, the development of genetic testing may prove to be a valuable asset. But users need to be properly informed about the advantages and limitations of these tests (Abitbol, 2017), which requires continuous dialogue between breeders, veterinarians and geneticists.

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