

COLOUR IN BULL TERRIERS – Part 2 – Inheritance of Colour – Short Version

As discussed in “Colour in Bull Terriers – Part 1 –Expression of Colour”, the colours and colour patterns we observe in Bull Terriers are created by the interactions of just four genes. A restricted gene pool and selective breeding have removed the effect of the ten other coat colour genes for dogs in the Bull Terrier breed.

Just as a reminder, there are 14 loci – particular locations on specific chromosomes where genetic material influencing coat colour can be found.

The loci that are identical in all Bull Terriers are:

The B-Series Locus – Black/Brown Pigment Series

All Bull Terriers are believed to have the genotype *BB* i.e. they have black pigment of the nose, eye rims and mouth.

The C-Series Locus – Pigment Depth or Albino Series

All Bull Terriers are believed to have the genotype *CC* i.e. they have full colour expression with no dilution.

The D-Series Locus – Pigment Density Series

All Bull Terriers are believed to have the *DD* genotype resulting in normal pigment density and no dilution.

The G-Series Locus – Progressive Greying Pattern

All Bull Terriers are believed to have the genotype *gg* i.e. no progressive greying pattern is exhibited.

The P-Series Locus – Pigment Dilution

All Bull Terriers are believed to be *PP* which means that both melanin pigments are not diluted at all.

The I-Series Locus – Intensity Dilution

All Bull Terriers are believed to be *II* i.e. intense colour with no dilution of the phaeomelanin pigment.

The M-Series Locus – Merle Pattern

This locus has no effect in Bull Terriers as all Bull Terriers are believed to be *mm* – no merle pattern.

The H-Series Locus – Harlequin Pattern

The *H* allele is only expressed if the *M* allele causing the merle pattern is also present. As all Bull Terriers are *mm* for no merle pattern, so they are also *hh* for no harlequin pattern.

The T-Series Locus – Ticking Pattern

As ticks are a fault as laid out in the Standard of the Bull Terrier, this phenotype has been selectively bred out. All Bull Terriers should have the *tt* genotype with no ticking.

The R-Series Locus – Roan Pattern

Roan often occurs in dogs which also show ticking. Future research may reveal that it is a variation of ticking rather than a separate pattern. At present, Bull Terriers are believed to be *rr* i.e. no roan pattern.

Remember genotype is the combination of alleles the dog possesses while its phenotype is what it actually looks like. Thus all Bull Terriers for these loci should have the following genotype: *BBCDDgghIIImmPPrrtt*. Of course in all of these loci, mutation of a gene could, and does occur,

causing a change from these genotypes. However as mutation is a random occurrence, it should not have any influence on the overall Bull Terrier population especially when selective breeding against these traits is being exercised.

The four loci which cause variation in colour in Bull Terriers are:

The A-Series Locus – Dark Pigment Pattern or Agouti Series

While there are six alleles possible in the A-Series loci, only two of these occur in the Bull Terrier breed. These two alleles are A^y and a^t . A^y is completely dominant over a^t . This results in three genotypes and their corresponding phenotypes:

$A^y A^y$ – causing a red/fawn phenotype;

$A^y a^t$ – causing a darker red/fawn colour;

$a^t a^t$ – black and tan pattern.

Basically there are two base coat options for a Bull Terrier: the red/fawn colour or a black pattern over the red/fawn colour where the red/fawn colour is visible as marks on the eyebrows and cheeks and edging the black on the chest and lower legs and on the bottom under the tail.

The K-Series Locus – Brindling Pattern

While there are three alleles possible in the K-Series loci, only two of these occur in the Bull Terrier. These two alleles are k^{br} and k^y where k^{br} is dominant to k^y . This results in three genotypes and their corresponding phenotypes:

$k^{br} k^{br}$ – A-Series colour with brindling pattern on the tan/sable;

$k^{br} k^y$ – A-Series colour with brindling pattern on the tan/sable;

$k^y k^y$ – A-Series colour with no brindling pattern at all.

As the k^{br} allele is dominant, if a Bull Terrier has this allele, it will display the brindle pattern and can pass on the brindle pattern. The only exception is in a white Bull Terrier carrying the k^{br} allele, which can pass on brindle but doesn't display it due to the white mask.

The E-Series Locus – Pigment Extension

While there are three alleles possible in the E-Series loci, only two of these occur in the Bull Terrier. These two alleles are E and E^m where E^m is dominant over E . This results in three genotypes and their corresponding phenotypes:

EE – Solid colour as defined by A-Locus Series – no dark mask;

EE^m – Colour as defined by A-Locus Series but with a dark mask;

$E^m E^m$ – Colour as defined by A-Locus Series but with a dark mask.

Originally the brindle markings were believed to be controlled by the E-Series but now it has been found that the E-Series is only responsible for the black mask being present or absent in Bull Terriers. The mask causes darker colour on the muzzle mainly extending up towards the eyes and sometimes visible on the top of the back and tail and is known as smut marking. Before a dog could either be brindle or smut but not both. With the discovery of the K-Series controlling brindle patterns, brindle dogs (in fact any colour) can also have smut markings even if they are not visible due to the dark overall colour. This gene is a difficult one to consider as the dark mask is only really properly visible in Red Solids (and Fawn Solids) causing Red Smut and Fawn Smut. In Red and White and Fawn and White dogs (and even in Brindle and White), the mask is covered by the white facial patches and can only be visible as black lip markings or black tear marks. In Brindle and Black and Tan colours, the dark mask is not seen unless in the case of Brindle, the Brindle colour is very pale. The back facial mask may be much more common than it appears to be.

The S-Series Locus – White Spotting Pattern

While there are four alleles known to occur in the S-Series loci, it is speculated that only two of these occur in the Bull Terrier. They are s^j and s^w with s^j dominant over s^w . This results in three genotypes and their corresponding phenotypes:

$s^j s^j$ – Little or no white confined to the blaze, chest and feet – known as a Solid-Coloured;



$s^j s^w$ – White blaze, chest, collar, underbelly, lower legs, feet and tail tip with white only extending over the back at the neck – known as Coloured & White;



$s^w s^w$ – All white – may have some colour markings confined to the head.

Bull Terriers are believed to only have the alleles s^i and s^w and not the dominant S allele that causes true solid colour. This idea may change with more research. There definitely is the occurrence of a Bull Terrier who appears solid coloured (with limited white markings) producing all white puppies (thereby proving it is not solid-coloured genetically), and the occurrence of a coloured dog with quite significant white markings unable to produce a white puppy (indicating that it is solid-coloured genetically). Plus and minus modifiers also act on this gene changing the way it is expressed.



Putting these four loci and their different possible allele combinations together there are 27 different genotype options which would describe the 12 different phenotypes observed in Bull Terriers. Remember dominant alleles can mask the effect of a recessive allele so you can have two dogs which are phenotypically the same e.g. black brindle solids but genotypically they can be different e.g. $a^t a^t k^{br} k^{br} s^i s^i$ and $a^t a^t k^{br} k^y s^i s^i$. All possible genotype options for an observable phenotype have been included in the tables below. For simplification, it has been decided to leave out the effect of the E-Series locus as the effects of this are not visible in most of the phenotypes.

WHITE BULL TERRIERS



Phenotype	Option	Genotype	Possible Offspring Colours
White carrying Red/Fawn 	1	$A^y A^y k^y k^y s^w s^w$	- can produce WHITE, RED & WHITE and BRINDLE & WHITE puppies depending on the colour of the mate.
	2	$A^y a^t k^y k^y s^w s^w$	- can produce TRICOLOUR and BLACK BRINDLE & WHITE puppies as well as all WHITE, RED & WHITE and BRINDLE & WHITE depending on the colour of the mate.
White carrying Brindle 	1	$A^y A^y k^{br} k^{br} s^w s^w$	- can only produce all WHITE and/or BRINDLE & WHITE puppies no matter what the colour of the mate.
	2	$A^y A^y k^{br} k^y s^w s^w$	- can produce all WHITE, BRINDLE & WHITE and RED & WHITE puppies depending on the colour of the mate.
	3	$A^y a^t k^{br} k^{br} s^w s^w$	- can produce all WHITE, BRINDLE & WHITE and BLACK BRINDLE & WHITE puppies depending on the colour of the mate.
	4	$A^y a^t k^{br} k^y s^w s^w$	- can produce all coloured & white options – BRINDLE & WHITE, BLACK BRINDLE & WHITE, RED & WHITE & TRICOLOUR as well as all WHITE puppies depending on the colour of the mate.

Phenotype	Option	Genotype	Possible Offspring Colours
White carrying Black & Tan 	1	$a^t a^t k^y k^y s^w s^w$	- can produce all coloured & white options – BRINDLE & WHITE, RED & WHITE, BLACK BRINDLE & WHITE & TRICOLOUR as well as all WHITE puppies depending on the colour of the mate.
White carrying Black Brindle 	1	$a^t a^t k^{br} k^{br} s^w s^w$	- can produce all WHITE, BRINDLE & WHITE or BLACK BRINDLE & WHITE depending on the colour of the mate.
	2	$a^t a^t k^{br} k^y s^w s^w$	- can produce all coloured & white options – BRINDLE & WHITE, BLACK BRINDLE & WHITE, RED & WHITE & TRICOLOUR as well as all WHITE puppies depending on the colour of the mate.


RED BULL TERRIERS


Phenotype	Option	Genotype	Possible Offspring Colours
Red/Fawn Solid 	1	$A^y A^y k^y k^y s^i s^i$	- can produce RED SOLID, BRINDLE SOLID, RED & WHITE and BRINDLE & WHITE puppies depending on the colour of the mate.
	2	$A^y a^t k^y k^y s^i s^i$	- can produce all solid coloured and coloured & white options – BRINDLE SOLID, BRINDLE & WHITE, RED SOLID, RED & WHITE, BLACK BRINDLE SOLID, BLACK BRINDLE & WHITE, BLACK & TAN SOLID and TRICOLOUR puppies depending on the colour of the mate.
Red/Fawn & White 	1	$A^y A^y k^y k^y s^i s^w$	- can produce RED SOLID, BRINDLE SOLID, RED & WHITE, BRINDLE & WHITE and all WHITE puppies depending on the colour of the mate.
	2	$A^y a^t k^y k^y s^i s^w$	- can produce all colour options – BRINDLE SOLID, BRINDLE & WHITE, RED SOLID, RED & WHITE, BLACK BRINDLE SOLID, BLACK BRINDLE & WHITE, BLACK & TAN SOLID, TRICOLOUR and all WHITE puppies depending on the colour of the mate.

BLACK & TAN/ TRICOLOUR BULL TERRIERS

Phenotype	Option	Genotype	Possible Offspring Colours
Black & Tan Solid 	1	$a^t a^t k^y k^y s^j s^j$	- can produce all colour options except WHITE – i.e. BRINDLE SOLID, BRINDLE & WHITE, RED SOLID, RED & WHITE, BLACK BRINDLE SOLID, BLACK BRINDLE & WHITE, BLACK & TAN SOLID and TRICOLOUR puppies depending on the colour of the mate.
Tricolour 	1	$a^t a^t k^y k^y s^j s^w$	- can produce all colour options – BRINDLE SOLID, BRINDLE & WHITE, RED SOLID, RED & WHITE, BLACK BRINDLE SOLID, BLACK BRINDLE & WHITE, BLACK & TAN SOLID, TRICOLOUR and all WHITE puppies depending on the colour of the mate.

BRINDLE BULL TERRIERS

Phenotype	Option	Genotype	Possible Offspring Colours
Brindle Solid 	1	$A^y A^y k^{br} k^{br} s^j s^j$	- can only produce BRINDLE SOLID and/or BRINDLE & WHITE puppies no matter what the colour of the mate is.
	2	$A^y A^y k^{br} k^y s^j s^j$	- can produce BRINDLE SOLID, RED SOLID, BRINDLE & WHITE or RED & WHITE puppies depending on the colour of the mate.
	3	$A^y a^t k^{br} k^{br} s^j s^j$	- can produce BRINDLE SOLID, BLACK BRINDLE SOLID, BRINDLE & WHITE or BLACK BRINDLE & WHITE puppies depending on the colour of the mate.
	4	$A^y a^t k^{br} k^y s^j s^j$	- can produce all colour options except WHITE – i.e. BRINDLE SOLID, BRINDLE & WHITE, RED SOLID, RED & WHITE, BLACK BRINDLE SOLID, BLACK BRINDLE & WHITE, BLACK & TAN SOLID and TRICOLOUR puppies depending on the colour of the mate.

Phenotype	Option	Genotype	Possible Offspring Colours
Black Brindle & White 	1	$a^t a^t k^{br} k^{br} s^j s^w$	- can produce BRINDLE SOLID, BLACK BRINDLE SOLID, BRINDLE & WHITE, BLACK BRINDLE & WHITE and all WHITE puppies depending on the colour of the mate.
	2	$a^t a^t k^{br} k^y s^j s^w$	- can produce all colour options – BRINDLE SOLID, BRINDLE & WHITE, RED SOLID, RED & WHITE, BLACK BRINDLE SOLID, BLACK BRINDLE & WHITE, BLACK & TAN SOLID, TRICOLOUR and all WHITE puppies depending on the colour of the mate.










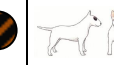



















































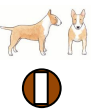
















































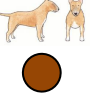
















































It would very useful for the Bull Terrier breeder to know what colours could be expected from the matings of different coloured parents. To do this, the breeder needs to know the genotypes of their breeding dogs and bitches. Remember - a particular phenotype may result from a number of different genotypes. For example, a Brindle & White Bull Terrier may have one of four different genotypes. While this phenotype is easily observable, its genotype is not so clear. If the parents of the dog are known, then it is possible to be able to identify which genotype is resulting in its Brindle & White phenotype. Thus genotype can be inferred by considering the colours of an individual's parents or from the colours of puppies already produced by that individual.

If the genotype of both parents of a litter is known, proportions of different colours for that litter can easily be calculated mathematically. (Tables of these colour proportions have been prepared in the article "Colour in Bull Terriers – Part 2 – Inheritance of Colour – Full Version"). It is important to note, that these ratios apply to large numbers of individuals and will not occur in small litters but they still give an indication of probability. To use a human example: while a mother may expect a 50% chance of a boy or a girl, she may in fact produce four sons in succession and the fact that she already has four sons does not change the probability that she could have another. She could still expect a 50% chance of another boy. As the number of puppies in a litter is tiny in statistical terms, the actual proportions of the different colours cannot be expected. However, these calculations do show which colours are not possible in particular matings.





















































































In this article "Colour in Bull Terriers – Part 2 – Inheritance of Colour – Short Version", a summarised version of colour breeding tables follow. These tables show possible colours resulting from matings but do not attempt to show either proportions within litters or the likely occurrence of these litter colour combinations (some colour combinations are much more likely to occur than others). For this more detailed information please consult the article "Colour in Bull Terriers – Part 2 – Inheritance of Colour – Full Version".

To use the tables, find the colour of the sire by looking across the top row to find the column heading corresponding to the colour, look down the left-hand column to find the row of the colour of the dam. The intersection cell of the column and the row show the colours possible.


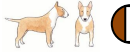





























































































































































Colour Possibilities when breeding with Red/Fawn-carrying Individuals

	White carrying Red 	Red & White 	Red Solid 	White carrying Black & Tan 	Tricolour 	Black & Tan Solid 	White carrying Brindle 	Brindle & White 	Brindle Solid 	White carrying Black Brindle 	Black Brindle & White 	Black Brindle Solid 
White carrying Red 	 or   or 	 or   or 	 or   or 	 or   or 	 or   or 	 or   or 	 or   or 	 or   or 	 or   or 	 or   or 	 or   or 	 or   or 
Red & White 	 or   or 	 or   or 	 or   or 	 or   or 	 or   or 	 or   or 	 or   or 	 or   or 	 or   or 	 or   or 	 or   or 	 or   or 
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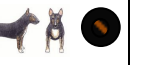
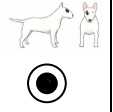



































































































































Colour Possibilities when breeding with Black & Tan-carrying Individuals

	White carrying Red 	Red & White 	Red Solid 	White carrying Black & Tan 	Tricolour 	Black & Tan Solid 	White carrying Brindle 	Brindle & White 	Brindle Solid 	White carrying Black Brindle 	Black Brindle & White 	Black Brindle Solid 
White carrying Black & Tan 	 or 	 or 	 or 				 or  or 	 or  or 	 or 	 or 	 or 	 or 
Tri-colour 	 or 	 or 	 or 				 or  or 	 or  or 	 or 	 or 	 or 	 or 
Black & Tan Solid 	 or 	 or 	 or 				 or  or 	 or  or 	 or 	 or 	 or 	 or 












Colour Possibilities when breeding with Brindle-carrying Individuals

	White carrying Red 	Red & White 	Red Solid 	White carrying Black & Tan 	Tricolour 	Black & Tan Solid 	White carrying Brindle 	Brindle & White 	Brindle Solid 	White carrying Black Brindle 	Black Brindle & White 	Black Brindle Solid 
White carrying Brindle 	 or  or  or 	 or  or  or 	 or  or  or 	 or  or  or 	 or  or  or 	 or  or  or 	 or  or  or 	 or  or  or 	 or  or  or 	 or  or  or 	 or  or  or 	 or  or  or 
Brindle & White 	 or  or  or 	 or  or  or 	 or  or  or 	 or  or  or 	 or  or  or 	 or  or  or 	 or  or  or 	 or  or  or 	 or  or  or 	 or  or  or 	 or  or  or 	 or  or  or 
Brindle Solid 	 or  or  or 	 or  or  or 	 or  or  or 	 or  or  or 	 or  or  or 	 or  or  or 	 or  or  or 	 or  or  or 	 or  or  or 	 or  or  or 	 or  or  or 	 or  or  or 

Colour Possibilities when breeding with Black Brindle-carrying Individuals

	White carrying Red	Red & White	Red Solid	White carrying Black & Tan	Tricolour	Black & Tan Solid	White carrying Brindle	Brindle & White	Brindle Solid	White carrying Black Brindle	Black Brindle & White	Black Brindle Solid
												
White carrying Black Brindle 	or  or  or  or  or 	or  or  or  or  or 	or  or  or  or  or 	or  or 	or  or  or  or 	or  or 	or  or  or  or  or 	or  or  or  or  or 	or  or  or  or  or 	or  or 	or  or  or  or 	or  or 
Black Brindle & White 	or  or  or  or  or 	or  or  or  or  or 	or  or  or 	or  or  or 	or  or  or  or 	or  or 	or  or  or  or  or 	or  or  or  or  or 	or  or  or  or  or 	or  or  or 	or  or  or  or 	or  or 
Black Brindle Solid 	or  or  or  or 	or  or  or  or 	or  or 	or  or  or 	or  or  or 	or  or 	or  or  or  or 	or  or  or  or 	or  or  or  or 	or  or 	or  or  or 	or  or 

SUMMARY – Total Possible Colours from each Phenotype for any mate

X	White carrying Red 	Red & White 	Red Solid 	White carrying Black & Tan 	Tricolour 	Black & Tan Solid 	White carrying Brindle 	Brindle & White 	Brindle Solid 	White carrying Black Brindle 	Black Brindle & White 	Black Brindle Solid 
Genotype Option 1	White Red & White Brindle & White	White Red & White Brindle & White Red Solid Brindle Solid	Red & White Brindle & White Red Solid Brindle Solid	White Tricolour Black Brindle & White	White Tricolour Black Brindle & White Black & Tan Solid Black Brindle Solid	Tricolour Black Brindle & White Black & Tan Solid Black Brindle Solid	White Brindle & White	White Brindle & White Brindle Solid	Brindle & White Brindle Solid	White Black Brindle & White	White Black Brindle & White Black Brindle Solid	Black Brindle & White Black Brindle Solid
Genotype Option 2	White Red & White Brindle & White Tricolour Black Brindle & White	White Red & White Brindle & White Tricolour Black Brindle & White Red Solid Brindle Solid Black & Tan Solid Black Brindle Solid	Red & White Brindle & White Tricolour Black Brindle & White Red Solid Brindle Solid Black & Tan Solid Black Brindle Solid				White Brindle & White Red & White	White Brindle & White Red & White Brindle Solid Red Solid	Brindle & White Red & White Brindle Solid Red Solid	White Black Brindle & White Tricolour	White Black Brindle & White Tricolour Black Brindle Solid Black & Tan Solid	Black Brindle & White Tricolour Black Brindle Solid Black & Tan Solid
Genotype Option 3							White Brindle & White Black Brindle & White	White Brindle & White Black Brindle & White Brindle Solid Black Brindle Solid	Brindle & White Black Brindle & White Brindle Solid Black Brindle Solid			
Genotype Option 4							White Brindle & White Black Brindle & White Red & White Tricolour	White Brindle & White Black Brindle & White Red & White Tricolour Brindle Solid Black Brindle Solid Red Solid Black & Tan Solid	Brindle & White Black Brindle & White Red & White Tricolour Brindle Solid Black Brindle Solid Red Solid Black & Tan Solid			

GENERAL RULES OF COLOUR INHERITANCE IIN BULL TERRIERS:

- Two White parents always produce all White puppies. These White puppies may have coloured marks on their heads but they will always be almost all White in colour. Two White parents cannot produce a predominantly Coloured puppy.
- A White parent can never produce a Solid Coloured puppy – it can only produce a Coloured & White or an all White puppy.
- A Solid Coloured parent will never produce an all White puppy. Even with a White mate, a Solid Coloured parent will produce Coloured & White puppies but never all White.
- Two Solid Coloured parents will produce all Solid Coloured puppies.
- A Solid Coloured parent and a White mate will produce all Coloured & White puppies.
- A Solid Coloured parent and a Coloured & White mate will produce half Solid Coloured and half Coloured & White puppies.
- A Coloured & White and an all White parent will produce half all White puppies and half Coloured & White puppies.
- In fact any Coloured & White parent will produce half Coloured & White puppies no matter what colour the mate is.
- Two Coloured & White parents will produce a quarter Solid Coloured and a quarter all White puppies with half Coloured & White.
- Brindle puppies will only result when either one of the parents is Brindle or White carrying Brindle. If a dog has a Brindle gene, they will show Brindle (either Brindle, Brindle & White, Black Brindle or Black Brindle & White) and only then can they pass Brindle on to their offspring. The only exception to this is if it is a White dog carrying that Brindle without any coloured marks to show it.
- Two non-Brindle parents can never produce a Brindle puppy.
- If Black & Tan, Tricolour, Black Brindle or Black Brindle & White dogs are bred with each other, the offspring will only be one of these four options.

It must be highlighted again that the actual proportions of the different colours presented in the tables will only be evident with very large numbers of puppies as a single litter of puppies is too small statistically to reflect this. The tables can however show possible colours that can result from a mating. In conclusion, coat colours in Bull Terriers are comparatively simple to understand as only four genes determine colour variation in our breed. Breeders can use the phenotype of an individual and the colours of the parents and grandparents to determine its genotype. Litters produced can confirm this genotype. Once the genotype is known, future possible litter colours can be predicted from these tables.

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