

Canine Genetics, Simplified

By Jody Haynes & Kim Miles

Introduction

People who know very little about wolfdogs often erroneously think of wolves and dogs in terms of 'black' and 'white'—with the wolf being an endangered wild species and the dog being man's best friend. Wolfdog owners are also sometimes a bit confused over the distinction between wolves, dogs, and wolfdogs.

Three of the most common questions that are asked—by wolfdog owners and non-owners alike—about the genetics of wolves, dogs, and wolfdogs are as follows: (1) Are 'wolf' genes stronger than 'dog' genes, or 'male' genes stronger than 'female' genes?; (2) Can genetic studies distinguish between a wolf and a dog?; and (3) Is there a genetic test to determine if an animal is a wolfdog, and if so, can the test determine what percentage of wolf is in the animal?

We will address these questions here, but first we will attempt to clarify the underlying science surrounding genetic studies of lupine-type canids.

Background on DNA

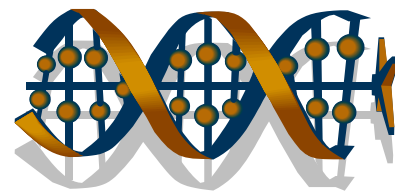
To understand the similarities and differences between wolves and dogs on a genetic level, a little background on DNA should prove helpful.

Animals have two types of DNA: nuclear (nDNA) and mitochondrial (mtDNA). **Nuclear DNA** is found in the nucleus of a cell, within tightly packed units called **chromosomes**. Each cell has two copies of each chromosome (this is termed 'diploid'). One pair of chromosomes is involved in sex-determination and is, therefore, referred to as the sex chromosomes. The other pairs of chromosomes are called autosomes. All mammals have only one pair of sex chromosomes, but the number of autosomes varies according to species. The genes coded for by nDNA are responsible for external or phenotypic characteristics (*i.e.*, for looks) and behavior, while they also have important regulatory functions inside the cells.

Mitochondrial DNA, on the other hand, is separate and distinct from nDNA and is found inside tiny structures known as mitochondria that reside inside cells. Mitochondria are responsible for producing energy for the cell by breaking down carbohydrates and other 'food' molecules in a process known as aerobic respiration. Mitochondria operate somewhat independently of the cells in which they reside, and they have their own DNA, which is replicated independently of nDNA. This mtDNA primarily governs the synthesis of the RNA and proteins that the mitochondria need for the specialized task of producing ATP, the energy currency of a cell.

Mitochondrial DNA is slightly different from nDNA. For one thing, mtDNA is a circular molecule that does not occur in pairs (this is termed 'haploid') and is inherited maternally, which means that it comes only from the female of the species. Secondly, mtDNA molecules do not undergo recombination, which means that the molecules are passed to the offspring intact, rather than in the nearly infinite combination of genes in nDNA that results from genetic recombination. Finally, mtDNA accumulates mutations at a faster rate than nDNA. For these reasons, scientists often choose to analyze mtDNA in studies of the genetic relationships of organisms.

Genes are discrete pieces of DNA that code for particular gene products known as proteins. Slightly different forms of the same gene are referred to as **alleles**. In nDNA, each chromosome pair has two alleles, one on each chromosome in the pair. Sometimes the two chromosomes within the pair have the same allele, and other times they have different alleles. Some alleles are dominant and are always expressed, while others are recessive and are only expressed when both alleles of a gene are recessive. In mtDNA, all genes are linked together on a circular molecule and all are expressed, since the mtDNA molecules occur singly, rather than in pairs. The combination of genes on the chromosomes in nDNA is known as a **genotype**, whereas the combination of genes in mtDNA is referred to as a **haplotype**.



DNA Strand

How is DNA Inherited?

Nuclear DNA is inherited in the form of chromosomes—half of which come from the mother and half from the father. During the process of meiosis, which takes place in the sex organs, haploid eggs are produced in females and haploid sperm are produced in males. (Remember that haploid refers to one copy of each chromosome.) During fertilization, these haploid sex cells fuse and restore the diploid condition to the embryo. (Diploid refers to two copies of each chromosome.)

As noted above, mtDNA is haploid and exhibits matrilineal inheritance, which means that it comes solely from the female parent. This occurs because animal eggs are typically large and carry mitochondria inside them. On the other hand, there is no room for mitochondria in the part of the sperm that fuses with the egg at fertilization. Therefore, mtDNA is passed from mother to offspring through the egg.

The following examples illustrate the differences between the ways in which nDNA and mtDNA are inherited—specifically with respect to wolves, dogs, and wolfdogs:

A female pure wolf breeds with a male pure dog — the pups will all receive the wolf mtDNA from the mother, and they will have exactly 50% nDNA from the dog parent and 50% from the wolf parent.

A female pure dog breeds with a male pure wolf — the pups will have the mtDNA of the dog mother, and the nDNA will again mix equally.

A wolfdog (of either sex) breeds with a wolf, wolfdog, or dog (it doesn't matter) — the mtDNA will always remain pure 'dog' or 'wolf', depending on the mtDNA of the mother (and the mothers' mother and so on). Once again, 'wolf' and 'dog' nDNA will mix, but this time it will not be equal; rather, the processes of genetic recombination and independent assortment will result in a nearly infinite number of possibilities of the relative proportions of 'wolf' and 'dog' nuclear genes in these pups.

In the first two cases above, all of the pups will appear to be exactly intermediate between the wolf and dog parents, but the mtDNA will be either 'dog' or 'wolf'. In the third case, the mtDNA of the pups will, again, be either 'wolf' or 'dog'; however, the nDNA will be a random mixture that would result in a variation in phenotype (looks) and behavior. The pups could look and act 'doggy' or look and act 'wolfy' or any of a multitude of combinations of the two depending on the relative proportions of 'dog' and 'wolf' nDNA that each *individual* pup inherits from its parents.

Three Questions Addressed

At the beginning of this article, we posed three frequently asked questions related to the genetics of wolves, dogs, and wolfdogs. In this section, we will provide answers to these questions.

Q: Are 'wolf' genes stronger than 'dog' genes, and/or are 'male' genes stronger than 'female' genes?

A: It is a myth that 'wolf' or 'male' genes are stronger than 'dog' or 'female' genes. Although certain alleles within a gene are dominant and others recessive, dominant alleles do not occur in higher frequencies in males or in wolves as opposed to females or dogs.

Q: Can genetic studies distinguish between a wolf, a wolfdog, and a dog?

A: The short answer to this question is yes. Scientists have identified both wolf-specific and dog-specific DNA markers. This means that DNA analyses can distinguish whether an animal has recent wolf and/or dog inheritance; in other words, scientists can distinguish between a wolf, a wolfdog,

and a dog. However, there is an important caveat to this information. Scientists cannot rely solely on mtDNA to distinguish between these three canines. Remember, mtDNA is matriarchal, so a wolfdog will contain 'dog' mtDNA if the mother is a pure dog (and vice versa); therefore, it is possible for a wolfdog to have 'dog' mtDNA—in which case the animal would be genotyped as a pure dog based on this DNA test alone. The flip side is also true; a wolfdog can show all 'wolf' mtDNA and be deemed a pure wolf. This means that using mtDNA alone to distinguish between a wolf, wolfdog, and dog is inaccurate and can yield an incorrect determination.

Researchers typically include other genetic tests, including nDNA and Y-chromosome DNA (paternal DNA), to increase the reliability of genetic analyses. The former test analyzes DNA inherited from both parents, while the latter focuses on genes specific to the Y-chromosome, which is inherited paternally and which only occurs in males; thus, it is a test that can only be performed on male animals.

It should also be mentioned that the nDNA analyses that have been developed so far examine only a very, very small proportion of an animal's DNA; if an animal happens to have all 'dog' genes in the regions analyzed by the test, the test will yield a 'dog' genotype and the animal will be considered a dog based on this analysis alone—regardless of the actual 'dog' or 'wolf' content in the animal. Combining mtDNA, nDNA, and Y-chromosomal DNA increases the likelihood of an accurate result in determining the genotype of wolves, wolfdogs and dogs.

Finally, scientists have not analyzed nDNA from all dog breeds and mixes or from a large number of wolves; thus, many more tests will need to be conducted, covering ALL breeds of dog and various mixes, to conclusively determine whether a particular nDNA marker is actually dog-specific vs. wolf-specific vs. occurring in both wolves and dogs.

Q: Is there a genetic test to determine the percentage of wolf (or dog) in a wolfdog?

A: To date, NO genetic tests have been developed that can determine the amount, or percentage, of wolf (or dog) content in a wolfdog. Some of the available genetic tests report a Q value for "dog" and a separate Q value for "wolf". These Q values represent the statistical likelihood of the animal being tested being a pure dog or a pure wolf, respectively. Some have erroneously equated Q values to percent content, but the two are not the same and one should never represent a Q value from a genetic test as an animal being "X" percent wolf or dog.

Concluding Remark

As we stated at the beginning of this article, many people erroneously believe that wolves and dogs are distinctly separate, one being 'black' and the other being 'white'. However, when wolfdogs are thrown into the mix, 'black' and 'white' are, in actuality, merely the ends of a continuum. Monty Sloan of Wolf Park put it simply: "There is no black and white in this issue, only shades of agouti gray."