

## **Genetic Testing: Genotype versus Phenotype 2**

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In the first article of this series, different genotypic and phenotypic tests were described for the three varieties of poodle. This article will expand upon those descriptions and explain how each test could be used in a breeding program to decrease the incidence of disease in a line of poodles. Please note that not every possible combination of tests will be described and that breeders must make their own choices in how they wish to utilize the tests in their individual breeding programs.

Genotypic testing is the “gold standard” of genetic testing in that it determines the actual genetic makeup of an individual through DNA markers identified for a particular disease. In the poodle breed, the only DNA testing available at this time is for von Willebrand’s (vWD) disease in all 3 varieties, for progressive retinal atrophy (pra) in the toy and miniature varieties, and for neonatal encephalopathy (NE) in the standard variety. There are laboratories working on identifying DNA testing for other diseases, including sebaceous adenitis, epilepsy, Addison’s disease, patent ductus arteriosis, and others. The DNA marker tests available for vWD, pra, and NE result in identifying an individual as either a clear, carrier, or affected dog. Once the breeder knows the status of her breeding bitch or stud, he/she can make informed choices on whom to breed into or out of the line in order to prevent reproducing the disease in question.

For example, in a disease which is inherited as a simple recessive, a clear poodle can be bred to either a carrier or an affected poodle and will not reproduce the disease. Please see Tables 1-6 for a breakdown of each breeding for trait “a”, inherited as a simple recessive in this case. All clear individuals will have the genetic makeup of “AA” while carriers will have the genetic makeup of “Aa” and affected individuals will carry two copies of the defective gene with the makeup of “aa”.

*Table 1* A A

A	AA	AA
A	AA	AA

a) breeding 2 clear (AA) individuals

*Table 3* A A

A	AA	AA
a	Aa	Aa

c) breeding a clear (AA) and a carrier (Aa)

*Table 5* A a

a	Aa	aa
a	Aa	aa

*Table 2* A A

a	Aa	Aa
a	Aa	Aa

b) breeding a clear (AA) and an affected (aa) individual

*Table 4* A a

A	AA	Aa
a	Aa	aa

d) breeding 2 carriers (Aa)

*Table 6* a a

a	aa	aa
a	aa	aa

e) breeding a carrier (Aa) and an affected individual (aa)

f) breeding 2 affected individuals (aa)

As you can see in Tables 1-3, you can breed a clear individual to any other individual and you will not reproduce the disease. However, you will get a different percentage of carrier puppies depending on the status of the other breeding individual. In the case of breeding clear to clear, 100% of the puppies will be clear, i.e. will also never reproduce the disease (Table 1). In the case of breeding a clear to an affected individual, 100% of the puppies will be carriers, but none of them will have the disease themselves (Table 2). In the case of breeding a clear to a carrier, 50% of the puppies will be clear and 50% will be carriers, but again none of the puppies will have the disease themselves (Table 3).

All other combinations of breedings will produce puppies affected with the disease in question. When breeding two carriers to each other, 25% of the puppies will be clear, 50% will be carriers, and 25% will be affected with the disease (Table 4). In the case of breeding a carrier to an affected individual, 50% of the puppies will be carriers, and 50% of the puppies will be affected with the disease (Table 5). When breeding two affected individuals, 100% of the puppies will also be affected with the disease (Table 6).

These tables are accurate only for diseases which are inherited as simple autosomal recessive characteristics. There are many diseases which are controlled by more than one set of genes, known as polygenic traits, such as the inheritance of hip dysplasia. Coat color is an example of a normal trait which is inherited by the interaction of multiple genes. Only a small number of traits are known to be inherited as a simple autosomal recessive. Discovering and creating DNA testing for polygenic traits is much more difficult. For these diseases breeders must rely upon pedigree research to determine the likelihood of a particular line for carrying a particular disease and therefore are relying upon the phenotypic expression of the gene – finding the affected individuals. The breeder must rely upon the knowledge of the lines to which they want to breed, as well as what genes may be present within their own lines. The use of the coefficient of inbreeding (COI) is helpful in determining whether or not breeding a particular pair is more of an outcross or inbreeding. The lower the COI, the less inbred an individual is when analyzing his or her pedigree. Ideally, the pedigree analysis extends to 12 generations or more.

Pedigree analysis has become much more feasible in the age of computers. Data is easier to retrieve and record in a computer program and makes analyzing 12 generations or more an attainable reality. However, a breeder must understand something of statistical analysis in order to put the information to use within their breeding program. There are many computer programs and websites available to a breeder who wishes to extend his or her knowledge in this area. Dr. John Armstrong and Dr. Jerold Bell have both published articles and information for the benefit of breeders. Dr. Bell has also hosted a canine and feline genetics conference through the Tufts University School of Veterinary Medicine for several years.

A breeder must understand and utilize an abundance of information in different forms when making breeding decisions. A small portion of information comes from DNA testing. The next package of information comes from phenotypic testing such as CERF exams, OFA or

PennHIP x-ray results, thyroid panels, etc. Finally, the breeder must be aware of what has been produced by the dogs in the pedigree, including analyzing siblings, and other parallel individuals rather than just direct ancestors. This is where the computer programs and use of COI can be helpful. If the COI is very high, and there is a particular trait which has shown up over and over in a pedigree, there is a good chance that puppies produced from the breeding will express this trait. Alternatively, if the COI is low, a particular trait has a lower chance of being expressed in the litter, unless it is present in abundance on both sides of the pedigree regardless of the fact that the individuals are not closely related.

The goal for a breeder is to reproduce a particular “type” within their line while at the same time maintaining health and temperament. Juggling type, health, and temperament is not always an easy thing to do. A breeding that is beneficial for one of these three goals may not be beneficial for one or both of the others. Also, breeders disagree as to which of the three goals is the most important. That can often be seen in the polls taken by *Poodle Variety* concerning these issues. It is very important not to focus solely on those diseases for which DNA testing is available, and limit the gene pool by trying to eliminate these diseases. However, using DNA testing to avoid reproducing affected individuals is a laudable goal. A breeder must focus on the goals of their breeding program as a whole, not as individual breedings.

Breeders can use DNA testing to avoid reproducing affected individuals by breeding carriers and affected individuals (if all other traits are desirable) only to clear individuals. At the same time, the breeder can utilize phenotypic testing, such as hip x-rays, etc. to breed to individuals who are not expressing the undesirable trait (they may still be a carrier), and lastly the breeder must consider utilizing 12 generation (or more) pedigree analysis to determine the COI of a pair while also focusing on the traits seen by ancestors as well as other related individuals. When breeding carriers and affected individuals, the breeder should attempt to keep a puppy from the next generation that expresses the desired traits for the line but is hopefully clear rather than a carrier. Eventually a breeder may be able to replace all carriers with clear offspring, but this will likely take many generations if it is even possible.

The problem with poodles, and other purebred dogs, is that the gene pool is very small and a large number of carriers may be present in the population, making it difficult, if not impossible, to completely eradicate the carrier population. Also, only a small number of genes actually have DNA tests available, and it is much more difficult to eradicate carriers based on phenotypic information. It is particularly difficult when breeders are not open and honest about what they have produced in their line; without the knowledge of what has been produced in the past, a breeder is working in a “black hole” of guesswork for the future. Many respected scientists are working on developing more DNA testing for poodles and other breeds. The more testing that is available and utilized by breeders, the more we can produce healthy as well as beautiful poodles. Breeders will hopefully begin to understand and utilize programs to help plan their breedings, using a combination of DNA testing, phenotypic testing, COI calculations, and pedigree analysis. By combining the science of breeding with that knowledge of picking the “special” puppy from the litter, breeders will continue to strive for the ultimate perfect poodle.