The Canine Diversity Project

DIVERSITY AND THE PUREBRED DOG

(The Poodle and the Chocolate Cake)

by John Armstrong

The Nature of Diversity

Think of genes as recipes. They carry the instructions for the various components that go into making up an organism. Each recipe specifies a particular component, and different individuals may carry different versions of the same recipe. (In the jargon of genetics, we say that they carry different alleles of a particular gene.) Individuals within a population often carry similar or identical recipes, for example, chocolate cake for a Poodle, lemon cake for a Beagle, and white cake for a Samoyed. A different canine species might be represented by a fruit cake. When you consider animals that are quite different, such as frogs and chickens, you will generally find "homologous" recipes, say for pies or puddings. Thus, there is more diversity among mammals than among carnivores, more among the carnivores than among the Canidae, and more among the Canidae than among the wolf group.

An organism carries a collection of recipes, and the collection defines the organism. The great diversity in the possible collections of recipes is the reason for the great diversity in the animal and plant kingdoms. The more closely related two individuals are, the greater the similarity in their collections. The number of combinations is huge, and during evolution, the recipe collection was undoubtedly reshuffled many times. The combinations that worked well survived and multiplied. Those that did not work quickly died out. In theory, one may make a meal of Champagne with tacos and Yorkshire pudding, but they don't really belong together. As time passed, exchange of recipes became difficult between animals that differed substantially in their physical and behavioural characteristics. Different groups, therefore, became constrained to work with only a subset of the total possible collection of recipes.

One definition of a species is that members of two different species bred to each other cannot produce a fertile hybrid. However, a more modern definition is that two species are geographically, physiologically, or behaviourally isolated such that they do not normally produce hybrids. Additionally, they should have features that differ sufficiently to allow them to be distinguished from each other. The domestic dog, wolf, coyote, and jackal can all mate with each others (barring size constraints) to produce viable and fertile hybrids. Yet, they have been considered different species (within the genus Canis) because they normally live in different places, behave differently, and can usually be told apart. (Though there has been a recent move to change *Canis familiaris* to a subspecies of *Canis lupus*.) However, a jackal will not mate with a dog unless they have been raised together from pups (presumably due to a learned behavioural difference). Furthermore, no Canis species can produce a hybrid with a fox. This is not because the kinds of genetic recipes are greatly different, but because foxes do not share the same number of chromosomes. (In other words, their recipes are filed under a different, incompatible system — somewhat akin to filing one under DOS and the other on a Mac.)

Genetic recipes may get modified when they are passed on. Many of the modifications will make no noticeable difference, or only a very subtle one. Some may improve the recipe and others will not. If we are making a chocolate cake and a critical ingredient is forgotten, or the cake is baked too long or at the wrong temperature, we end up with a disaster. (If we don't understand what has gone wrong, we will likely throw out the recipe and look for a new one.) We may even make deliberate modifications in an attempt to get a more memorable cake. Among the "chocolate cake" population, there will be a variety — or diversity — of recipes and, therefore, of cakes.

This, I would say, is a "good" thing. Do we always want the **same** chocolate cake? Surely we will tire of it, and even if we don't, we lose the pleasure of anticipation. If, for some unforseen reason, everyone suddenly loses their taste for **THE** chocolate cake, it will surely go extinct. ***To have the potential for evolution and adaptation, we must risk the possibility of the bad.*** That is the "cost."

In a large, naturally breeding population, we will end up with a number of versions (alleles), some so slightly different that we will never notice, some perceptibly different (but still functional), and some that just don't work at all. However, if we remove the diversity we lose the potential for evolution and for surviving unexpected change. To have the potential for evolution and adaptation, we must risk the possibility of the bad. Geneticists call that cost **genetic load**. This "bad" group persists because every individual carries two copies of every recipe, and often having just one "good" copy is enough for normal function. In most populations, every individual carries a portion of the load — three to five bad recipes out of several thousand. The load is so well distributed that if two individuals compare their recipe collections they will generally not have two copies of the same bad recipe.

Loss of Diversity

Suppose we start a new population with only six or eight founders. (A number of breeds have started with that few.) We will get rid of hundreds of bad recipes, but the remaining dozen or two will be encountered much more frequently. Furthermore, if there are several good or excellent recipes, the chance of dropping one of these from the collection grows greater as the number of founders diminishes, and the risk of losing one remains high as long as the effective population size remains low. Working with small numbers will inevitably decrease the diversity, simply because individuals do not pass on their recipes equally to the next generation and some recipes are accidentally lost. This has the superficially desirable result of giving a more reproducible phenotype, but at the expense of an overall reduction in quality, health, and longevity.

If breeders had the ability to recognize each individual recipe and choose only those that were excellent, breeds could be produced with a small number of individuals that lacked genetic problems. However, what we see (the phenotype) is the product of all the recipes and, for the most part, we cannot distinguish the individual recipes. Moreover, we do not have the option of selecting recipes individually. When we select an animal for breeding, we are forced to accept a complete set. Even in those few cases where we now have a DNA test for a bad recipe (allele), we do not possess the ability to correct or selectively discarded it. We are therefore forced to work around it, or to discard the whole collection, with the attendant risk of discarding something excellent along with it.

The common practice of almost everyone rushing to breed to the currently-popular male show champion is probably the most significant factor reducing whatever diversity remains. Consider your own breed (the situation for most breeds is similar). Can you find one or more males that appear in most pedigrees? Almost everyone decides they like the recipes of (*insert name*) — or at least the ones they can see readily — and abandons other recipes with little thought to the eventual consequences. In a few generations, almost everyone has a substantial number of his recipes, though not necessarily his exceptional ones, and many excellent alternatives are very hard to find.

How precious is the individual that comes along with some of the missing recipes and relatively few of the "popular" collection? Do we hesitate because there are also a few bad recipes in this alternate collection? Are we now so accustomed to dealing with the more-popular collection that we have lost the vision of the "memorable" chocolate cake?

Population Genetics and the Breeder

What is often called **Mendelian** genetics deals with the outcome of specific crosses. **Population genetics** deals with the distribution of alleles in a population and the effects of mutation, selection, inbreeding, etc., on this distribution. As a breeder, you are a practicing geneticist. A knowledge of both Mendelian genetics and population genetics is critical, not only to your own success, but also to the survival of your breed.

Because many early geneticists believed that there were only two possible alternatives for a gene — "good" alleles that functioned normally and "bad" alleles that didn't — they expected to find little genetic variability in a population. The majority of individuals were expected to be homozygous for the good allele for most genes.

But with the advent of modern biochemical and molecular tools, geneticists studying populations found far more variability (diversity) than they had expected. There are a number of possible reasons for this, and even the experts are not in total agreement on the most likely reason(s). However, geneticists have also discovered that populations lacking genetic diversity often have significant problems and are at greater risk from disease and other changes in their environment. The conclusion is that genetic diversity is desirable for the health and long-term survival of a population.

Are purebreds dogs genetically diverse? Some may regard that as a contradiction in terms. The very concept of creating a breed with characteristics that are distinctly different from other breeds implies a certain limitation on diversity. Nevertheless, within the standards for a breed, diversity should still be possible for genes that do not affect the essential characteristics that distinguish one breed from another. If, in order to maintain breed identity, one has to compromise on genes that relate to general structural soundness, good health, intelligence, and temperament, perhaps this breed should not exist. However, as long as these essentials are not compromised, I see no reason why one cannot have different breeds with different appearances and different talents.

For those genes that establish breed identity, there will be markedly less variability within a breed than within *Canis familiaris* as a whole. The tricky bit is restricting variability for those genes that make a breed distinctive without sacrificing the variability/diversity that is necessary for good health and long-term survival of the breed. In many cases, this has not been achieved, and we are now paying the price in terms of high incidence of specific genetic diseases and increased susceptibility to other diseases, reduced litter sizes, reduced lifespan, inability to conceive naturally, etc.

Why has this happened?

1. Many breeds have been established with too few founders or ones that are already too closely related.
2. The registries (stud books) are closed for most breeds; therefore you cannot introduce diversity from outside the existing population.
3. Most selective breeding practices have the effect of reducing the diversity further. In addition, the wrong things are often selected for.
4. Even if the founders were sufficiently diverse genetically, almost no one knows how their genetic contributions are distributed among the present day population. Consequently, breeding is done

without regard to conserving these contributions, which may be of value to the general health and survival of the breed.

Do we have to accept it as an inevitable consequence of creating a breed? I don't think we do.

A role for the breed clubs

Each breed needs a database with all the breedable animals recorded with all their ancestors back to the founders. This would most appropriately be the task of the breed club. Are any actually doing this (outside some of the rare breeds)?

Such a database would enable breeders to identify which individuals are most likely to carry the genes from each founder. At the level of the individual breeder, it would enable him/her to make intelligent, informed choices when selecting mates. Measures might also be considered to re-balance the breed, in order to ensure that the remaining diversity is more evenly distributed and that, therefore, there is less risk of loss.

Reference

Hartl, D.L. **A Primer of Population Genetics**, Sinauer, Sunderland, MA, 1988.

Notes

A population is regarded as genetically diverse if a substantial proportion of the genes are polymorphic. A polymorphic gene is one for which the most common allele has a frequency of less than 0.95 (95%). Mammals are about 15% polymorphic.

A gene that is not "polymorphic" is called "monomorphic", but this does not imply only one allele. Most monomorphic genes have rare alleles, generally occurring at frequencies below 0.005.

Revised July 15, 2001