Genetic Technologies – Genetic Testing

The team behind our Genetic Testing is at the forefront of canine DNA technologies and research, pioneering advances in pedigree dog profiling, genetic disease and trait testing. Over 5,000 worldwide professional breeders have benefited from these sophisticated and proven DNA testing services.

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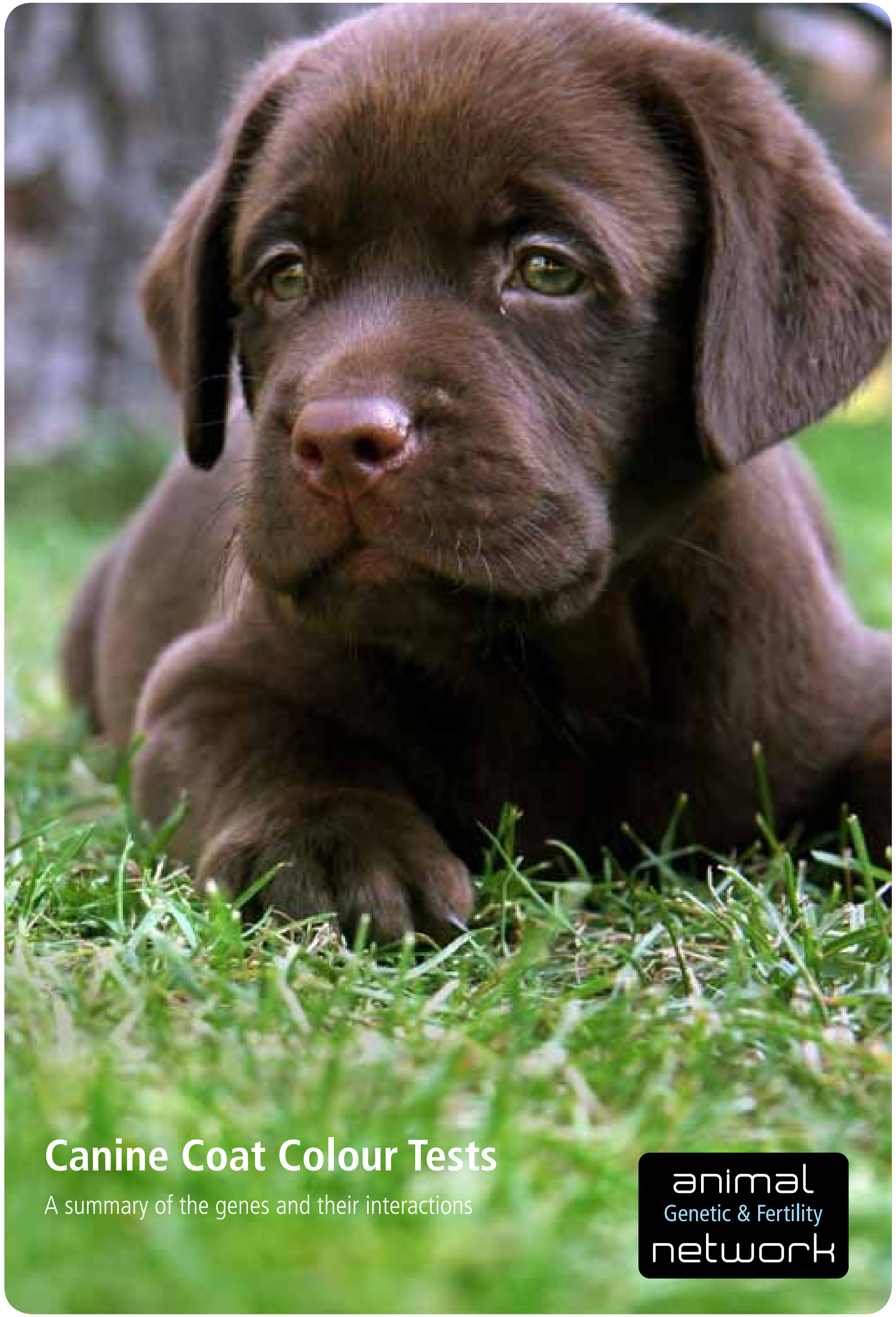


Canine Coat Colour Tests

A summary of the genes and their interactions

animal Genetic & Fertility network

Coat Colour Testing

Breed your dog with the confidence of expected outcomes.

Genetic Technologies coat colour testing identifies the hidden colours that are in your dog and allows breeding with the knowledge of expected outcomes.

Your Canine Coat Colour Report

Your report will inform you of the alleles detected in your dog and will contain a unique report number should you have any enquiries about your result. Note: Your dog's result will only be certified if postive identification has been provided eg. microchip number

genetic technologies

Canine Genetic Test Report

Coat Colour - Melanistic Mask (Em) Locus

Type of Test:	Melanistic Mask (Em) Locus*	Test performed
Dog's Registered Or Intended Name:	J	
Microchip or Tattoo Number:		
Registration Number:	N/A	
Breed:		
Sex:		
Date of Test:	28-May-09	
Report Date:	28-May-09	
Certified Result:	Yes	Certified result
Owner:		
Result of Test:	Em,E	Alleles detected

Report Number:

Results reviewed and confirmed by:

George Sofronidis
Manager of Companion Animals

Craig McLure PhD
Senior Scientist

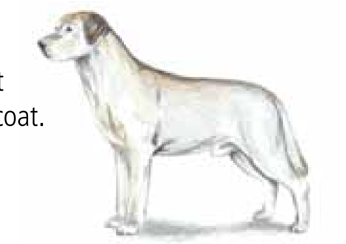
* According to the mutation reported by Schmutz et al (2003) Journal of Heredity 94(1):69-73
Disclaimer
The test identifies a polymorphism that is believed to be the causative change resulting in the Melanistic mask phenotype. It is possible that the polymorphism reported is not the causative variant but is in strong linkage with the actual variant. It is therefore possible that in some instances the genotype will not relate to the phenotype.

healthy dogs healthy pedigrees

Genotypes and Phenotypes

Each dog's genotype not only determines it's coat colour, but also relates to it's nose and possible hidden colours in their coat.

For example, the Labrador Retriever:



Genotype	Coat Colour	Nose Colour	Hidden Colours
EEBBDD	Black	Black	None
EeBBDD	Black	Black	Yellow
eeBBDD	Yellow	Black	Black
EEBbDD	Black	Black	Chocolate
EeBbDD	Black	Black	Yellow, Chocolate
eeBbDD	Yellow	Black	Brown
EEbbDD	Chocolate	Brown	None
EebbDD	Chocolate	Brown	Yellow
eebbDD	Yellow	Brown	Brown

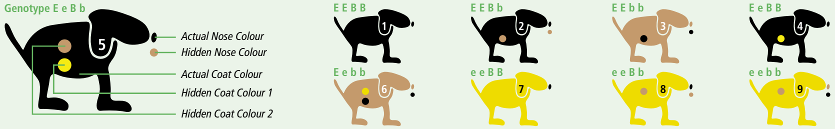
Labrador Retriever Coat Colour Chart – E&B Loci

This chart illustrates the potential colours in the Labrador Retriever and is designed to assist in possible colour combinations of puppies.

For the E and B Loci there are nine possible genotypes that each result in a unique combination of coat, nose and hidden colours.

The potential colours of puppies will depend on the genotypes inherited from both parents. For example, if the sire is genotype "5" (black with a black nose) and the dam is genotype "2" (black with a black nose), the puppies can be either black with a black nose (75%) or brown with a brown nose (25%) and they will never produce a dog which is yellow.

Example of Results (Legend) 5



					1	2		3	4		5				6		7	8		9
				Hair	Black	Black		Brown	Black		Black				Brown		Yellow	Yellow		Yellow
				Nose	Black	Black		Brown	Black		Black				Brown		Black	Black		Brown
				Genotype	E E B B	E E B b		E E b b	E e B B		E e B b				E e b b		e e B B	e e B b		ee b b
	Hair Colour	Nose Colour	Genotype	Comb	E B	E B	E b	E b	E B	e B	E B	e B	E b	e b	E b	e b	e B	e B	e b	e b
1	Black	Black	E E B B	E B	1	1	2	2	1	4	1	4	2	5	2	5	4	4	5	5
2	Black	Black	E E B b	E B	1	1	2	2	1	4	1	4	2	5	2	5	4	4	5	5
				E b	2	2	3	3	2	5	2	5	3	6	3	6	5	5	6	6
3	Brown	Brown	E E b b	E b	2	2	3	3	2	5	2	5	3	6	3	6	5	5	6	6
4	Black	Black	E e B B	E B	1	1	2	2	1	4	1	4	2	5	2	5	4	4	5	5
				e B	4	4	5	5	4	7	4	7	5	8	5	8	7	7	8	8
5	Black	Black	E e B b	E B	1	1	2	2	1	4	1	4	2	5	2	5	4	4	5	5
				e B	4	4	5	5	4	7	4	7	5	8	5	8	7	7	8	8
				E b	2	2	3	3	2	5	2	5	3	6	3	6	5	5	6	6
				e b	5	5	6	6	5	8	5	8	6	9	6	9	8	8	9	9
6	Brown	Brown	E e b b	E b	2	2	3	3	2	5	2	5	3	6	3	6	5	5	6	6
				e b	5	5	6	6	5	8	5	8	6	9	6	9	8	8	9	9
7	Yellow	Black	e e B B	e B	4	4	5	5	4	7	4	7	5	8	5	8	7	7	8	8
8	Yellow	Black	e e B b	e B	4	4	5	5	4	7	4	7	5	8	5	8	7	7	8	8
				e b	5	5	6	6	5	8	5	8	6	9	6	9	8	8	9	9
9	Yellow	Brown	e e b b	e b	5	5	6	6	5	8	5	8	6	9	6	9	8	8	9	9

Note *Colours have been predicted based on the assumption that other loci are fixed for specific alleles. There are alleles at the K and D loci that would affect the predictions made in this table. These alleles are rare in the Labrador Retriever. The D and K loci are additional tests that can be requested if required.*

Introduction

It is important to understand that there are many genes involved in canine coat colour. The formation of breeds and the introduction of breed standards has restricted the number of recognised coat colour variants in each breed. As a result, undesirable colours and variations have been eliminated from each breed through selective matings over many generations.

Today, most breeds exhibit only a limited number of coat colour variations. One of the reasons for this is that many of the genes involved have become fixed[1] and only a specific allele[2] of the gene remains. Another reason is that many of the colour variations are recessive[3] and require two copies of the allele in order to exhibit the colour. The individual breeds differ in the genes that are fixed and the genes that are polymorphic[4].

Currently, genetic testing can interrogate six of the genes involved however, there are many others.

Summary of the loci (genes) involved

Solid colour vs white/colour variations

Canine coat colour originates from a specific type of skin cell called a melanocyte. For hair to be coloured, the cells from which the hair originates, must produce and incorporate melanin into the hair. If these cells are unable to produce melanin, the hair will be white in colour.

Several genes determine melanocyte development, survival and migration. Modifications to any of these genes may result in animals that are either solid, piebald, ticked, roan or a combination of all.

A frequently observed trait is a white chest and/or white paws. This is normally caused by incomplete melanocyte migration to the extremities during embryonic development. The genetics for the development, survival and migration of melanocytes remains unclear, however a limited number of important genes have been identified and tests for these should be available in the future.

Black vs Red/Yellow pigment

There are two forms of melanin; pheomelanin, which is red/yellow and eumelanin, which is black. All other colours are modifications of these two pigments. Three genes determine whether pheomelanin or eumelanin is produced, these are explained below.

Melanocortin 1 Receptor (E Locus: E,e)

The first and most important is the Melanocortin 1 receptor *(MC1R)* or the E locus. If an individual has at least 1 copy of the wild type (WT) allele (E) then they will be able to produce black eumelanin. If a dog has two copies of the non-functional "e" allele, then it will only ever produce the red/yellow pheomelanin.

Agouti Signal Peptide (A Locus: a^y, a^t, a)

The second is the Agouti Signal Peptide *(ASIP)* or the A locus. Specific alleles at this locus can interact with a functional *MC1R* and interfere with its production of black eumelanin.

Breeds Covered and Recommended Loci

Individual dogs develop their coat colour based on the gene variants inherited from their parents. These same varients determine the potential coat colour it can pass onto its progeny.

Afghan Hound (E, E^M, A)
Australian Shepherd (E, B, D)
Belgian Shepherd (Groen) (K, A)
Belgian Shepherd (Laek) (E, E^M, A)
Belgian Shepherd (Malin) (A)
Belgian Shepherd (Tervn) (A)
Border Collie (E, B, A, E^M, D, K)
Briard (E, E^M, K)
Brittany (E, B)
Cocker Spaniel (American) (E, B)
Cocker Spaniel (E, B)
Collie (Rough) (A)
Collie (Smooth) (A)
Curly Coated Retriever (E, B)
Dachshund (Long) (E, A, B)
Dachshund (Min. Long) (E, A, B)
Dachshund (Min. Smooth Haired) (E, A, B)
Dachshund (Min. Wire Haired) (E, A, B)
Dachshund (Smoot Haired) (E, A, B)
Dachshund (Wire Haired) (E, A, B)
Dalmatian (E, B)
Doberman (B, D)
English Setter (E, K, B)
English Springer Spaniel (E, B)
Field Spaniel (E, B)
Flat Coat Retriever (E, B)
French Bulldog (E, B)
German Shepherd Dog (E, E^M, A)
German Shorthaired Pointer (E, B)
German Wirehaired Pointer (E, B)
Great Dane (E, E^M, D)
Greyhound (E, E^M)
Japanese Chin (E, K, A)
Labrador Retriever (E, B, D)
Large Munsterlander (E, B)
Lowchen (E, B)
Newfoundland (B, D)
Pointer (E, B)
Pomeranian (E, B)
Poodle (Miniature) (E, B)
Poodle (Standard) (E, B)
Poodle (Toy) (E, B)
Portuguese Water Dog (E, B)
Pug (K)
Schnauzer (Miniature) (E, K)
Shar Pei Apricot/Cream (K, A, B)
Shar Pei Black (E, E^M, K, A, B)
Shar Pei Chocolate (E, E^M, K, A)
Shar Pei Fawn (E, E^M, A, B)
Shar Pei Patterned Sable (E, E^M, B)
Shetland Sheepdog (A)
Staffordshire Bull Terrier (E, E^M, A)
Welsh Corgi (Cardigan) (E, E^M, A, B)
Whippet (E, E^M)

Key

E *is the Extension – Red/yellow vs black*
E^M *is the Melanistic Mask – Black mask on fawn and brindle coloured dogs (present but not evident if dog is black)*
B *is the Chocolate – Modifies what is normally black to brown*
D *is the Dilute – Modifies black to blue (grey) and brown to isabella (light brown)*
A *is the Agouti – Stops E locus from making black pigment and leads to fawn, black and tan, sable*
K *is the Dominant Black – Interacts with A variants and overides any agouti modifications*

Definitions

1	*Fixed*	*All individuals within the breed have two copies of the same allele.*
2	*Allele*	*A variant of a gene.*
3	*Recessive*	*Requires two copies for the phenotype[6] to be expressed.*
4	*Polymorphic*	*More than one form of the gene exists.*
5	*Dominance hierarchy*	*Alleles differ in their dominance over other alleles.*
6	*Dominant*	*Requires only one copy for the phenotype to be expressed.*
7	*Phenotype*	*The change that can be observed or quantified.*
8	*Genotype*	*The two alleles at a particular locus.*

References

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Schmutz, S. M., T. G. Berryere, et al. (2002). "TYRP1 and MC1R genotypes and their effects on coat color in dogs." Mamm Genome 13(7): 380-7.

Four alleles have been identified at this locus; these have a dominance hierarchy[5] whereby $a^y > a^w > a^t > a$. The a^y allele is inherited as the dominant[6] allele in this series. It produces the fawn or sable coat, where the majority of the coat is red/yellow hair and some black hairs are intermingled within the coat. The next in the series is the wild type, a^w allele. This allele causes some hairs to be banded with eumelanin, pheomelanin and eumelanin pigments from base to tip. These banded hairs are normally distributed on dorsal (back) surfaces of the dog.

The third allele in the series is the black and tan allele (a^t). This allele results in animals that are primarily black but have areas of pheomelanin, which are normally seen on ventral (legs and belly) regions of the dog, the side of the head and spots above the eyebrows. The amount and distribution of pheomelanin in black and tan dogs differs between individuals and breeds. The coding sequence of the "a^t" allele is identical to the "a^w" allele, suggesting that undefined differences in the non-coding regions distinguish these alleles. The a^t allele is responsible for the tricolour pattern in dogs that have white points.

The last allele in the series is the recessive black (a). This allele causes no modification to the production of Eumelanin. The a^y, a^t (same as a^w) and a alleles have been characterised genetically.

Beta-defensin 103 (K Locus: K,k)

The third gene is beta defensin 103 (*BDEF103*) or the K locus. This locus has been referred to as the "dominant black" locus as the K^B allele overrides the effect of *ASIP* alleles on *MC1R*. Three alleles have been described at this locus and have the following dominance hierarchy: $K^B > K^{Br} > k$.

The first is the dominant K^B allele already discussed. The second allele (K^{Br}) results in brindling, which is the expression of eumelanin and pheomelanin stripes in the regions that are normally fawn (the entire coat in a^y animals and the fawn regions in a^w and a^t individuals). The last allele in this series is the wild type k allele and has no effect on the *ASIP* allele interactions with *MC1R*. Current genetic tests can distinguish the K^B and the k alleles. At this stage we cannot determine the difference between the K^{Br} and the k alleles and breeders should rely on pedigrees to exclude or include the brindled phenotype.

Modifications of the colours defined by E,A and K

Melanistic Mask (E^M Locus: E, E^M)

Some breeds of dog can produce a black mask when the rest of their heads are either fawn or brindle. This phenotype[7] is caused by the dominant E^M allele at the E^M locus. The no-mask E allele is the same as the dominant allele at the E locus. The mask phenotype is hidden in solid and spotted black, blue and brown dogs, however it may become obvious for a period of time if they fade to grey as they age. The E^M allele has been characterised genetically.

Brown or Chocolate (B Locus: b^s,b^c,b^d)

The brown or chocolate phenotype is caused by modifications to the Tyrosinase Related Protein 1 *(TYRP1)* gene or the B locus. There are 4 alleles described at this locus; the wild type "B" allele is dominant over the other three alleles, b^c, b^s and b^d. If an individual has any two of b^c b^s or b^d then all black hairs will, in most instances be modified to brown. There are exceptions where this does not apply. If you receive a result that is b^c,b^s or b^c,b^d your dog may only carry chocolate. Please contact GTG if you receive this result if you are interested in more information.

Therefore, in brown dogs the individual must first be able to produce eumelanin and thus have at least 1 normal *MC1R* "E" allele, and second have any two of b^c, b^s or b^d alleles. Interestingly, the B locus also affects leather regions, such as the nose, eye rims and pads and this is irrespective of their E locus genotype[8]. In individuals that are "ee" at the E locus and "bb" at the B locus, their coat will be red/yellow, however their leather regions will be modified from black to liver. Individuals with brown coats will also have brown or chocolate leather regions. Note this modification of the nose leather is different to the fading, seasonal change of the nose from black to cream, observed in some breeds.

Dilution (D Locus: D,d)

Many genes cause colour dilution in the canine. The D and G loci cause dilution of both black eumelanin and Red/Yellow pheomelanin, however the effect on eumelanin is much more obvious than pheomelanin.

The D and G loci produce the dilute black (blue, slate, grey) and the dilute brown (isabella, lilac) phenotype in dogs that are normally black or brown. The difference between the two loci is that D locus, dilute phenotype is present at birth, whereas the G locus dilute phenotype usually occurs with age and is commonly referred to as "progressive greying".

The D locus is a modification of the Melanophillin *(MLPH)* gene and as mentioned, individuals are born with the dilute phenotype. There are two alleles described at this locus. The wild type allele (D) is dominant to the dilute allele (d). Therefore in order to be dilute, the individual must have two copies of the "d" allele. The D locus also dilutes the nose, pads and eye rim leather.

The G locus or "progressive greying" locus is unknown in canines, however a recent study in the horse has demonstrated an association with a specific allele of the Syntaxin 17 gene *(STX17)*. Future studies will hopefully permit testing the G locus for the progressive grey phenotype.

Other loci are believed to dilute only pheomelanin and some only in "ee" individuals. These loci cause the variation in red/yellow pigment that is observed in breeds such as the Labrador Retriever, Poodle and Afghan Hound where colour can range from white to fox red.

Conclusions

As described, many genes control hair colour in dogs. Currently we can test for six of these loci. Colour predictions are unique to each breed and are made through evidence accumulated about the breed and the assumption that some of the loci are fixed for particular variants. In rare cases, recessive alleles may exist at low frequencies, at the predicted "fixed" loci of a breed. Through chance, these may be inherited from both parents, and the offspring will show a modified phenotype. By requesting tests for all loci available and not just the minimum recommended will limit the possibility of offspring displaying a modified phenotype.