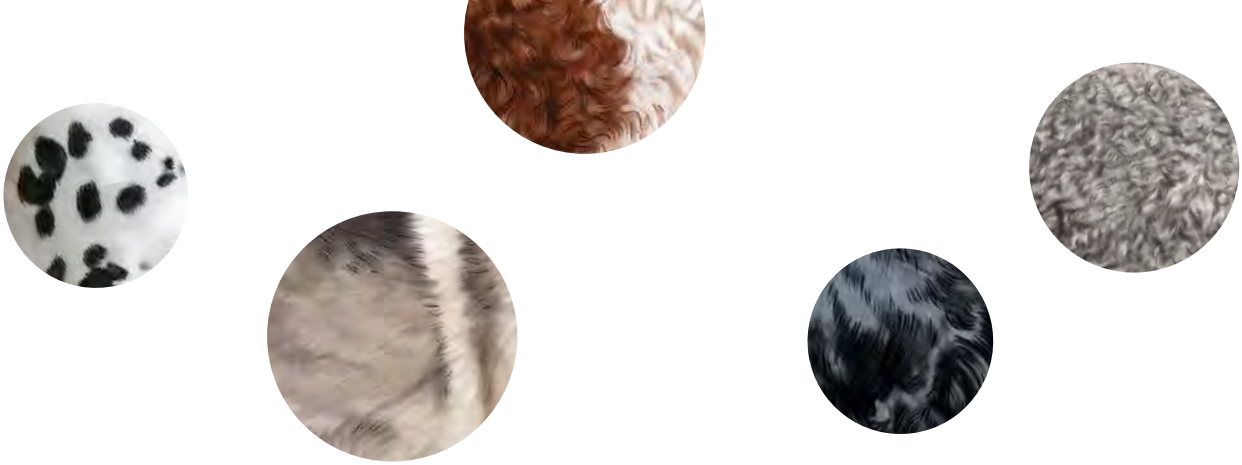

DOG COAT

DESCRIPTION • NOMENCLATURE • GENETICS

COLOURS

ROYAL CANIN®
ÉDITIONS

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DOG COAT COLOURS

DESCRIPTION • NOMENCLATURE • GENETICS

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"A reference in the field since its first edition."

This work is a new edition of the "Dog Coat Colours" guide, which has been a reference in the field since its first edition. Pursuing the work of the Zootechnical Commission and Professor Denis on the "Nomenclature of Dog Coat Colours", this new guide has been updated thanks to the expertise of Dr Abitbol and the support of the SCC and its Health and DNA department, made up of Dr Courtin and Mrs Missant.

It was crucial for us to keep the guide up to date by adding the latest molecular genetics findings while also responding to two major requirements: providing an educational document suitable for novice or experienced coat color enthusiasts and establishing a valid coat color nomenclature for all breeds which can be used internationally.

Offering a window onto the exciting world of genetics, this new edition invites you to discover the basics of the subject right through to deciphering its sometimes complex expressions. It is so satisfying understanding the mechanisms behind the wonderful blends that are possible, from solid colours to the most sophisticated markings!

This work is therefore of particular interest for anyone wishing to understand the different colours, the genetics behind them and why certain colours are prohibited by the breed standards or not advised for breeding. Now that we are entering the era of genomics, a remarkable step forward in the early detection of hereditary disorders and the prediction of our companions' coat colours, it seems easier to open the scope of possibilities with this practical guide, which is created by Royal Canin.

Tamás Jakkel
FCI President

Yves de Clercq
FCI Administrative Director

"A priceless aid for all dog fanciers."

It is clear that it is so important to use terminology which acts as a reference point and reflects an identical concept for all users. This applies to many fields in everyday life, be they professional, private or even sporting.

For many of us, dogs are part of our private lives, for others, an essential component of their profession. Some even have the good fortune of being able to combine utility and pleasure by having transformed their passion into a veritable career. Our dogs have coats of different colours, shades and tones. How can we define, evaluate and describe them while also being sure that everyone from judges and exhibitors to breeders and owners are all talking about the same colour and shades? This excellent publication provides a clear answer to this problem. Accessible to novices, specialists and scientists alike, it will no doubt become a reference work. The Fédération Cynologique Internationale (FCI) is proud to be associated with this publication. The problem of coat colour and texture terminology is a difficult obstacle to overcome for an organisation such as ours, which works with four official languages (French, English, German and Spanish) in eighty countries.

From this aspect alone, the publication brought to us by Royal Canin will be of immense help. As always, Royal Canin offers the reader a perfectly written and beautifully illustrated book; the subject called for a high quality visual support to which Royal Canin was attentive and sensitive. It is therefore with undisguised pleasure that we invite you to discover and exploit this mine of information, which is overflowing with details, photos, and information. You will find this guide of paramount importance for your responsibility as breeder, driven by knowledge of and respect for the animal. It will also enable you to share your professional knowledge as a breeder with those close to you or your colleagues in the dog-world.

Loïc Moutault
Royal Canin CEO

THE FUTURE, IS NOW!

Breeding is a profession of expertise and passion first and foremost.

For more than 50 years, this thirst for knowledge and immeasurable interest in animals have fuelled the shared history between you, the professionals of the animal world, and the ROYAL CANIN® brand.

Moreover, this historical partnership was born of the deep respect that we have for your work as breeders. We see you as veritable animal experts with whom we share a common objective: animal health and well-being. It is therefore only natural that we collaborate with you on a daily basis. As breeders, you breed, raise and educate animals for the pleasure of dog fanciers.

At Royal Canin, our vocation is to help these animals express the best of themselves, which is why we are constantly adapting the nutrition we offer to suit the specific needs of each individual. Our support for your daily work as breeders is also an integral part of this partnership. To this end, we are committed to supplying suitable breeding management tools to enable you to grow and to provide a framework of sustainable development for your business.

Healthy puppies that meet the desired morphology and temperament of their breed are the result of planned, conscientious selection.

Therefore, knowledge and respect form two of our core principles. They constitute the fundamental values of animal well-being, which are essential in the quest for physical performance and aesthetic qualities. Moreover, it is during the major dog shows that these two inseparable parameters – skin health and hair quality, described as the mirror of the dog's general health – come together.

Coat colour and quality are undeniable the result of genetic selection and regular coat maintenance. Its optimal expression depends on several parameters, of which nutrition is one of the essential components. This is evidenced in the fact that up to 30% of a dog's daily protein requirement is used to renew skin and hair.

The coats of our dogs are of such varied colours, textures, lengths and patterns that they contribute to the wealth and beauty of dog breeds and varieties.

When you open this guide, let yourself be charmed by the volume of the coat of a German miniature spitz, examine the technical complexity of the impermeable coat of the Labrador retriever, marvel at the hypoallergenic coat of the poodle, contemplate the sumptuous coat of the Afghan hound, be amazed at the corded hair of the Puli and lastly, admire the singularity of the Xoloitzcuintle.

Royal Canin is thus proud to be associated with the work of Prof. Bernard Denis and to collaborate with him on the 3rd edition of the Nomenclature of Dog Coat Colours.

This edition invites you to rediscover the current nomenclature familiarise yourself with the basics of genetics, and gain deeper insight into the latest genetic and genomic research being conducted into dog coat colour and texture. Together, they give this work a practical character.

Please view this guide as a veritable aid to understanding genetics which, combined with genetic tests, will enable you to make the best breeding choices, fulfil your daily commitments and, together, create a better world for animals. I hope you enjoy reading it!

TABLE OF CONTENTS

Professeur Bernard Denis

Veterinary surgeon, honorary professor
of Zootechnics at Nantes Veterinary College,
member of the Agricultural Academy of France
and president of the Société d'Ethnozootechnie.

A LOOK BACK AT THE ORIGINS OF THE GUIDE

This guide is a new, updated and revised version of the guide "Les couleurs de robes chez le chien" published by Royal Canin and Diffomédia in 2008. This was itself a new edition of the eponymous brochure published in 1984 by the Société Centrale Canine (SCC), a second edition of which was published in 1989.

The original plan in 2008 was to produce a third edition of the SCC brochure which was very similar to the preceding editions but updated and enriched with abundant quality illustrations.
However, it was finally decided to design a **"practical guide" in line with Royal Canin traditions to facilitate the work of readers wishing to initiate and familiarise themselves with the new dog coat nomenclature.**

But, before we continue, let's go back to the origins of this work.
The main goal of the SCC brochure was to propose a standardised nomenclature for dog coats which, since then, has been known as the "new nomenclature".
The idea of revising the nomenclature came from the SCC itself due to the fact that new colour descriptions were invented each year, while the list of dog coat colours kept increasing and was becoming very confusing. In addition, breed clubs were generally not interested in knowing how the coat which they were working hard to describe was referred to in other breeds.

Dog coat colours, 1984.

To us, three points appear to characterise the traditional nomenclature:

- **It is specific to a given breed;** references to other species (such as the horse, which has been a subject reference for a long time) and other breeds having been mostly ignored.
- **It is beautiful,** in the sense that it uses flattering images or expressions which are often short and therefore easily remembered: silver-grey, fallen leaf, peach blossom, lilac, hare's coat, salt and pepper etc. As a result, breeders and fanciers of a given breed very quickly know how to identify and name the coats of "their" breed.
- **It applies mainly to colour,** without really taking into consideration the exact nature of the coat. It is clear to all of us that when the coat texture or hair length varies, or there is a heavy or light overlay, the visual impression is completely different even though it is fundamentally the same coat.

CENTRALE CANINE

If you take all breeds into account, the abundance of terminology ended up bordering on the absurd with the same coat often being given different names depending on the breed or the same word being used to describe very different coats. It was therefore essential to clarify the situation, a fact which had by no means escaped the SCC committee. From the very beginning, we were inspired by the idea of carrying out a true typology of the different coats, while ignoring variations in shade, and taking into account, where possible, knowledge from coat colour genetics as these could help clarify the situation.

Our method was explained in the SCC brochure.

To summarise:

- Our starting point was a veterinary doctorate thesis we had supervised (Buffet, 1976).
- Our colleague Patrick Costiou, Professor of Anatomy & External Appearance at Nantes Veterinary College, collaborated with us on drafting the initial report.
- With the help of Emile Guillet (then vice-president of the SCC and Raymond Triquet (president of the FCI Standards Commission until 2007), we examined hundreds of dogs, compared the old and new nomenclatures and validated our opinions. The SCC committee approved the "Proposals for dog coat colour nomenclature" report in 1982 and the proposed method was gradually implemented in France.

A true typology of the different coats taking into account knowledge about coat colour genetics.

25 years on, what lessons have we learned?

As expected, there was strong opposition from many judges and breeders because well-established habits were being overturned and replaced by a system which they felt was too complicated and, often, clumsy. Many of them felt it was too much effort to try and understand or use the new nomenclature and instead decided to use simple equivalents without really understanding what they were doing. However, at the same time, we were suprised by the **high number of dog enthusiasts who, having made the effort to "get into" the new nomenclature, told us that they found it simple and logical and that it worked well in terms of reaching the goal of universalisation.** Looking back, we think it would have been a good idea to invite some of these "enlightened fanciers" to speak at our conferences rather than our colleague, Costiou, or ourselves.

> *"The difficulty of this new nomenclature is only an impression."*

We are the first to admit that some of the retained expressions are heavy and inelegant but it was impossible to make every expression rigourous, precise and concise. Inevitably, the beauty and poetry of some traditional expressions had to sacrificed for rigourous, scientific nomenclature. As for the difficulty of this new nomenclature, we can state from experience that it is only an impression: once any justifiable reluctance has been overcome and users accept that they must work at it, success is assured.

However, whether or not this new nomenclature would be put into use was not our main concern. We answered a request from the SCC by submitting a scientific report and it was the board which considered it practical enough to merit official recognition and application.

Regardless of what happened over the next 20 years, the SCC renewed its interest in this work by instigating the publication of "Dog coat colours" in 2008. By doing so, it restated and confirmed that the new nomenclature was official in France. Very quickly, **in 2009, the Fédération Cynologique Internationale (FCI) decided to make the new coat nomenclature official in France.**

Nobody is offended that breeders continue to use the traditional terminology between the themselves. Habits are starting to slowly change, particularly with the help of judges who have an important educational role. However, there are still breeders who remain staunchly attached to the traditional terminology. **It may encourage these breeders if they understood that there are at least three reasons to use the new nomenclature. It will help them to:**

- **understand how to write a proper description** when requested by the SCC rather than restricting themselves to a simple statement;
- **identify any coat colour in any breed;**
- **gain a better understanding about coat colour genetics** if they wish. This topic is widely covered in this publication as the new nomenclature is largely influenced by genetics. Being able to precisely identify a coat colour means the expressed gene is naturally described and, if necessary, enables breeders to predict the results from mating.

As the subject of coat colour generally tends to arouse interest even in the absence of defined breeding programmes it is worth adding that **when we worked on the new nomenclature, we also considered its possible application to other species.**

In the future we hope to publish a review demonstrating that, apart from a few specific features, it can be adapted to other domestic mammals.

Work in this area has already been carried out on rabbits, horses and cattle and we have begun the study on cats.

This means that **making the effort to understand the new nomenclature for dog coats and their genetic origins naturally leads to an understanding of the basic genetics of all coats, whatever the species.**

This practical guide is therefore the ideal tool with which to consolidate and expand your knowledge of the nomenclature and genetics of dog coat colour.

CHANGES SINCE THE 2008 VERSION

Since the 2008 version, some additions – mainly synonyms – have been made **to the standardised coat colour nomenclature. However in this edition, it remains largely identical. It has been enriched with a detailed study of coat texture,** which in the previous edition had been given only a passing mention in relation to genetics.

The work on this new edition has allowed us to give this guide a more educational and hands-on dimension, in particular for use by judges and breeders.

It aims to help them learn to identify coat colours, unify and standardise their designations, understand the logic behind the nomenclature and,

familiarise themselves with the "mechanics" of coat colour genetics.

The overall layout has therefore been modified slightly. We felt it preferable to start with a general presentation of dog coat colour, including the colour and texture nomenclatures. We feel that this first chapter is less related to genetics than it was in 2008 and that at a pinch it can be studied on its own. **That said, coat colour and texture provide an excellent introduction to genetics and readers preferably should not separate the two disciplines, particularly since the Société Centrale Canine and Royal Canin have designed this guide to raise breeder awareness about the science of heredity.**

To date (February 2022), more than 300 mutations have been identified in the canine species. Genomics is therefore also a means of improving dog health.

In 2008, **molecular genetics led to some modifications in the list of coat colour loci.** However, they were scarcely mentioned. The argument at the time was to wait for probable new and more extensive data, particularly since the conventional interpretations enabled most situations encountered by breeders to be explained. But we might be justified in thinking that as far as the genetics are concerned, the previous edition of the book was published at the wrong time: either too late, or too early!
Today, the entire genetics section needed to be updated.

Developments in molecular biology techniques and in particular **DNA sequencing** (DNA: deoxyribonucleic acid), **improvements in IT tool performance** (to analyse these sequences) and **parallel progress in the genomics** (the science of the genome) **of human and model species** (especially mice) **have enabled huge advances to be made in genetics,** and subsequently in canine genomics. This brought together conventional coat colour genetics and the discovery of genes and mutations.

The molecular origin of a large number of loci and alleles has now been revealed. It is possible to have a dog genetically screened for these alleles and **thus reliably determine its genotype (genetic composition) for several coat colour or texture loci.** Molecular genetics has made it possible to confirm the existence of numerous loci and alleles postulated by conventional genetics, and reattribute certain alleles to new, previously unknown loci (for example, the K locus and brindle coat).

The recent commercialisation of DNA tests for coat colour and texture makes it possible to determine a stud dog's genotype and so adjust mating to obtain puppies of the desired colour and texture. Dog breeding has entered the era of genomics!

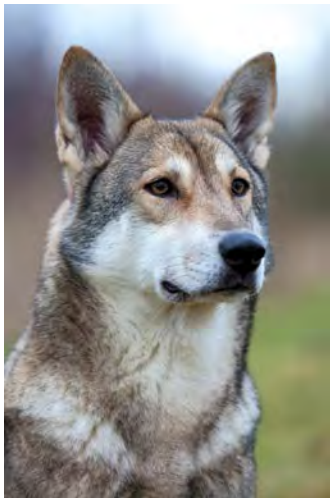
While genomics enable advances to be made in dog breeding in terms of visible skin appendage characteristics such as coat and nails, the field of application for gene and mutation discoveries goes far beyond coat colour. To date (February 2022), more than 300 mutations have been identified in the canine species, most of which govern hereditary diseases. **Genomics is therefore also a way of improving dog health and is where its greatest added value lies.**

1

GENERAL KNOWLEDGE, NOMENCLATURE AND DESCRIPTION

FROM THE WOLF'S COAT TO THE DOG'S

Wild animal species generally only display one coat colour and texture, which makes them appear phenotypically homogeneous (phenotype refers to the observable characteristics determined by the geneotype).



In fact, accidental coat colour mutations have no chance of being conserved in the wild because natural selection eliminates them in different ways including:

- the variant animal not being recognised by its mother or other members of its group resulting in the possibility of it being killed or abandoned;
- the variant animal not being recognised by potential partners, should it reach reproductive age. This means they are unable to procreate and therefore cannot pass on their mutated characteristic;
- **the coat colour being unsuitable for the environment since it has the primary function of camouflage** thus enabling prey to be approached unseen.

"These colour variations in wolves have probably always existed."

However, despite grey being the familiar colour of the modern wolf (Canis lupus), other colours have been observed in certain circumstances: almost completely white, different shades of fawn, cream and ochre, as well as brown and black. These colour variations in wolves have probably always existed, even though the debate is now focused on the fact that cross-breeding between wolves and domestic dogs have contributed to the diversity of colours. In this respect recent studies have shown that **certain determinants of modern dog coats were present in canids at least 10,000 years ago.** Other variants have undoubtedly appeared since and become established in the canine population through breed creation practices. **This means that the pattern and colour palette of modern dogs is the result of numerous ancient and recent genetic events that are now established in the population.**

"The diversity of coats is the result of a veritable selection carried out by man, whether consciously or not."

Since the start of domestication, humans could provide a certain degree of protection to animals with coat colour mutations, and even decide to breed these animals thus increasing the prevalence of the new coat colour. In parallel, over a long period of time, the natural aggression of the domesticated species towards humans reduced, since this is the primary condition of domestication, and, to a lesser extent, towards other animals. **The colour variations were gradually accepted and were no longer a systematic obstacle to procreating.**

The prevailing impression is that the dog coat, as we know it today, is extremely diversified. It may not be more so than in other domesticated species but it is more easily noticed. This diversity initially originated from the accumulation of mutations which humans permitted to enrich the range of existing colours.

Subsequently, the deliberate, conscious and unconscious selection carried out by humans gradually modified the phenotypic expression of the pre-existing coats.

The wild coat is a good example. For a long time, this was described as wolf-grey. However, as we shall see, this expression has been improved by replacing it with "sand with dark overlay" or "agouti". When observing wolves in a zoo, it can be observed that sometimes sand is replaced by fawn, making the coat "fawn with dark overlay" or that the amount of overlay varies.

In dogs - as we shall see in detail - selection was conducted in two opposite directions, either by reducing the overlay until it has almost disappeared or significantly intensifying it.

Obviously, the results are very different. Even though the wild coat is the most common in dogs, it has become extremely polymorphic giving an impression of diversity which, in reality, is only secondary.

Through selection, humans have created an infinite number of variations of some colour shades or aspects of the coat (such as ticking on white areas) which further increases the apparent diversity.

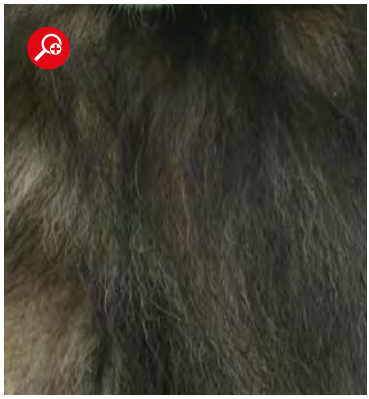
Breeders and fanciers are very sensitive to the originality of their breed's coat and have gone to great lengths to describe it in an original way to distinguish it from coats of other breeds.

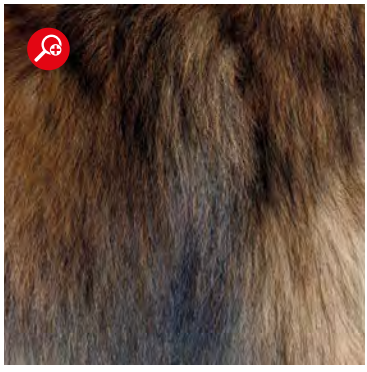
It is precisely this rich terminology which instigated the revision of the coat nomenclature provided in this practical guide.

The dog is no exception with regard to the common belief that coat colours have diversified enormously in comparison to the wild ancestor. **Even though this diversity is often just the colour shade or a detail, it contributes to the "beauty" of dog breeds and varieties.**

The degree of overlay is highly variable on dogs.

Belgian Shepherd Dog (Laekenois)





Belgian Shepherd Dog (Tervueren)

CANINE COAT COLOURS AN OVERVIEW

PRELIMINARY COMMENTS

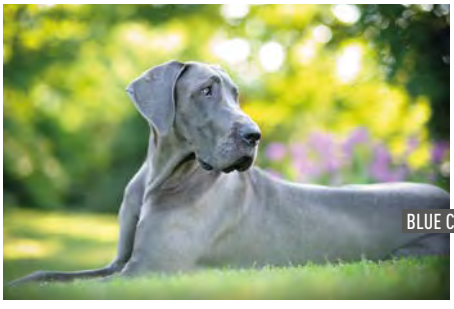
THE **NEW NOMENCLATURE TERMINOLOGY**

The new nomenclature includes traditional terms to which precise meanings have been added, along with invented words and expressions.

Certain habits could not be completely ignored:

- **For a long time, a diluted black coat in dogs has been referred to as *blue*** by breeders and geneticists alike. In all logic, it should have been called "grey", as black paint diluted with white produces grey. But, **in certain breeds and according to some geneticists, grey is traditionally considered to be a mixture of black and white hairs.** We therefore kept to these well-established habits, while being well aware that for the given example, problems will arise when the nomenclature is applied to other species;
- *Fawn with black overlay* is a classic in some breeds. We had to retain this expression, even though we would have preferred *"shadowed fawn"* because *"fawn with brown overlay"* is not correct: the overlay is in reality *"black like coal"*.

There are other examples which explain the existence of some points in the new nomenclature which seem to be illogical.



Great Dane

Dachshund

Jagdterrier

General comments

Hair, skin, and iris colour comes from the presence of melanin pigments which exist in two forms:

- **Eumelanin** or dark pigment, producing black or brown (pure brown);
- **Phaeomelanin** or pale pigment, producing fawn.

In the absence of pigment, white is produced.

© Grossemy

Newfoundland

Labrador retriever

Golden Retriever

West Highland White Terrier

There are therefore four basic colours: black, brown, fawn, and white.
The first three can be diluted and/or express significant variations in shade. A coat can consist of just one colour or several associated colours. Depending on the colour composition, the shade variation, and the degree of predominance of one colour in relation to another (or others) an extremely diverse range of colours can be obtained. Coats can be classified in different ways, none of which are exempt from criticism. The classification into solid, combination or mixed coat colour, a classic convention dating from Lesbre (1930), was not retained because it was not sufficiently in line with genetic data.

The initial report, *Proposals for canine coat colour*, suggested distinguishing between:

- **primary coats,** composed of identically coloured hairs;
- **derived coats,** composed of different coloured hairs but without any white areas;
- **patched coats,** where white hairs cover areas which are more or less spread over the animal's body.

Obviously, this classification remains valid. However, it was criticised for considering fawn coats with a slight dark overlay as "primary" since the hairs are not identically coloured (many are fawn and a small proportion appear to have a black band).

After having verified that authors prior to Lesbre did not hesitate to use their own classification or employ the same terminology according to sometimes differing beliefs, we finally decided to create a new classification which does not change coat colour descriptions.

These will be classified as **solid, mixed and modified** coats. The former has a single pigment, the two latter coats have two pigments. Modified coats refer to either a solid or combination coat which is identified through careful examination, but which has undergone phenotypic expression modification.

We will come back to these different categories in the context of a comprehensive presentation. **The different coats are described in detail in the relevant sections.**

Skye Terrier

GREYING COATS

Greying coats are one of the three types of modified coats, along with merle coats, which have partial lightening of the ground colour, and spotted coats.

Belgian Shepherd Dog (Laekenois)

FAWN WITH BLACK OVERLAY

Fawn coats with black overlay belong to the group of mixed coats (along with masked, brindle, fawn markings and fawn with mantle coats).

STANDARDISED NOMENCLATURE **OF COAT COLOURS**[1]

Komondor

To recap, hair colour comes from the presence of melanin pigments which exist in two forms:

- **Eumelanin,** or dark pigment, producing black or brown (pure brown);
- **Phaeomelanin** or pale pigment, producing fawn.

In the absence of pigment, white is produced.

Black pigment | Brown pigment | Fawn pigment | Light fawn pigment | Sand pigment

(1) This chapter was included in an initial publication by the Zootechnical Commission of the Société Centrale Canin: *Le chien, morphologie, esthétique, jugement*, publ. by Castor et Pollux, Chaumont, 2013.

SOLID-COLOURED COATS

Solid coats only have one pigment, either dark, pale or none whatsoever.

> 3 TYPES: DARK, PALE AND WHITE COATS.

DARK COATS

Black coat

Brown coat

Beige coat

Blue coat

PALE COATS

Sand coat

Light fawn coat

Dark fawn coat

WHITE COATS

White coat

Giant Schnauzer

Italian Greyhound

Weimaraner

Irish Water Spaniel

DARK COATS

The hairs contain eumelanin (or dark pigment). Eumelanic coats are naturally black or brown. They are blue or beige when the pigment is diluted.

The **black** coat

is unproblematic.
The nose is also black. The hair is uniformly coloured, sometimes a little lighter at the base. Reddish tints can occasionally occur, especially in long-haired dogs, due to climatic or nutritional factors. These disappear when the animal moults.
Black coats should not be confused coats which appear blackish (fawn with a complete black overlay), in which all the hairs are bi-coloured (banded or agouti). A very heavy fawn brindle can also cause confusion.

The **blue** coat

is obtained though black pigment dilution. The nose is always blue, and the animals are blue from birth. Shade variations are possible. *Slate* is the conventional term for certain dark blue shades.

The **brown** coat

(or **liver** or **chocolate**) comes in various shades. It can be darker or lighter, in which case, we can use a qualifier: *dark brown, pale brown*.
With long or woolly coats, the shade is always paler than smooth coats. The nose is always brown. As for the iris, it tends to be paler than with black coats.

The **beige** coat,

a rare colour, results from the dilution of brown.
There are wide variations in shade, which have been referred to as *lilac, silver,* etc. The nose is beige (it appears to be pale brown). The iris is always paler, sometimes extremely pale. Occasionally, it can be the shade known as *bird of prey* (traditionally considered yellow).

PALE COATS

The hairs contain phaeomelanin (or pale pigment).
They are fawn if the pigment is not diluted, and sand if it is diluted.
There is an enormous variety of shades in fawn or sand coats.

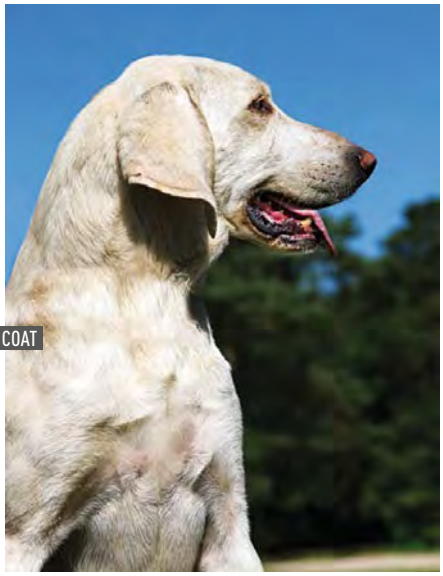
The **fawn** coat

varies from pale to mahogany red through orange fawn, dark fawn, etc. The hair is often pale at the base but remains "tone on tone". The nose is usually black, brown, or reddish fawn.
This range of possibilities can be explained by genetics, but this is not the subject of this chapter.
As an initial approximation, blue noses can also be accepted (the coat, identified as fawn, being dark sand in reality).
The shade is often paler on the sloping parts of the body and at the extremities, especially in long-haired dogs. The paleness can sometimes resemble a sand coat with fawn mantle (cf Akita): in this case, we can qualify it as *fawn with strong lightening on the distal parts.*

The **sand** coat

is obtained through lightening of the fawn colour. There are a variety of shades, ranging from a sort of cream to a whiteish colour in the palest animals. Sand can also be referred to as *ivory, silver, platinum,* etc. The boundary between pale fawn and sand is impossible to set objectively, especially as the coat texture interferes with the expression of the characteristic (as with woolly coats, for example).
The nose, always pigmented, can be of any colour, not diluted or diluted. Depending on the genetic origin of the dilution, a sand coat may appear quite bright, or dull and matte.

Billy



Irish Red Setter

Labrador Retriever

Golden Retriever

Akita

WHITE COATS

In white coats, the hairs have no pigment whatsoever.
All nose colours are possible, including partial or total depigmentation (pink, Dudley or flesh colour). It is often difficult to obtain perfect pigmentation of the nose and eyelids in dogs with white coats.

Samoyed

West Highland White Terrier

MIXED COATS

Mixed coats contain two pigments, dark or pale, but white is totally absent. They are therefore uniformly coloured and bi-pigmented. Depending on how the eumelanin and phaeomelanin are distributed:

> WE CAN IDENTIFY FIVE COAT COLOUR TYPES, WITHIN WHICH THERE ARE A CERTAIN NUMBER OF VARIATIONS: **FAWN MASKED, FAWN WITH BLACK OVERLAY, FAWN BRINDLE, BLACK WITH FAWN MARKINGS AND FAWN WITH MANTLE.**

FAWN (OR SAND) **MASKED**

FAWN (OR SAND) **WITH BLACK OVERLAY**

FAWN (OR SAND) **BRINDLE**

BLACK WITH FAWN (OR SAND) **MARKINGS**

- Black and tan -

FAWN (OR SAND) **WITH MANTLE**

- Saddle tan -

FAWN (OR SAND) **MASKED**

has a eumelanic mask spread to a greater or less extent over the face. Often, sparse dark hairs are present on the ears, topline, tail, and even the forechest. Uncertainty can arise between *fawn* masked and *fawn with a very slight black overlay,* but this is not important as the two coats can are genetically identical.

On its own, *masked* means *with a black mask*. Otherwise, it should be qualified as *with a brown mask or with a blue mask,* etc. The nose is the same colour as the mask. It should be noted that masks, which are very common in dogs, can also be present in any of the following four coat colours.

FAWN (OR SAND) WITH **BACK OVERLAY**

is characterised by the presence of bicoloured hairs on all or part of the body, which appear as a black overlay in the areas concerned. It is not usual to call these hairs *black overlay,* but they could be referred to in this way. They are usually referred to as *banded* or *agouti* hairs.

The amount of dark pigment varies considerably, giving *fawn with black overlay* a very diverse phenotypical expression, ranging from almost fawn to a blackish colour and all the intermediary shades. It is therefore necessary to describe the abundance of overlay with five qualifiers:

- **with very slight** black overlay: it is very close to fawn, the dark pigment occurring around the edge of the ears, the topline and on the tail;
- **with slight** black overlay;
- **with moderate** black overlay: by consensus, this category is used in the absence of any precision;
- **with heavy** black overlay;
- **with very heavy** black overlay; fawn remains at the extremities of limbs. It may be that the whole body has black overlay (see below).

Of course, placing the degree of overlay into one category or another is partly subjective. On its own, *with overlay means with black overlay.* Otherwise, it should be qualified as *with blue overlay or with brown overlay,* etc. For example: *fawn coat with a slight brown overlay.* Moreover, this kind of coat is often masked.
In this case, we say: *fawn with overlay and mask.* The nose is always the same colour as the overlay and the same of course also applies to the mask.

Like solid fawn coats, fawn coats with overlay are sometimes paler on the sloping parts of the body and at the extremities. This applies solely to pale pigment. This paleness may be so pronounced that it resembles sand markings. If we wish to emphasise this particularity, we can add the following qualification to the coat description: *with strong lightening on the distal parts.* For example, *fawn with slight brown overlay and strong lightening on the distal parts.* The expression is obviously rather clumsy, but it is also very precise.

Bullmastiff

FAWN MASKED COAT

Picardy Shepherd

FAWN WITH BLACK OVERLAY

Saarloos Wolfhond

WILD AGOUTI COAT

The special case of the fawn (or sand) coat with a complete overlay:

All the hairs are clearly bi-coloured and at first glance the animal looks almost black (or blue, or brown). The term *fawn (sand) with a complete overlay (or a blue or brown overlay)* is best, but there are recognised synonyms, such as agouti, with the variants *blue* ***agouti*** or brown ***agouti.***

Pragmatically, we can describe these coats, which are not far from being uniformly coloured, as ***blackish, blueish, or brownish.*** Fawn with overlay in one form or another is the most common coat colour in dogs. Fawn with complete overlay (blackish) corresponds to the wolf's coat (but with fewer variations in that species and frequently *sand with overlay,* which gave rise to the traditional term, still in conventional use, of *wolf-grey*). The hairs are agouti.

FAWN (OR SAND) **BRINDLE**

In the **fawn (or sand) brindle coat,** the eumelanin is condensed into vertical bands. Present in greater or lesser amounts, they can even produce a near-black appearance. It is therefore necessary to qualify the abundance of brindle (very slight, slight, moderate, heavy, very heavy); the absence of any precision can be considered as synonymous with *moderate brindle.*
It is likely that *completely brindle* dogs exist, but in this case, it is impossible to distinguish between a brindle and a solid coat.

FAWN BRINDLE COAT

Fila Brasileiro

Boxer

SAND COAT, LIGHT BLUE BRINDLE WITH MASK

Whippet

Brindle coats are frequently masked. In this case, we add the qualifier: *fawn brindle with mask*. On its own, *brindle* means *with black brindle.* Otherwise, it should be qualified as having blue brindle or brown brindle, etc. For example: *sand coat with heavy blue brindle, masked.*
The nose is always the same colour as the brindle and the same applies to the mask.
A fawn (sand) brindle coat is easy to identify on short coats.
If the brindle is abundant, it is more difficult to identify on long coats (unless the coat is short on the head and the front of the limbs) and sometimes on wirehaired coats. Like fawn coats with black overlay, fawn brindle coats may be paler on sloping parts of the body and at the extremities.
The distal extremities may also be much lighter, which we can emphasise, if necessary, as suggested for fawn coats with overlay.

BLACK WITH FAWN (OR SAND) MARKINGS

- Black and tan -

corresponds to the "black and tan" found in traditional nomenclatures.
The fawn markings are found on the extremities: mouth, points over the eyes (pips), throat, two marks on the forechest, feet, front of the thighs, and the ischial protuberance. These markings are always at the same places but can spread somewhat depending on the breed and individual. Due to the presence of fawn points above the eyes, the coat colour was occasionally described as a "4-eye" coat.

BLACK WITH FAWN MARKINGS

German Hunting Terrier

The variants occur first and foremost due to the replacement of the black by brown, blue or beige, giving rise, for example, to coats that are *blue with sand markings,* or *brown with fawn markings*. There even used to be beige *with sand markings,* described as *Isabella* in the Doberman and Miniature Pinscher. **The nose is always the same colour as the eumelanin in the coat.** A mask can prevent the expression of fawn on the face and lips, which can be qualified by the term *black with fawn markings and mask*.

Dark overlay, or even brindle, is sometimes found on the fawn markings at the extremities of the limbs. We can emphasise these features by talking, for example, of *black with fawn brindle*.
Fawn (sand) markings can be observed on a coat with complete overlay (or agouti), thereby creating another variant, *fawn with black overlay with fawn markings (meaning with complete overlay)*. We can also speak of agouti rather than *fawn with complete overlay,* which is expressed, for example, as *agouti with fawn markings, brown agouti with sand markings,* etc.

FAWN (OR SAND) **WITH MANTLE**

- Saddle tan -

In the case of **fawn (or sand) with mantle and its variants,** there is much less eumelanin than in the previous example, being reduced sometimes to just a saddle.

Welsh terrier

The mantle may be black, blue, brown, or even beige. **The nose is the same colour as the eumelanin of the coat.**

It is possible to introduce a qualifier concerning the extent of the mantle.

For example: *fawn with mantle – minimum extension, sand with brown mantle – maximum extension, etc.*

The hairs of the mantle can be banded, usually with a large dark apical band. In this case, we speak of *fawn with black overlay mantle* or, better, *fawn with agouti mantle.*

Fawn (sand) with mantle coats are sometimes difficult to determine. For example, when:

- The mantle is particularly extensive: we hesitate between *black with fawn markings and fawn with mantle.* There is no objective answer and both possibilities are acceptable;
- We cannot decide between *fawn with black overlay mantle* and *fawn with overlay.* Here again, the answer is subjective.

MODIFIED COATS

In the case of modified coats, the base coat, whether solid or combination, cannot be identified but it has undergone a modification which has changed the appearance.

> 3 MECHANISMS: GREYING, MERLE, WHITE SPOTTED.

GREYING COATS

MERLE COATS

WHITE SPOTTED COATS

GREYING: GREYING COATS

The coat is a solid colour during the first weeks, then gradually becomes interspersed with whitish hairs to various degrees depending on the breed and individual.

Yorkshire Terrier

Poodle

All coats can be subject to greying. The classic adjective is **grey,** which corresponds to a mixture of black hairs and white hairs (the animals are black at birth and gradually turn grey, which allows a distinction to be made with blue coats, for which the animals are blue at birth). The following terms can also be used: **grey-beige** (a mixture of brown and white), and **roan** (a mixture of fawn and white).

In all other cases, it is preferable to keep the description of the base coat followed by *greying* **after a comma.** For example, for the Yorkshire Terrier's coat: *fawn with mantle, greying* instead of *roan with grey mantle.*

It is possible to introduce the intensity of the greying: *black, very slight greying* (frequent in the Briard), *fawn with complete overlay, moderate greying.* This description is of course only valid at the time it is given, as most greying coats change.

“The solid colour remains in the form of randomly distributed, ragged patches, the smallest resembling splashes.”

MERLE: MERLE COATS

In some breeds, traditional nomenclatures tend to prefer the term harlequin.

Australian Shepherd

Only the dark pigment (eumelanin) is involved. The lighter zones (phaeomelanin) are unaffected (or scarcely so) and are almost always of solid appearance except for a short period during youth, often passing unnoticed.
The base coat is pale (dilution, greying, or both at the same time), or even unpigmented, while the solid colour remains in the form of randomly distributed, ragged patches, the smallest resembling splashes.

Conventionally, we use *blue-merle, with black* spotting (simplified to *blue-merle*), *beige, with brown spotting and fawn markings (red-merle with fawn markings),* black, with white spotting etc., starting with a description of the modified base colour.

WHITE SPOTTING: WHITE SPOTTED COATS

The term "spotted" has come to be synonymous with "white spotted". Spotted coats are therefore characterised by the presence of white patches of various sizes and distribution on any of the colour patterns described so far.

Consequently, the white spotting can be:

- **very limited:** one small white spot on the forechest and, possibly, discreet white marks on the toes;
- **limited:** the white spreads to the limbs, forechest, abdomen, collar, and head (with a blaze). The presence of a white collar represents the greatest extent of this type of spotting;
- **moderate:** the coloured and white patches are more or less equal but of very variable expression;
- **invasive:** the dominant colour is distinctly white;
- **very invasive:** the colour persists only on the ears and the edges of the ears, and at the base of the tail.

Of course, there is no mathematical limit between the different classes and subjectivity intervenes in judgements.

The process of describing the coat firstly involves identifying the base colour in the coloured patches, even if these are no more than patches of colour on the ears and the initial impression is that the dog is white. After this, we add: *with moderate white spotting, with invasive white spotting, etc. For example: black with fawn markings, limited white spotting; sand with black overlay, masked and moderate white spotting; fawn brindle, with very invasive white spotting.*

Different expressions are possible, as illustrated by the following examples:

- fawn, with slight white markings;
- black with fawn markings andwhite markings (which can be transformed into black with fawn and white markings);
- sand with overlay,mask, and white. "And" signifies that the spotting is moderate;
- fawn brindle, invaded with white;
- fawn with overlay, strongly invaded by white.

There are doubtless other ways of expressing it, but in the context of the standard nomenclature we will conserve the above terms.

SADDLE TAN COAT WITH EXTENSIVE SPOTTING

Fox Terrier Wire Hair

Siberian Husky

Special case

In some Nordic or primitive breeds of dog we can observe very light pigment intensity of the ventrum or underside (a modification called *urajiro*), which can be confused with white.

However, the distribution of the colour on the head and tail is not the same as with white spotting and it is this that allows the distinction to be made.

That said, with some dogs, there can be additional limited spotting: this cannot be seen at the extremities of the limbs or on the forechest because it blends in with the lighter coat colour, but if the tip of the tail appears white, the presence of spotting is confirmed.

French Pointer - Pyrenean type

Australian Shepherd

Cases of white **spotted** coats **with special features**

The white patches can be immaculate. Nevertheless, they often have special features. Spotted coats may have **ticking** (with tiny spots of colour, sometimes referred to as *ticking* if they are black and *fawn ticking* if they are fawn), **mixed** (a mixture of white hairs and coloured hairs[2]), or **with skin markings** (small spots, or blotches, on the skin, the hair remaining white).

We can qualify the intensity of these special features, for example: *fawn, with moderate white spotting and ticking; black with fawn markings with invasive white spotting, heavily ticked; brown and mixed white; fawn, with overlay and white with heavy skin markings*, etc.

These special features are not present at birth, the spotting being immaculate at that time. They appear gradually after a few weeks.

Comment: the important thing with modified coats is to always identify the base coat (even if this is reduced to no more than a few patches) before constructing the description of the whole coat colour. Unless a term is consecrated by usage (for example: grey), the modification must always appear after a comma: base coat, *modification*.

Flesh colour

Flesh colour refers to more or less extensive depigmentation of the mucous membranes: nose, lips, eyelids, vulva, etc. It is associated with white spotting.

Certain cases of iris depigmentation (heterochromia, China Eyes) have a similar explanation.

In the dog world, flesh colouring used to be thought of as a sign of degeneration and this belief has not completely disappeared. However, it is not true; it is a question of aesthetics.

When an animal's head is coloured, but depigmentation is observed starting at the median furrow or around the nose, this is not really flesh-colour. It can be explained by different nutritional, hormonal or pathological factors.

(2) A mixture of hairs looks grey, but it concerns the white patches, whereas greying affects zones of colour.

COLOUR OF THE EYES **AND EXTREMITIES**

Iris colours vary widely, but these are mainly variations in shade. The adjectives used to describe them are extremely diverse.

In essence, there are four base colours: **dark** (dark brown), **hazel** (a shade referred to as "intermediary"), **yellow** (bird of prey), **blue** (China or blue eyes).

On the whole, iris colour is independent of coat colour. Nevertheless, there are cases where the latter influences the former:

- Certain diluted coats (blue, for example) also express a paler iris;
- With brown eumelanin, the eyes are normally lighter. This is particularly marked with beige coats, owing to the dilution of the brown;
- Merle coats often go hand in hand with unilateral heterochromia or bilateral heterochromia (China Eyes);
- Heterochromia can also be observed with white coats due to invasive white spotting (see *flesh-colour* above).

Schipperke

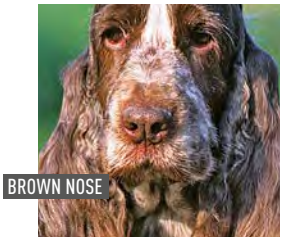
Weimaraner

Norwegian Hound

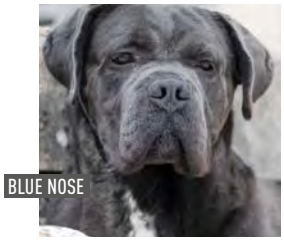
Siberian Husky

The only extremities considered for the moment are the nose and nails. Their base colouring varies in the same manner.

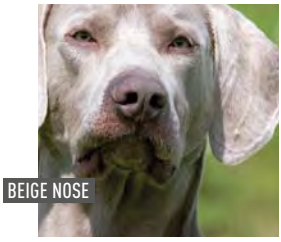
Basenji



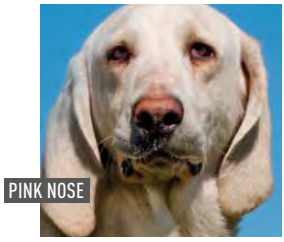
English Cocker Spaniel



Cane Corso



Weimaraner



Billy

We have often mentioned the colour of the nose when presenting coat colours. The nose can be **black** or **blue, brown** or **beige,** or **pink** (i.e. completely depigmented). Any association with the coat can only be made via the genetics of colour, which is not covered here.

As for the nails, their colour is sometimes difficult to judge. Therefore, we will not be studying it in any more detail

SKIN & COAT[3]

The coat is the external appearance of the hairs covering the body. The hair and structure of the skin are intrinsically related elements: improved insight into these structures ensures better understanding of the coat as a whole.

(3) This chapter draws on the information published by Jean-François Courreau in Le chien. Morphologie, esthétique, jugement (cf note 1).

THE **SKIN**

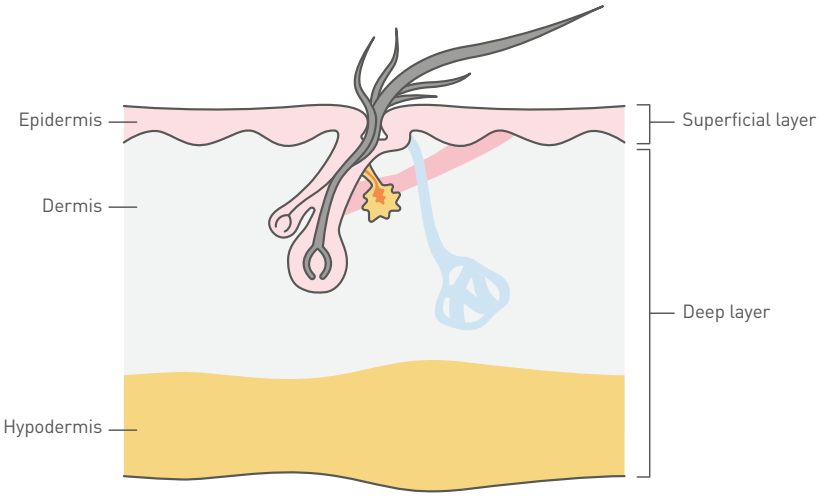
The skin is the boundary between the body and the external environment. It is made up of two structures: the skin itself which is a keratinised organ, and its associated structures, such as the hairs and glands.

The skin has three layers:

- **The epidermis** is the outermost layer. It acts as a physical barrier, protecting against external aggressors such as heat, cold, infectious agents and UV.
- **The dermis** is the intermediate layer. It is a thick layer (ranging from 1.3 mm on the back to 2.5 mm on the pads), containing elastin fibres and collagen, which give the skin its solidity and elasticity
- **The hypodermis** is the deepest layer and contains a large number of adipocytes, cells which store fat.

Only the dermis and hypodermis are vascularised and innervated, meaning they contain nerves.

Structure of the skin



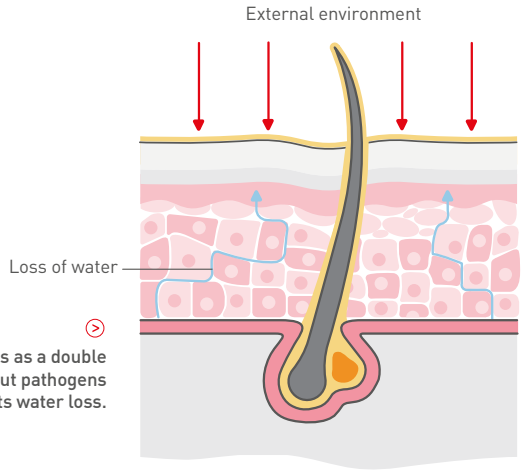
The skin has numerous functions

- **Barrier and mechanical function**
  It retains water, ions and macromolecules inside the body. Inversely, water, certain molecules and bacteria cannot enter the body. However, when the cells of the epidermis are saturated with water, certain substances are able to penetrate the body. The skin also plays a mechanical role, absorbing impacts and offering protection against aggressors such as biological agents or infrared and ultraviolet radiation.

- **Exchange function**
  The sweat produced by the sweat glands in the nose and paws helps provide local cooling of the skin in dogs. Remember that dogs only sweat through the nose and the skin between their toes. Sebum produced by the sebaceous glands in hair follicles provides protection by killing bacteria.

- **Metabolic function**
  The skin plays a role in fat storage thanks to the adipocytes in the hypodermis, but also, to a very small degree, in the synthesis of vitamin D3 via the action of ultraviolet light on the external layers of the epidermis.

- **Sensory function**
  The nerve endings in the dermis and hypodermis enable the skin to inform the body about temperature, pressure, pain, or contact with an object.



Healthy skin acts as a double barrier: it keeps out pathogens and prevents water loss.

Associated structures

- **Hairs and their follicles** are comprised of cell sheaths and connective tissue that surround the root of the hair, a sebaceous gland and a small muscle called the arrector pili, which makes the hair stand on end.

- **The sweat glands.** These can be apocrine or eccrine. In the latter case, the sweat they produce is released directly onto the skin. These are only found on the nose and in the skin between the toes.

- Other glands, such as **the anal glands or the supracaudal gland,** which is present on the upper part of the tail, are involved in olfactory marking.

THE **COAT**

HAIR **STRUCTURE AND FORMATION**

A dog's coat also fulfils several functions, such as **heat regulation, physical and immunological protection** against external aggressors, but also **sensory perception** and **social interaction.**

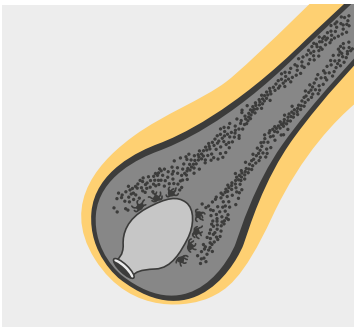
The hair is produced by a hair follicle, which is an invagination of the epidermis into the dermis. From the base to the extremity there is:

- **The hair bulb,** at the bottom of the invagination.
- **The root,** the base of the hair shaft, which is implanted in the skin.
- **The shaft,** the dead, visible part, the subterminal section of which is slightly swollen and the terminal section tapers to a point.

The structure of **the shaft** makes it **light, resistant** and **insulating.** From the exterior to the interior, it is made up of:

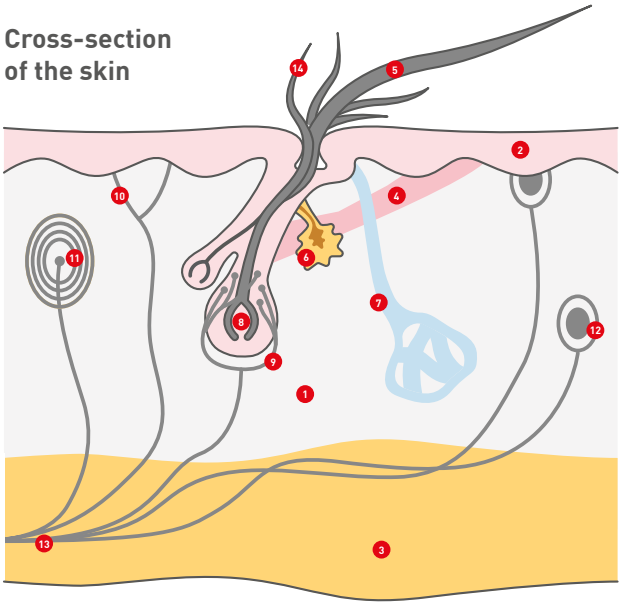
- **The cuticle:** a single layer of highly keratinised cells that form protective scales arranged rather like tiles, with the free edge facing upwards.
- **The cortex:** a group of keratinised, fusiform cells bound tightly together and oriented down the shaft, which give the hair its rigidity and contain the pigments.
- **The medulla:** A bundle of envelopes of dead cells with air-filled spaces between them, hence the hair's lightness and insulating property. It is absent in the tip.

The hair follicle is connected to the sebaceous and sweat glands, the secretions of which are discharged to the base of the hair. These contain both lipids and proteins and therefore protect the skin and hair, making the latter glossy.



The pigment granules migrate from the matrix to the cortex as the hair grows.

Cross-section of the skin

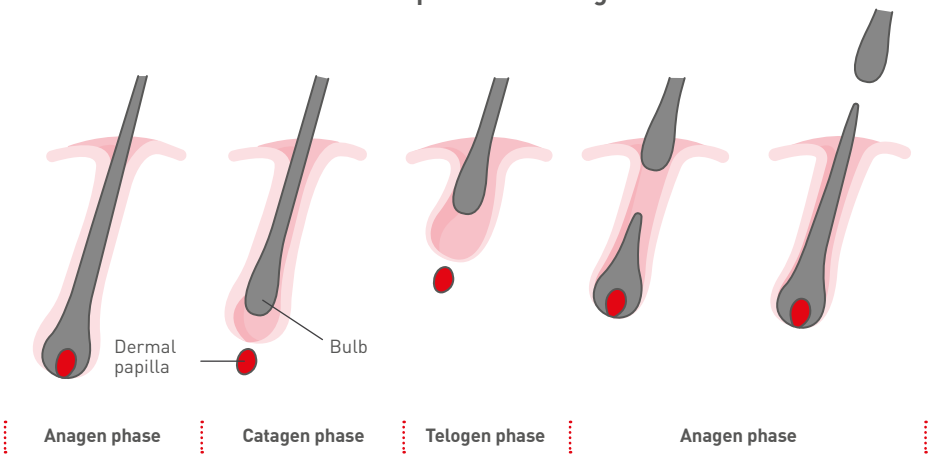


1. Dermis
2. Epidermis
3. Hypodermis
4. Arrector pili muscle
5. Guard hair
6. Sebaceous gland
7. Sweat gland
8. Dermal papilla
9. Touch receptor
10. Pain receptor
11. Vibration receptor
12. Thermoreceptor
13. Sensory nerve
14. Undercoat hair

The hair follicle develops within the skin, proliferating from the base of the hair bulb. The cells produced become keratinised and pigmented as they rise towards the surface.

At the end of hair growth, the follicle shortens and the bulb moves towards the epidermis, gradually losing its vascularisation. It takes on a club shape and simply becomes the point where the hair is anchored in the skin. When it falls out naturally or is pulled out, a new hair will grow.

The three phases of hair growth



The cycle comprises a growth phase (anagen phase), followed by a transition phase (catagen phase), and is concluded by a resting and moulting phase (telogen phase).

Did you know?

HAIR GROWTH DIFFERS FROM BREED TO BREED!

The hair of a Yorkshire Terrier is more like a human hair than a dog hair. One single hair emerges from each follicle, whereas three to five hairs usually emerge from each follicle in other dog breeds.
Another unusual feature is that its hairs grow continuously by 1 to 1.5 cm per month, and they have no undercoat hair, which moults in other breeds.
The Yorkshire Terrier is therefore a breed that moults very little or not at all; its skin is therefore more exposed and it is more sensitive to environmental influences such as heat, cold and rain.

TYPES OF HAIR

Hair follicles are usually **grouped in threes,** with a larger central follicle (called the **primary** follicle) and two lateral follicles (called **secondary** follicles). The hairs produced by a primary follicle and its associated secondary follicles emerge from the same orifice, forming a strand of 8 to 15 hairs. At birth, only the primary follicles are present giving puppies their fine, soft coat. In adults, they will produce long, thick hairs called guard hairs.

The secondary follicles appear within the first six months of life and produce the undercoat hairs.

- **Guard hairs** are protective hairs par excellence. Large in diameter and pigmented, they give the coat its fundamental appearance and are especially abundant on the back.
- **Undercoat hairs** make up the deepest layer of the coat and play an essential role in thermal protection. They also participate in the appearance of the coat: the more of them there are, the more the guard hairs stand out making the coat appear more abundant.
- **Vibrissae** are tactile hairs. They are large in diameter, rigid and tapered. They are present on the face, aligned above the lips, towards and sometimes on the front of the chin, behind the commissures and at the inner tip of the eyebrow. Their follicle is heavily innervated making them extremely sensitive to touch. Renewal is independent of moulting and is related solely to wear.

COAT **VARIATIONS**

By convention, we often talk about dog hair when we ought to talk about the coat. Here, when we talk about hair we mean the component, presented above, that forms the coat, with the coat accounting for the overall appearance. While length is the key criterion, other characteristics, such as texture and wave, also contribute largely to the coat appearance.

COAT **CHARACTERISTICS**

Length is the characteristic that has undergone the greatest variation due to selection.

- **No hairs:** some breeds with sparse hairs are called **hairless. This is not, technically speaking, a type of coat. However, it is customary to speak of it as such.** If some hairs are present, they are very short (no longer than 1.5 cm).
  ⊳ *Peruvian Hairless Dog, Chinese Crested Dog.*

- **Very short to short hair:** These coats vary greatly in length. Very short-haired coats are rarely more than 1.5 cm long. In the case of short-haired coats (up to 4 cm), the presence of an abundant undercoat gives an impression of a thick coat (German spitz). If it is moderately abundant, the guard hairs lie flat, as if the coat were flattened against the body (Labrador retriever).
  This type of hair corresponds to the "wild" phenotype.
  ⊳ *Very short hair: Miniature Pinscher, Weimaraner, Boxer, Whippet, Great Swiss Mountain Dog, Billy, Hungarian Short-Haired Pointer (Vizsla).*
  Short hair: Beauce Sheep Dog, Beagle, Jack Russell Terrier, Appenzeller Sennenhund.

- **Medium-length hair:** By convention, no longer than 7-8 cm.
  The hairs are around the same length all over the body, but not necessarily on the head, where the cascading eyebrows and full whiskers and beard provide a distinctive, "scruffy" appearance. An abundant undercoat will provide a "bushier" appearance (Bouvier des Flandres). If it is relatively sparse, the guard hairs will lie flat despite their stiffness (German wire-haired pointer).
  ⊳ *English Setter, Golden Retriever, Saint Bernard, Alpine Dachsbracke, Siberian Husky, Irish Water Spaniel, Cairn Terrier.*

- **Long hair:** In certain breeds this can be more than 20cm long. Obviously, this is the result of artificial selection among moderately long-haired dogs. It is characterised by even greater differences in length than the type above. It is mainly among this type of coat that we encounter corded coats (Komondor).
  ⊳ *Maltese, Afghan Hound, Yorkshire Terrier, Rough Collie, Continental Toy Spaniel.*

Chinese Crested Dog

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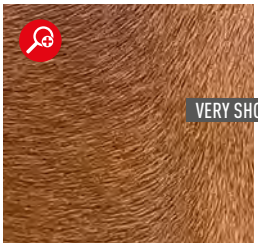
HAIRLESS

Peruvian Hairless Dog



VERY SHORT HAIR

Miniature Pinscher

Weimaraner

Appenzeller Sennenhund

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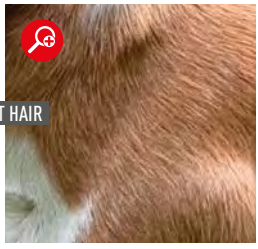
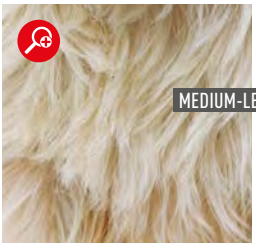
SHORT HAIR



Beagle

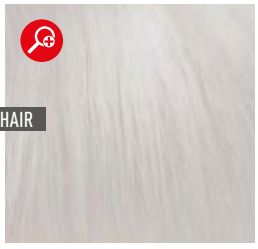


MEDIUM-LENGTH HAIR

Cairn Terrier

Irish Water Spaniel

LONG HAIR



Maltese

Komondor

The **texture** also covers a very broad phenotypic range, but judging it is a matter for the connoisseur.

- **Soft hair:** a particularly pleasant feel, called silky or woolly depending on whether it is shiny (Yorkshire terrier) or matt (Poodle). It is derived from smooth hair and was selected in parallel for greater finesse.
  ⊳ *Australian Silky Terrier, Afghan Hound, Maltese.*

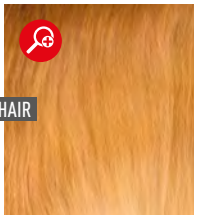
- **Smooth hair:** a pleasant feeling "wild" type of hair which is the most common in dogs.
  ⊳ *French Spaniel, Great Dane, Dalmatian, Basenji, American Foxhound, Long-Haired Dachshund, German Shepherd, Pharaoh Hound, Border Collie.*

- **Harsh hair:** like goat hair, quite floppy but feels "scratchy" when you stroke it. Should be considered as the first stage of wire hair.
  ⊳ *Pyrenean Sheepdog, Briard, Old English Sheepdog.*

- **Wire hair:** stiff, feeling rough beneath your fingers, and the shorter it is the more so.
  ⊳ *Wire-Haired Pointing Griffon Korthals, Jack Russell Terrier, Airedale Terrier, Wire Fox Terrier, Affenpinscher, Border Terrier, Griffon Bruxellois, Irish Terrier, Scottish Terrier, West Highland White Terrier.*


© Grosseny

Poodle



Afghan Hound

Long-Haired Dachshund

Rhodesian Ridgeback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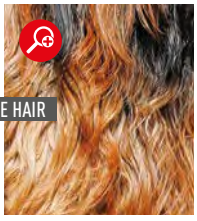
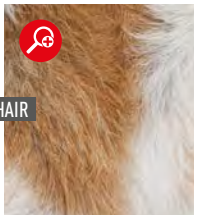
Pyrenean Sheepdog



Briard

Border Terrier



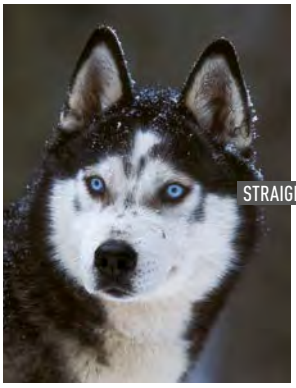
Jack Russell Terrier

Waviness has two extreme types and one variable intermediate type where the appearance depends on the length of the hair.

- **Straight hair:** this is rectilinear, but less clearly so if long, its length conferring a suppleness that gives an impression of generous waves. This represents the "wild" phenotype.
  ⊳ *Yorkshire Terrier, Kangal Shepherd Dog, Siberian Husky, Rough Collie*

- **Wavy hair:** this appears to have a wave running through it, the waviness being due to the structure of the hair, and thus independent of its length.
  ⊳ *Newfoundland, Borzoi, Continental Toy Spaniel.*

- **Curly and frizzy hair:** tends to wind around itself, forming a curl or frizz.
  ⊳ *Bichon Frisé, Irish Water Spaniel, Portuguese Water Dog, Curly Coated Retriever, Russian Black Terrier, Barbet.*



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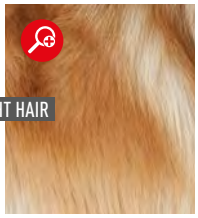
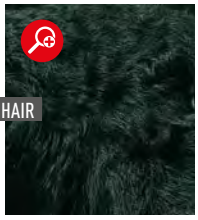
Siberian Husky


Rough Collie

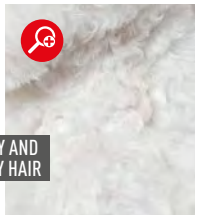
© Labat/Rouquette

Borzoi


Newfoundland

© Hermeline/Diffomédia

Barbet


Bichon Frisé

Did you know?

GENETIC TESTS, A PRECIOUS TOOL FOR PHENOTYPE SELECTION

Progress in canine genetics has made it possible to diagnose or screen for hereditary diseases, but not only that!

We can also identify the genes responsible for morphological characteristics of interest. Certain variations in hair length, texture or colour can now be screened for thanks to DNA testing.

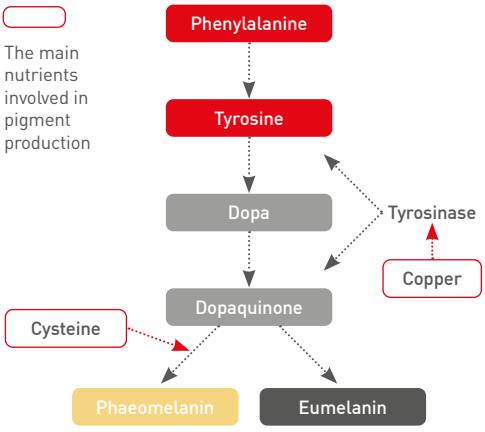
PIGMENT SYNTHESIS

The genes responsible for hair colour act on pigment synthesis, or the way pigments are transferred to the hair cells at the base of the hair follicles. Alongside the hair formation site, we find cells called melanocytes, which produce and emit the two pigments responsible for coat colour: eumelanin (for black and brown) and phaeomelanin (for fawn and sand).

A hair is derived from keratinocytes, cells which divide rapidly. These cells are situated at the base of the follicle and form what is known as the "bulb". The bulb receives a large supply of nutrients from the blood stream. Most of the pigments formed in the melanocytes, inside tiny structures called melanosomes, are diffused into the cells that make up the centre of the hair, the cortex.

Biochemically, synthesis of the two pigment types starts with a shared pathway: tyrosine (or phenylalanine subsequently transformed into tyrosine) is converted into a molecule called DOPA, then into dopaquinone by a key enzyme, tyrosinase, the activity of which depends on copper. After this, the pathway splits: phaeomelanin synthesis requires the addition of cysteine, which is not the case for eumelanin. The introduction of cysteine enables formation of red polymers, which are essential for fawn or sand pigments.

Biochemical process: synthesis of melanin from phenylalanine

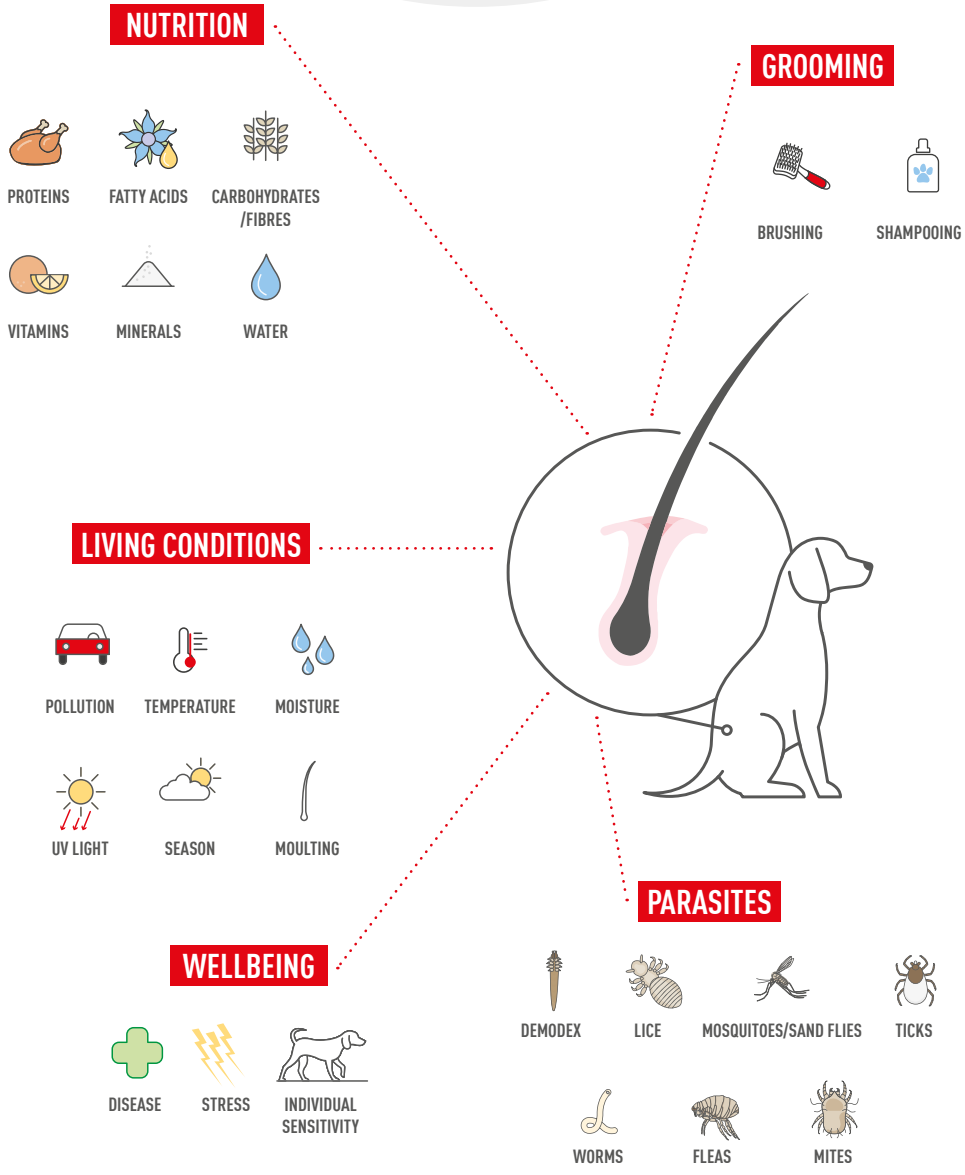


Did you know?

TYROSINE, AN ALLY OF DARK COATS

In dogs with dark coats, it is possible to prevent reddening of the coat with a sufficient supply of tyrosine. The response time varies depending on the hair cycle. If most of the hairs are in the telogen phase, they will be replaced rapidly. The hairs which turn red at the time of moulting remain red, even with an aromatic amino acid supplement (tyrosine, phenylalanine).

CONTRIBUTION OF NON-GENETIC FACTORS



Note: phenotype results from the interaction between the environment and an individual's genetic characteristics.

NUTRITION

"Let food be thy medicine and medicine be thy food."

Hippocrate (460-370 BC)

It is often said that **the coat mirrors health,** but its natural qualities can only be expressed if food supplies the nutrients essential for its growth and renewal.

The entire process of formation, renewal and maintenance of a dog's coat is very nutritionally demanding. Depending on the length of the coat, **the protein requirement alone accounts for between 10% and 30% of a dog's daily protein intake.** A deficiency can lead to keratinisation disorders and diffuse alopecia, with a dull, dry coat.

So how can we ensure that nutritional intake is sufficient for the animal's health?

It is important to know that the value of the ingredients in pet foods resides in the nutrients they supply. In other words, what counts is not so much the ingredients that are consumed, but the nutrients assimilated by the animal.

Note that the nutritional value of a food depends on the quality of the raw ingredients that go into it.

As for the quality of the raw ingredients, that depends on their source, how they are preserved and the different transformations they undergo.

The way the ingredients are ground and cooked has a considerable impact on their digestibility. For example, maize in its raw state has a fibrous external envelope, but when ground and cooked correctly, the beneficial nutrients are more easily assimilated. Inversely, overheating during the process of cooking meat and animal by-products may reduce the digestibility and bioavailability of certain amino acids. This will reduce the amount of protein digested and absorbed. A good way of evaluating the quality of a raw ingredient is its digestibility, meaning how well the animal can digest and absorb it. Stool quality makes it possible to judge this in part.

In other words, an ingredient may be rich in nutrients but difficult to digest, resulting in low absorption of the nutrients in the intestine and low amounts in the blood.

Thus, to guarantee a constant level in the end product and to meet the physiological needs of the animal, the greatest care must be taken to guarantee the balance and availability of the minerals and vitamins in the food.

How can we determine a nutritional profile?

An excess of nutrients can be just as harmful as deficiency.

A suitable dosage can be achieved by following the official recommendations for the animal species in question which are based on breed, age, lifestyle, sensitivities, and individual state of health. Through their own observations and diagnoses, vets can recommend the food best adapted to each animal.

According to the National Research Council, over 40 nutrients are essential for dogs. Among them, more than ten play an especially important role in skin health and the beauty of the coat.

They can be grouped into **4 major nutrient families: amino acids, fatty acids, minerals and vitamins.**

Amino acids

A certain amount of sulphur-containing amino acids is necessary for a high-quality, healthy coat.

Although we have long been aware of the importance of a suitable supply of protein to keep the coat in good condition, more recent studies have revealed the link between nutrition and optimum coat quality, especially its colour.

To recap, hair colour depends on the relative proportions of eumelanin and phaeomelanin, which are controlled by the enzyme tyrosinase activity. A low rate of enzymatic activity promotes the production of phaeomelanin, whereas a higher rate fosters eumelanin.

Moreover, it is proven that tyrosine stimulates enzymatic activity, which increases eumelanin production.

A completely black coat requires the almost exclusive presence of eumelanin, whereas a lack of melanin or the presence of very diluted phaeomelanin produces white hair.

Studies of growing animals clearly show the role that nutrition plays in coat colour expression. However, they do not fully explain the pigment dilution often observed in adult dogs.

A recent study has shown the importance of phenylalanine and tyrosine in hair pigmentation, notably in dogs with black coats such as Labrador Retrievers. Phenylalanine and tyrosine supplements make the hair richer in colour. Reducing them leads to a reddening effect.

The study also showed that the duration required to observe a change in coat pigmentation was four months. **As it is not possible to introduce new melanin pigments in hairs that are already formed, it is crucial to wait for new growth to observe any difference.** As complete hair growth in an adult Labrador Retriever takes around 14 weeks (Diaz et al., 2004) and 80% of the hair is in the rest phase (telogen phase), it takes at least 16 weeks to see a significant number of hairs emerging with enriched melanin content.

Optimal coat expression therefore requires food enriched in phenylalanine and tyrosine.

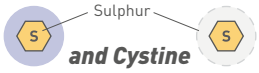
Did you know?

GREATER NEED FOR PHENYLALANINE AND TYROSINE

Studies of black Newfoundland and Labrador Retriever puppies show that the levels of phenylalanine and tyrosine needed for optimum coat pigmentation are double the levels needed for hair growth. Tyrosine supplements therefore appear to intensify coat colour.

As mentioned above, tyrosine can come directly from food or be obtained through hydroxylation of phenylalanine. This is why these two amino acids are essential for coat colour.

Role of amino acids in skin and coat



- ***Methionine and Cystine***

(Sources: egg protein, fish, milk casein and corn protein)

Collagen and keratin are the main proteins in the skin and coat.
They are very rich in sulphur-containing amino acids: methionine and cystine.
A healthy skin and coat require sufficient intake of these.

- ***Phenylalanine and tyrosine***

(Sources: soy protein, animal protein, free tyrosine)

Phenylalanine and tyrosine are precursors of melanin, the pigment responsible for skin and hair colour. They contribute to the maintenance of coat colour.
Insufficient intake leads to a reddening of the coat, which is especially visible in black-haired dogs.

Fatty acids

Essential fatty acids, which the body does not produce, are the main components of fats. They play a structural role in cells as well as being a major source of energy for animals. They also promote the absorption of vitamins by the body.

They also make the coat glossy. Deficiency can result in a dull, dry, and sparse coat and affect skin barrier integrity the, making the skin more susceptible to dehydration and infection.

Role of fatty acids in the skin and coat

Two essential fatty acids are of particular interest:

- ***Omega-6 (ω6)***

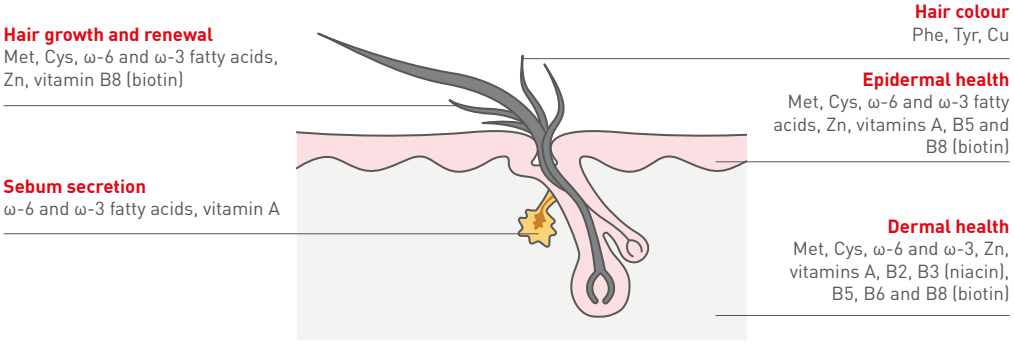
(Sources: vegetable oils (borage oil, linseed, soybean, maize), pork or poultry fat)

These fatty acids are a component of sebum and make keratin with the hairs more elastic and supple.

- ***Omega-3 (ω3)***

(Sources: vegetable oils (flax, rapeseed, soybean), fish oil and algae oil (EPA-DHA)

These fatty acids also help protect the skin and keep the coat glossy. The long-chain fatty acids (EPA and DHA) modulate inflammation and help fight against inflammatory conditions such as allergies. Combined with the omega-6 fatty acids, they prevent dryness of the skin and poor coat condition.



Vitamins

Numerous vitamins, such as vitamins A, B2, B6, pantothenic acid (B5), folic acid (B9), nicotinic acid (B3) and biotin (B8) play a role in regulating skin cell growth, sebum production and the expression of coat colour.

Role of vitamins in the skin and coat

- ***Retinol (vitamin A)***

(Sources: vitamin and mineral supplements, liver, meat, eggs, dairy products)

Vitamin A plays a role in skin regeneration (skin cell growth regulation) and sebum production.

- ***Riboflavin (vitamin B2)***

(Sources: vitamin and mineral supplements, yeast, cereals, liver, eggs, milk and all milk derivatives)

Riboflavin is involved in cellular energy metabolism. It contributes to coat and skin quality. Deficiencies are associated with skin inflammation.

- ***Niacin (vitamin PP)***

(Sources: vitamin and mineral supplements, cereals, yeast, fish, meat, eggs)

Niacin is essential for energy production in cells. It is involved in tissue integrity and contributes to skin health and coat quality. In combination with other B vitamins and one amino acid (histidine) in particular, niacin promotes skin impermeability.

- ***Pantothenic acid (vitamin B5)***

(Sources: vitamin and mineral supplements, yeast, meat, eggs, dairy products)

Pantothenic acid is a component of coenzyme A, which is also involved in energy metabolism. In combination with other B vitamins and one amino acid (histidine) in particular, pantothenic acid plays an effective role in skin protection.

- ***Pyridoxine (vitamin B6)***

(Sources: vitamin and mineral supplements, yeast and wheatgerm)

Pyridoxine promotes protein metabolism, and therefore the synthesis of collagen and keratin.

- ***Biotin (vitamin B8)***

(Sources: vitamin and mineral supplements, yeast, liver)

This is one of the most important vitamins for good-quality skin and coat as it stimulates hair growth. It is produced by the intestinal flora.

Biotin deficiency can cause alopecia (hair loss) of varying severity.

Minerals

A distinction can be made between minerals that are present in great quantities, called macro-elements (calcium, phosphorous, potassium, sodium, magnesium), and those present in very small quantities, called trace elements (iron, zinc, copper, iodine).

Role of minerals in the skin and coat

- ***Zinc***

(Sources: vitamin and mineral supplements, meat (lamb, pork, poultry, beef) and liver)

Zinc is essential for skin and coat health. Zinc deficiency due to reduced intake or factors reducing its absorption, such as low-quality food, causes greying of the hair.

- ***Copper***

(Sources: vitamin and mineral supplements, meat and liver)

Copper is essential for coat colour, as it plays a role in pigment synthesis. In the event of deficiency, tyrosinase activity is affected, which compromises the first stage of melanin synthesis. Deficiency causes greying of the coat, with colour dilution. Copper is also involved in collagen synthesis.

In summary, healthy skin and a quality coat require a complete diet which provides all the amino acids (proteins), fats, minerals and vitamins essential to a dog's needs. It must also be balanced with the nutrients present in the right proportions and be of good quality so as to be perfectly assimilable.

LIVING CONDITIONS AND **WELLBEING**

Environmental factors or factors linked to individual sensitivity can greatly influence coat colour. For example, UV rays, humidity, temperature, and certain diseases, including hormonal disorders.

In dogs, moulting periods are linked to temperature, but also to daylight duration (photoperiod). Dead hair replacement occurs all year round, with two more intense periods in the autumn and spring. These give rise to the summer and winter coats which, in a context of good health, will differ to a greater or lesser extent depending on the breed of dog, its hormonal balance, its diet and its habitat (daylight duration, temperature).

It is also important to consider the fact that some puppies are not born with their definitive coat colour or texture. Coat characteristics stabilise during the first weeks or months of life. The puppy is born with a downy coat which changes gradually until the end of its growth. This change is more or less marked depending on the breed. Some will see their coat darken, lighten, become covered in patches, or even be radically transformed, as with the Puli, which is born without its cords.

Similarly, a dog's coat may tend to lighten slightly during its life, and an old dog might have a greying coat. This greying phenomenon can also be observed, for reasons not yet fully understood, in younger dogs. It is likely that genetic factors and nutrition are the cause.

Prevention is better than cure.

Skin diseases or irritation can also give the impression of a change in colour. For example, excessive licking can lead to a reddening of the hairs due, among other things, to saliva oxidation on the coat.
Dogs may also react to environmental (pollen, dust) or food allergens. These allergies can cause redness, skin inflammation, rashes, itching or chronic ear infections and substantially change the appearance of the skin and coat. Similarly, certain endocrine disorders, such as hypothyroidism, can cause hair loss from the flanks, itching and scratching, as well as other signs.
It is important to consult your vet as soon as the first symptoms appear.

PARASITES

Parasites, such as fleas, ticks or ringworm, can infect the coat and cause skin reactions, such as itching and hair loss.
In this case, a visit to the vet is necessary to obtain an appropriate course of treatment taking into account the dog's age, breed and living conditions, as well as the infestation level of the different parasites.

GROOMING

Regular maintenance with a brush and suitable shampoo help keep the coat looking beautiful. It should be remembered that our shampoos are not suitable, as our skin is more acidic and so even mild products can dry out a dog's skin.

Genetics, food and hygiene are the three main pillars guaranteeing the health and beauty of the skin and coat.

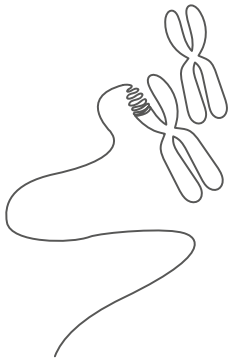
2

GENETICS OF COAT COLOUR AND TEXTURE

CURRENT GENETIC KNOWLEDGE

BASIS FOR THE **DOG COAT STUDY**

Understanding all the ins and outs of genetics can be challenging, and while some breeders have long been leveraging it – to the point of being able to perfectly interpret what they see and even plan breeding schedules – for others, genetics remains a mystery.



Genetics is the cornerstone of the new dog coat nomenclatures.

The study of dog coats can be approached from two angles: the detailed description of individual coats to classify them into families and the genetic origin of each coat. The two approaches are complementary. A quick presentation of the major discoveries in genetics and an overview of the basics of canine genetics follows as a prelude to the chapter on genes that govern coat characteristics.

Please note there is no need to immerse yourself in genetics to reap the benefits from this publication; the descriptions and illustrations should, we hope, be sufficient to convey specific and useful information. However, significant advances in canine genetics in recent years have yielded a solid scientific underpinning for the description and classification of coat colours and textures.

Australian Shepherd

A SHORT HISTORY OF GENETICS

MENDEL

GENES AND HEREDITY

The friar Gregor Mendel played a very important role in the discovery of genes and heredity.
He is recognised as the founding father of genetics, and his experiments in pea hybridisation helped explain the patterns of heredity.

LEVENE

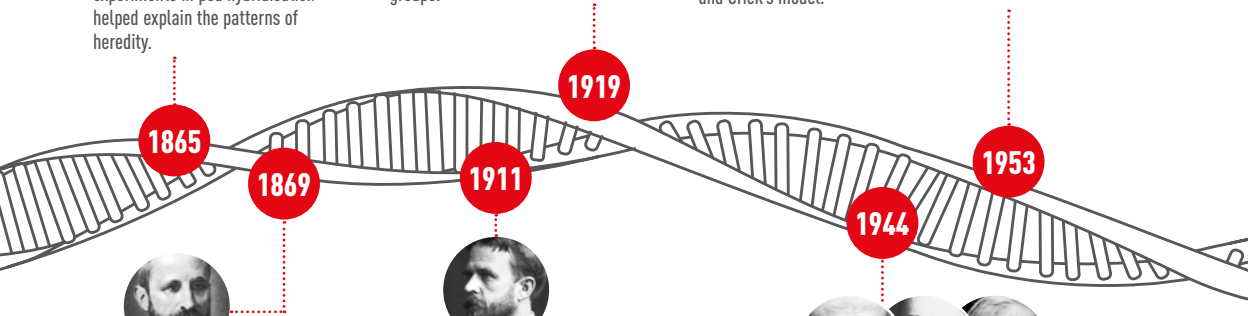
ACGT + SUGAR + PHOSPHATE

By identifying the base-sugar-phosphate structure of the nucleotide unit, Phoebus Levene hypothesised that DNA is a chain of nucleotide units linked together by phosphate groups.

WATSON, CRICK, FRANKLIN, WILKINS

DNA STRUCTURE

James Watson and Francis Crick discovered the double helix structure of the molecule by analysing X-ray images of DNA fibres. The earlier work of Rosalind Franklin and Maurice Wilkins in X-ray crystallography was not published until later, but it supported Watson and Crick's model.



MIESCHER

NUCLEIN

The Swiss physician Friedrich Miescher was the first to isolate DNA from pus found on bandages.
Because it was located in the cell nuclei, he called it nuclein.

MORGAN

CHROMOSOMES AND GENES

The work of Thomas Hunt Morgan on the transmission of hereditary traits in the common fruit fly *(Drosophila melanogaster)* enabled him to demonstrate that chromosomes carry genes. In 1933 he received the Nobel Prize in Medicine.

AVERY, MACLEOD, MCCARTY

**DNA:
THE GENE CARRIER**

An experiment conducted by Oswald Avery, Colin Munro MacLeod and Maclyn McCarty demonstrated that isolated DNA is made up of genes and chromosomes.

***Gregor Mendel** became the founder of the field of genetics with his experiments on **pea hybridisation**. The advantage of working with this plant lies in its diverse traits (plant height, round or wrinkled seed shape, pod appearance) and pollination control. Each pea flower has male and female organs and is thus self-pollinating.*

To understand how a trait is passed down from one generation to the next, Mendel artificially pollinated the female organ of a pure line "round seed" flower with pollen from a male organ of a pure line "wrinkled seed" flower. This produced a generation of only "round seeds", which he allowed to self-pollinate to produce a third generation in which the "wrinkled seed" trait reappeared.

After a series of several similar experiments, he discovered the underlying principles of heredity, including three laws:

- *It is not the trait itself that is passed on during reproduction, but the "factors" responsible for that trait. These "factors" were not called "genes" until much later, in the early twentieth century.*
- *Every organism inherits two "factors", one from the father and one from the mother.*
- *One "factor" may have a trait that is "dominant" over another, which is described as "recessive". Traits do not mix together but are expressed or not. However, the recessive trait does not disappear and the organism then becomes a carrier of this factor.*

MULLIS

POLYMERASE CHAIN REACTION

Kary Mullis was the first to describe the polymerase chain reaction (PCR).
This chain reaction replicates, or creates many copies of, small amounts of DNA.

HUMANS

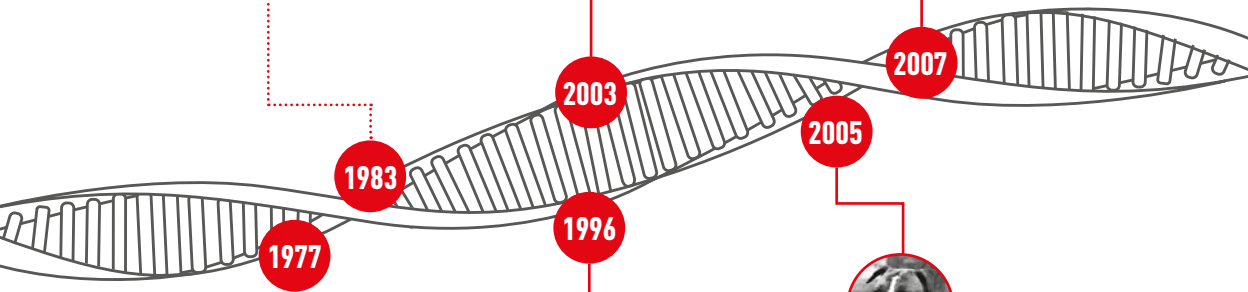
SEQUENCING

The Human Genome Project (the world's largest collaborative biological project) is coming to an end after 15 years of research. Scientists can now confirm that the human genome consists of more than 20,000 genes. The aim of identifying and modelling the human genome is to understand, detect, prevent and attempt to cure genetic diseases.

CATS

SEQUENCING

The feline genome has been fully sequenced based on the DNA of a four-year-old Abyssinian cat named Cinnamon.
It consists of 20,285 genes.



SANGER

DNA SEQUENCING

Frederick Sanger and his colleagues developed the Sanger method for sequencing DNA molecules. This major advance makes it possible to sequence long strands of DNA quickly and reliably.

DOLLY

CLONING

Dolly was the first mammal cloned from cells of an adult sheep.

DOGS

SEQUENCING

The first sequencing of the canine genome was carried out on a Boxer named Tasha.
It consists of just under 20,000 genes.

In the 1990s, after years of research and development, new technologies such as DNA microarrays (sometimes called DNA chips) emerged and improved diagnostic techniques.

It was during this period that laboratories open to the general public made genetic testing more widely available for the livestock industry.

It is now possible to perform genetic testing of dogs for the following purposes:

- *To identify individuals by DNA and verify kinship.*
- *To screen for genetic diseases to prevent or control disease onset.*
- *To predict the appearance of litters to select for or avoid a phenotypic trait.*

GENETIC CONCEPTS

A dog's body is made up of tens of billions of cells. Each individual cell contains the same genetic information, which is carried by the chromosomes within the cell nucleus.

This genetic information, also called the genome, plays two essential roles:

- **it triggers the synthesis of proteins that are essential for the architecture and functioning of the organism, such as tissue proteins, enzymes or hormones;**
- **it passes on inherited traits to offspring during reproduction.**

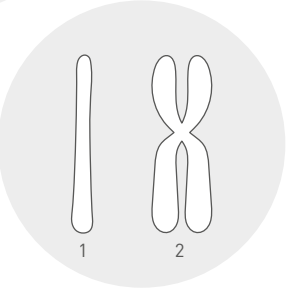


Illustration of a chromosome
1. Each chromosome is formed by a deoxyribonucleic acid (DNA) molecule rolled into a ball
2. Duplicated chromosome

GENES: **ARCHITECTS OF LIFE**

The genetic information in the cell nucleus is always the same, regardless of where the cell is (heart, skin, etc.). However, each cell uses a very tiny part of the complete genetic programme.

Within each nucleus are long strands of DNA (deoxyribonucleic acid) which, when condensed, form the chromosomes. Each chromosome is formed by a DNA molecule rolled into a ball.

When a DNA molecule is uncoiled, its very specific double helix structure is revealed.

A single DNA molecule contains enough information to fill an encyclopaedia of several thousand pages. If you were to line up all the DNA molecules in the chromosomes of a cell, they would extend to about one metre!

The number of chromosomes in the cell nucleus is always identical for each given species.

Dogs have 78, while humans have 46.

Chromosomes come in pairs; it is more exact to say that dogs have 38 pairs of chromosomes, plus one pair of sex chromosomes (XY for males, XX for females). Chromosomes carry inherited traits. In each pair of chromosomes, one chromosome was inherited from the father via the sperm, the other was inherited from the mother via the egg.

Chromosomes contain information in the form of genes. Genes are the structural and functional units of genetic inheritance.

In simpler terms, a chromosome can be represented as a hollow rod divided into thousands of segments. Each segment hosts a particular gene. A gene therefore represents a piece of chromosome, i.e. a piece of DNA molecule.

Each gene has its own fixed location on a chromosome: this is called the locus.

A gene contains all the genetic information a cell needs to synthesise a specific protein. **There are approximately 20,000 different genes in dogs, whereas humans have 25,000.**

An individual's genetic makeup is called a **genotype.** Its expression is called a **phenotype.** A phenotype may include morphological (size, coat colour), physiological (athletic ability, behaviour) or biochemical (blood type) traits.

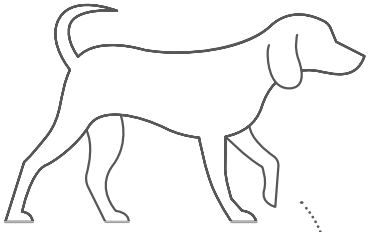
Did you know?

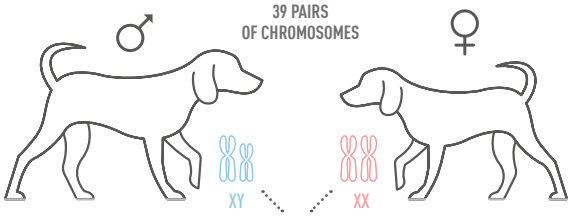
GENETICS AND THE FUTURE OF BREEDING

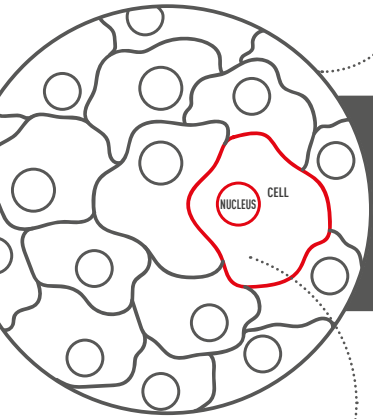
Recent advances in genetics have made reliable and affordable DNA testing available to breeders. This type of testing provides valuable insights into canine genetics to improve understanding of how morphological traits and single-gene disorders are passed on. The widespread availability of genetic testing today enables breeders to better manage mating pairs to produce healthy puppies that conform to breed standards. This proactive and responsible approach is increasingly used in the breeding world, whether for pre-breeding tests or as part of a more general health-prevention plan.

In particular, there are breed-specific panels that only target diseases that are known to have an impact on the breed. To perform this testing, several types of DNA sampling are possible, the most common of which is swabbing the inside of the animal's mouth (buccal swab).

DNA testing is also a good way to predict the genetic status of litters. It is sometimes enough to adapt mating pairs without having to exclude dogs carrying a disease or undesirable phenotypical trait from breeding.





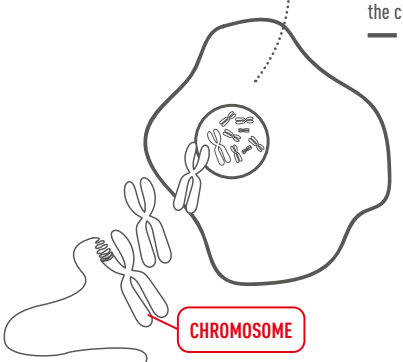


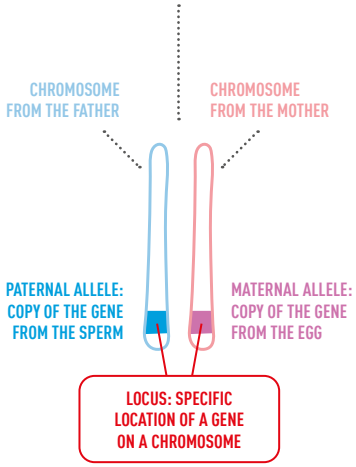
A dog's body is made up of

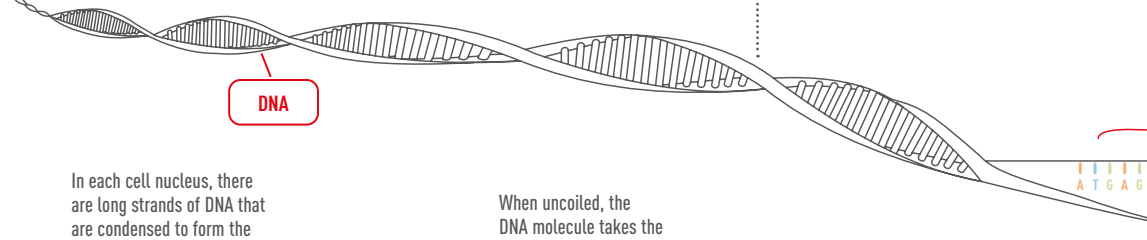
TENS OF BILLIONS OF CELLS.

Dogs have 39 pairs of chromosomes:
38 pairs of "autosomes" (non-sex chromosomes) common to males and females and one pair of sex chromosomes: XX for females and XY for males. Each pair consists of one chromosome from the mother and one from the father.
This means there are two copies of each gene.

Each cell has a nucleus that contains the chromosomes.



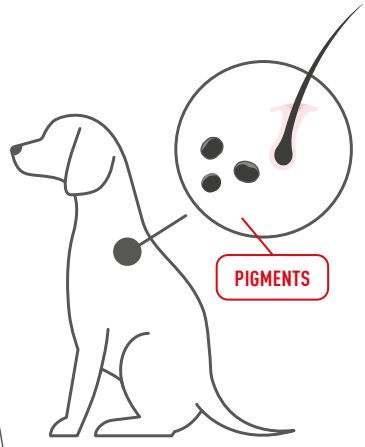




In each cell nucleus, there are long strands of DNA that are condensed to form the chromosomes.

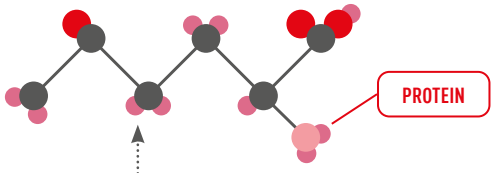
When uncoiled, the DNA molecule takes the shape of a double helix.

For example, a gene encodes a protein, which may be a pigment-synthesising enzyme (tyrosinase). This is what gives the hair its colour.



MUTATED GENE

When a gene or chromosome is altered or suppressed, the proteins involved are not produced properly or at all.
The result is a new "mutated" version of this gene. This is what produces the beautiful diversity in living organisms, but it is also sometimes the cause of certain diseases or degenerations.

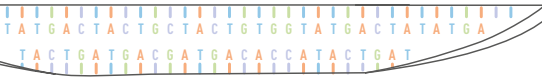


TRANSLATION PHASE

From the genes, the cells synthesise specific proteins that are essential for the organism's architecture and functioning.

TRANSCRIPTION PHASE

GENE



Genetic information is carried by segments called "genes" that tell each cell what its role is in the organism.

Dogs have approximately
20,000 GENES.
They form the genetic inheritance that is unique to each individual and passed down by ancestors.
The entire set of genes is called the genome.

DNA is made up of a series of the following four nitrogenous bases: A (adenine), T (thymine), C (cytosine), G (guanine).

GENES: **MEMORY OF LIVING ORGANISMS**

Chromosomes come in pairs (one chromosome from the father, the other from the mother): a dog therefore has two copies of the same gene.

When a change in a gene occurs, a new, "mutated" version of that gene is produced. Mutations occur spontaneously.

The different versions of the same gene are called alleles. The alleles contain different genetic information which, when decoded by a cell, will produce different proteins from the original version. The different combinations of alleles contribute to heterogeneity in the species and give rise to the different breeds.

At a given locus (i.e. for a given gene), a dog has two alleles. It inherits one of these alleles from its father and the other from its mother.

If the two alleles are identical, the dog is homozygous. If they are different, the dog is heterozygous.

Not all alleles of the same gene are expressed equally.

An allele is dominant if it is present in only one copy and expresses the phenotype.

An allele is recessive if it must be present in two copies to be expressed.

Thus, in a heterozygous dog, the dominant allele is expressed (you can see the result in the dog) and the recessive allele remains hidden.

In a homozygous dog, the trait governed by a recessive allele is expressed if the dog is homozygous for that allele (has two copies of that allele).

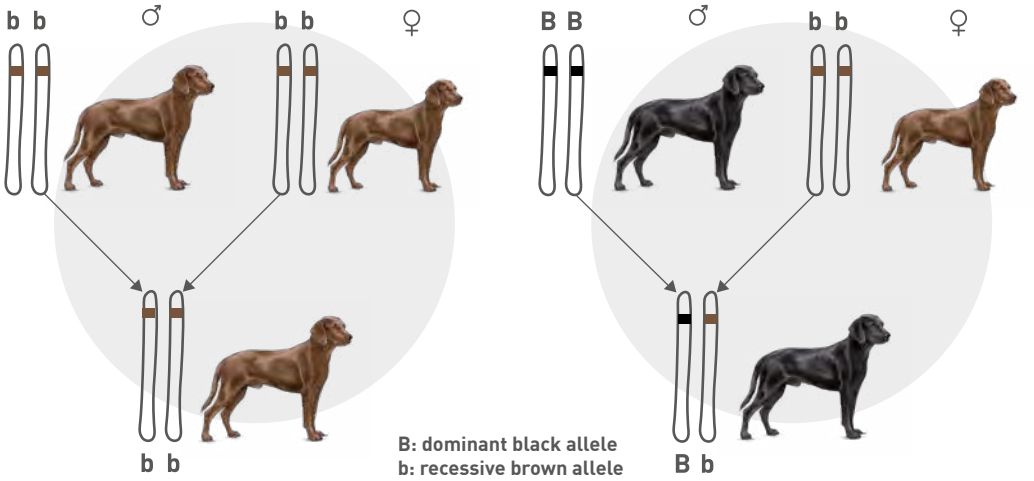
Example of three alleles at the *K* locus

Black: K^B

Fawn brindle: k^{br}

Fawn: k^y

Homozygous/heterozygous comparison – example of the *B* locus



If the two alleles of a gene at a given locus are identical, the dog is considered to be **homozygous** for that gene.

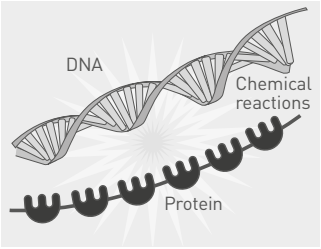
If the two alleles are different at a given locus, the dog is **heterozygous** for that gene.

GENETICS NOMENCLATURE GUIDELINES

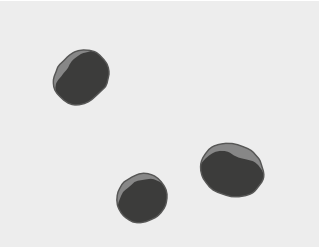
- **The locus of a gene is designated by a letter and its different alleles are noted in superscript.** Example: the *A* locus refers to the *Agouti* locus. A^y refers to the yellow (fawn) allele of the *Agouti* locus.
- **The dominant allele is capitalised.**
- **The recessive allele is written in lowercase.**
- **The "wild" (original, before mutation) allele is indicated by the (+) sign** For example: *B* for the *Brown* locus, which governs the dark pigment colour, with B^+ (dominant) for the *Black* colour allele and *b* (recessive) for the brown colour allele.
- **When one allele is dominant over another, we write: $A^y > a^t$** meaning that the A^y allele is dominant over the a^t allele.
- **When a dog is homozygous for an allele, such as A^y, the notation is A^y/A^y.**
- **The notation A^y/a^t means that the dog is heterozygous at the *A* locus:** in this particular case, the A^y allele is dominant over a^t, so the heterozygous dog will express its A^y allele.
- **Sometimes observing the dog's phenotype only makes it possible to determine part of the genotype:** if it is known that the dog carries at least one dominant A^y allele but the other allele is not known, we will then note $A^y/-$.

Example of protein synthesis from DNA

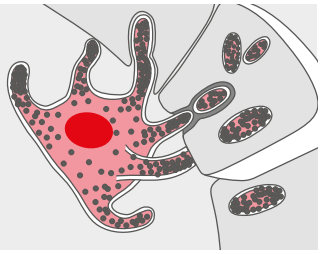
Phases of hair colouration



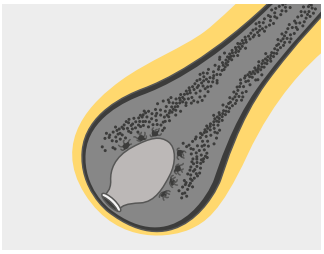
A gene encodes a specific protein responsible for coat colour. For example, the enzyme tyrosinase is involved in pigment synthesis.



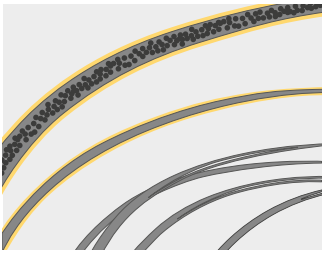
The enzyme tyrosinase is involved in synthesising the pigments in the granules.



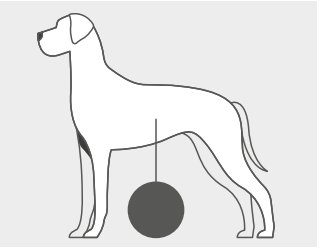
These granules are secreted by melanocytes, which are cells located in the epidermis and the hair matrix.



As the hair grows, the pigment granules migrate from the matrix to the cortex.



The nature and concentration of pigments are responsible for the coat colour.

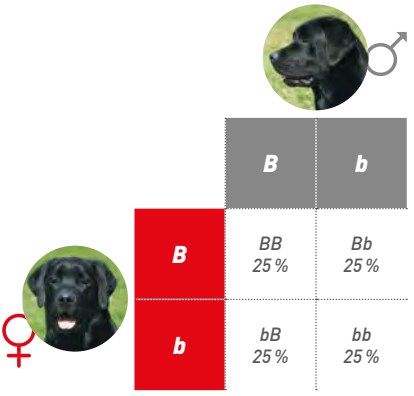


A dog's appearance is therefore written in its genes.

A WORD FROM THE EXPERT

"When I breed two black dogs carrying the brown allele (B/b), I get mainly black puppies, but I sometimes have about a quarter of the litter with brown (b/b) puppies. These puppies express the brown recessive allele because they have two copies. The other puppies in the litter are either homozygous black (B/B) or heterozygous black carrying a brown allele (B/b), where the B allele is dominant and so the black is expressed for both genotypes."

Sylvie,
Labrador retriever breeder



Conclusion

The genetic inheritance in each cell of a dog's body determines its appearance and, in particular, the coat colour because the synthesis and distribution of the pigments responsible for the hair colour depends on the genotype. A dog's coat includes a wide variety of different shades.

Shar Pei - Fawn masked

Chinese Crested Dog - White

Bergamasco Shepherd Dog - Black

French Pointer - Gascogne type
Brown with invasive white spotting and ticking

Portuguese Water Dog - Black

Peruvian Hairless Dog - Black

Lapponian Herder - Brown with sand markings

West Highland White Terrier - White

German Miniature Spitz - Fawn

Labrador Retriever - Sand

Standard Poodle - Brown

Dachshund - Fawn with heavy overlay

PIGMENTS ET EFFECTS OF THE LOCI

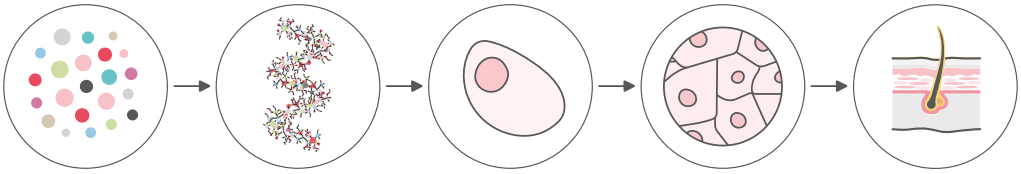
As we have previously explained, the pigments (called melanins) are almost entirely responsible for the hair, skin and iris colour in mammals. They exist in two forms:

- **eumelanin or dark pigment (black or brown);**
- **phaeomelanin or pale pigment (fawn to sand, i.e. red to yellow).**

However, for these pigments to be produced, there must be a sufficient quantity of various elements in the cell that are essential for their synthesis, specifically trace elements (copper) and aromatic amino acids such as tyrosine and phenylalanine.

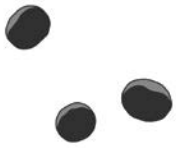
These two amino acids, among others, play a role in the formation of proteins and their derivatives, which are essential for the functioning and creation of the organism's cells and tissues.

Amino acids serve as building blocks



Deficiencies in these elements result in colour modification. Nutrition therefore plays an important part in allowing different shades of colours to express themselves in the multitude of coats which we see in dogs.

EUMELANIN
AND PHAEOMELANIN



Eumelanin
(dark pigment: black or brown)

Phaeomelanin
(pale pigment: fawn to sand)

These pigments are present in the form of granules, almost oval in shape, with a diameter of between 0.1 and 2 microns depending on the animal species and the type of melanin; for example, eumelanin granules are generally bigger than phaeomelanin granules.

"White" does not exist as a colour.

In the absence of pigment granules, this colour results from air being trapped in a solid, translucent substance, in this case the hair cortex (this also explains why snow is white – because air is trapped between ice crystals).

A certain number of alleles at different loci are capable of acting on:

- eumelanin synthesis in all or part of the body or hair;
- the redirection of this process towards phaeomelanin, in all or part of the body or hair;
- the inhibition of pigment synthesis in all or part of the body;
- the colour and intensity of eumelanin and phaeomelanin;
- the distribution of pigment granules in the hair;
- the distribution of pigment cells in the dog's body.

The loci concerned can be classed as:

- loci determining the base colour of the coat;
- loci modifying the base colour;
- loci responsible for spotting (white spots).

Did you know?

ARE DOGS WITH WHITE COATS ALBINO DOGS?

No. Oculocutaneous albinism as seen in humans or mice is part of a group of inherited disorders affecting pigment production in the skin, hair, and eyes. White coats, found in the Samoyed, Maltese, or White Swiss Shepherd dog breeds, is not due to albinism. In fact, the genes responsible for this coat colour have no visible effect other than a white coat: thus the eyes, nose and lips present dark pigmentation.

White hair: White does not exist as a colour.
The visible colour is the result of the absence of pigment. The hair cortex is translucent. In the absence of pigment, the air inside makes it white.

LOCI THAT DETERMINE **THE BASE COLOUR**

The base colour of a dog's coat is determined by the effects of genes at four different loci: ***B (Brown)***, ***A (Agouti)***, ***K (BlacK)*** and ***E (Extension)***. French bulldogs also have a special feature: the co-locus, also known as ***Cocoa***.

***B* locus** (*Brown*), *TYRP1 gene* (*Tyrosinase-Related Protein 1*)

The *B* locus allows the expression of an enzyme called "tyrosinase-related protein 1". There is no debate on this locus. It has two alleles:

- ***B*⁺ (or *B*): the eumelanin is black.**
- ***b*: the eumelanin is brown.**

The shade of brown may vary under the influence of modifier genes or because of interactions with other colour loci (e.g. *D* dilution locus), but it is definitely recessive with regard to the black colour.

B⁺: the eumelanin is black

b: the eumelanin appears brown

***Co*-locus** (*Cocoa, brown*),
HPS3 gene (Hermansky-Pudlak Syndrome type 3)

The *Co*-locus has been identified in the French Bulldog and is responsible for producing a brown colour from the eumelanin that is darker than the brown from the B locus. It has two alleles:

- ***Co*⁺ (or *Co*): the eumelanin is black.**
- ***co*: the eumelanin is dark brown (cocoa).**

The shade of brown may vary under the influence of modifier genes or because of interactions with other colour loci (e.g. *D* dilution locus or *B* locus explained above), but it is definitely recessive with regard to the black colour.

co: the eumelanin is dark brown (cocoa)

INTERACTIONS BETWEEN LOCI

The alleles of the different loci interact with each other in complex ways:

- When an *A* allele remains **invisible** (i.e. is not expressed) in the presence of another *B* allele, we say that *A* is **hypostatic** with respect to *B*.
- When an *A* allele **exerts its effect** on another *B* allele, we say that *A* is **epistatic** with respect to *B*.

Example of the *Co*-locus – interactions with the *B* locus:

- A Co^+/Co^+ (or heterozygous Co^+/co) subject has black eumelanin.
  Co+ is hypostatic with respect to *b*.
  This produces a Co^+/Co^+ and *b/b* subject: brown eumelanin. ***b/b* prevails.**
- A *co/co* subject has a dark brown (cocoa) eumelanin.
  Co is epistatic with respect to B^+.
  This produces a *co/co* and B^+/B^+ subject: dark brown eumelanin (cocoa). ***co/co* prevails.**

In short: in the presence of certain loci, a dominant allele will not necessarily win out.

Cocoa

***A* locus** *(Agouti)*,
ASIP gene (*Agouti-Signalling Protein*)

It gets its name from the agouti, a South American rodent, which offers a typical example of the "wild" markings characteristic of many mammals.

The different mutant alleles on the A locus have the effect of altering the extension of eumelanin and phaeomelanin both on the hair and across the entire coat:

- **on the hair:** the band of phaeomelanin can be quite invasive, with the eumelanin being pushed to the tip; there's a chance that the coat can even become entirely fawn. The opposite can also occur, with the dark band increasingly extending throughout the entire hair shaft;
- **across the entire coat:** the processes described above may differ according to the part of the body; for example, this may occur to the extent that the animal appears black on the back and sides and fawn on the underside.

***A*^{y}** Varying degree of overlay

***a*^{w}** agouti (wolf grey)

Fawn with mantle ***a*^{t}** Black with fawn markings

a black

Agouti hairs with a varying degree of phaeomelanin extension

Typical agouti hair: a single phaeomelanin band interspersed between eumelanin bands.

The following alleles are assumed to exist at the *A* locus (in order of dominance, i.e. $A^y > a^w > a^t > a$):

- ***A^y* (y for "yellow") produces fawn and fawn with dark overlay coats.**
  Similar to the wild coat, this combination is common and highly variable depending on the degree of overlay: it varies from a fawn with no overlay to a fawn with a very dark overlay.

- ***a^w* (w for "wild") produces the coat commonly known as "wolf grey".**
  Each hair is bi-coloured, although the dark band at the tip is very reduced on the lighter parts of the coat (limbs especially).
  This allele is the wild ancestral allele of canids, and has also been identified in wolves and coyotes.
  It is present in some Nordic dogs (Norwegian Elkhound Grey, Keeshond, etc.) as well as in the German Shepherd, especially in the working lines ("grey" coat).

The a^w gene produces coats which are traditionally called "wolf grey" or "agouti".

Norwegian Elkhound Grey

- ***a^t* produces fawn with mantle coats as well as coats with fawn markings.**
  The overlay, sometimes composed of black hairs and sometimes of bi-coloured hairs, may be limited to a saddle pattern or become so invasive that it becomes almost black with fawn markings. Modifier genes can influence the size of the overlay.
  A second gene, called RALY, modifies the extension of the black and determines whether the coat has more of an overlay or whether the fawn areas are limited to fawn markings.

Influence of the *RALY* gene on the expression of the *at* allele

Fawn with mantle

Black with fawn markings

• ***a* is described as "recessive black".**

In the vast majority of cases, it is not responsible for the uniform blackness in the dog; instead, this occurs due to another locus called *K (black)*. The a allele is only found in a few breeds such as the German Shepherd or the Puli.

In this Swedish Vallhund (Vizigothic Spitz) a^w characterises the wolf-grey or agouti coat, which corresponds to the wild coat in canine species. ⓥ

ⓢ In this Belgian Shepherd Dog (Tervueren), a^y is response for the sand with black overlay coat, which is very similar to the wild coat due to a^w.

ⓐ The intensity of the overlay – slight on this Belgian Shepherd Dog (Laekenois) – is governed by genetic factors which have yet to be discovered.

***E* locus (*Extension*),**
MC1R gene (*Melanocortin 1 receptor*)

The *E* locus controls the production of eumelanin.
The E^+ (or *E*) wild-type allele is not expressed and the alleles at the *A* and *K* loci are expressed.
Three other alleles are present at this locus: E^M, E^G and *e*.

The E^M allele at the *E* locus tends to concentrate eumelanin on the foreface, thus explaining the mask.

- **The E^M gene tends to concentrate eumelanin on the foreface, thus explaining the mask.**
  The mask is always melanistic. It can be black or brown, or diluted by the effect of the *D* (dilution) locus, appearing either blue or beige.

FAWN MASKED COAT

- **E^G extends the fawn areas of the black coat with fawn markings into a fawn with mantle, specifically in the Saluki (grizzle coat), the Afghan Hound (domino coat) and the Borzoi.**
  E^G is dominant over E^+ and *e*, but not E^M.
  Moreover, E^G is only expressed in a black (or brown) dog with fawn markings, i.e. a^t/a^t.
  It has no effect on other coats.

E^+ allows *K* to be expressed K^B/K^B *black dog.*

- **E^+ is the wild-type allele, which enables the production of eumelanin across the body.**
  The E^+ allele is recessive with respect to E^M and dominant over *e*.

e/e suppresses the effect of *K*: *e/e* fawn dog.

- ***e* completely removes the eumelanin from the coat, giving the animal a uniform fawn appearance.**
  There are no eumelanin hairs in the coat.

K **locus (*Black, dominant black*),**
CBD103 gene (*Beta-Defensin 103*)

The *K* locus governs the distribution of eumelanin and phaeomelanin in the dog's coat, as does the *A* locus.

- **K^B (for "black" or dominant black) produces the solid eumelanic colour (black or brown and their respective dilutions, blue and beige).**

- **k^{br} (for "brindle") is responsible for the presence of eumelanic markings concentrated in vertical streaks in the coat: these are the brindle markings.**

k^{br}/k^{br} fawn brindle dog

- **k^y (for "yellow", or fawn) is the wild-type allele and produces the expression of the alleles at the *A* and *E* loci.**

The dominant black found in many dog breeds is due to the K^B allele. The *a* allele at the *A* locus, responsible for recessive black, is restricted to a small number of breeds.

FAWN BRINDLE COAT

Dutch Shepherd Dog

INTERACTIONS BETWEEN THE *A*, *E* AND *K* LOCI

Complex relationships exist between the alleles of the three *A*, *E* and *K* loci. Some examples are given below:

- **E^M is hypostatic (remains invisible) with respect to *a* and K^B.**
  recessive black (*a/a*) or dominant black (K^B/-) cannot express its mask. With A^y, the mask is added:
  an A^y/- and E^M/- dog will have a fawn overlay coat and a mask.
  Similarly, a fawn brindle dog may also have a mask.

- ***e* is epistatic (exerts its effect) on all *A* and *K* alleles.**
  An *e/e* dog will have a fawn coat (without eumelanin hair), regardless of its genotype for the *A* and *K* loci.

- **K^B is epistatic over A^y and a^w.**
  A dog with one or two K^B alleles will have a solid eumelanin coat (black or brown and their dilutions), even if genetically it is fawn or wolf grey at the *A* locus (e.g. A^y/A^y and a^w/a^w).

- **a and a^t are epistatic over k^y.**
  A k^y/k^y and *a/a* dog will not be fawn but rather solid black (or brown). Similarly, a k^y/k^y and a^t/a^t dog will not be fawn but rather black (or brown) with fawn markings or a fawn with mantle (depending on the effect of the *RALY* gene).

The k^{br} allele produces the brindle pattern.

© Duhayer / Royal Canin

Greyhound

LOCI THAT DETERMINE THE BASE COLOUR

Some loci can modify or completely suppress the expression of the base colour. The effects of these loci therefore take precedence over those of the *A*, *E* and *K* loci.

Locus *I (intensity),*

MFSD12 gene (*Major Facilitator Superfamily Domain containing 12*)

The I locus governs the phaeomelanin intensity, which can range from intense red to very pale yellow (sand, cream) or white. Two alleles are present at this locus:

- ***I*$^{+}$: dominant wild-type allele, which produces an intense, unmodified phaeomelanin.**
- ***i*: recessive allele, which lightens the phaeomelanin (sand, cream, or white dog).**

In the presence of A^{y}, the I locus lightens the phaeomelanin resulting in a sand with overlay.

White coats (with black tips and skin), such as those of the West Highland White Terrier, the Sealyham Terrier or the White Swiss Shepherd dog, are due to *I*. In the case of a white dog with black tips, it is also important to distinguish it from very invasive spotting *(see below)*.

Sealyham terrier

White Swiss Shepherd Dog

***D* locus (*Dilution*),**
MLPH gene (*Melanophilin*)

The *D* locus affects pigmentation intensity.

The number of pigment granules does not decrease, but they cluster together, which reduces light absorption and makes the colour appear lighter – for example, black becomes blue (visually grey).

Two alleles are known at this locus:

- ***D*⁺: wild-type dominant allele, no effect.**
- ***d*: recessive allele, which dilutes the eumelanin but has very little effect on the phaeomelanin.**

Dilution of black produces blue, while dilution of brown produces beige and dilution of fawn produces sand (this sand is matte, but the intensity is not considerably lighter and should not be confused with sand due to *I*).

Coats that are diluted by *d*, especially those that are blue, seem to be prone to a certain form of alopecia (temporary hair loss), known as colour dilution alopecia. We do not know if this is related to a pleiotropic effect (effect on several traits) of d or if it is induced by another gene, or possibly an as yet unidentified *D* allele. However, many *d/d* dogs do not end up with alopecia.

HOW TO KNOW IF DILUTION IS DUE TO THE *I* LOCUS OR *D* LOCUS?

- If both phaeomelanin and eumelanin are diluted (look at the nose or the mask, if the dog has one), it is the *D* locus that is responsible. However, there is the possibility that the *I* locus is adding to the effect.
- The *I* locus effect keeps the sand shade shiny, while *D* produces dull, matte shades. Additionally, phaeomelanin is less diluted by *D* than *I*.

Ⓐ Dilution of black eumelanin produces blue.

Great Dane

Greying is the result of whitish hairs appearing in a coloured coat.

Brown, greying coat

G locus (*Progressive greying*), gene not yet identified

It is widely accepted that there are two alleles at this locus:

- ***G* likely causes the gradual appearance of whitish hairs on an intensely coloured coat. These hairs intermingle with coloured hairs and end up lightening the coat to a varying degree.**
- ***g*⁺ is the wild-type allele: it likely has no effect.**

The dominance of *G* over *g*⁺ is likely incomplete and the effect is gradual; this results in the greying occurring later and in a less noticeable manner in *G*/*g*⁺ animals than in *G*/*G* animals. Moreover, the effect of *G* seems to be more or less marked depending on the breed: the poodle and the Bedlington Terrier are completely grey, whereas the Kerry Blue Terrier is much less so.

In this Pumi, the greying is expressed on a black base coat, rather than a fawn base coat, as in this Bouvier des Ardennes.

Kerry Blue Terrier

A WORD FROM THE EXPERT

"The first reference to the Kerry Blue Terrier in literature appears to date from 1847: the author describes a 'bluish, slate-coloured' dog. This is the colour that gave the dog its name, but in fact, my dogs are black at birth. They have a mixture of black and white hairs and a black nose, which gives them a grey coat rather than blue. The final colour stabilises between 9 and 18 months."

James,
Kerry Blue Terrier breeder

***M* locus (*Merle*),**
SILV gene (*Silver = PMEL17*)

There are several alleles at this locus.
The two main ones are:

- ***M*: dominant allele, responsible for streaks/ patches.**
- ***m*⁺: wild-type recessive allele, no effect.**

***m*⁺/*m*⁺**: black dog.

***M*, in the heterozygous state, has a very clear effect on eumelanin (dark coat).**

It lightens the undercoat while leaving uneven patches of base pigment here and there, which produces:

- a blue merle from a black coat;
- a blue merle with fawn markings from a black coat with fawn markings;
- a beige merle from a brown coat;
- a beige merle with fawn markings from a brown coat with fawn markings.

***M*/*m*⁺**: blue merle (from black). When the *M* allele is present, a dark coat is only visible in the form of irregular patches.

***M* has a much more subtle effect on phaeomelanin.**

The contrast between the patches and the base coat is only apparent in puppies and is mostly not seen in adults. Some animals that are clearly fawn in adulthood can turn out to have a fawn merle coat and transmit the *M* allele. Thus, DNA tests are incredibly helpful in breeding to determine the genotype of the breeding stock and to control allele transmission in the litters.

If an animal carrying *M* is also a carrier of a spotting allele, then *M* tends to increase the spread of the white patches.

M*/*M: almost white dog.

Often *M/m*$^{+}$ dogs have one or two blue eyes.

The *M*^{c} allele (cryptic merle)

The M allele is dominant over the *m*$^{+}$ allele. However, sometimes when phenotypically non-merle dogs are mated to non-merles, they will produce merle puppies. This phenomenon is due to the presence of a modified *M* allele, which is called cryptic merle or hidden merle (*M*^{c}). The dog carrying such an allele does not appear to be merle, regardless of the base colour (black, brown, or fawn), but may produce merle puppies when mated with a non-merle.

It has also been shown that there are several *M* alleles whose effects on the coat can vary, inducing a range of different merle modifications.

M/M GENETIC COMBINATION

When homozygous, *M* can lead to near total depigmentation or induce the appearance of sometimes invasive white patches on a dog which is not a carrier of a spotting allele. This *M/M* genetic combination is undesirable as it frequently leads to eye abnormalities (microphthalmia) and varying degrees of deafness. It is therefore highly inadvisable to breed *M/M* (double merle) dogs: for this reason, an *M/m*$^{+}$ dog should be mated with an *m*$^{+}$/*m*$^{+}$ non-merle dog while two *M/m*$^{+}$ merle dogs should never be mated.

In some cases, it may also be worthwhile to have the breeding stock tested for the *M* locus to determine whether or not they are cryptic merles.

BEIGE MERLE (BROWN) WITH FAWN MARKINGS AND LIMITED WHITE SPOTTING

Australian Shepherd

***H* locus (*Harlequin*),**
PSMB7 gene (*Proteasome Subunit Beta 7*)

There are two alleles at the *H* locus:

- ***H*: dominant allele, responsible for the harlequin phenotype.**
- ***h*⁺: wild-type recessive allele, no visible effect.**

The gene responsible for the white merle colour (harlequin), located at the *H* locus, is a modifier gene of *M*. The harlequin coat (only recognised in the Great Dane) is due to the effect of the *H* locus on a coat that has already been modified by the *M* locus. **A dog with a harlequin coat is therefore always *M/m*⁺ at the M locus.**

The *H* allele is lethal in the homozygous state and results in embryonic mortality in *H/H* pups. Harlequin Great Danes (white merle) are therefore heterozygous for both the *M* locus and the *H* modifier locus: **they are *M/m*⁺ and *H/h*⁺.**

When the *M* allele is absent, the *H* modifier gene has no visible effect.

WHITE MERLE COAT

Great Dane

Oculocutaneous albinism (*OCA4*),

SLC45A2 gene (*Solute Carrier Family 45, member 2*)

In both animals and humans, there are numerous loci responsible for oculocutaneous albinism. In dogs, the *OCA4* locus has been identified and various breed-specific mutations have been described. These alleles all result in the same phenotype: depigmentation of the skin, hair, and eyes, which is typical of albinism. The dogs appear pale cream to white, with pale blue eyes.

At the *OCA4* locus, there are two alleles:

- ***OCA4*⁺: wild-type dominant allele, no effect.**
- ***oca4*: recessive allele, responsible for albinism. Albino dogs are therefore homozygous for *oca4/oca4*.**

This albinism phenotype has been described in Dobermann, Lhasa Apso, Pekingese, Pug, miniature spitz and crossbreeds.

Did you know?

GENETIC MUTATIONS TO AVOID

It is important to note that an albino dog is more likely to develop ocular or cutaneous melanoma and may have photophobia (sensitivity to bright light). Mutations in the genes involved should not be selected as they pose a health risk to the dog.
In particular, a mutation in the *SLC45A2* gene is responsible for albinism in the Dobermann.
A simple DNA test will aid appropriate genetic selection for responsible breeding.

OCA4

WHITE SPOTTING LOCI

In dogs, white spotting depends on the effects of several loci and alleles, including some that are as yet unidentified.

S locus *(White spotting)*,
MITF gene (*Microphthalmia-associated Transcription Factor*)

Most authors recognise the existence of four alleles at this locus, in the following order of dominance:

- ***S*** (Solid)*: coat with very limited or no white spotting** (e.g. small white spot on the chest).
- ***s**^{i} (irish spotting)*: limited white spotting.**
- ***sp (piebald)*: moderate white spotting.**
- ***s**^{w} (white)*: invasive white spotting.**

No white spotting

Limited white spotting

Moderate white spotting

However, the existence of these four alleles has not yet been confirmed by molecular genetics. The discovery in 2007 of the *MITF* gene as a major white spotting gene in dogs brought a complex situation to light. Several mutations have been found in this gene. They are not all transmitted identically between breeds and partially overlap the four alleles as based on assumptions in classical genetics.

Other white spotting loci

At least one other white spotting locus, separate from *S* (*MITF*), has been identified in dogs: the ***KIT*** gene ***(KIT proto-oncogene receptor tyrosine kinase).*** Two mutations responsible for white spotting have been identified in this gene, one in a line of Weimaraners and a second in a line of German Shepherds.

WHITE SPOTTING TRANSMISSION ACCORDING TO BREED

- **White spotting is a recessive trait.**

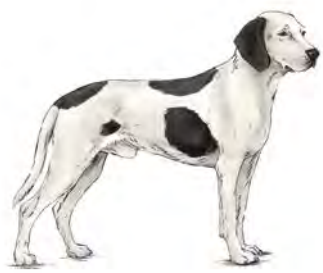
Only homozygous dogs show white spotting.

- **White spotting has a semi-dominant inheritance pattern.**

Heterozygous individuals with a white spotting allele have a limited to moderate white spotting phenotype and homozygous individuals have an invasive white spotting phenotype. This is the case, for example, with the Boxer or Bull Terrier, where s^p/S^+ dogs have limited white spotting and s^p/s^p dogs have invasive white spotting (a white dog corresponding to the classic s^w allele).

- **White spotting can appear in set patterns.**

This is the case with the Irish spotting pattern in the Bernese Mountain Dog or the Australian Shepherd. For these breeds, the *S* locus and the *MITF* gene would not necessarily be involved, as other white spotting loci may be present.



Invasive white spotting

White

T locus (*Ticking*, causing ticking on white area) and *R* locus (*Roan*, causing mixture of white hairs and solid coloured base hairs)

USH2A gene (*Usherin*)

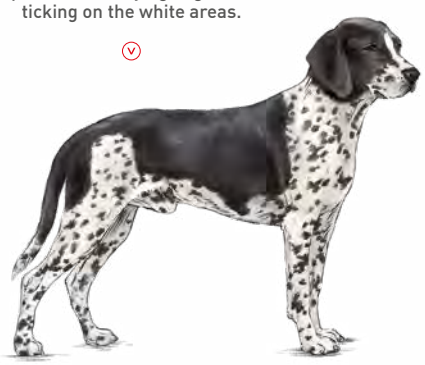
Many dogs with white spotting display varying degrees of ticking in white zones. Ticking is thought to be caused by a dominant allele at the *T* locus.

There are questions as to whether or not mixed white originates from the same gene. Ticking and mixed white do not appear to have sufficiently clear edges to suggest the existence of a dominant allele for a second *R* locus (*roan*). Molecular genetic studies have also supported the hypothesis of a single locus for ticking and mixed white.

There are three alleles at the *T* locus:

- ***T*: dominant allele that produces ticking.**
- ***T*^{R}: dominant allele that produces mixed white.**
- ***t*: recessive allele that produces spotting that is not ticked or mixed white.**

In a subject with white spotting, a dominant allele at the *T* locus produces a varying degree of ticking on the white areas.



The *T* and T^R alleles are likely codominant.

Ticking can also be mixed white (giving a kind of mouldy appearance).

It should be noted that the *T* and T^R alleles do not appear at birth: as the puppy grows, the ticking and mixed white gradually appear in the coat. A perfect illustration of this can be found on page 189.

Finally, the circular spots in Dalmatians have also been linked to the *USH2A* gene, but it is possible that another locus could influence the appearance of regular, well-defined spots.

The *T* locus expresses itself progressively from birth (here, in an English Setter).

FAWN COAT WITH INVASIVE WHITE SPOTTING AND TICKING

LOCUS THAT RESTRICTS PIGMENTATION

***C* locus (*Colour, pigment restricting*),**

TYR (*Tyrosinase*) gene

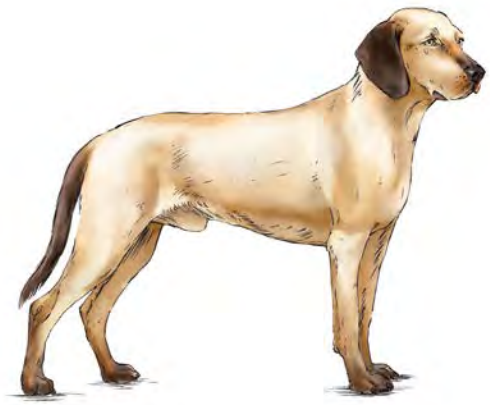
A particular mutation has been identified in the Dachshund at the *C* (colour) locus which codes for the enzyme tyrosinase (the enzyme responsible for pigment synthesis). This mutation restricts pigmentation to the extremities. This is due to a peculiarity of tyrosinase: it only works well at a temperature slightly below body temperature. Thus, the warmer areas of the body (flank, abdomen, and back) remain light (very little pigment production), while the cooler areas (extremities: head, legs and tail) are coloured. Pigmentation restriction corresponds to partial albinism and is characterised by blue eyes.

This specific colour is the equivalent of the coat pattern called colourpoint in cats; the Siamese is an emblematic example of this pattern.

There are two alleles at the *C* locus:

- ***C**: wild-type dominant allele, no effect.**
- ***ch* (*Himalayan*): recessive, pigment-restricting allele.**

***Himalayan* dogs are therefore homozygous for *ch/ch*.**



C

COLOUR
OF THE EYES, SKIN AND EXTREMITIES

Eye coulour

Certain loci governing coat colour are likely to influence iris colour:

- ***d/d* dilutes the eye colour** (*smoky eyes*).
- ***b/b* lightens the iris compared to *B/B* dogs.**
- **The effect of s^w/s^w could, in some cases, reach as far as the iris** (after having affected the eyelids, either partially or totally). In this case, a China eye would correspond to the expression of depigmentation. This could explain the effect in Dalmatians, but it does not explain every case.
- ***M/m*$^+$ can result in one or both eyes being totally or partially blue** when a zone of pigment restriction extends to the iris.
- ***ch/ch* is associated with a blue eye colour.**

Blue eyes can appear in any coat colour

Note: In the Siberian Husky, a specific mutation unrelated to coat colour was identified in 2018 as being responsible for the common occurrence of blue eyes in the breed.

Most of the time, yellow eyes (often called "bird of prey" eyes) lead to disqualification at shows. They are only rarely accepted, such as in the Weimaraner or Vizsla breeds.

China eyes are also rejected, except for when they are associated with a merle coat or found in specific breeds (Dalmatian, Siberian Husky).

In dogs, depigmented (blue) irises can have several causes:

- a merle coat;
- depigmentation along with invasive white spotting with an effect on the iris;
- true albinism, although very rare in dogs;
- genetic origin independent of coat colour, as observed in the Siberian Husky, which may have one or two depigmented irises.

The nose and **nails**

Their base colours vary in the same manner but this is more difficult to determine with the nails.

Nose colour falls into the following categories:

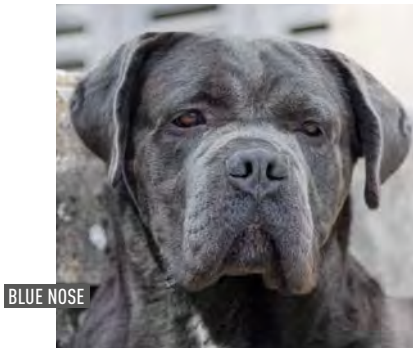
- **black or blue.**
- **brown or beige.**
- **reddish** (a beige nose, which is rare, could be confused with this colour if the coat colour does not eliminate any doubts).

The reddish-coloured nose is the result of the total inhibition of eumelanin due to *e/e*; it is, therefore, definitely associated with the colour fawn.

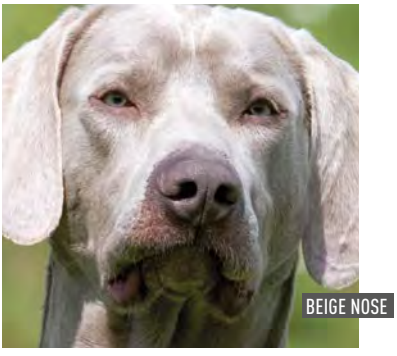
- **pink** (complete depigmentation).

A nose that shows eumelanin pigmentation can also be encountered in fawn subjects; the eumelanin production is completely inhibited on the body but is produced in the nose. To date, no hypothesis has been identified to explain this phenomenon in *e/e* fawn dogs. It should be noted, however, that some fawn dogs with black noses get their colouring due to the effect of A^y and not *e*.

Reddish noses (due to phaeomelanin) and flesh-pink noses (due to depigmentation) must not be confused with each other. Flesh-pink noses are only encountered in subjects with white spotting and correspond to depigmentation which has extended to the nose. While this can be a desired feature in certain breeds (Ibizan Hound), in most cases it is not.



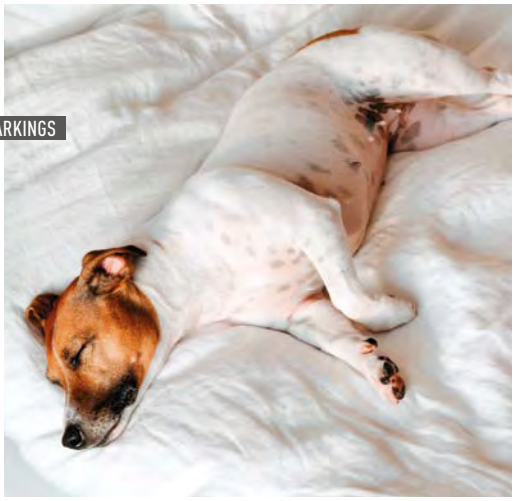
Cane Corso



Weimaraner

Australian Shepherd

SKIN MARKINGS



Flesh colour

This term applies to all depigmentation of the skin or mucous membranes and is easily visible. The fact that it is easy to observe restricts its use to areas where the hair is scarce or absent: nose, lips, eyelids, vulva, scrotum.

Flesh colouring is related to white spotting. Thus it is not observed on solid-coloured animals; the lighter zones which can be seen on a coloured subject, especially along the median furrow, are not flesh coloured.

With flesh colouring, the white spotting appears to "not know" that it should stop at the boundary of the nose and other mucous membranes and sometimes overruns them (even reaching the iris, as we have seen). Obtaining proper pigmentation of the nose, lips, and eyelids on a dog with a partially white or completely white head is a real puzzle.

About skin markings

In theory, when pigmentation has disappeared under the effect of a white spotting locus, it should also disappear from the skin. But we know that this is often not the case and the pigmentation remains, in differently spread patches, at skin level, whereas the corresponding hair is white. **These small patches of colour, only on the skin, are called "skin markings".** As far as we know, no genetic theory has been developed about them.

Remarks: in dogs whose coats are diluted by the I locus, the skin remains coloured. It is possible to include the presence of these markings in the coat description, by referring, for example, to a black and white coat with slight skin markings.

LENGTH ET TEXTURE OF THE COAT

When it comes to the hair, it is not just the colour that can be affected; the shape and general appearance can also modified by several genes. When extended to all hairs, these changes result in marked differences in coat texture: long or short, wire or smooth, wavy or straight.

L locus (*Length*),

FGF5 gene (*Fibroblast Growth Factor 5*) (see p.58)

The "long hair" trait is governed by the L locus, which has two alleles:

- ***L*⁺: wild-type dominant allele, which governs short hair.**
- ***l*: recessive allele, which governs the medium to long hair.**

A long-haired individual is *l/l* homozygous.

Variations in coat length can be explained by incomplete dominance of the *L*⁺ allele over the *l* allele (*L*⁺*/l* individuals may have a slightly longer coat than *L*⁺*/L*⁺ homozygous individuals) and by the presence of modifier genes. It should also be noted that in some breeds a selection has been made to obtain individuals with very long hair. This is probably also a result of complex polygenic determinism.

Traditionally, there was no distinction made, genetically speaking, between the Spaniel-type coat (long hair on the trunk, fringes on the legs and tail, short hair on the head and front of the legs) and the Old English Sheepdog-type coat (long hair all over the body, including the head). The *W* locus (see below) has recently provided more insights.

Afghan Hound

French Poiner

***W* locus (*Wire*),**

RSPO2 gene (*R-spondin 2*) (see p.60)

The "wire hair" trait and the presence of furnishings (moustaches, eyebrows, and beard) are governed by the *W* locus.

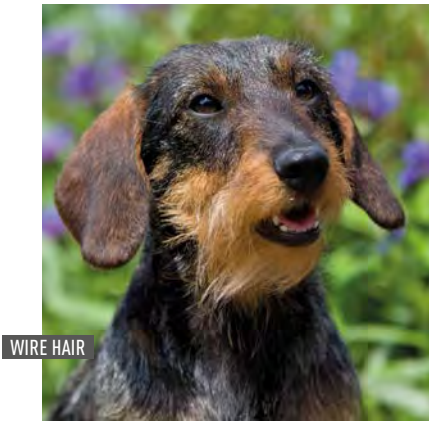
There are two alleles:

- ***W*: dominant allele, which governs the wire hair and furnishings.**
- ***w*$^{+}$: wild-type recessive allele, which governs the smooth hair and the absence of furnishings.**

The *w*$^{+}$ wild-type allele is also responsible for the phenotype typical in the Portuguese Water Dog, called the "improper coat" (IC). In a *w*$^{+}$/*w*$^{+}$ homozygous dog, this phenotype produces no facial hair, short hair on the lower limbs and a shorter coat on the rest of the body.

The phenotypic expression of the wire-haired coat means that *W* is associated with *L*$^{+}$ (short hair).

With *l*/*l* (long hair), the effect of *W* is very difficult to detect because the length of the hair, and possibly its wavy texture, alters its expression. The long hair on the head corresponds to the above mentioned furnishings. Dogs with long hair over the whole body are genetically *W*/- and *l*/*l*.



Dachshund

Dachshund

Cu locus (*Curly hair*),

KRT71 gene (*Keratin 71*) (see p.61)

The "curly hair" trait is governed by the Cu locus.
Two alleles are distinguished:

- ***Cu*$^{+}$: wild-type dominant allele, which produces straight hair.**
- ***cu*: recessive allele, which produces curly hair.**

The dominance of *Cu*$^{+}$ over *cu* is incomplete and may vary between breeds.

This means that *Cu*$^{+}$*/cu* heterozygous dogs may have a smooth, wavy (in places or all over the body) or almost curly coat.

A WORD FROM THE EXPERT

"The Komondor is known for its curly, corded coat, but my puppies are born with a fluffy, slightly curly coat. The dog's characteristic coat will only develop after several months. It has two layers of hair, one of which is a dense, soft, woolly undercoat. The undercoat will gradually become trapped in the outer layer of hair. The two layers intertwine to form tight loops. This cording process is natural, but requires special care to separate the cords to keep them from matting. The coat is not brushed but rather untangled. Meticulous grooming is necessary to prevent dirt from getting lodged in the cords."

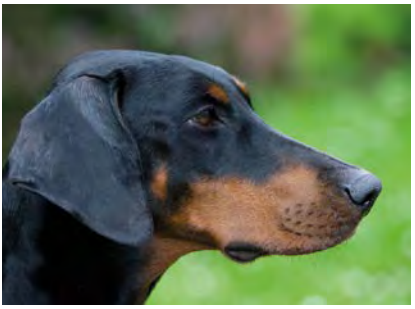
Dóra,
Komondor breeder

Yorkshire Terrier

Irish Water Spaniel

C

Golden Retriever



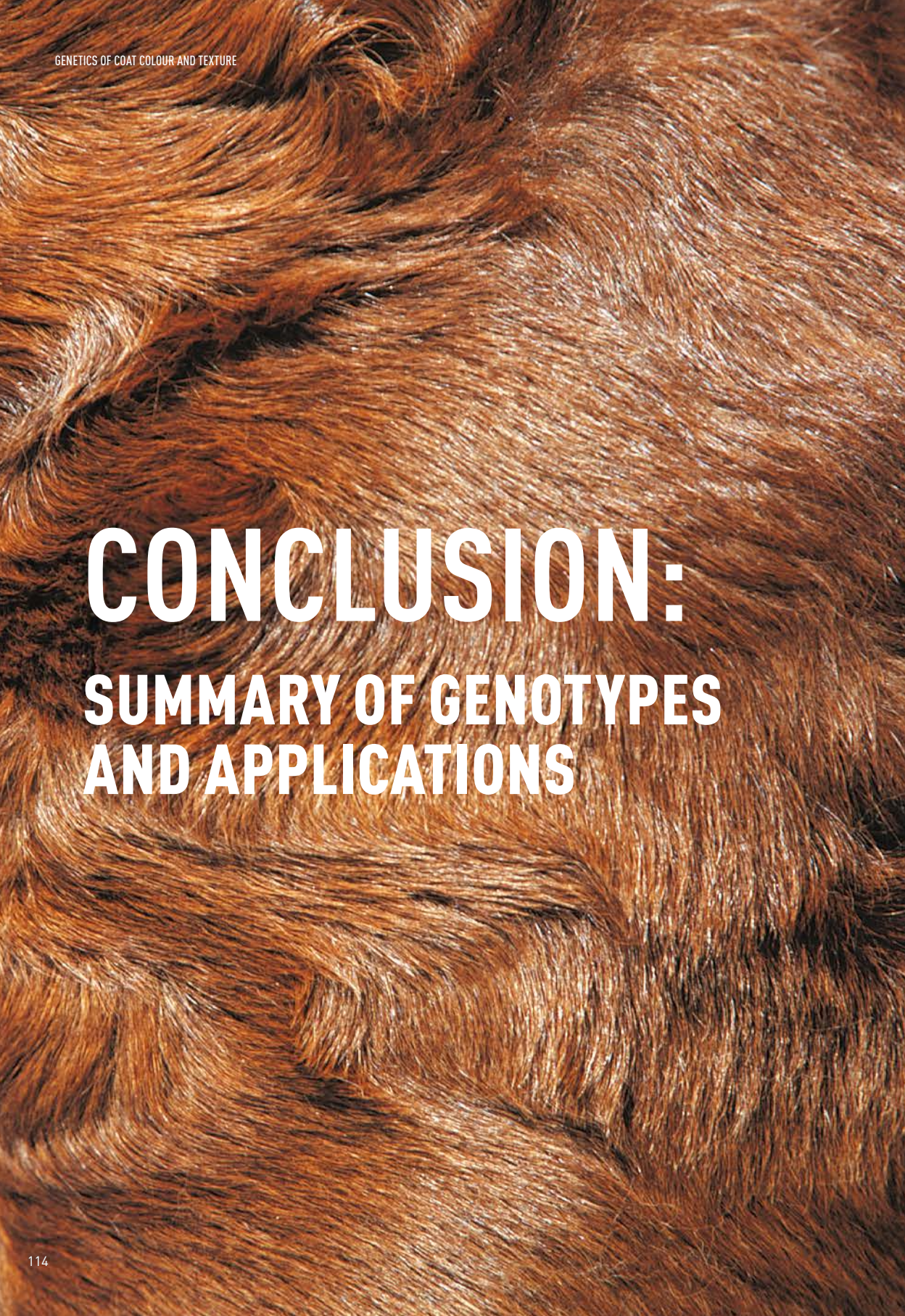
Dobermann

Bichon Frisé

Jack Russell Terrier

The combined effects of the *L*, *W* and *Cu* loci produce the variety of coat textures and lengths seen in dog breeds:

- Smooth, short-haired dogs without whiskers or eyebrows (e.g. Dobermann).
- Long- and smooth-haired dogs without whiskers or eyebrows (e.g. Golden Retriever).
- Wire-haired dogs with whiskers and eyebrows (e.g. wire-haired Jack Russell Terrier).
- Long- and curly-haired dogs with whiskers and eyebrows (e.g. Bichon Frisé).



CONCLUSION:
SUMMARY OF GENOTYPES AND APPLICATIONS

COAT TEXTURE AND LENGTH

LOCUS	ALLELE	HAIR TYPE	DOMINANCE	ILLUSTRATION
L	L	Short hair	$L^+ > l$	
	l	Medium-length to long hair		
W	W	Wire hair	$W > w^+$	
	w^+	Smooth hair		
Cu	Cu^+	Straight hair	Incomplete dominance	
	cu	Curly hair		

LOCI THAT DETERMINE THE BASE COLOUR

LOCUS	ALLELE	EFFECT	DOMINANCE	ILLUSTRATION
B	B^+	Black eumelanin	$B^+ > b$	
	b	Brown eumelanin		
Cocoa	Co^+	Black eumelanin	$Co^+ > co$	
	co	Dark brown eumelanin		
A	A^y	Restriction of eumelanin (fawn and fawn with black overlay).	$A^y > a^w > a^t > a$	
	a^w	Agouti, wolf grey		
	a^t	Fawn with mantle and black with fawn markings (depending on the effect of the *RALY* gene).		
	a	Recessive black (rare)		
E	E^M	Melanistic mask		
	E^G	Grizzle (Saluki) and domino (Afghan Hound). Visible only on a^t/a^t dogs.		
	E^+	Allows the effects of other loci		
	e	Total suppression of eumelanin production in the coat (fawn coat, no black hair).		

LOCI THAT DETERMINE THE BASE COLOUR				
LOCUS	**ALLELE**	**EFFECT**	**DOMINANCE**	**ILLUSTRATION**
K	K^B	Solid eumelanin colour ("dominant black")	$K^B > k^{br} > k^y$	
	k^{br}	Fawn brindle coat		
	k^y	Fawn coat. Allows the effects of other loci		
Interactions between *A*, *E* and *K* *NB: the allele of a locus is epistatic on the allele of another locus when the former masks the expression of the latter*	K^B	Epistatic on all *A* alleles and on E^+ and E^M alleles		
	A^y	Allows E^M to be expresse		
	a^t	Expressed simultaneously with k^{br} (effect of k^{br} limited to fawn zones only). Epistatic on k^y		
	a	Epistatic on k^y		
	k^{br}	Epistatic on A^y. Allows E^M to be expressed		
	e	Epistatic on all *A* and *K* alleles (eumelanin production suppressed)		

LOCI THAT AFFECT PIGMENTATION INTENSITY

LOCUS	ALLELE	EFFECT	DOMINANCE	ILLUSTRATION
I	i	Lightening of phaeomelanin	$I^+ > i$	
	I^+	No effect		
D	D^+	No effect	$D^+ > d$	
	d	Dilution of eumelanin (very visible) and phaeomelanin (not very visible)		
Oca	$OCA2^+$	No effect	$OCA2^+ > oca2$	
	$oca2$	Oculocutaneous albinism		
G	G	Coat normal at birth, gradual appearance of white hairs with age (greying)	$G > g^+$	
	g^+	No effect		
M	M	Merle coat (see below)	$M > m^+$	
	m^+	No effect		
	M/M, known as "double merle", refers to an all-white or partially white coat with adverse effects on vision and hearing. *M/m*$^+$ produces a merle coat, sometimes with one or two blue eyes.			

LOCI THAT AFFECT PIGMENTATION EXTENSION

LOCUS	ALLELE	EFFECT	DOMINANCE	ILLUSTRATION
C	C^+	No effect	$C^+ > c^h$	
	c^h	Restriction of pigmentation to the extremities		

WHITE SPOTTING LOCI

LOCUS	ALLELE	EFFECT	DOMINANCE	ILLUSTRATION
S	S^+	Very minimal to no white spotting	All the alleles express complex dominance relationships. The effect of the modifier genes is also significant.	
	s^i	Irish spotting (limited white spotting)		
	s^p	Moderate white spotting		
	s^w	Invasive white spotting		
T	T	Ticking in white areas	Incomplete dominance	
	T^R	Mixed white (roan in white area)		
	t^+	No effect in white area		

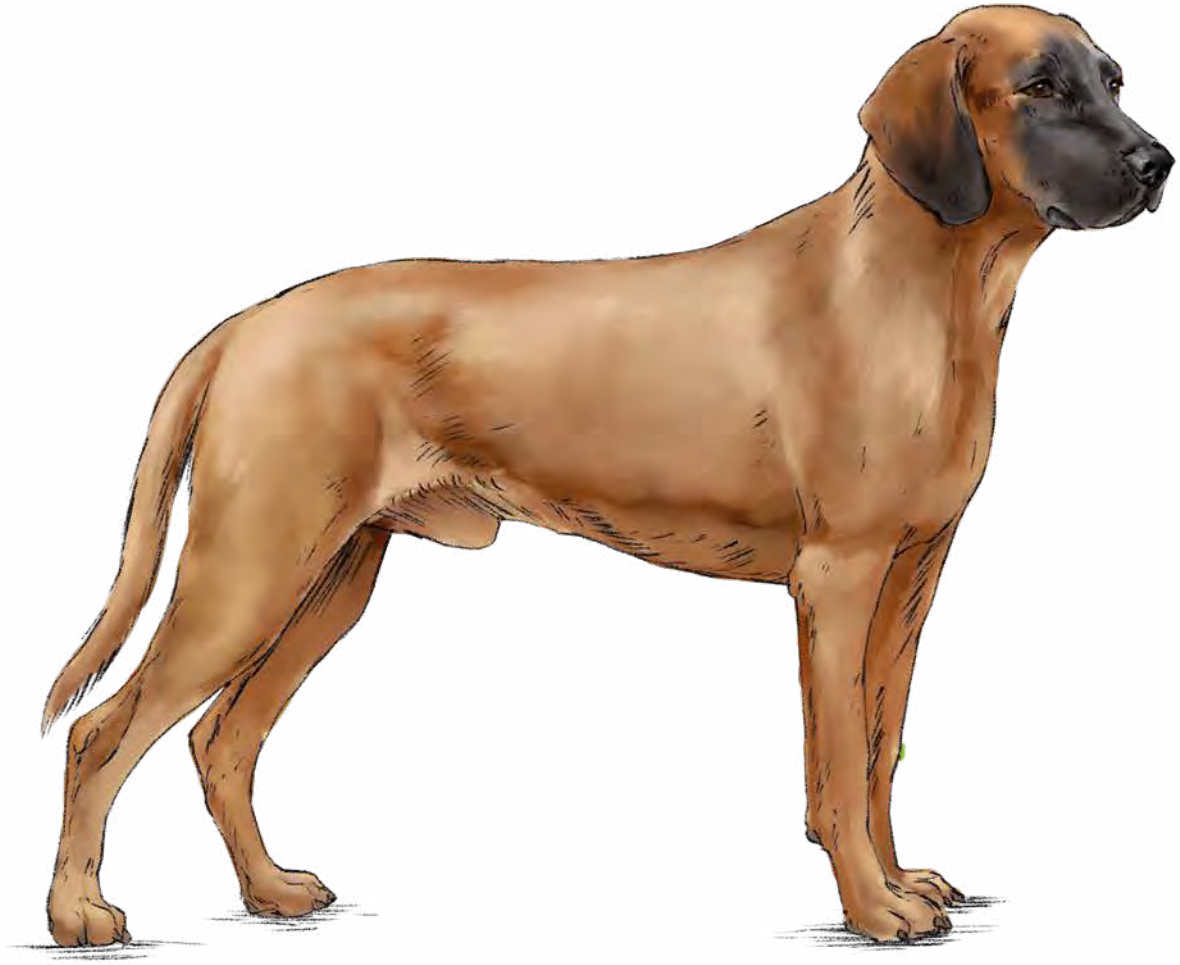
UNDERSTANDING COATS
STEP BY STEP

> FAWN MASKED
> FAWN WITH MANTLE, MASKED
> FAWN WITH MANTLE, MASKED, WITH WHITE SPOTTING AND TICKING

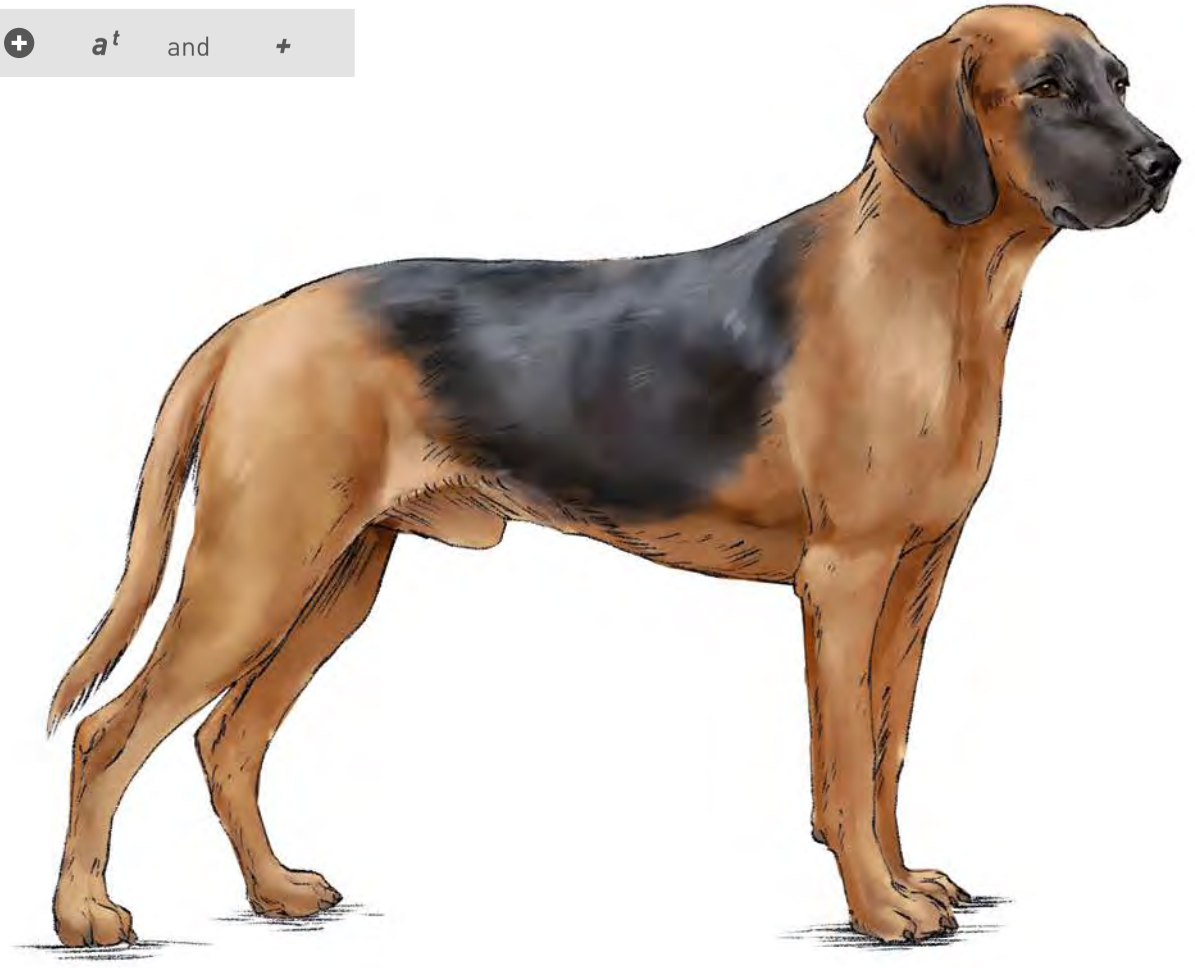
Major allele	*E* locus	*A* locus	*RALY* locus	*S* locus	*T* locus
Fawn masked	E^M				
Fawn with mantle, masked	E^M	⊕ a^t	and +		
Fawn with mantle, masked, with white spotting and ticking	E^M	⊕ a^t	and +	⊕ s^P	and *T*

NB: in this pedagogical approach, only the major alleles determining these colours have been indicated for the sake of simplification.

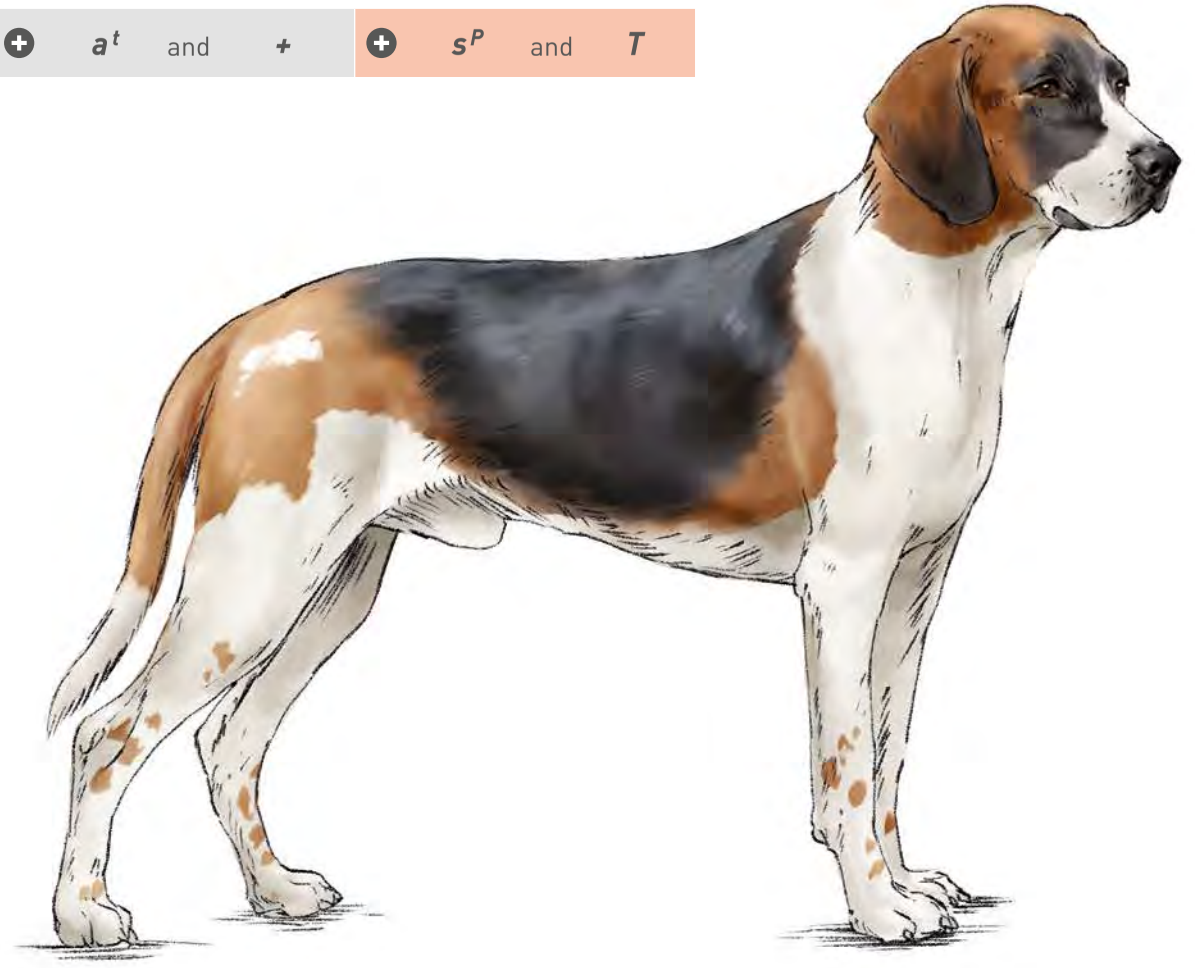
EM



E^M ⊕ a^t and +



E^{M} ⊕ a^{t} and + ⊕ s^{P} and T



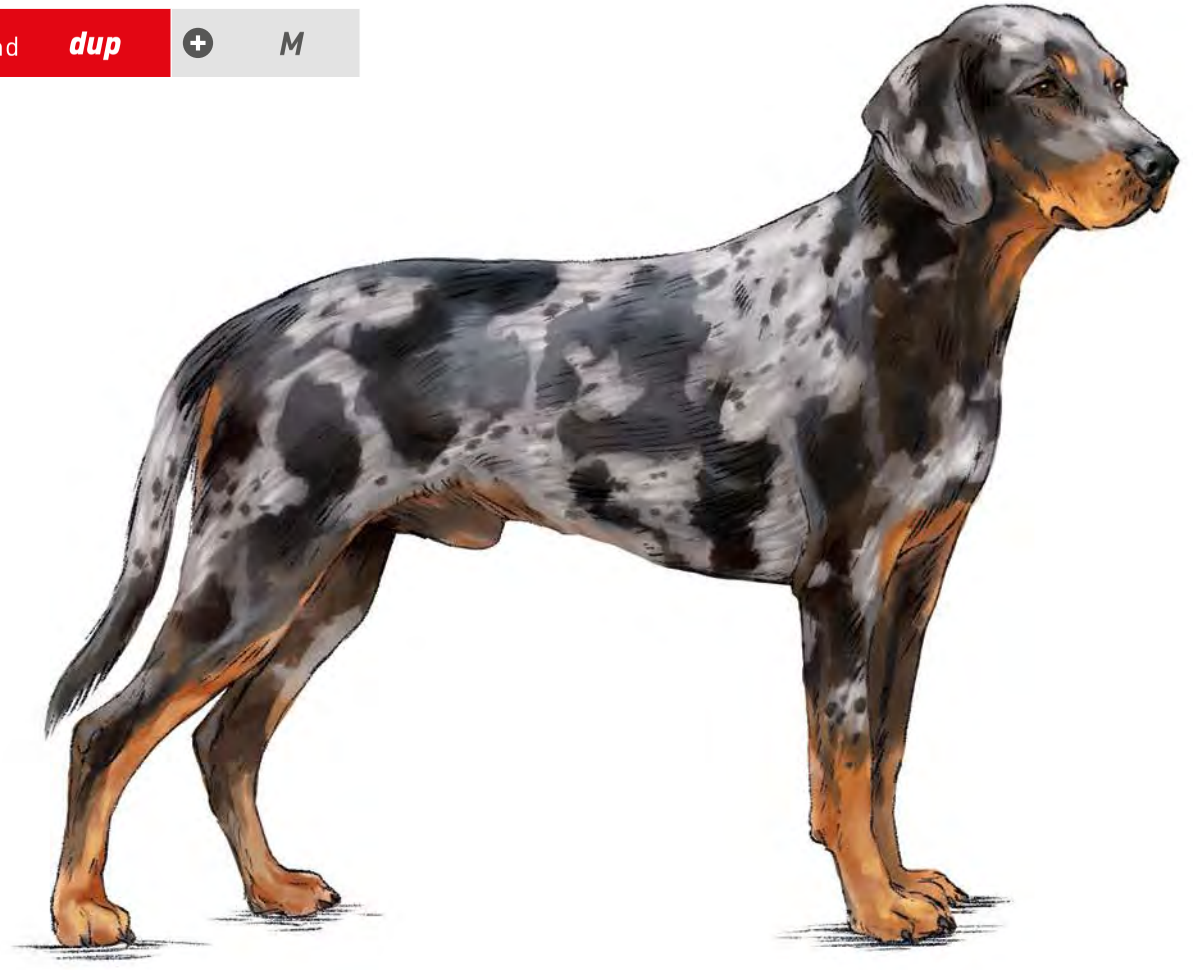
UNDERSTANDING COATS
STEP BY STEP

> BLACK WITH FAWN MARKINGS
> BLUE MERLE WITH FAWN MARKINGS
> BLUE MERLE WITH FAWN MARKINGS AND WHITE SPOTTING

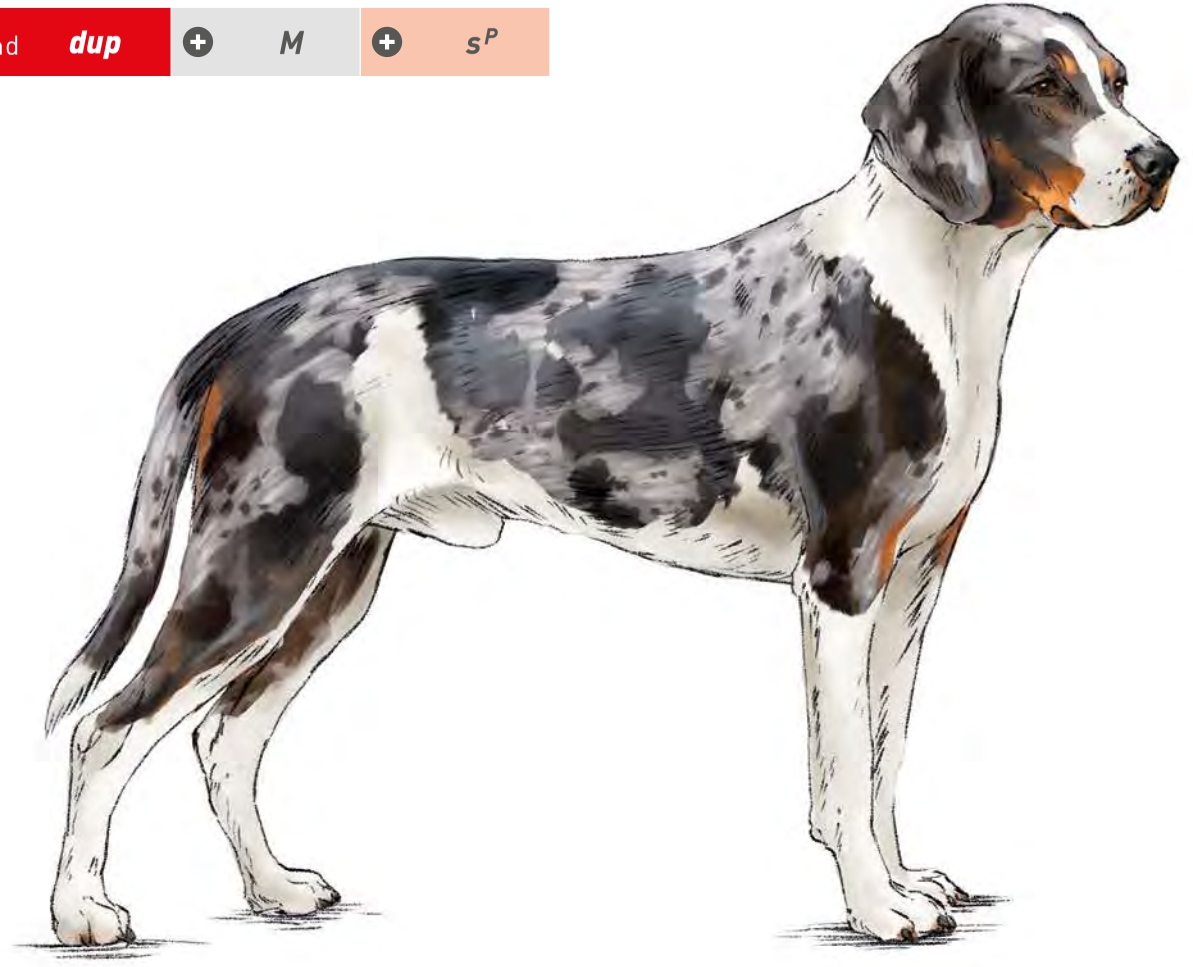
Major allele	*A* locus		*RALY* locus	*M* locus		*S* locus	
Black with fawn markings	a^t	and	***dup***				
Blue merle with fawn markings	a^t	and	***dup***	⊕	***M***		
Blue merle with fawn markings and white spotting	a^t	and	***dup***	⊕	***M***	⊕	s^P

a [t] and ***dup***

a^t and ***dup*** ⊕ *M*



a^t and ***dup*** ⊕ *M* ⊕ s^P

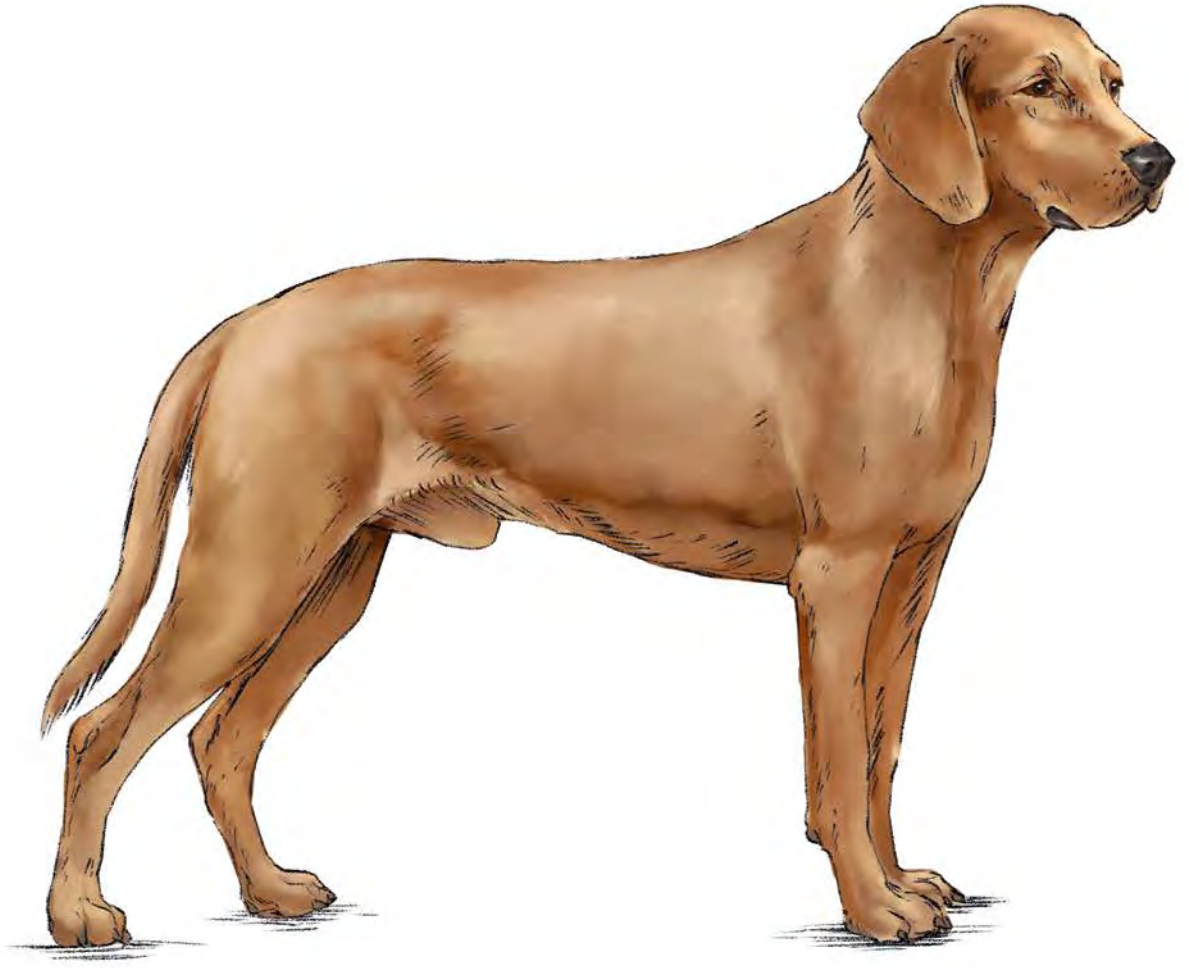


UNDERSTANDING COATS
STEP BY STEP

> FAWN
> FAWN BRINDLE
> FAWN BRINDLE, WITH WHITE SPOTTING AND TICKING

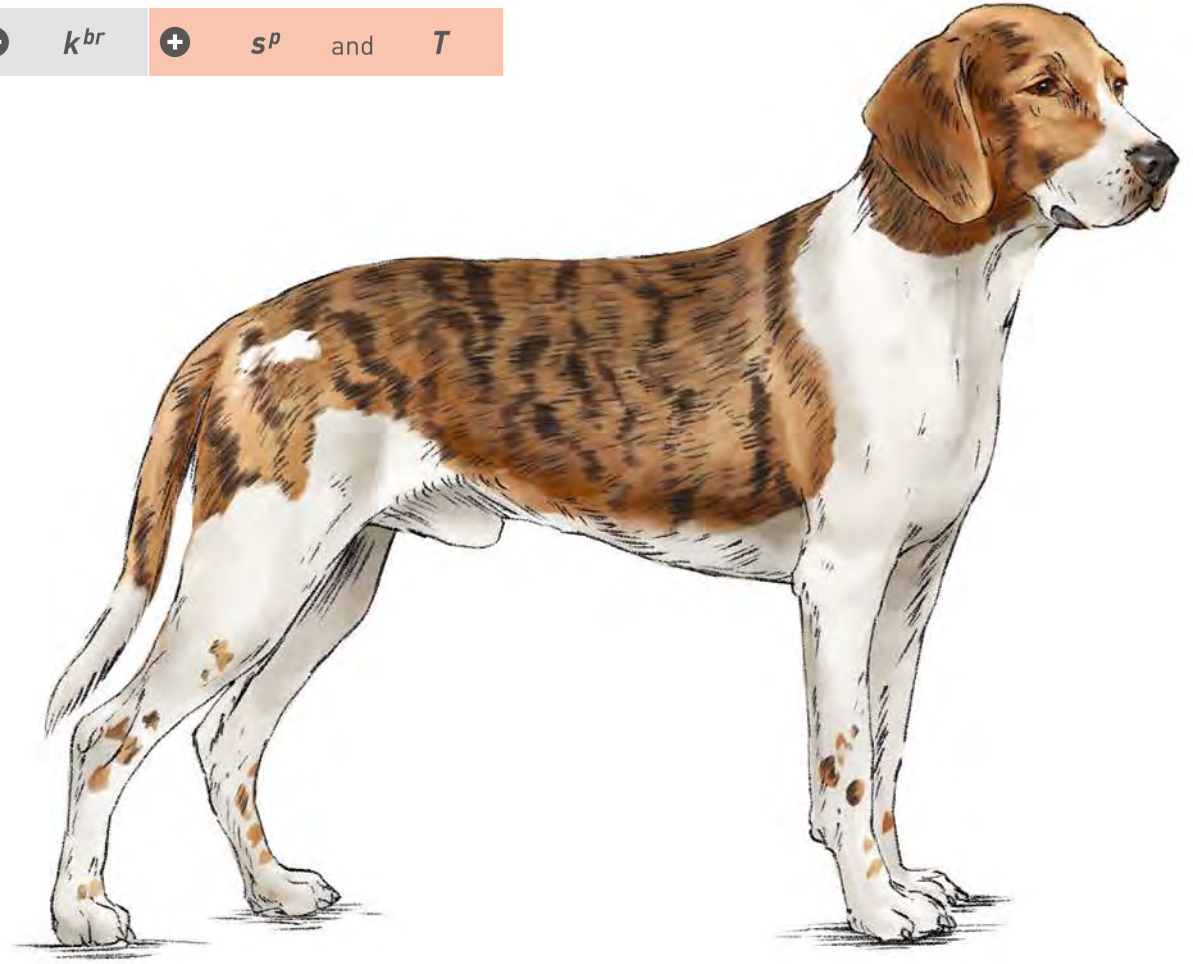
Major allele	*A* locus	*K* locus	*S* locus	*T* locus
Fawn	A^y			
Fawn brindle	A^y	⊕ k^{br}		
Fawn brindle, with white spotting and ticking	A^y	⊕ k^{br}	⊕ s^p	and T

Ay



A^{y} ⊕ k^{br}

A^{y} ⊕ k^{br} ⊕ s^{p} and T



FROM LOCUS TO COAT

SOLID-COLOURED COATS

SOLID-COLOURED COATS

As expected from their name, solid-coloured coats are one colour. They contain only one pigment, dark or pale, or none at all. We therefore distinguish three types: dark, pale or white coats.

DARK COATS

The hairs contain eumelanin: they are black or brown if the pigment is not diluted, and blue or beige if it is diluted.

Black coat

Brown coat

Beige coat

Blue coat

PALE COATS

The hairs contain phaeomelanin; they are fawn if the pigment is not diluted and sand if diluted. There is an enormous variety of shades in fawn or sand coats.

Sand coat

Light fawn coat

Red fawn coat

WHITE COATS

The hairs contain no pigment.

White coat

BLACK
COAT

B

K

Main associated loci and genotypes

B locus	$B^{+}/-$
K locus	$K^{B}/-$

Definition

The hair is black from the root to the tip, without any real lightening of the colour.
The nose is also black.

Comments

At first glance, some coats appear to be black, but a thorough examination reveals that it is not a true black and that the hairs are banded. In reality, this is a fawn coat with a complete black overlay (agouti).

A heavily brindled fawn also gives rise to confusion sometimes.

In some breeds, the black coat is not dominant (K^{B} allele), but recessive and due to the *A* locus, and more specifically the *a/a* genotype.

BREEDS DEMONSTRATING THE COAT

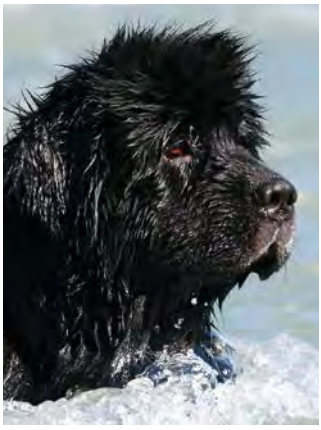
Scottish Terrier, Schnauzer, Belgian Shepherd Groenendael, Newfoundland, Barbet, German Spitz, Great Dane, Pug, Puli, Poodle, Curly-coated Retriever, Labrador Retriever, Affenpinscher.

Puli

© Duhayer / Royal Canin

© Duhayer / Royal Canin

Giant Schnauzer



© Grosserny

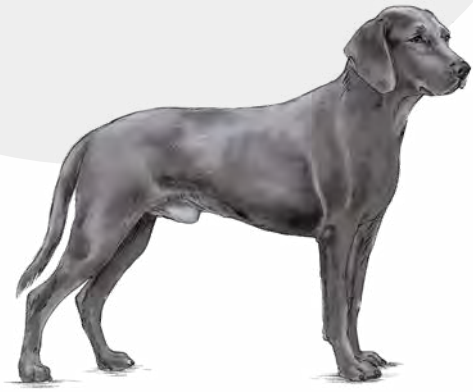
Newfoundland

BLUE
COAT

B

K

D



Main associated loci and genotypes

B locus	$B^{+}/-$
K locus	$K^{B}/-$
D locus	***d/d***

BREEDS DEMONSTRATING THE COAT

Chihuahua, Great Dane, Italian Greyhound (sighthound), Whippet, Staffordshire Bull Terrier, Cane Corso.

Definition

The blue coat is obtained though black pigment dilution. It is a grey-blue colour that varies in intensity, and when it becomes darker, it is actually closer to a slate colour. The entire coat and the nose are blue from birth.

Comments

In some breeds, coats are traditionally – and mistakenly – referred to as blue. This means that some can be excluded as being true blue coats:

- coats resulting from a progressive greying of the black (mixture of black and white hairs) in dogs that are black at birth with a black nose. These are in fact grey coats (e.g. Poodle, Kerry Blue Terrier).
- coats in which the blue appearance is actually due to the combination of black and white hairs in spotted areas (ticking, mixed white). These are modified coats (e.g. Auvergne Pointer, Great Gascony Blue, Australian Cattle Dog).

Coat-linked risks

Blue coats are often associated with colour dilution alopecia. The genetic explanation (linked to the *D* locus) is still uncertain, as some dogs with a diluted coat do not have the problem, whereas it can be observed in dogs without a diluted coat.

© Grosseny

Italian Greyhound (sighthound)

© Coline Derin

Cane Corso

BROWN
COAT
- Liver or chocolate -

B

K

Main associated loci and genotypes

B locus	***b/b***
K locus	$K^B/-$

Definition

The brown coat is composed of solid brown hair. The dog's nose is also brown. This brown colour comes in various shades which can sometimes justify more exact terminology such as dark and light brown. The texture of the coat plays a role, for example, the shade is always paler on long or woolly coats.

Comments

With a brown coat, the iris tends to be lighter than with a black coat. The defect is conventional and must be accepted.

The brown coat is sometimes confused with the fawn coat. If there is any doubt, remember that if the nose is black, the coat must be fawn. However, fawns with brown noses do exist.

In the French Bulldog, brown can be obtained through the effect of the *B* locus as well as the *Cocoa* locus (co-locus).

BREEDS DEMONSTRATING THE COAT

Newfoundland, Poodle, Barbet, Labrador Retriever, Chesapeake Bay Retriever, Flat-coated Retriever, Field Spaniel, Pudelpointer, Sussex Spaniel, German Short-Haired Pointing Dog, German Long-Haired Pointing Dog.

German Long-Haired Pointing Dog

© Radomir Rezny

With a brown coat, the eyes are often lighter, as in this Ⓥ Labrador Retriever.

Retriever du Labrador

© Duhayer / Royal Canin

Field Spaniel

© Duhayer / Royal Canin

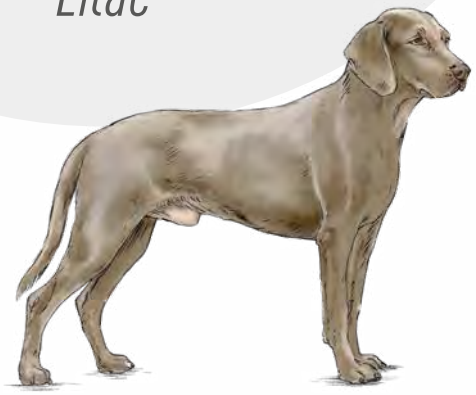
Pudelpointer

BEIGE
COAT
- Lilac -

B

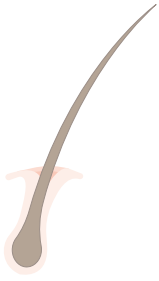
K

D



Main associated loci and genotypes

B locus	***b/b***
K locus	***K^B/-***
D locus	***d/d***



Definition

The beige coat is obtained by dilution of brown. All the hairs and the nose are beige, with the nose appearing closer to pale brown. This coat is rare in dogs. There are a variety of different shades, particularly lilac and silver.

Comments

With a beige coat, the iris is even paler than with a brown coat, sometimes even what is known as “bird of prey”.

The same can be said for blue coats when colour dilution alopecia occurs.

Since beige is rare in dogs, the chance of confusing it with pale fawn or sand is also rare. When in doubt, look at the nose: if the nose is blue or pink, it is a sand coat, if it is beige, the coat is beige.

A beige coat may sometimes be inappropriately described as an Isabella or sand (light fawn) coat due to their very similar colour. But genetically, these are two different coats: the beige coat is due to eumelanin dilution while the Isabella or sand coat gets its colour from phaeomelanin.

BREEDS DEMONSTRATING THE COAT

Weimaraner, Chihuahua, Italian Greyhound (sighthound).

Ⓐ Yellow eyes ("eyes of prey") are quite common in Weimaraners with a beige coat.

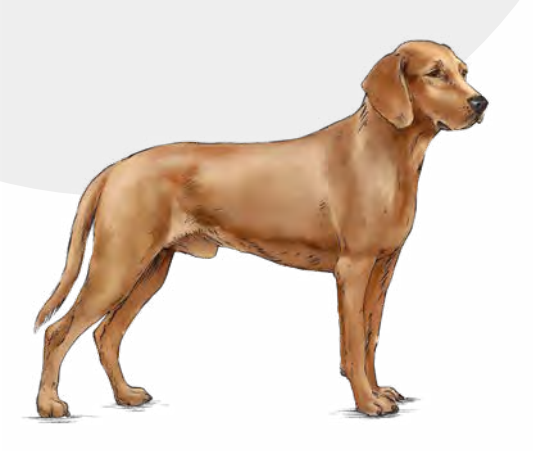
The Weimaraner's beige coat expresses shades that are more visible when comparing long- and short-haired dogs. This dog appears darker than the long-haired Weimaraner on the left. Ⓥ

FAWN COAT

E

K

A



Main associated loci and genotypes

E locus	***e/e***
K locus	k^y/k^y
A locus	$A^y/-$

Definition

The general term "fawn coat" covers all the shades resulting from the hair being coloured by phaeomelanin alone. Because there is so much variety, subclasses (which we will voluntarily limit to four) are useful:

- **Red fawn coat:** a deep, warm shade, close to that of mahogany. The coat is solid red, without becoming paler on the underside of the body. The Irish Red Setter is a particularly notable example.
- **Dark fawn coat:** characterised by a dark colour which, even though it can tend towards red, it never achieves the warm shade of red fawn. It always appears duller, even in short-haired dogs. The coat can be lighter on the underside of the animal, making these regions appear less pronounced in colour.
- **Orange fawn coat:** includes all the intermediate shades of fawn between dark and light. This coat is characterised by an overall golden yellow colour, which explains the very evocative traditional names used to describe such coats (golden, apricot, etc.) encountered in Cocker Spaniels, Brittany Spaniels, King Charles Spaniels, Cavalier King Charles Spaniels, Golden Retrievers, etc. As in the previous case, the coat can be a lighter colour on the underside of the body; these areas can be light fawn.
- **Light fawn coat:** the colour is yellow without any darker shade whatsoever. It is observed in Labrador Retrievers for example.

The nose colour can vary in fawn coats; sometimes it is fawn (seen as reddish), but it can also be black, brown, blue or even beige.

Comments

The different shades, which vary from red to light fawn, could be due to one or more genes.

While the *d/d* genotype can make the coat colour lighter, it would not spontaneously be described as sand. As already seen, the effect of the *D* locus on phaeomelanin is definitely less pronounced than that of *I*; the fawn appears to be duller, rather than diluted. This is why we can speak of fawn with a blue nose even though, in genetic terms, it is sand with a blue nose. This is an example of total disagreement between the nomenclature and genetics. Regardless of whether the same coat is called light fawn by some and sand by others, it is only when breeders wish to perform a genetic analysis that they must consider the possible involvement of the *D* locus.

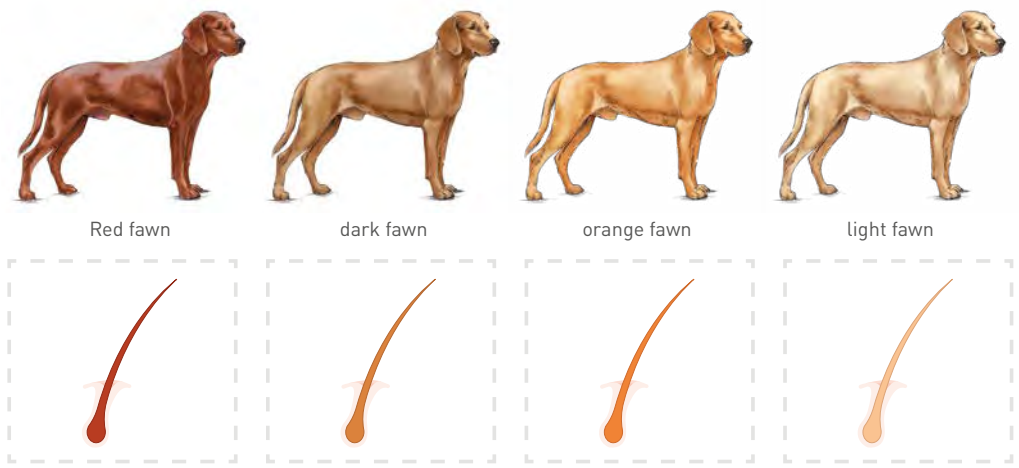
There is one breed which perfectly illustrates this point: the Golden Retriever.

Some of them have a warmly toned fawn coat with a black nose. Others, of which there seem to be many at present, have a slightly lighter fawn colour.

A lighter shade on the underside of the body and extremities is frequently observed in the dark fawn and orange fawn classes at shows.

The lighter areas (which correspond to sand) can often seem well defined, to the point of resembling markings seen on black with fawn markings coats or fawn with mantle (when the saddle is extensive). The description "fawn with sand markings" can even be justified to describe these coats. This description was not retained, but we agree that it is an easy one to invent, showing how amenable the nomenclature is to adaptation. One breed which illustrates this fawn coat with lighter extremities or even "fawn with sand markings" remarkably well is the Akita.

It is probable that an undiscovered special gene is responsible for these sand markings on a fawn coat.



BREEDS DEMONSTRATING THE COAT

Irish Terrier, Irish Red Setter, Chow Chow, Akita, Basset Fauve de Bretagne, English Cocker Spaniel, American Cocker Spaniel, King Charles Spaniel, Golden Retriever, Poodle, Labrador Retriever, Hungarian Short-Haired Pointer (Vizsla).

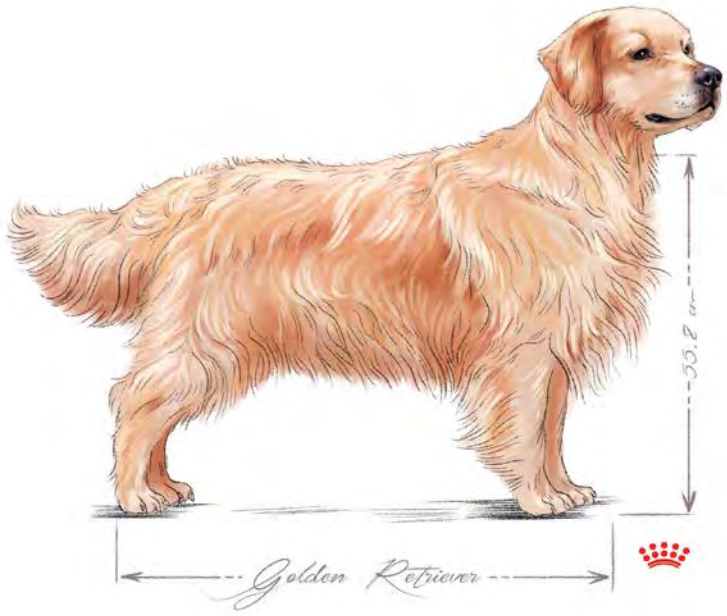
Brief genetics reminder

- Fawn coats with a reddish nose are definitely *e/e*. It is impossible to identify other elements of the genotype with certainty.
- Fawn coats with dark noses can be:
  - either *e/e*, but with incomplete eumelanin inhibition since it is still visible on the nose (the mechanism involved remains unknown);
  - or Ay without the overlay due to a long polygenic selection.

When the nose is dark due to eumelanin, it is possible to complete the genotype for *B* (*B*$^{+}$/- or *b/b*) and *D* (*D*$^{+}$/- or *d/d*).

Ⓐ In the Irish Red Setter, fawn appears more mahogany (red fawn).

Ⓥ The paler shades which are visible on the ears, limbs and topline of this English Cocker Spaniel are caused by a modification of the hair texture on these areas (light fawn coat).

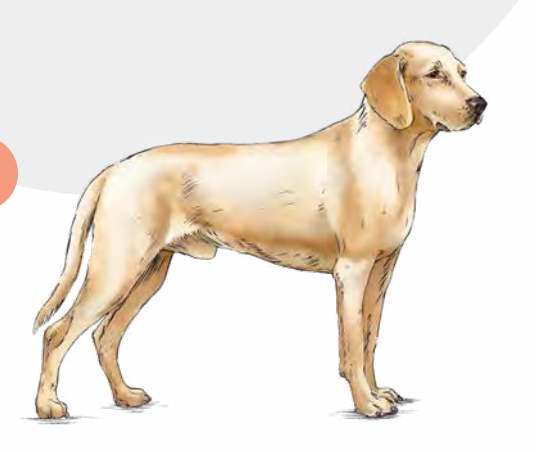


Ⓥ On a wire-haired coat, fawn often appears dull, like on this Irish Terrier.

Ⓐ In the King Charles Spaniel, the fawn coat is traditionally called "ruby".

SAND COAT

E K A I



Main associated loci and genotypes

E locus	***e/e***
K locus	k^Y/k^Y
A locus	$A^y/-$
I locus	***i/i***

NB: the D locus dilutes the base colour. Its very weak effect on phaeomelanin does not make it a main locus for the sand coat.

Definition

Due to dilution, there is a great variety of fawn shades ranging from a cream colour to a whitish colour. All these coats are grouped under the term "sand".

Among the many shades observed, three characteristic shades stand out:

- **Ivory sand coat:** characterised by a bland yellow colouring similar to a light beige (these coats include those traditionally referred to as cream and Isabella).
- **Silver sand coat:** even paler than the ivory coat, it evokes a kind of silver-grey. It is sometimes difficult to distinguish it from the next example.
- **Platinum sand coat:** appears as white with a metallic sheen and is well distinguished from white (massive dilution of phaeomelanin).

Comments

When caused by the effect of the I locus, sand coats always retain a relatively sharp tone.

The polygenic effects also contribute to the differences in shade, as with fawn.

In very pale sand coats, the lightening effect may not be the same over the entire body so that the ears, tail and possibly the topline are a darker, almost fawn shade.

BREEDS DEMONSTRATING THE COAT

Golden Retriever, Labrador Retriever, Bedlington Terrier, Whippet, Chihuahua.

ivory sand

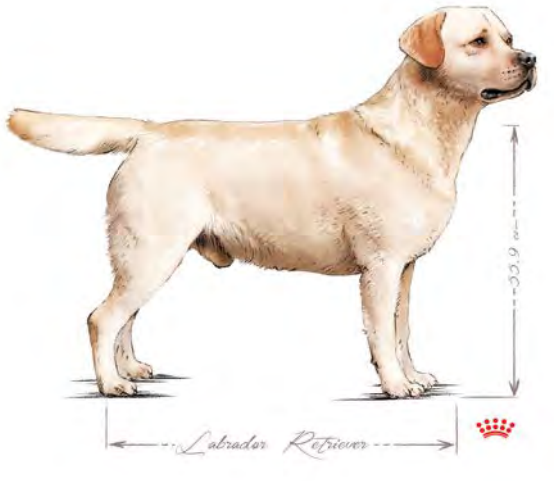
silver sand

platinum sand

Brief genetics reminder

All the information relating to fawn coats is also relevant to sand coats.

If, in certain cases, the effect of *d/d* is enough to produce a relatively dark sand (often confused with fawn, as noted previously), it is usually the effect of I (*i/i* genotype) which has lightened the phaeomelanin. It can be the case that both dilute genes are active.

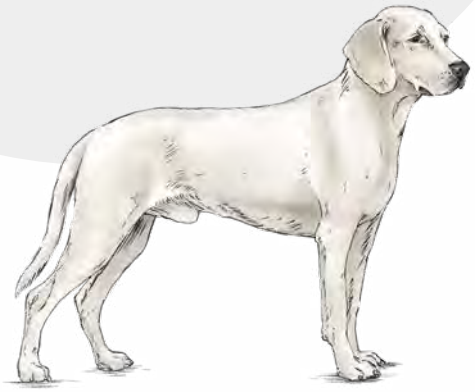


Golden retriever

Traces of colouration are visible on the ears and tip of the tail of this platinum sand Golden Retriever.

WHITE COAT

E I S



Main associated loci and genotypes

E locus	***e/e***
I locus	***i/i***
S locus	s^p/s^p

Definition

The hair appears to be perfectly white without any trace of colour. If there are very limited zones of colour (ears, tail base), which indicates the effect of very invasive white spotting, the coat should not be qualified as white but as "extreme white".

Brief genetics reminder

Most of the time, white is due to the complete action of the *S* locus (it is incomplete when a small amount of colour remains, especially on the ears).

However, in some breeds, the white coat is due to the combined effect of *E* (*e/e*) and *I* (*i/i*), which lighten the phaeomelanin until it becomes white (e.g. White Swiss Shepherd Dog or Samoyed).

In white dogs, skin pigmentation is not well understood.

BREEDS DEMONSTRATING THE COAT

West Highland White Terrier, Kuvasz, Maremma and the Abbruzes Sheepdog, Pyrenean Mountain Dog, Samoyed, Maltese, Coton de Tulear, Dogo Argentino, Bichon Frisé, White Swiss Shepherd Dog, Tatra Shepherd Dog, Poodle.

Coton de Tulear

Did you know?

BROWN COLOURATION: MANY UNKNOWNS.

In white dogs, it is not uncommon to see a brown colouration around the eyes or mouth. It is assumed that this common phenomenon is due to an overgrowth of chromogenic yeast (Malassezia) in the warm, moist areas of the animal's body. This is why these brown marks are found at the corners of the eyes, corners of the mouth or between the toes. Once the brownish colour has set in, it does not fade away. The hair will only be white when it grows in again.

Another possibility could be the interaction of the hair with tears or saliva, which contain coloured compounds called porphyrins.

It is unlikely that this phenomenon is directly related to diet and there is no evidence of this link. It is more likely due to a natural process of porphyrin excretion.

Comments

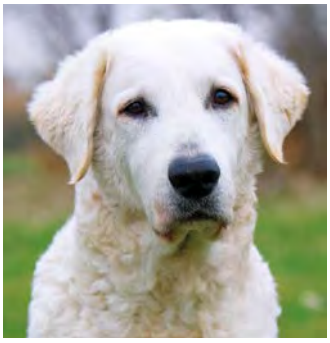
When the white is caused by extensive spotting, it is difficult to obtain white dogs with perfectly pigmented noses and eyelids through selection (as breeders have to work with polygenic modifiers). The effect of the *S* locus tends to extend towards the mucosa. Of course, white dogs with properly pigmented eyelids and nose do exist. The problem does not arise with white coats due to the combined effect of *E* and *I*. The term "flesh-coloured" is used in the dog world for the nose and eyelids, but the depigmentation also occurs on the anogenital mucosa and in the mouth.

In dogs with a white coat due to extensive spotting (effect of *S*), a predisposition to deafness has been demonstrated. This does not apply to white coats due to *E* and *I*. The two types of white coats do not have the same biological origin: extensive spotting is caused by an absence of pigment cells (melanocytes), whereas white coats due to *E* and I are due to pigment synthesis by melanocytes which are indeed present.

Pyrenean Mountain Dog

White Swiss Shepherd Dog

Tatra Shepherd Dog



Kuvasz

Samoyed

3

FROM LOCUS TO COAT

MIXED COATS

MIXED COATS

Mixed coats contain two pigments, dark and pale; white is totally absent. This means they are bi-pigmented and not bi-coloured. Depending on how the eumelanin and the phaeomelanin are distributed, we can identify five coat types.

FAWN (OR SAND) MASKED

This coat is fawn (or fawn with black overlay or sand) with a black mask, which covers the face to a varying degree. It should be noted that masks, which are very common in dogs, can also be present in any of the following four coat colours.

FAWN (OR SAND) WITH BLACK OVERLAY

This coat is characterised by the presence of bi-coloured hairs (called banded or agouti) or fawn (or sand) and black hairs. The degree of dark pigmentation can vary considerably, resulting in coats ranging from almost fawn to blackish and anywhere in between, including the typical wolf coat, which is a sand with a heavy dark overlay. This coat, often called "wolf-grey", corresponds to the wild phenotype. The abdomen and the inside of the legs usually appear lighter.

Comments

For all these coats, the fawn may be replaced by sand, and the black may be brown, blue, or beige, with many different combinations possible.

Examples: fawn with brown overlay, sand with blue brindle, beige with sand markings (very rare).

FAWN (OR SAND) **BRINDLE**

The eumelanin condenses into vertical stripes called brindling. The degree of brindling varies and can even appear black if sufficiently extensive.

BLACK WITH FAWN MARKINGS AND VARIATIONS

- Black and tan -

This very familiar coat corresponds to the "black and tan" found in traditional nomenclatures. The tan (fawn) or sand markings are found on the extremities.

FAWN WITH MANTLE (OR SAND) AND VARIATIONS

- Saddle tan -

In the case of a fawn with mantle, eumelanin is (much) less invasive than in the previous example, and is sometimes limited to just a saddle-shaped pattern, hence the traditional term "saddle tan". The hairs of the saddle pattern may be banded, in which case the coat can be called fawn with black overlay mantle.

FAWN (OR SAND) MASKED

E

Main associated loci and genotypes

E locus | $E^{M}/-$

Definition

The fawn masked coat is a completely fawn coat with a mask which is more or less spread over the face.

Careful examination will also often reveal the presence of sparse dark hairs along the topline, on the tail and even on the fore chest.

Fawn masked implies a black mask, but a brown mask is also possible. Genetically, the fawn coat can only be masked with a black or brown mask. Similarly, sand coats can only be masked with a blue or beige mask (dilution). For example, it is not genetically possible to have a sand coat with a black or brown mask.

The nose is the same colour as the mask.

Comments

In case of doubt, there is no need to spend much time deciding between a fawn (or sand) masked and a fawn (or sand) with a slight black overlay and mask. Roughly speaking, they are the same coat type.

BREEDS DEMONSTRATING THE COAT

Belgian Shepherd Dog (Malinois or Tervueren), Bullmastiff, Dogue de Bordeaux, Pug, Sloughi, Shar Pei.

Brief genetics reminder

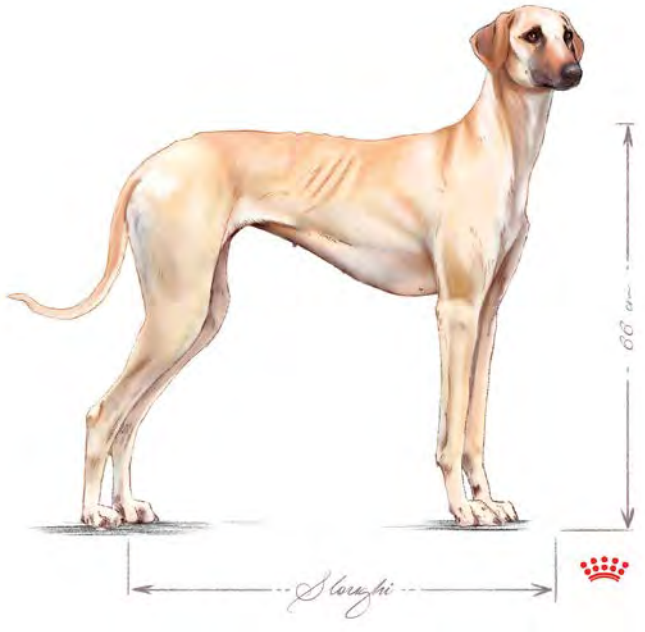
The colour of the mask is produced by the same loci which determine black, brown, blue, and beige.

© Labat/Rouquette

Majorca Mastiff

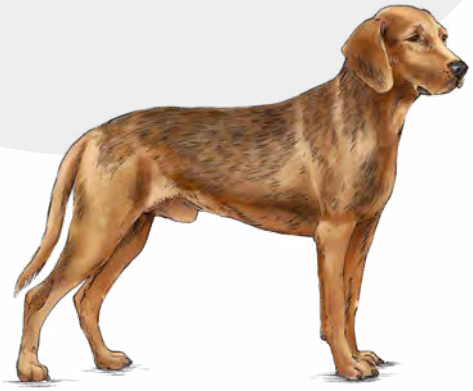
© Grossemy

In the Dogue de Bordeaux, the mask is often brown.



FAWN (OR SAND) WITH BLACK OVERLAY

A ***k***



Main associated loci and genotypes

A locus	$A^y/-$
k locus	k^y/k^y

BREEDS DEMONSTRATING THE COAT

Leonberger, Belgian Shepherd Dog (Malinois or Tervueren), Picardy Shepherd, Griffon Bruxellois, Schnauzer, Dogue de Bordeaux, Mastiff, Whippet, Italian Greyhound (sighthound), German Spitz, Czechoslovakian Wolfdog.

Definition

Fawn with black overlay is characterised by its bi-coloured hairs, often fawn at the root and dark on the tips, along with some black hairs. This coat type is extremely variable depending on the abundance of the overlay (from slight to entirely black). This depends on the width of the dark band on the hair, the latter being subject to variation depending on the part of the body. The fawn (or sand) with overlay (i.e. with black overlay) is the most common coat in the canine species.

When the black pigment is replaced by brown, the result is *fawn with brown overlay,* which is quite rare but possible in the Dogue de Bordeaux.

Similarly, the sand with blue overlay coat can be observed in the Whippet due to the effect of the dilution locus on the eumelanin. The fawn colour often gives way to sand, mainly due to the effect of the I locus on the phaeomelanin, which produces sand with overlay (black, brown, blue or beige).

All of these coats express the same degree of overlay extension as those already mentioned.

Very often dogs with a fawn with black overlay or the sand with overlay coat are also masked. The nose is the same colour as the overlay (and the mask when it exists).

Comments

A fawn coat with a very light overlay can understandably be mistaken at first glance for a fawn coat due to the presence of only a few black hairs on the ears.

However, in the case of a fawn or sand coat with a heavy overlay, it is important to check for the presence of agouti hairs before classifying it as "roughly" black or blue (a situation encountered, for example, in the Italian Greyhound).

Picardy Shepherd

Fawn Cane Corso with blue overlay (and blue mask).

The fawn (or sand) with overlay (i.e. with black overlay) is the most common coat in the canine species. Many breeds display this coat, often with a mask. Examples of those with a uniformly coloured coat include the Leonberger and Belgian Shepherd Dog (Tervueren and Malinois). In Leonbergers, the intensity of the overlay is highly variable.

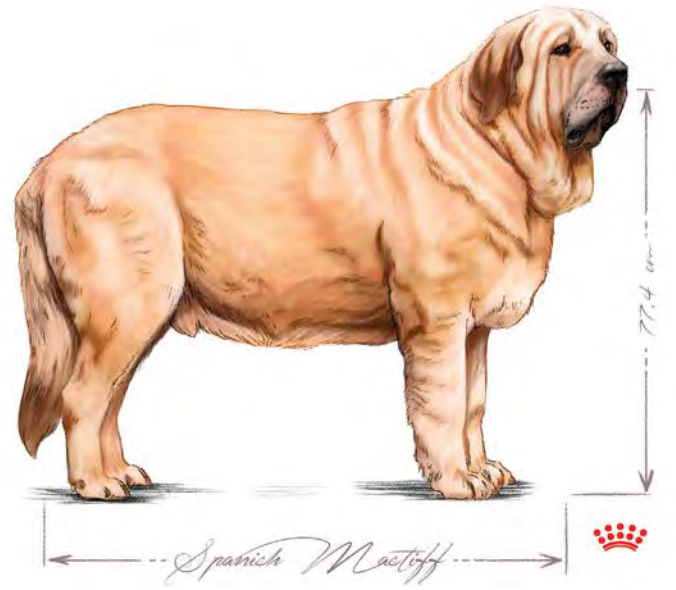
The appearance of the overlay differs depending on the hair texture and length, as in these Dachshunds.

Griffon bruxellois

© Français/Cogis

In salt and pepper Schnauzers, all the hairs are agouti but the pale bands remain larger compared to the black bands. The coat can also be described as sand with very heavy overlay, sand with complete black overlay or pale agouti.

The wild wolf-grey coat is a sand or sand with heavy overlay coat. The hairs are agouti, not grey.



FAWN (OR SAND) **BRINDLE**

K

A

Main associated loci and genotypes

K locus	$k^{br}/-$
A locus	$A^{y}/-$

Definition

The fawn (or sand) brindle coat is characterised by dark vertical stripes, called brindling, on a pale base colour. Brindling is normally black but can also be brown, blue, or beige. The degree of brindling varies from light brindle (fine, widely spaced stripes) to heavy brindle (broad, very dense stripes, minimising the fawn or sandy areas).

The stripes can sometimes even run into one another (very heavily brindled coat) to give the appearance of a dark, solid coat, but careful examination will reveal signs of pale pigment here and there.

The nose is the same colour as the dark pigment in the coat. Brindle coats can also be masked.

BREEDS DEMONSTRATING THE COAT

Mastiff, Boxer, Dutch Shepherd Dog, Greyhound, Neapolitan Mastiff, Kai, Presa Canario, Saint Miguel Cattle Dog, Spanish Greyhound, Boston Terrier.

Saint Miguel Cattle Dog

Comments

Brindling is always distinct on smooth coats. It is difficult to identify on wire-haired coats and long coats (unless the head and the front of the limbs have a short coat, in which case the identification is made on these areas).

The rare sand with blue brindling coat is common in Neapolitan Mastiffs.

Dutch Shepherd Dog

Very heavily brindled coat or solid-coloured coat?

Very heavily brindled coats are often considered solid-coloured coats. From a strictly descriptive point of view, this is not a major mistake, because it corresponds to what we see spontaneously without careful examination.

However, it does prevent correct interpretation and planning with regard to genetics.

Sand brindle in a Spanish Mastiff.

Boston Terrier

© Simon/Cogis

Whippet

These Boxers display two types of brindling, with the one on the right showing spreading to point of being nearly solid.

BLACK FAWN (OR SAND) MARKINGS AND VARIATIONS

- Black and tan -

A

RALY

Main associated loci and genotypes

A locus	a^t/a^t
RALY locus	***dup/dup***

REEDS DEMONSTRATING THE COAT

Beauceron, Rottweiler, Bloodhound, Gordon Setter, Dobermann, German Hunting Terrier, Dachshund, Polish Hunting Dog, Manchester Terrier, Lakeland Terrier, Prague Ratter, Lancashire Heeler, Tibetan Mastiff, Hovawart, Slovakian Hound, Chihuahua, Finnish Lapponian Dog, Schnauzer.

Definition

The black with fawn markings coat results from fawn/tan (or sand) markings with a black base colour. These markings are distinctly located on the extremities: mouth, lips, cheeks, upper eyelids, throat, two marks on the fore chest, feet, front of the thighs, ischial tuberosity and anus. These markings are always at the same place but can spread somewhat depending on the breed.

Black can be replaced by brown, blue, or beige, and the fawn by sand.

All four dark coat types existed in the Dobermann, including the rare beige with sand points (which was called Isabella), but blue and beige coats were banned in this breed because of the risk of developing colour dilution alopecia.

Sometimes fawn markings can be seen at the extremities on a fawn with black overlay coat, producing the fawn with black overlay and fawn markings which is well-known, for example, in wire-haired Dachshunds.

Fawn with overlay and fawn markings

Comments

Black with fawn markings
Dogs with this coat are sometimes described as having "eyebrows", which are actually called "pips", because of the fawn dots over their eyes. In the Beauceron, the term "Bas-Rouge" (which means "red stockings" in French) was used to describe dogs with this coat.

Black with sand markings
In the hunting community there are breeds in which "pale tan" is sought after. This expression is a way of describing black with sand markings.

Black with brindle fawn markings
It happens, albeit rarely, that fawn (or sand) markings are brindle and thus the coat could be described, for example, as black with brindle fawn markings.

Black with fawn black overlay markings
The fawn markings may also have an overlay, especially on the forelimbs. The presence of this overlay, often considered undesirable, is no doubt due to polygenetic influence and can only be eradicated progressively.

Black with fawn markings, masked
Finally, masks can be associated with this coat. This can be identified due to the fact that the muzzle is entirely dark.

Brief genetics reminder

***A* locus – a^t allele**
Any coat with fawn markings is due to the effect of the a^t/a^t genotype on the black, brown, blue, and beige colours. Classically, the fawn with black overlay and fawn markings is associated with the A^y/a^t genotype, with incomplete dominance of A^y over a^t. This is sometimes seen in the Shetland Sheepdog. According to this interpretation, the coat cannot be pre-determined, but this does not appear to apply to all situations.

German Hunting Terrier

Ⓐ In the Chihuahua, all colours are allowed (except merle). Here, from left to right, the coat colours are: black with sand markings, brown with fawn markings and spotting, and blue with sand markings.

Polish Hunting Dog

This Finnish Lapponian Dog is brown with sand markings.

This long-haired Dachshund has a blue merle coat with fawn markings.

This Schnauzer's coat is black with sand markings.

FAWN (OR SAND) WITH MANTLE AND VARIATIONS

- Saddle tan -

A

RALY

Main associated loci and genotypes

A locus	a^t/a^t
RALY locus	***+/-***

BREEDS DEMONSTRATING THE COAT

German Shepherd, Bloodhound, Welsh Terrier, Airedale Terrier, Lakeland Terrier, Schiller Hound, Yorkshire Terrier.

Definition

The fawn (or sand) with mantle coat has less eumelanin extension than the previous coat. The result can vary as different phases can be observed between a large black area that extends over the forehead, topline, sides of the body and a small saddle pattern.

The mantle can be black, brown, blue, or even beige and the fawn colour may be replaced by sand (e.g. brown and fawn, blue and sand).

The mantle sometimes appears to be a solid colour and sometimes to have an overlay but, even in the first case, the hairs are often bi-coloured, with a dark band along the tip.

This coat is sometimes masked.

Comments

Black with fawn markings or fawn with mantle?
There can be some hesitation when determining if a coat is black with fawn markings or fawn with mantle because the distal phaeomelanin markings remain quite distinct but very spread out. In this case, the decision is a matter of subjective judgement.

These two Bloodhounds have eumelanin mantles of different sizes. The first has a smaller mantle with overlay (the hairs are agouti) and the second has a mantle that extends from the head to the base of the tail.

© Français

Like the Bloodhound above, this Lakeland Terrier has a very small mantle with overlay.

Schiller Hound

The eumelanin mantle on this Bloodhound is brown, which can also be confirmed by the colour of its nose.
This dog has a fawn coat with a brown mantle.

Contrary to widespread belief, the pale zones are not white (even if they appear as such), but a very pale sand. To be convinced, one only needs to note the way the white spotting extends over the body (see "Spotted coats"). However, white spotting may also be present on this coat but go unnoticed. Nevertheless, a careful examination will reveal the presence of white at the end of the tail.

Ⓥ Sand with back overlay mantle in an Alaskan Malamute.

Ⓐ Sand coat with brown mantle in a Siberian Husky.

3

FROM LOCUS TO COAT **MODIFIED COATS**

MODIFIED COATS

The base coat (whether single or double) can be identified, but it has undergone a modification which has changed the appearance. Three actions could be responsible for this: greying, merle, and spotting.

GREYING COATS

The base coat is normal at birth and during the first weeks before it becomes interspersed with white hairs to various degrees which are sometimes significant. The coat may be **grey** (a mixture of black and white hairs), **beige-grey** (a mixture of brown and white) or **red-roan** (a mixture of fawn and white). In reality, all coats are subject to greying. It is obviously not possible to invent a special name for each case encountered. To denote the existence of grey, it is easier to add greying to the description of the coat.

Examples: *greying fawn with black overlay or greying sand with blue mantle.*

MERLE COATS

Merle coats are also traditionally called *harlequin* in some breeds. Only the dark areas (due to eumelanin) of the coat can have a merle colour pattern. Merle coats are characterised by the presence of dark patches which are normally pigmented but of a ragged, splashed appearance on a pale base colour (diluted and/or greying) or even white.

WHITE SPOTTED COATS

White spotted coats are characterised by patches of white, which vary in degree and distribution. They can be found on any of the colour patterns discussed so far. Spotting runs the gamut from very **limited spotting** (a small white patch on the chest and, possibly, discrete white markings on the toes) to **very invasive spotting** (colour is found only on the ears and sometimes at the base of the tail), with a range of possible variations between these two extremes (limited, moderate and invasive spotting).

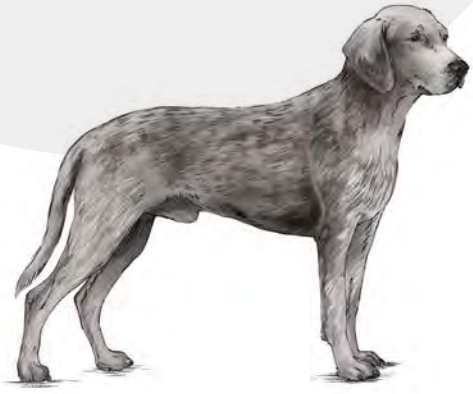
Depending on the degree of white spotting, coats could be described as "fawn with mantle, **with white spotting**" or "sand with blue brindle, **with white spotting.** The chosen description always indicates the base colour first then the degree of white spotting.

White spotting may be **ticked** (small coloured spots called blotches), **roan** (mixture of white and coloured hairs) or show **skin markings** (small spots of pigmented skin over which the hair remains white).

The degree of this type of colouring may be described as *brown, with invasive white spotting, light ticking, heavy mixed white with fawn markings* or *black, with invasive white spotting and skin markings.*

GREYING
COAT

G



Main associated loci and genotypes

G locus | ***G/-***

BREEDS DEMONSTRATING THE COAT

Poodle, Skye Terrier, Dutch Schapendoes, Picardy Shepherd, Yorkshire Terrier, Bearded Collie, Deerhound, Irish Wolfhound, Bouvier des Ardennes.

Definition

A grey coat is comprised of closely intermingled black hairs and white hairs.

It is preferable to limit the term "blue" to the solid coat previously described: an animal born blue and with both a blue coat and blue nose. An animal with a grey coat is born black and becomes grey with age, while the nose remains black.

Similarly, it would be advisable to avoid calling coats grey that actually fall into other categories:

The iron-grey on the Scottish Terrier is in fact a sand brindle, while the iron-grey on the German Shepherd is a sand with black overlay (see the corresponding section).

The grey coat **evolves gradually,** changing its appearance with time, especially when dogs are young. The greying intensity and the rate at which it is expressed varies from one individual to another. The process also appears to occur in two different ways: **centrifugal** (from the body towards the extremities) or **centripetal** (from the extremities towards the body).

Beige-grey and red-roan coats are granted a special description, even though they are not at all common.

In the first instance, it is a brown coat which becomes grey and in the second, a fawn coat. It is likely quite difficult to recognise greying on a sand coat.

Comments

Any coat is capable of greying, but apart from breeds having grey in their standards, this factor is not generally desirable. Therefore, no polygenetic selection was used to accentuate the degree of greying and it can remain relatively discreet. Breeders do notice that coats lighten with age, but they do not necessarily associate this with the greying gene. Often the greying appearance is deliberately ignored and the description of the base coat is kept.

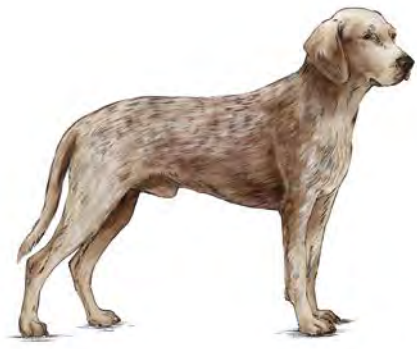
On a **greying fawn with mantle,** the process is, of course, much more distinct on the black mantle area than on the fawn areas. Thus, the Yorkshire Terrier is born with a fawn with mantle coat that is later described as fawn with grey saddle, overlooking the fact that the fawn has become lighter. In reality, it is a **red-roan with a grey mantle** or a **greying fawn with mantle** as the greying gene acts on the entire coat. As a side note, it is clear that the new nomenclature is very adaptable.

Bearded collie

Brief genetics reminder

***G* locus – *G* allele**

A grey, beige-grey, or red-roan dog has the alleles for black, brown, or fawn, respectively, plus thet *G* greying allele. The effect of the *G* G locus is not as pronounced depending on the combination of the *G* and g^+ alleles:
in heterozygous *G/g*$^+$, greying is less clear and comes in later than in homozygous *G/G*.



The first example is a brown coat which becomes grey and the second is a fawn brindle.

Beige-grey or red-roan can be seen in Poodles when the *G* allele has been introduced by inadvisable mating with dogs with a greying coat. They are not usually identified as such and are instead considered as an unsatisfactory brown or apricot fawn.

Skye terrier

In Yorkshire Terriers, the greying allele affects the entire body, with a coat that should be described as *red-roan with grey mantle.* It could just as well be described as *greying fawn with mantle.*

The greying gene can affect any coat. Depending on the extent of the overlay, the coat may be described as *greying fawn with slight overlay or red-roan,* as on this Bouvier des Ardennes.

The degree of greying varies according to the breed.
It is not very pronounced in the Picardy Shepherd, so the animal remains dark.

MERLE
COAT

M

H

Main associated loci and genotypes

M locus	***M/m⁺***
H locus	***h⁺/h⁺*** or ***H/h⁺***

BREEDS DEMONSTRATING THE COAT

Rough Collie, Welsh Corgi Cardigan, Great Dane, Longhaired Pyrenean Sheepdog, Australian Shepherd, Shetland Sheepdog, Norwegian Hound, Chihuahua, Miniature American Shepherd.

Definition

The merle coat (also *harlequin*) is characterised by the presence of ragged-looking spots randomly distributed over the animal's body.

The spots are always a deeper colour (non-diluted pigment) than the base colour, which is a dilution of the same pigment (black patches on blue or brown patches on beige).

The base colour may also be entirely or partially grey instead of blue, but to avoid complicating the terminology, it is not necessary to take this into account.

The most common coat patterns are:

- **blue merle** (blue base colour, black spots, black nose);
- **beige merle** (beige base colour, brown spots, brown nose);
- **white merle** (totally or mostly white base colour, dark patches which are often black or brown).

The sand merle (fawn spots on a sand base colour) is very difficult to identify in adulthood because the merle pattern fades as the puppy grows.

Comments

These coats also frequently have fawn or sand markings; we therefore refer to blue merle with fawn markings.

In harlequin Great Danes, the base coat could have lightened to the point of becoming white. Even if some small areas remain blue, we will limit ourselves to the description of white merle.

China eyes are often observed with merle coats. It is possible that a white merle also carries a white spotting gene in its genotype.

The merle coat is typical in the Harlequin Great Dane, which has many irregular black spots on a white base coat. The dog is a white merle.

Brief genetics reminder

Classically, the merle coat is due to the action of the *M/m*$^{+}$ *genotype*.

The *M/m*$^{+}$ genotype has a very clear effect on eumelanin (blue merle, beige merle) and a much more subtle effect on phaeomelanin (only visible in puppies).

The *M/M* genotype is unfavourable (microphthalmia, deafness).
Mating two *M/m*$^{+}$ merle dogs is therefore highly inadvisable.

The white merle colour (harlequin) is due to the action of an *M* modifier gene located at the *H* locus. The *H/H* genotype is lethal. Harlequin dogs must therefore be *M/m*$^{+}$ and *H/h*$^{+}$.

On this Australian Shepherd, the merle gene is acting on a brown coat with fawn markings, producing a *beige merle with fawn markings* and white spotting.

On this Shetland Sheepdog, the merle gene is acting on a black coat with fawn markings. Here, the fawn markings are not visible on the front legs because the white spotting has spread to the feet.

WHITE SPOTTED COAT

S

Main associated loci and genotypes

S locus | s^p/s^p or s^p/S^+

BREEDS DEMONSTRATING THE COAT

Boxer, Rough Collie, Pyrenean Mountain Dog, Great Gascony Blue, Tornjak, Australian Cattle Dog, Istrian Wire-haired Hound, Picardy Spaniel, Azawakh, Bernese Mountain Dog, Irish Red and White Setter.

Definition

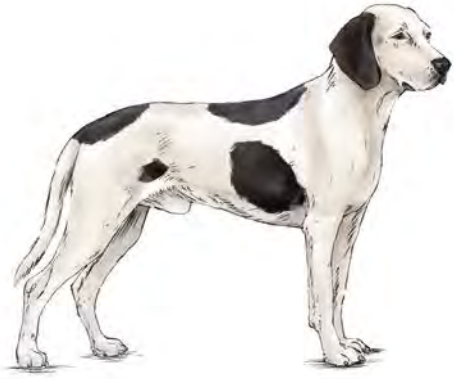
White spotted coats are characterised by patches of white, which vary in degree and distribution. Classically, there are three main groups depending on the size of the white patches:

- coats with **limited white spotting:** the base colour is dominated by the initial colour, which in turn simply carries white markings;
- coats with **moderate white spotting:** coloured and white patches are more or less equally distributed;
- coats with **invasive white spotting:** the dominant colour is distinctly white.

Among these different modifications is **Irish spotting,** characterised by a white collar, often extending over the chest, a blaze, and white markings at the bottom of the legs and tail.

Limited white spotting

Moderate white spotting



Invasive white spotting

Comments

In many solid-coloured breeds we are often obliged to accept subjects with very slight white markings (very limited spotting).

Moreover, it is common that, in a given breed, different types of white spotting coexist. White spotting is always invasive in the Pyrenean Mountain Dog.

Brief genetics reminder

In some breeds, white spotting is transmitted recessively: only homozygous individuals show white spotting.

In other breeds (Boxer, Bull Terrier), white spotting has a semi-dominance inheritance pattern: heterozygous s^p/S^+ dogs have limited to moderate white spotting and homozygous s^p/s^p dogs have invasive white spotting.

The s^i allele (Irish spotting) would produce limited white spotting (typical in the Bernese Mountain Dog) while the s^w allele would produce invasive spotting. However, the existence of these two alleles has never been proven from a molecular point of view. It is also possible that another spotting locus, distinct from *S*, determines Irish spotting.

COATS WITH LIMITED WHITE SPOTTING

The coat only has white spots on the extremities or surrounding areas. Minimum spreading is represented by a small tuft of white hairs on the forechest. In the case of maximum spreading, the spotting is characterised by white patches on the limbs, chest, abdomen, neck, and head, with a blaze.

The presence of a collar indicates an extreme spreading of this type of spotting.

To sum up, the **white patches are always limited** with the major part of the coat being coloured. All the following coats display limited white spotting: from the most subtle to almost moderate white spotting.

Broholmer

Canaan dog

Appenzeller Sennenhund

COATS WITH MODERATE WHITE SPOTTING

White extends over the entire body of the animal, with colour persisting in patches which are irregular in size, shape, and number. Because of the extensive surface covered by the white spotting, at first glance one could say that there are equal amounts of coloured and white parts. This white spotting pattern is therefore a transition between coats with distinct dominant colour and those with distinct dominant white.
Even though white may be the dominant colour, it is still important to describe the coat starting with the base colour. For example, black, with moderate white spotting.

Drentsche Partridge Dog

Borzoi

Beagle

Ibizan Podenco

COATS WITH INVASIVE WHITE SPOTTING

In this case, white spreads over much of the initial coat colour and only a few coloured spots remain on the head, base of the tail and, sometimes, the sides.
White dominates the entire coat.
Despite the fact that white is the predominant colour, genetics dictate that we still use the base colour first. For example, brown, with invasive white spotting. We know that the extreme limit of white spreading corresponds to the total disappearance of colour, which is confined to the eyes and nose (except in the case of a Dudley nose); in this case, the dog is completely white.

Comments

White spotted coats are often referred to as *piebald* coats in different species of domestic mammals. This term was not retained here as it only distinguishes between two types: *coloured pied,* which refers to moderate and invasive spotting; and *pied coloured* in the case of distinct dominance of colour.

The term "spotting" has a wider meaning than "white spotted". Geneticists gradually associated it with the presence of white patches, and it then became routine to do so.

When the mucous membranes (nasal, ocular, anal, vulvar) are surrounded by white, it is possible that they are affected by depigmentation (see white coat in the Genetics chapter).

It is also interesting to note that coats with invasive white spotting without patches of colour on the ears are, like all-white coats due to white spotting, frequently associated with an increased risk of congenital deafness (single or bilateral).

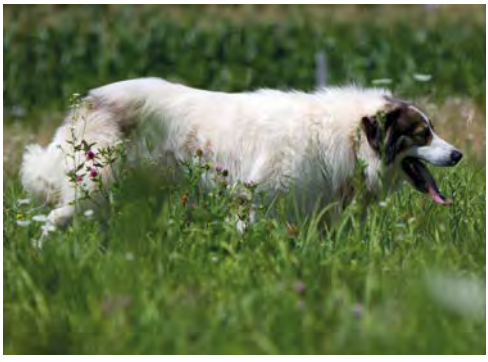
Japanese Terrier

© Duhayer / Royal Canin

Briquet Griffon Vendeen

© Labat / Rouquette / Royal Canin

Jack Russell Terrier



Tornjak

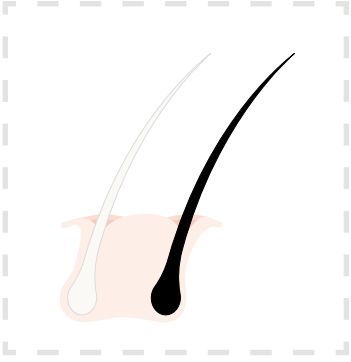
Irish Red and White Setter

T WHITE SPOTTED COATS WITH SPECIAL FEATURES

On many subjects, the white spotting presents either coloured patches or a mixture of hairs indicating the base coat colour. These are either ticking or with mixed white, skin markings can also be added to this group.

Main associated loci and genotypes

T locus | ***T/-***



BREEDS DEMONSTRATING THE COAT

English Cocker Spaniel, French Pointing Dog - Pyrenean type, Small Blue Gascony, Dalmatian, Picardy Spaniel, Auvergne Pointer, Large Munsterlander, Brittany Spaniel.

WHITE SPOTTED COATS WITH TICKING

It looks as though tiny, coloured spots were allowed to remain during the white spotting invasion process.

These tiny spots, only a few millimetres in diameter and with rounded edges, are the colour the coat would have been on these parts if there was no white spotting.

The abundance of the spots can be indicated by completing the name with: slightly, moderately or heavily ticked.

If there are only a few isolated spots which are very far from one another, the coat is slightly ticked. On the contrary, numerous spots, very close together with only a little white showing through, produce a heavily ticked coat.

© Duhayer / Cogis

The Dalmatian's special coat is a black coat with very invasive white spotting and black ticking which has undergone selection for the size of its spots.

© Grossemy

Brown and white Brittany Spaniel with slight ticking.

In practice, when the intensity of a feature is not specified, it is moderate. This Large Munsterlander has a black coat with white spotting and ticking which means the extent of the ticking is moderate.

© Duhayer / Royal Canin

Brief genetics reminder

Mixed white (Roan) and ticking are related to the effect of a single locus, *T*. Incomplete dominance of T and T^R alleles over the t^+ allele could explain the difference observed between the slightly (T/t^+) and heavily ticked (T/T) and slight (T^R/t^+) and heavy roan (T^R/T^R).

MIXED WHITE COATS

- Roan -

Main associated loci and genotypes

T locus | $T^R/-$

BREEDS DEMONSTRATING THE COAT

Wirehaired Pointing Griffon Korthals, Australian Cattle Dog, English Cocker Spaniel, Burgos Pointing Dog.

Definition

The coat displays white zones where the white hairs are closely intermingled with hairs of the initial coat colour. In traditional nomenclatures concerning domestic animals in general, roan was used to describe a mixture of white and fawn hairs (at the outset, brown hairs as well), and greying for a mixture of white and black or blue hairs. However, red-roan has become ambiguous while greying has a more general meaning, as we have already discussed. It is therefore wiser to keep to **mixed white** used with a specific colour to describe the colour the coat would have had if there had not been white spotting in its place.

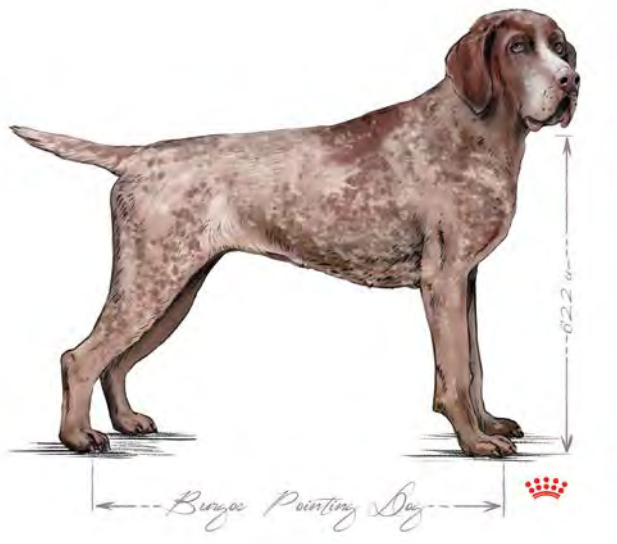
Depending on the density of the coloured hairs, the amount of white in mixed coats can vary from slight to moderate or heavy.

© Yves Lanceau

On this Wire-Haired Pointing Griffon Korthals, the white spotting and mixed white are extensive.

© Dühayer / Royal Canin

The mixed white on this German Spaniel is less pronounced than on the previous Wire-Haired Pointing Griffon Korthals. There is also ticking.



Comments

Coats with heavy or very heavy mixed white are often difficult to identify for those who have not yet mastered the new nomenclature because it is hard for them to admit that, where they see a coat which is "more or less" of even colour, it is in reality a white spotted coat. The best way to decide is to observe puppies in the given breed: **ticking and mixed white are not visible at birth,** so the white patches appear immaculate. **Ticking and mixed white only appear progressively.**

These patterns do not preclude depigmentation problems or a predisposition to deafness, especially if the white is invasive and present on the ears.

In the first weeks of life, the particular spotting features (ticking, mixed white) are not visible. They will appear gradually, with the coat becoming identical to the mother's after a few months. The puppies above are showing one stage of the coat development.

Picardy Spaniel

SKIN MARKINGS

Normally, the disappearance of pigmentation on white zones should involve skin as well as hair. However, skin pigmentation can remain here and there in the form of patches of varying size while the corresponding hairs are white. We refer to these patches, where the skin is pigmented but the hair is white, as **"skin markings".**

The presence of these markings can be indicated in the description of the coat by referring, for example, to a *black and white coat with slight skin markings.*

4

PRACTICAL EXERCISES

1 SAND WITH MODERATE WHITE SPOTTING

Here, the dog is not *d/d* because, if it were, the nose would be blue.
The sand (cream) hair colour is due to the combination of the *e/e* (fawn) and *i/i* (lightening of the fawn phaeomelanin to sand) genotypes.
The white patches are due to the s^p allele at the *S* locus (white spotting).

Borzoi

2 BLACK WITH FAWN MARKINGS AND WITH INVASIVE WHITE SPOTTING AND HEAVY MIXED WHITE

Here, the highly pigmented areas around the eyes indicate that the rest of the body is covered with a **heavy mixed white**.
The base coat is **black with fawn markings due to the a^t/a^t genotype.**
Australian Cattle Dogs are born with **invasive white spotting due to the s^p/s^p genotype,** which is pure white.
The mixed white develops as the dog grows.

Australian Cattle Dog

3

FAWN, HEAVY BRINDLE, MASKED

The **brindle pattern** can be detected at the tail and, to a lesser extent, along the topline. There is also a **mask, due to the to the E^M allele.** Here, the dog is **heavily brindled (k^{br}/k^{br} genotype) with a mask.**

© Serge Sanchès

Cairn terrier

4

BLUE MERLE COAT WITH FAWN MARKINGS, WITH WHITE SPOTTING

This is a coat commonly **known as "blue merle" (M/m^+ genotype) with fawn markings (a^t/a^t genotype), with white spotting.** Here, the specific white spotting is not due to the s^p allele of the *S* locus but to another allele not yet identified.

Australian Shepherd

Quiz

What is the name given to this spotting pattern, commonly found in the Australian Shepherd?

Answer: Irish spotting.

5

SAND MASKED COAT

We can observe the presence of a **mask: the coat is sand masked (*E*^{M} allele).**
Even though the **overlay is not very clear, it is indeed the *A*^{y} allele that is expressed at the *A* locus.** The dark appearance on the chest is probably due to the black pigmentation of the skin.

Spanish Mastiff

6

FAWN WITH BLACK OVERLAY

This Shikoku has a **fawn with black overlay or agouti** coat, **due to the presence of the ancestral *a*^{w} (agouti) allele, with significant lightening in the distal parts,** as often observed in some dogs of primitive or Nordic breeds. The presence of **dark overlay** on the neck clearly indicates that the very pale areas are not due to white spotting.
This colour is described as "sesame" and is also present in the Shiba.

Shikoku

© Coline Derin

Brazilian Terrier

7

BLUE WITH FAWN MARKINGS, WITH MODERATE WHITE SPOTTING

In this Brazilian Terrier, the **fawn areas appear dull and the dark areas are diluted** (black to blue), as is the nose. Thus, it has a **blue base coat with fawn markings, due to the *d/d* genotype** for dilution. This locus has little effect on phaeomelanin, which means the markings look fawn, not sand. The white patches are due to the s^p allele at the *S* locus (moderate white spotting).

8

SAND BRINDLE MASKED COAT

The base coat is **sand.** Black striped areas are observed on the body: these are **brindle (k^{br}/k^y genotype).** Both dogs have a black mask (E^M/E^+ genotype). They have a **sand brindle masked coat.**

© Français/Cogis

Sloughi

WHITE COAT

9

Only the hair allows for the identification of a **white coat**. Extreme lightening of the fawn colour due to the *I* locus (*i/i* genotype) is the most likely cause for this dog's white coat. However, some or all of the white coat colour may be related to the ***S* locus** (white spotting).

© Grossemy

Chinese Crested Dog

Quiz

What indicates that the dog is *B/-* and *D/-* ?

Answer: its black nose. If the nose was brown, it would be *b/b*. If its colour was diluted, then the dog would be *d/d*.

FAWN COAT **WITH BLACK OVERLAY, MASKED**

10

Despite the lightening of the long, woolly hair, a **fawn with black overlay** coat can be discerned, especially along the topline **(k^y/k^y genotype and A^y/a^t).** The dog's dark head indicates the presence of a **black mask (due to E^M).** The coat is therefore a **fawn with black overlay, masked.**

© Simon/Cogis

Afghan Hound

© Labat/Rouquette

French Pointer - Pyrenean type

11

BROWN COAT **WITH WHITE SPOTTING AND TICKING**

The base coat is **brown (*b/b* genotype) with moderate to heavy white spotting (*S*$^{+}$/*s*^{p}),** on which **brown ticking** can be seen.

12

FAWN COAT **WITH VERY INVASIVE WHITE SPOTTING**

We should automatically examine the sparse coloured zones. In this example, there is a **fawn marking** on the head.
This is a **fawn with no overlay, due to the *e/e* genotype, at the *E* locus. The very invasive white spotting is due to the *s*^{p}/*s*^{p} genotype.**

© Duhayer/Royal Canin

Istrian Wire-Haired Hound

13 BROWN WITH FAWN MARKINGS AND HEAVY MIXED WHITE

In the first weeks of life, the particular white spotting features (mixed white) are not visible. They gradually express themselves and the coat acquires its definitive colours after a few months. Here, this puppy displays a stage of this evolution: **the white spotting is still visible,** but its composition has changed, and we start to observe a coat with **intermingled white and brown hairs**. In addition, there are **fawn markings on the ends of the legs, due to the *a^t/a^t* genotype. The brown colour is due to the *b/b* genotype.**

© Hermeline / Diffomédia

Picardy Spaniel

Quiz

Why can this dog not have a greying brown coat?

Answer: Given the puppy's young age, it is more likely that the brown hair will spread into the white areas rather than the other way around.
Greying generally occurs with age.

14 AGOUTI COAT WITH FAWN MARKINGS

Dachshund

Fawn markings appear on a full overlay background. **The coat is agouti with fawn markings.** The name traditionally used for this colour is "wild boar".

It is the a^w allele that governs the agouti coat.

15 BLACK WITH FAWN MARKINGS, WITH INVASIVE WHITE SPOTTING AND TICKING

To determine the colour of this dog, you must first look at the pigments. On the head, there is a **black area** as well as **fawn markings** above the eyes, on the cheeks and on the legs, indicating that the base colour of the **coat is black with fawn markings (a^t/a^t genotype).** The whole coat is also **white (spotting due to s^p)** with coloured patches in it: this is an **invasive white spotted coat with ticking.** This is not a blue merle with fawn markings.

English Setter

FAWN WITH MERLE MANTLE, WITH LIMITED WHITE SPOTTING

16

Norwegian Hound

The effect of the *M* allele of the merle gene is mainly visible in the dark pigments expressed in the black mantle on this dog (which appears as blue merle).

The fawn patches are almost unchanged by the effect of this gene.

17 BROWN COAT WITH HEAVY TICKING

While the coat might seem to be solid brown, on closer inspection, there are very dense areas of **ticking** separate to solid brown patches. This dog is therefore **brown with heavy ticking.**

Burgos Pointing Dog

18 BLACK, WITH VERY INVASIVE WHITE SPOTTING AND BLACK TICKING COAT

In this dog, as in all Dalmatians, there is **white spotting** all over the body with **black circular spots.**
The coat is therefore black, with invasive white spotting, more simply described as **white spotted.**
Here, the dog is *B/-* because its spots are black. However, Dalmatians are born white, and the spots only develop as they grow.

Dalmatian

Quiz

What colour would the spots be if the alleles were *b/b* on this *B* locus?

Answer: The spots would be brown.

Genotypes for the practical exercises

Genotypes for the main testable colouring genes for these dogs. These are examples, but other genotypes are possible to explain these same coats.

Photo no.	*E* locus	*K* locus	*A* locus	*RALY*	*B* locus	*D* locus	*I* locus	*M* locus	*H* locus	*S* locus
1 Barzoi, sand with moderate white spotting	e/e	k^y/k^y	A^y/A^y	+/+	B^+/B^+	D^+/D^+	i/i	m^+/m^+	h^+/h^+	S^+/s^P
2 Australian Cattle Dog, black with fawn markings and with invasive white spotting and heavy mixed white	E^+/E^+	k^y/k^y	a^t/a^t	dup/dup	B^+/B^+	D^+/D^+	I^+/I^+	m^+/m^+	h^+/h^+	s^P/s^P
3 Cairn Terrier, fawn, heavy brindle, masked	E^M/E^M	k^{br}/k^{br}	A^y/A^y	+/+	B^+/B^+	D^+/D^+	I^+/I^+	m^+/m^+	h^+/h^+	S^+/S^+
4 Australian shepherd, blue merle coat with fawn markings, with white spotting	E^+/E^+	k^y/k^y	a^t/a^t	dup/dup	B^+/b	D^+/D^+	I^+/I^+	M/m^+	h^+/h^+	S^+/S^+
5 Spanish Mastiff, sand masked	E^M/E^M	k^y/k^y	A^y/A^y	+/+	B^+/B^+	D^+/D^+	i/i	m^+/m^+	h^+/h^+	S^+/S^+
6 Shikoku, fawn with black overlay	E^+/e	k^y/k^y	a^w/a^w	dup/dup	B^+/B^+	D^+/D^+	I^+/I^+	m^+/m^+	h^+/h^+	S^+/S^+
7 Brazilian Terrier, blue with fawn markings, with moderate white spotting	E^+/E^+	k^y/k^y	a^t/a^t	dup/dup	B^+/b	d/d	I^+/I^+	m^+/m^+	h^+/h^+	S^+/s^P
8 Sloughi, sand brindle, masked	E^M/E^+	k^{br}/k^y	A^y/A^y	+/dup	B^+/b	D^+/D^+	i/i	m^+/m^+	h^+/h^+	S^+/S^+
9 Chinese Crested Dog, white	e/e	K^B/k^y	A^y/A^y	+/dup	B^+/b	D^+/D^+	i/i	m^+/m^+	h^+/h^+	S^+/s^P
10 Afghan Hound, fawn with black overlay, masked	E^M/E^G	k^y/k^y	A^y/a^t	+/+	B^+/B^+	D^+/d	I^+/i	m^+/m^+	h^+/h^+	S^+/S^+
11 French Pointer- Pyrenean type, brown with white spotting and ticking	E^+/E^+	K^B/K^B	a^t/a^t	+/dup	b/b	D^+/D^+	I^+/I^+	m^+/m^+	h^+/h^+	S^+/s^P
12 Istrian Wire-Haired Hound, fawn, with very invasive white spotting	e/e	k^y/k^y	a^t/a^t	dup/dup	B^+/B^+	D^+/D^+	I^+/I^+	m^+/m^+	h^+/h^+	s^P/s^P
13 Picardy Spaniel, brown with fawn markings and heavy mixed white	E^+/E^+	k^y/k^y	a^t/a^t	dup/dup	b/b	D^+/D^+	I^+/I^+	m^+/m^+	h^+/h^+	s^P/s^P
14 Dachshund, agouti with fawn markings	E^+/E^+	k^y/k^y	a^w/a^t	dup/dup	B^+/b	D^+/D^+	I^+/I^+	m^+/m^+	h^+/h^+	S^+/S^+
15 English Setter, black with fawn markings, with invasive white spotting and ticking	E^+/E^+	k^y/k^y	a^t/a^t	dup/dup	B^+/B^+	D^+/D^+	I^+/I^+	m^+/m^+	h^+/h^+	s^P/s^P
16 Norwegian Hound, fawn with merle mantle, limited white spotting	E^+/E^+	k^y/k^y	a^t/a^t	+/+	B^+/B^+	D^+/D^+	I^+/I^+	M/m^+	h^+/h^+	S^+/S^+
17 Burgos Pointing Dog, brown with heavy ticking	E^+/E^+	K^B/K^B	a^t/a^t	dup/dup	b/b	D^+/D^+	I^+/I^+	m^+/m^+	h^+/h^+	S^+/s^P
18 Dalmatian, black, with very invasive white spotting and black ticking coat	E^M/E^+	K^B/K^B	a^t/a^t	dup/dup	B^+/b	D^+/D^+	I^+/I^+	m^+/m^+	h^+/h^+	s^P/s^P

***E* locus: "extension"**
E^M: melanistic mask
E^G: grizzle or domino
E^+: no effect
e: suppression of eumelanin

***K* locus: "blacK", noir**
K^B: solid eumelanin colour ("dominant black")
k^{br}: brindle
k^y: fawn

***A* locus: "agouti"**
A^y: fawn, fawn with black overlay
a^w: agouti, wolf grey
a^t: black or brown with fawn markings
a: solid eumelanin colour ("recessive black")

***RALY*: fawn with mantle or with fawn markings**
+: eumelanin saddle
dup: with fawn markings

***B* locus: "Brown"**
B^+: black eumelanin
b: brown eumelanin

***D* locus: "Dilution"**
D^+: no effect
d: eumelanin dilution is very visible, phaeomelanin is hardly visible (blue, beige, sand)

***I* locus: "Intensity"**
I^+: no effect
i: phaeomelanin lightening

***M* locus: "Merle"**
M: merle
m^+: no effect

***H* locus: "Harlequin"**
H: harlequin
h^+: no effect

***S* locus: "Spotting"**
S^+: no spotting
s^P: spotting

CONCLUSION

Progress in canine genetics and genomics has resulted in great advances in understanding coat genetic origin. Loci predicted by classical genetics have been confirmed, while some hypotheses of colour transmission were refuted, and new genes have been identified. In general, canine coat colour inheritance models have been shown to be accurate, but sometimes too reductive to explain the full extent of variation found in dog breeds.

DNA tests for alleles governing coat colour and texture are now commercially available. They improve breeding oversight and give breeders the possibility to confirm the observations of the animals and to change mating pairs to obtain puppies as close as possible to their expectations. **Breeders can therefore use the result as an additional selection criterion,** in the same way as the morphological or behavioural criteria that are assessed beforehand.

Canine genomics has also evolved in other areas, **with medical genetics benefiting most from these advances.** The discovery of genes and mutations involved in various hereditary diseases and predispositions has led to **the commercialisation of DNA tests that are essential tools for improving the dog health.** A simple buccal swab can reveal a dog's genotype for various genes coding for coat colour and texture, but more importantly for various genes coding for diseases, sensitivities, and predispositions. Adequate veterinary follow-up based on the animal's status can help avoid risky situations, adapt the dog's lifestyle, and adjust mating pairs.

The future is not what will happen to us, but what we will do.

Henri Bergson

When it comes to predispositions, one example is drug sensitivity in several breeds of sheepdogs, which was identified through genetic screening. As a result, the use of certain drugs can be controlled. Another example is screening for coagulopathy: when identified, the animal's living conditions can be adapted to avoid critical situations. **Canine genomics has thus entered the field of canine preventive medicine.**

With regard to hereditary diseases, many deleterious mutations can be detected with DNA testing. For example, when a breeding animal is a healthy carrier of a mutation, a non-carrier mate is chosen to avoid producing puppies affected by the mutation.

The latest addition to this genomic revolution are test panels. With these, a single DNA sample can be used to search for several hundred mutations at a reasonable cost. Since hereditary diseases and predispositions are very often breed or group specific, the question of interpretation of such tests arises. **The contributions and collaboration of all stakeholders** (owners, breeders, stud bookkeepers, veterinarians, geneticists, laboratories) **are therefore essential to ensure these new tools are used to their full potential.**

Genetics is a complex science that requires knowledge and skills for its applications to be used appropriately. **Coat colour genetics is an enjoyable yet rigorous approach to dog genetics.** We hope this guide has given you a deeper look into this field, whose applications for dog breeding, health and welfare are only just emerging.

NOMENCLATURE
OF COAT COLOURS
IN DOGS

White

Platinium sand

Silver sand

Ivory sand

Himalayan

Light fawn
- Isabella -

Orange fawn

Dark fawn

Red fawn

Fawn masked

Fawn with mantle and mask
- Saddle tan with mask -

Fawn with mantle maximum extension
- Saddle tan maximum extension -

Fawn with mantle
- Saddle tan -

Fawn with mantle minimum extension
- Saddle tan minimum extension -

Fawn with black overlay

Fawn brindle

Fawn brindle, with white spotting

Black, with invasive white spotting

Black, with moderate white spotting

Black, with limited white spotting

Black, with white spotting and ticking

Black and mixed white
- Black roan -

Fawn with mantle and mask, with moderate white spotting
- Saddle tan with mask and moderate white spotting -

Blue merle with fawn markings, with limited white spotting
- Blue merle with tan points and limited white spotting -

Blue merle

Blue merle with fawn markings
- Blue merle with tan points -

Black with fawn markings
- Black and tan -

Black

Blue

Greying

Cocoa

Brown
- Liver or chocolate -

Beige
- Lilac -

Brown, greying

Agouti
- Sand with black overlay -

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BREED **INDEX**

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The illustrations on pages 204 and 205 are intended to show a coat colour and not to represent a breed.

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