THE AMERICAN STAFFORDSHIRE TERRIER
Color and color genetics

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MountainGarden

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INHOUD

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1 INTRODUCTION

Amstaff come in a large variety of colors. This variety is an important treat of the breed and should be cherished in future generations to preserve that variety, disregarding certain color fashions that may pose a risk to that preservation. As all colors are permitted, but pigmentation is clearly anchored in the breed standard, it is in particular important to ensure sufficient attention for those colors that are linked to good black pigmentation. Black, red and brindle dogs are usually those with the best pigmentation.

To ensure proper recognition of the colors the section below provides an overview of the known colors in our breed.

Following that the document provides an overview of the results of research in the color genetics of our breed and what this means in breeding and appearance.

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2 COLORS

There are two basic skin colors; the dominant Black color and the recessive Brown. In the coat an additional color, red, can be present. The intensity of the color (or rather the dilution) is regulated by other genetic traits, providing different diluted versions of the basic colors. In addition the separate trait for brindle can cause brindle versions of practically every available color. This is all explained in more detail in section 3 Color genetics.
In the overview below, behind each variety, we have provided the genotype for that variety, as explained in section 3 Color genetics. In the genotype coding we use the '-' sign in the second position of an allele if the value of that particular position can be any of the known values for that allele, but it's real value does not change the outcome.

2.1 Color varieties

2.1.1 Black (E-K^B-B-D-a^y- or E-K^B-B-D-a^{t}- or E-K^B-B-D-a-)

This color shows as a solid deep jet black with a glossy appearance. Absolutely no reddish or brown tones should show and this color will not lose its intensity in time.

2.1.2 Seal (E-K^Bk^yB-D-a^y- or E-K^Bk^yB-D-a^t-)

Seal is believed to be a black coat with incomplete dominance. A seal dog will appear black in general, however when viewed in direct sunlight, you can detect shades of brown/red laying like a glow over the black coat.
As for the genotype we do not exactly know what causes the seal look, so in principle the genotype is the same as for a black dog)

2.1.3 Blue (E-K^B-B-dda^y- or E-K^B-B-dda^ta^t)

Blue is a dilution of the black basic color and can range from a light blue to a deep blue color. The blue itself can have shades between bluish and grey. All blue dogs have a blue (gray) nose leather, though some can have such good pigmentation that their noses almost appears black (genetically speaking, it is impossible for a blue to have a black nose).

2.1.4 Red (E-k^yk^yB- a^ya^yD-)

Red is the deepest of the warm hues, ranging in color from orange-reds to deep, intense mahogany.

2.1.5 Blue fawn (E-k^yk^yB- a^ya^ydd)

Blue fawns have a solid fawn coat with distinct bluish tint (and generally a blue mask too). The nose leather is always blue (grey) on blue fawn, though it can be dark enough to appear black.

2.1.6 Fawn (E-k^yk^yB-a^ya^yD-)

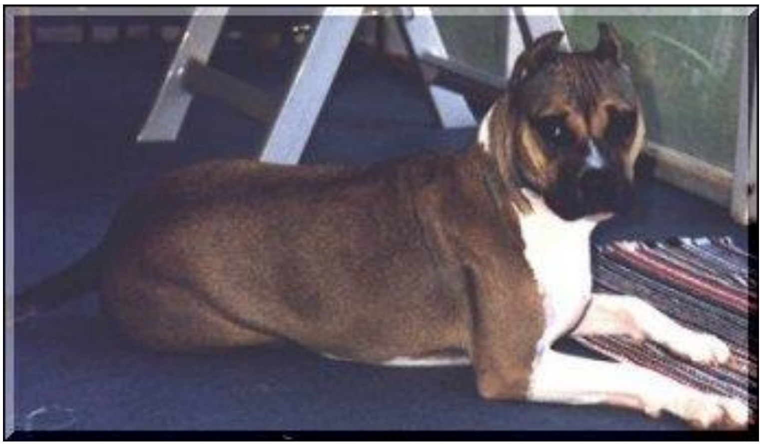
Fawn has no gold or red tones, it ranges from tans, buffs, and light browns.
It is uncertain what causes the dilution of the coat color, it could be either the I locus (color intensity, only affecting phaeomelanin) or possibly even Chinchilla dilution, c^{ch} on the C locus (which affects both eumelanin and phaeomelanin), although earlier studies found the breed always homozygous for CC.

2.1.7 Buckskin (E-k^yk^yB-a^ya^yD-)

Buckskin resembles fawn except for the black masking and black hairs down the middle of the back and dark hairs going down the tail. There is also some shading throughout the middle of the back. This can also come with several shades as the basecoat such as red, red/fawn or the traditional fawn.

2.1.8 Sable (E-k^yk^yB-a^ya^yD-)

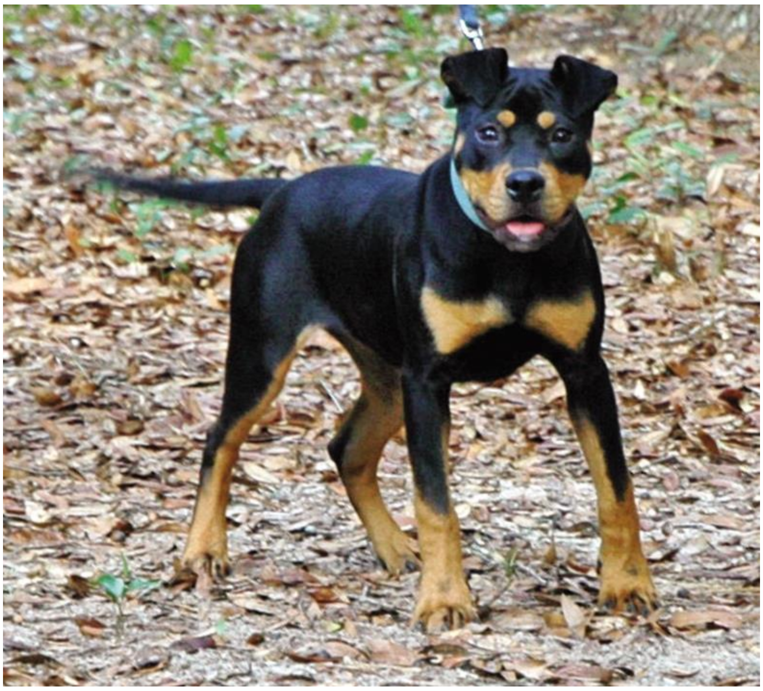
Sable means black tipped, so fawn sable is a basic red or fawn dog with black sabling over the body. Her base coat is fawn but she has a heavy black overlay that creates a heart-shaped pattern on the face. It is not the same as a tri-color or tan point. Sometimes the overlay will be heavier and sometimes it will be very light. The overlay can also appear as a darker red over the fawn or in blues as a darker blue/fawn overlay. This is essentially just a buckskin with a very heavy overlay.



2.1.9 Liver (E-K^B-bba^y-D- or E-K^B-bba^ta^tD-, dilute possible with dd instead of D-)

A uniform chocolate/brown, with equally pigmented lips, nose, pads etc. Eyes generally have a yellowish hue and are undesirably light. Liver is not to be encouraged.

2.1.10 Black and Tan / tri-color (E-k^yk^yB- a^ta^tD-)
Black with tan markings or points.



2.1.11 Blue and Tan / tri-color) (E-k^yk^yB- a^ta^tdd)
Blue with tan markings or points.

2.1.12 White

A white dog will usually have only some patches of solid color, mostly at the ears or back. More than 80% white not to be encouraged.

2.2 Brindle

This provides for dark stripes on the basic coat color. The name used for the brindling is determined by the most prominent color. So a dog with a black and red striping will be a black brindle if the coat shows more black than red, and a red brindle if it shows more red than black.

2.2.1 Black brindle (E-k^{br}-B-$a^y a^y$D-)

This variety provides for tan colored stripes over a basic black coat.

2.2.2 Blue brindle (E-k^{br}-B-$a^y a^y$dd)

Blue Brindles have a blue background color, with pale cream/gold stripes. As with the blue variety a blue brindle will always have a blue (gray) nose leather.

2.2.3 Red brindle (E-k^{br}-B-$a^y a^y$D-)

Black stripes on a red background.

2.2.4 Blue Fawn brindle (E- k^{br}-B- $a^y a^y$dd)

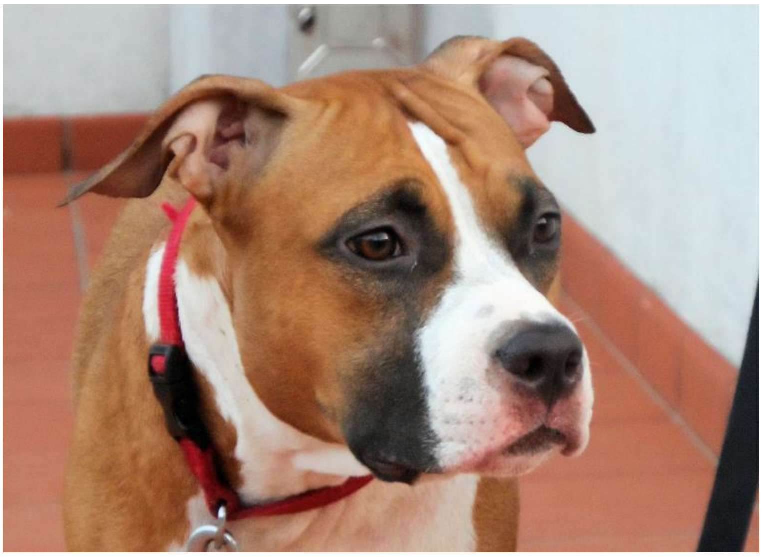
Black stripes on a blue fawn background.

2.2.5 Fawn brindle (E-k^{br} k^{br}B-$a^y a^y$D-)

Black stripes on a fawn background.

2.3 Mask (E^M)

This provides for a dark colored mask in the dog's face, and will show only with light (reddish) colored dogs. Depending on the pigmentation the mask will appear black or blue (greyish)



2.4 Marking varieties

There are also some varieties in the pattern of the color of an Amstaff.

2.4.1 Solid Colored (S)

This is self explaining. The dog is solidly colored. This can be combined with local white markings on the extreme ends of the body and a white spot on the chest.

2.4.2 Irish spotting (S^i)

Irish spotting is responsible for the more pronounced white markings, also responsible for the flashy white collars frequently seen in the breed.

2.4.3 Piebald Spotting (S^P)

Piebalds have their color in patches. They are 20-60 percent colored, with the coloring broken up into spots.

2.4.4 Extreme White (S^W)

Essentially what was shown before as a white dog

2.4.5 Ticked (T)

Ticked would look like the example in the picture. Research seems to indicate that this trait is actually not present in the breed. Marks like those on the picture can be created by rare other combinations though, or rare exceptions.

3 COLOR GENETICS

3.1 Introduction

The color description on a pedigree provides a description of the dogs actual color as it can be seen (phenotype). This color description is used for identification only and in many cases does not predict what color combinations the individual dog will produce in its offspring. That question can only be answered based on information regarding the genetic makeup (genotype) of the individual dog.

The determination of coat color in dogs has long been a mystery. While most mammals share the same genetic mechanism to determine coat color, dogs seemed to be an exception. Only a couple of years ago researchers identified a new gene in dogs that acts in addition to the two main coat-color genes recognized in other mammals.

This document is not intended to teach the reader about the general principles of genetics, but although we encourage the reader to look for other resources to learn about this subject, a short explanation is required before we provide results of research into the color genetics of the Amstaff and from that look at some particular conclusions and cases.

3.2 Two different types of pigment

The key to understanding dog genetics is simply this: there are two types of pigment which create coat color in dogs. Pigment is what gives each strand of hair its color, just like pigment in paint or dye. All coat colors and patterns in dogs are created by these two pigments. Each of the pigments has a "default" color, and it can then be changed by various genes.

3.2.1 Eumelanin

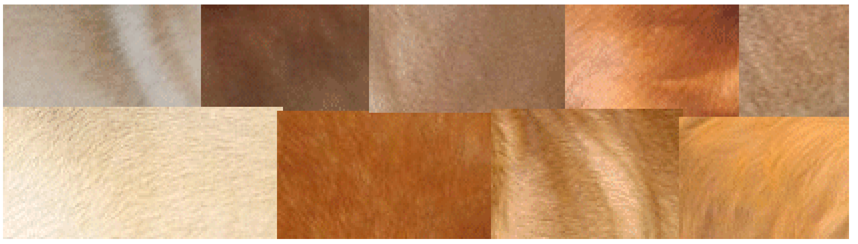
Eumelanin is black pigment. All black areas on a dog are caused by cells producing eumelanin. However, there are genes which turn eumelanin into other colors; liver (brown), blue (grey), or isabella (a dusty pale brown). If a dog has any of the genes to turn its black eumelanin into liver, blue or isabella then all of the black in its coat will be changed. This is because these genes restrict and/or alter the production of eumelanin, so the cells aren't able to produce full-strength pigment.
We call blue and isabella dogs "dilutes" for this reason. They either lack the genes which tell their cells how to produce proper eumelanin, or their cells know how to produce it but can't.

As well as being found in the coat, eumelanin is present in the other parts of the dog that need color, most notably the eyes (irises) and nose. The nose will be black, liver, blue or isabella depending on the type of eumelanin the dog can produce. The color in irises is produced by layers of pigment, and brown eyes like most dogs have are caused by black eumelanin in those layers. When a dog has altered/restricted production of eumelanin, the irises are also unable to produce full-strength eumelanin. This means that the dark pigment in the eye becomes lighter, and the eyes turn into a light brown color, known as amber or gold. Dogs cannot produce green color, only brown and blue.

This shows the variation in color of eumelanin. Black is the default, then it can be turned into liver by one set of genes, and black and liver can be turned into blue or isabella by another set of genes. Blue is diluted black and isabella is diluted liver.
When we talk of dogs that are "black pigmented", "liver pigmented", etc, we mean that is the color of eumelanin that the dog can produce. Sometimes these dogs have no eumelanin at all in their coats (their skin cells produce only the other type of pigment, phaeomelanin), but we can tell what their "pigment color" is by looking at their nose. A black nose means the dog produces black eumelanin, and so on. It's confusing to talk of a dog's "pigment color" like this, because as we know, eumelanin isn't the only type of pigment.

3.2.2 Phaeomelanin

The second type of pigment, less important than eumelanin, is phaeomelanin. This is red pigment. The term "red" covers everything from deep red (like Irish Setters) to light cream, encompassing gold, yellow and orange. Whenever we talk of red, we mean the whole range of tan colors.
Phaeomelanin is produced only in the coat. It does not occur in the eyes or the nose, so any genes which affect the color/intensity of phaeomelanin will not affect the eyes or nose. Only eumelanin occurs in those areas, and so only genes which affect eumelanin can affect the eye or nose color.



This shows the variation in color of phaeomelanin. Unlike eumelanin, it doesn't occur in two distinct colors (black and liver, with dilutes counting as shades of those), but rather just one color, which varies in intensity. The most intense phaeomelanin color is Irish Setter red. The default color is probably golden, with different genes causing it to be more or less intense (i.e. telling the cells to produce a higher amount of pigment particles, so making the color stronger, or a lower amount, making the color weaker, so lighter).

3.2.3 White

So far so good, but this doesn't seem to explain all the coat colors in dogs - how about white?
White isn't really a color, so white hair on animals isn't caused by pigment but a lack of pigment. It is a lack of both eumelanin and phaeomelanin. White areas on animals are simply caused when the cells cannot produce any pigment at all. Sometimes the whole animal is affected, like in albinos, and sometimes just parts of it are affected, like in dogs with white markings. It can affect the production of eumelanin in eyes and noses too, turning noses pink and eyes blue (or red in proper albinos). There is also a second type of white, which is caused by a gene called chinchilla. The chinchilla gene dilutes red (phaeomelanin) pigment, making the cells produce less pigment particles than normal, so the color gets lighter. If it is diluted enough, it can become white. Many white dogs have a slight ivory/cream sheen to their coats because their cells are still producing a very small amount of pigment. This sort of white does not affect eumelanin, so any black/liver/blue/isabella areas on the coat will stay dark, and the eyes and nose will do too.

3.3 Distribution of pigment

The colour genes in dogs do two things - they determine the eumelanin and phaeomelanin colours/shades, and they control the distribution of these two pigments. They tell certain cells to produce eumelanin, others to produce phaeomelanin, and sometimes they tell them to not produce pigment at all. Exactly which cells are told to produce what is determined by the exact set of genes, although it can be random to a certain degree (e.g. puppies may have slightly different white markings to their parents, or patches in different places). Sometimes genes can even tell cells to switch which type of pigment they are producing every once in a while. This means that as a hair grows, it becomes banded with black and red, because the cell produces black (eumelanin) for a while, then changes to red (phaeomelanin), then back to black, etc. It's a bit like when you highlight your hair and after a while the roots start to show through. The overall colour of an animal with this sort of black and red banding will generally be a muddy brown from a distance, and close up you will be able to see the black parts of the hairs. It's called agouti, and it's the colour of wild rabbits and mice, as well as a large amount of other mammals. It's popular amongst wild animals because it provides very good camouflage. It also occurs in dogs, but it looks a bit different (like the colour of a wild wolf rather than a rabbit) and isn't very common.
The concept just described are crucial to your understanding of dog genetics.

3.4 Genetic principals

3.4.1 Terminology

Genes

Genes control just about everything about a living creature. They control how the creature grows and develops, how it functions and how it looks too. In this document we are focusing on just one aspect of looks; color.
A gene is basically a set of instructions which tells the cell how to produce something (in this case pigment). Genes come in pairs, one copy being obtained from each parent during fertilization. A pair of genes constitutes a genotype.
When we write about genes we use letters to denote them, for example a and b.

Loci

Genes are all tied together into a long strand of DNA. Each point on this strand of DNA is called a locus (loci is the plural). At each locus there are two genes.
The genes present at each locus are picked from a list of possible genes, which is called a series. There may be any number of genes in a series, but it's usually 2-5. Each locus has its own series, and the genes in that series can only occur at that locus. For example, in the E series in dogs there are three genes - E, E^M and e. Each dog has a combination of two of those genes from the E series on its E locus. It might have one copy of e and one of E, or maybe two copies of E^M. In this section the terms "series" and "locus" will be used pretty much interchangeably.

Dominant and recessive

Although every dog carries two genes at each locus, only one of those genes can be expressed (meaning only one can actually be used, and the other will just lie dormant). Which of the genes is expressed depends on dominance. The most dominant gene will always be the one which is expressed. A recessive gene is one which is less dominant.
Dominant genes are generally written with a capital letter, for example B. Recessive genes are written with a lower case letter, for example b. Sometimes there is more than one dominant or recessive gene on a locus. When this happens, there is usually an order of dominance, so one of the dominant genes is more dominant than the other, and one of the recessive genes is more recessive than the other. But traits from one locus can also influence another locus. In that relationship we call dominant epistatic (above), and recessive hypostatic (below).
A dog with the BB genotype has two dominant genes, and so it can only express B. A Bb dog will also express B because B is dominant over b. bb is the only genotype where the dog will express b.
It's also worth noting that sometimes both of the genes on a locus will be expressed. This is called incomplete dominance, and only happens on particular loci. The resulting dog will have a mixture of the two genes, but its markings will generally lean more towards the more dominant gene. For example, the S series controls white markings, and the genes in it display incomplete dominance over one another. s^i is the gene for Irish spotting (white legs, muzzle, tail tip and collar), and s^w is the gene for extreme white piebald (a piebald with very few patches). A s^is^i dog will be Irish spotted, but even though s^i is slightly more dominant than s^w, a s^is^w dog won't have the normal Irish spotting pattern (as you would expect if a dog can only express its more dominant gene). Instead it will have a "flashy" irish spotting pattern (i.e. more white than normal), because it is able to partly express it's more recessive gene (extreme white piebald).

Heterozygous and homozygous

A heterozygous pair of genes is one where the two genes are different. A homozygous pair of genes is one where the two genes are the same. We generally talk of a dog being, for example, "homozygous for merle" (two copies of the merle gene, M) or "heterozygous for merle" (one copy of the merle gene).

- bB, Dd, a^ya^t, and s^ws^i are all examples of heterozygous pairs of genes.
- bb, DD, a^ya^y, and s^ws^w are all examples of homozygous pairs of genes.

Color study

The study of color genetic within a breed can be complex, as there are many different locations (loci) on the chromosomes that effect the final color that you see in your dog. At each loci are two or more alleles, or gene choices, that interact according to their dominance-recessive relationships. At loci that have more than two alleles, the relative dominance in the series have been listed in order of their dominance

3.4.2 Inheriting

Each dog, like humans, inherits one half of their genetic make-up from their sire and one half from their dam. All dogs 78 chromosomes, quite a lot more than the 46 of a human being. The chromosomes appear in pairs and consist of chains of DNA material. Small sections of these DNA chains make up genes, the genetic code for the production of certain proteins in the individual dog.

The genetic material for particular traits in the dog are located in certain regions on the chromosomes called loci (plural) or locus (singular). The different assortment of genes that are possible at a particular locus are called alleles. In many different breeds, through selective breeding, only one allele is found at a particular loci, leading to all members of the breed having the same trait. This is why purebred dogs will breed true, for those characteristics that distinguish one breed from another.

3.5 Basic color

3.5.1 Locus A Series: Dark Pigment Pattern

The "agouti series", which affects the distribution of eumelanin and phaeomelanin.
This locus has four known alleles possible in the canine population. Only three are present in the Amstaff.

- (a^y) Sable (red with or without black tipping)
- (a^w) Agouti (banded hairs)
- (a^t) Tan points (tan 'Doberman like' markings on a solid coat)
- (a) recessive Black

The A alleles are pattern factors that control the amount and area distribution of dark and light pigment. They act within the hair follicle to switch pigment synthesis between light and dark. It is important to remember that alleles at this locus interact with Locus E alleles.

- (a^y) - SABLE (red with or without black tipping)
  The (a^y) allele restricts dark pigment, producing yellow colors. When homozygous, the coat can be clear gold, but often has black tipped hairs, especially on the head and down the back. (this allele is often indicated as dominant "A^Y", but we follow Schmutz in using the epistatic "a^y"
- (a^w) - AGOUTI (banded hairs)
  Like sable above, but the hairs all over are banded with black. This is most likely the gene responsible for wolf grey. The competition is going on as the hair is growing, which results in a hair that changes color along its length. In breeds with very long hair there may be even more alternating bands of phaeomelanin and eumelanin. Although this allele was once fixed in dogs, if we assume that they all descended from the wolf, it is not a very common allele in dog breeds today
- (a^t) – TAN POINTS
  Tan points (black body with red on muzzle, chest, eyebrows, legs and vent). Only dominant over recessive black (below), so a dog needs to be homozygous for tan points in order to express them (or heterozygous for recessive black and tan points, but recessive black is very rare)
  The typical tan points are above each eye, on each cheek, on the lips and lower jaw, extending under the throat, two spots on the chest, below the tail, and on the feet to the pasterns and hocks, extending up the inner sides of the legs.
- (a) – RECESSIVE BLACK (solid black with no red in the coat at all)
  Solid black with no red in the coat at all.

While initially this locus was believed to hold a Dominant Black allele (A^S) this is now defined at its own locus; K.

3.5.2 Locus B Series: Black/Brown Pigment

The "liver series", affecting the color of eumelanin

- (B) black pigment
- (b) brown pigment

This locus contains only two alleles, the dominant (B) producing black skin and nose pigment and the (b) recessive allele, producing brown pigment. In dogs that are red or buckskin, the Locus (B) alleles are expressed in skin color, most visible around the eyes and nose. The black nose indicates the genotype is (BB) or (Bb), both which would be expressed as black nose because of the dominance of the (B) allele. A light brown or red nose is (bb), or homozygous recessive. Being homozygous recessive, both parents must contribute one recessive (b) gene to the offspring to produce the red nose. When breeding two dogs with the (bb) genotype, the only resulting combination in the pups would be (bb) or red nose.
The nose leather, pads, and eye rims are also affected by this gene. They are black if a B allele is present but brown if not. Hence all brown dogs (liver in Amstaff) have a brown (liver) nose and all black dogs have a black nose but red, fawn, sable, white, etc. dogs could have either black or brown noses.

3.5.3 Locus E Series: Extension

The "extension series", affecting the distribution of eumelanin.

- (E^M) black mask
- (E) extension of dark pigment

- (e) restriction of dark pigment

The Locus E alleles affect the extension of dark pigment, and all of the alleles at this locus interact with those of loci A and K. This gene has two common alleles E and e. Dogs that are e/e are red or yellow due to phaeomelanin production, and this is the recessive genotype. When E is present in a dog, it usually has some black or brown in its coat because of the production of eumelanin. The E allele is dominant to the e allele. Although the e/e genotype is the most recessive at this locus, it is epistatic or masks other genotypes at other loci, such as the K and A locus. See more about those loci on separate pages.

- (E^M) - BLACK MASK
  This allele is dominant to all others in the series and is expressed as a black mask on dogs that are not solid black.
  The mechanism by which a black mask is formed is an interaction between the E gene with the agouti protein and melanocyte stimulating hormone. The E^M allele allows agouti to bind some of the time and cause fawn pigment to be made on the body and the melanocyte stimulating hormone to bind on the face instead. Because of this any phaeomelanin pigmented dog (i.e. yellow, fawn, red, cream) with a mask, must be so colored due to an agouti genotype. Such dogs cannot be "e/e" because an E^M allele is required for the production of a melanistic mask. Since the mask is inherited as a dominant trait, a dog could be heterozygous or homozygous for mask. The extent of the mask or depth of color do not seem to be affected by the number of copies of E^M.
  Melanin pigment can be black, grey or brown and therefore the term "melanistic" mask includes all these types of masks. Dogs that are black or brown or blue do not show their mask against their similar body color.
- (E) – EXTENSION
  The E allele produces normal extension or expression of dark pigment. It interacts with Locus A an K alleles to produce a variety of effects:
  - K-E- black/brown
  - a^y-E- red or buckskin with or without black ticked hairs (on head and back) referred to as sable in other breeds
- (ee) – RESTRICTION
  The homozygous (ee) alleles restricts the expression of dark pigment, producing the yellow shades by light pigment. It does allow the expression of dark pigment on the nose, lips and eye rims. It is recessive to all other alleles in the E series. Homozygous (ee) alleles interferes with the expression of most Locus A alleles. "e/e" dogs are restricted from having any black hairs in the coat. So a dog that appears sable in color could not be an "e/e" dog since "ee" wouldn’t allow for a mask or black tipped hairs.

3.5.4 Locus K Pair:

The "black series", affecting eumelanin.

- (K^B) solid black
- (k^{br}) brindle
- (k^y) non-solid black

The Locus K allele K^B overrides the effect of the Agouti series on the the Locus E alleles.

- (K^B) – SOLID BLACK
  This allele is dominant to all others and overrides the effect of the A (agouti) series on the E series. Any genes on the A locus will not be expressed. "Solid" does not mean that no white markings occur. A few people call this "self black"
- (k^{br}) - BRINDLE PATTERN
  The brindle allele produces the brindle pattern with stripes or bars of dark pigment on a background of light pigment. A single copy of the k^{br} allele in the presence of a k^y allele is sufficient to cause the dog to express the phenotype known as brindle. Although it was assumed that in dogs with the dominant (K^B) allele, which produces a solid coat of dark pigment (brown or black), the (k^{br}) allele is masked because there is no light pigment on which it can act recent studies show that some brindles may actually carry the K^B allele (and could be K^Bk^y'. Brindle dogs will express whichever genes are on their A locus, but the red parts of the coat (phaeomelanin) will be brindled (black parts will not be affected). In our breed, interactions with alleles at the B D and E loci produce a rich variety of brindle colors:
  - A^y-B-D-k^{br}- black brindle
  - A^y-B-ddk^{br}- blue brindle
  - A^y-bbD-k^{br}- liver brindle
  - A^y-bbddk^{br}- fawn brindle

    (The (-) as the second allele at the locus pair denotes an allele that is uncertain because of the dominant nature of the first allele. It could be homozygous or heterozygous with any of the other alleles.)
- (k^y) – NON-SOLID BLACK
  This allele is recessive and a k^yk dog will express whichever genes are on its A locus..

3.6 Diluted color

3.6.1 Locus C: Albino

This is the "albino series", and affects the complete removal of all (melanin-based) pigment, not just phaeomelaninand is thus responsible for albino in many species of mammal, and generally lightens or removes all (melanin-based) pigment.
Until recently it was thought that the C locus was responsible for the intensity of phaeomelanin (red) pigment in dogs, causing the difference between rich Irish Setter red and the almost pure white seen on breeds such as the Samoyed and German Shepherd Dog. However, it has now been shown that ivory and white dogs do not have any mutations on the C locus. A new locus has been hypothesised for phaeomelanin dilution - I (for Intensity).
There are no known C locus mutations in dogs, and as yet no pure white dogs have tested positive for true albino. A true albino is completely unable to produce melanin, so it would be completely white with red/pink eyes and a pink nose.
The full range of alleles is yet unknown.

- CC full color
- Unknown

3.6.2 Locus D pair: Pigment density

The "dilution series", which affects the intensity of eumelanin.

- (D) intense pigment density
- (d) dilute pigment density

The locus D pair modifies the density of the pigment. The dominant (D) gives full density in both the heterozygous (Dd) or the homozygous (DD) combination. The homozygous recessive (dd) alleles dilute the color. When the dogs basic color is produced by dark pigment, genotype (Bbdd) or (BBdd) yields the color known as blue. The black coat is modified as well as the skin pigment to a gray or blue pigment around the eyes, pads and nose. When the dogs basic color is produced by a light pigment the genotype bbdd (dilute brown pigment) produces a fawn with a silvery cast known in our breed as a fawn/bluish. The skin pigment around the eyes is flesh colored as well as a red or brown colored nose.

3.6.3 Locus G pair: Progressive Graying

The "greying series", affecting how eumelanin keeps its itensity over time.

- (G) progressive greying throughout life
- (g) uniform color throughout life

Research concludes that the AST breed are homozygous (gg) with dogs retaining their coloring throughout their lifetime. The G dominant allele present in other breeds produces a silvering or graying of the coat over time and the recessive (g) allele, giving a uniform color throughout the dog's lifetime.

3.6.4 Locus I: Pigment intensity

This is the "intensity series", and affects the intensity of phaeomelanin.
Until recently it was thought that the C locus was responsible for this treat But this has now been hypothesised to occur on the I locus - I (for Intensity).
The alleles on this locus may cause the light pigments to be diluted out in various degrees accounting for the varying shades found in many littermates depending on these alleles.
The range of alleles is yet unknown.

3.7 White marking

3.7.1 Locus H Pair: Harlequin Pattern

The "harlequin series", affecting the intensity of eumelanin.

- (H) harlequin
- (h) non-harlequin

Harlequin is a completely unique modifying gene which affects only dogs with the merle gene. It turns the areas between the dark patches into pure white (occasionally with some grey ticking or patches). This means a blue (black) merle will become white with black patches, because all the grey in its coat is turned to white. What is even more interesting about this gene is that it also affects phaeomelanin (red), not just eumelanin (black, liver, blue, isabella) like other merle modifiers. That means that a sable dog with the merling gene won't just be affected on the parts of its coat that are black (tipping, mask etc), but the whole of the coat will be harlequin. It will become what is known as a "fawnequin" - tan (sable) patches on a white base, with black patches where it would have shown black merling. The patches on the fawn section of the dog are located where the dog would have had black patches if it had been a solid blue (black) merle.

Harlequin is thought to occur on its own locus - H. It is dominant, so H is the harlequin gene and h is the non-harlequin gene. It is inherited separately to merle.

3.7.2 Locus M Pair: Merle Pattern

The "merle series", affecting the intensity of eumelanin.

- (m) uniform pigment

Research has shown that our breed has only the recessive (m) allele at this locus. The homozygous recessive (mm) produces a uniform pigment in the breed. The (M) dominant allele produces the merle or dapple pattern. The dominant (M) allele has been identified in Collies, Shetland sheepdogs, Australian Shepherds, Cardigan Welsh Corgis, Great Danes, Louisiana Catalhoula, Spotted Leopard Dogs and Dachshunds.

3.7.3 Locus S Series: White Pattern

The "spotting series", which affects the distribution of all pigment.
The alleles of the Locus S series produce the white markings that are often seen in our breed. Researchers do not agree on the mechanism of white markings caused by this series. Some suggests that a recessive allele controls "white-mottling" in dogs in varying amounts and when it is homozygous, the dog has a considerable amount of white. When it is absent the white markings are either not present or minimal, usually on the feet, tail tip and chest. Others identify four alleles at this locus:

- S solid color
- s^i Irish spotting
- s^p piebald spotting
- s^w extreme piebald spotting

The above sequence reflects the decreasing areas of pigmented hairs. There is some question about the relative dominance of and interaction between the alleles in their heterozygous forms because the expression is complicated by modifier polygenes which affect all of the alleles. Our breed, which research shows carries all four of the alleles, show all ranges of white markings from solid colors to all white.

- (S)- SOLID COLOR
  The homozygous (S) alleles produce a solid colored coat. The modifiers will, on occasion, produce a small amount of white markings on the throat, chest, toes, abdomen and belly.
- (s^i) - IRISH SPOTTING PATTERN
  This allele produces a pattern of white on the muzzle, forehead, chest, belly, feet and tail tip. The varying size of the white area is affected by the plus and minus modifiers. Breeds thought to be homozygous for this are the Boston Terrier, Basenjis and Collies.
- (s^p) - PIEBALD SPOTTING PATTERN
  This allele produces a widely varying areas of white. In the homozygous ($s^p s^p$) genotype you would see a white dog with dark patches.
- (s^w) - EXTREME PIEBALD SPOTTING PATTERN
  This allele further decreases the pigmented area and, depending on the plus or minus modifiers, the pattern can range from solid white to white with spots on the ears, around the eyes, and in the tail area.

3.7.4 Locus T Pair: Ticking

The "ticking series", affects distribution of all pigment.

- (T) Ticking

- (t) no ticking

Research has shown that our breed has only the recessive allele (t) at this locus which in the homozygous recessive (tt) allows no ticking. The dark ticking that we see in our breed is determined by other combinations of genes in the A, E and K locus, not on the Locus T Pair. In some breeds this is known as a sable. In the Amstaff, traditionally this coloring is called black or brown ticked. There are modifier polygenes that control the location and extent of the black ticking in the breed. The dominant (T) allele at this locus causes the tiny flecks of pigmented hair in otherwise non pigmented (or white) areas. The T allele is typical in breeds such as the English setter and many of the hound breeds.

3.7.5 Genotype summary

A general summary of the function of all genes (bold marks the alleles known in Amstaff):

- A locus
  - **a^y - sable**
  - a^w – agouti
  - **a^t - tan points**
  - a – recessive black
- B locus
  - **B - non-liver**
  - **b – liver**
- C locus
  - **C - normal phaeomelanin**
  - c -
- D locus
  - **D - no dilution**
  - **d - dilution of eumelanin to blue or Isabella**
- E locus
  - **E^M - black mask**
  - **E - normal extension (no mask)**
  - **e - recessive red**
- G locus
  - G – progressive greying
  - **g - no greying**
- H locus
  - H - harlequin
  - **h - non-harlequin**
- I locus
  - unknown
- K locus
  - **K - solid black**
  - **k^{br} - brindle**
  - **k - non-solid black**
- M locus
  - M - merle
  - **m - non-merle**
- S locus
  - **S - no white spotting**
  - **s^i - irish spotting**
  - **s^P - piebald**
  - **s^w - extreme white**
- T locus
  - T - ticking
  - **t - no ticking**

3.8 How does it work?

All these series working together may be confusing. So in simplified terms, how does it really work?
In trying to describe that we will stick to the traits that are known in our breed.

3.8.1 Determining base color

Well the first step is to determine the basic colors of the dog. There are two of these; the skin color (most notably seen in the nose) and the coat color.

We start with the skin color, which is the simplest:

1. We look at the B series, and we only look at the basic color (not any dilution) which can be black or brown/liver. The allele combinations BB or Bb will provide for black pigmentation, bb for brown/liver.

Then we look at the coat color, where we need to follow several steps:

1. The first data is again from the B series, so we start with either black or brown/liver.
2. Then we have a look at the E series.
   a. If the dog has any of the combinations E^ME^M, E^ME and E^Me this will result in the dog having a dark mask in its face.
   b. The combinations EE and Ee will mean the dog will express the colors as defined by the A series (in combination with K)
   c. If the dog has the combination ee it will not be able to produce any black in its coat, overriding any other allele on any series that would cause this to happen. These dogs have one solid, light color. They can still have dark skin pigment, so they can have a dark nose, eye rims, etc.
3. Next we look at the K series.
   a. If the dog has any of the combinations KK, Kk^{br} or Kk the dog will be black. We call this dominant black, and the K allele will inherit dominantly.
   b. If the dog has k^{br} k^{br} or $k^{br}k$ the dog may be a brindle, if the base color is not the same as the stripes, and if the dog is able to produce dark pigment (so not ee in the E series)
   c. If the dog has the combination kk in this series, well, then we need to go to the next step
4. Lastly we look at the A series.
   a. If the dog has a^ya^y, a^ya^t or a^ya the dog ‘s basic color will be red, with or without black hairs mixed in (sable, etc)
   b. If the dog is a^ta^t or a^ta it will be a black and tan
   c. If the dog has the combination aa in this series it will be black. This is recessive black, and the a allele will inherit recessively. Recessive black is quite rare, and it is actually not known if this allele occurs in our breed, so if your dog is black, it is likely to be determined at the K series.

While we look at the basic color there is one more thing we need to point out. A frequently observed trait in our breed is a white chest and/or white paws. Because melanocytes migrate down from the spinal column during embryogenesis, not all animals complete this process by birth or thereafter. In dogs, it is therefore not uncommon to see white toes on an otherwise black or red dog. This is probably more a random event than the result of a specific allele. Another common "white spot" on dogs occurs on the chest. This must again be a site where melanocytoe migration occurs very late in fetal development and a cold or other developmental delay prevents the completion of melanocyte migration. Simply said, the color just didn’t get to those spots during the development, and they therefore remain white.

3.8.2 Determining dilution

Now that we have established the base color of the dog we go on to the second step, the diluted colors.

1. We start by looking at the D series.
   a. A dog with the combination DD or Dd will not be diluted. So depending on the basic color that dog will be either Black, Brown/liver or Red. Brindle varieties of these colors are also possible, although these will only show on the red dogs.
   b. A dog with the combination dd in this series will have a diluted skin color (so nose blue rather than black, or pinkish rather than brown), and will have a diluted coat color.
2. The rest of the dilution of the coat color depends on the I series, of which we do not know more about the specific alleles.
3. Albino (series C) and progressive greying (series G) play no role in our breed.

3.8.3 Phenotypes with genotypes

In most cases it is possible to do a backward reasoning from the phenotype to the genotype, although it is not always possible, by just looking at the dog, to know if it is homozygous or heterozygous for certain traits. Some laboratories can perform DNA tests to determine a number of genetic color traits. In other cases more information can come from looking at a dog's pedigree and/or offspring.
For example a black dog that has one red parent, or a black dog that produces even a single red offspring, cannot be homozygous for dominant black (K^B)

In the overview below we use the '-' sign in the second position of an allele if the value of that particular position can be any of the known values for that allele, but it's real value does not change the outcome.
So K^B-, means a dominant black dog. Since the K^B is dominant, the resulting phenotype will be the same for either K^BK^B, K^Bk^{br} and K^Bk^y, and therefore we use K^B- rather than writing out the whole series of combinations.

We also left out a number of alleles as they should not be important for our breed:

- We assume the rare recessive black trait does not exist in our breed or is so rare we can leave it out of this overview
- All Amstaffs have CC at the C series (no albino or Chinchilla dilution)
- All Amstaffs have gg at the G series (no progressive greying)
- All Amstaffs have BB at the B series. If there would be dogs with bb or even Bb we would see liver color dogs with brown/liver noses. These may occur in our breed, but again are so rare we do not take them into account.

A summary of genotypes in the American Staffordshire Terrier:

- Black: E-K^B-D- (a^y- or a^ta^t)
- Blue: E-K^B-dd (a^y- or a^ta^t)
- Black & Tan: E-$k^yk^ya^ta^t$D-
- Blue & Tan: E-$k^yk^ya^ta^t$dd
- Red with mask: E^M-$k^yk^ya^ya^y$D-
- Red mask: E-$k^yk^ya^ya^y$D-
- Red sable: E- $k^yk^ya^ya^y$D-
- Blue Fawn with mask: E^M-$k^yk^ya^ya^y$dd
- Blue Fawn mask: E-$k^yk^ya^ya^y$dd
- Fawn: E-$k^yk^ya^ya^y$dd
- Fawn sable: E-$k^yk^ya^ya^y$dd
- Black or Red brindle with mask: E^M-k^{br} k^{br} a^ya^yD-
- Black or Red brindle: E-k^{br} k^{br} a^ya^yD-
- Blue Brindle with mask: E^M-k^{br} k^{br} a^ya^ydd
- Blue Brindle: E-k^{br} k^{br} a^ya^ydd
- Fawn brindle: E-k^{br} k^{br} a^ya^yD-

Can we eliminate some of the unknowns? For example, you have a black dog (E-K^B-D- a^y- or a^ta^t). This does not give you much certainty about the way the dog will inherit.
Some clues:

- Black:
  Is the dog K^BK^B or K^BK^y? If any of the parents had a red base color, or any offspring shows a red based color, then we know the dog in question cannot be homozygous and will be K^BK^y.
- Dark pigment:
  Is the dog DD or Dd? If any of the parents had a diluted color, or any offspring shows a diluted color, then we know the dog in question cannot be homozygous and will be Dd.
- Pigment extension:
  Is the dog EE or Ee? If any of the parents missed the pigment extension (had no black hair in the coat), or any offspring misses the pigment extension, then we know the dog in question cannot be homozygous and will be Ee.

4 LITERATURE

The following books and documents were used, directly or indirectly, to produce this document:

- http://www.doggenetics.co.uk/
- http://homepage.usask.ca/~schmutz/dogcolors.html
- http://news.ucsc.edu/2007/11/1769.html
- http://www.tenset.co.uk/doggen/indexus.html
- Genes affecting coat colour and pattern in domestic dogs: a review, S. M. Schmutz and T. G. Berryere
- The Genetics of Breed Color In The American Pit Bull Terrier by Amy Greenwood Burford B.S. (Warning; this document is outdated)

On the site http://www.tenset.co.uk/doggen/indexus.html a free software product is available to calculate the outcome of a breeding based on genotype of the parents. It is also a useful tool to see what the phenotype with a certain genotype is (selecting genotype for one of the parents)