

Genetics of Coat Color



Coat Color Traits

Genetic Terms

Study of Color Traits in Bearded Collies

Loci Affecting Color

Summary

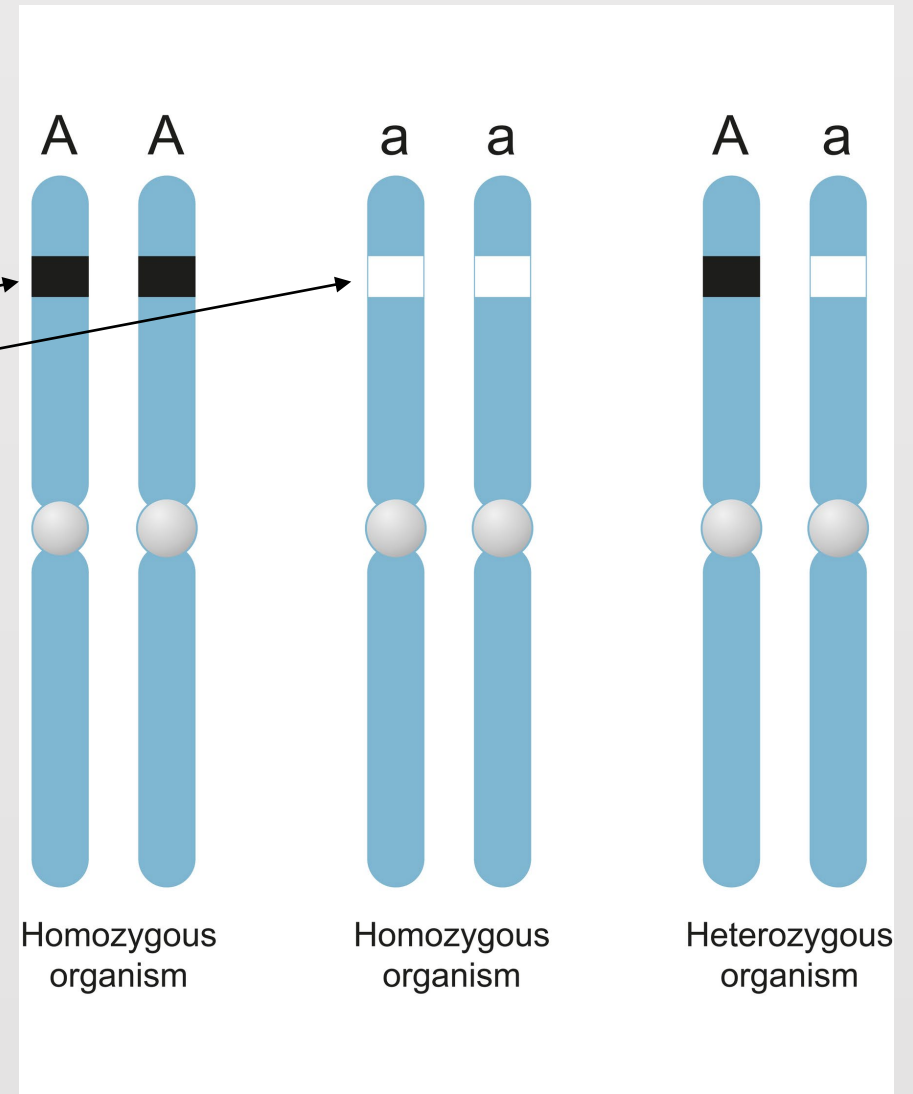
Coat Color Change with Age

Terms

- **Genotype:** the set of genes that an individual carries
- **Phenotype:** all an individual's observable characteristics that are influenced by the genotype and/or the environment
- **Masking:** functions of one gene can mask the function of another gene

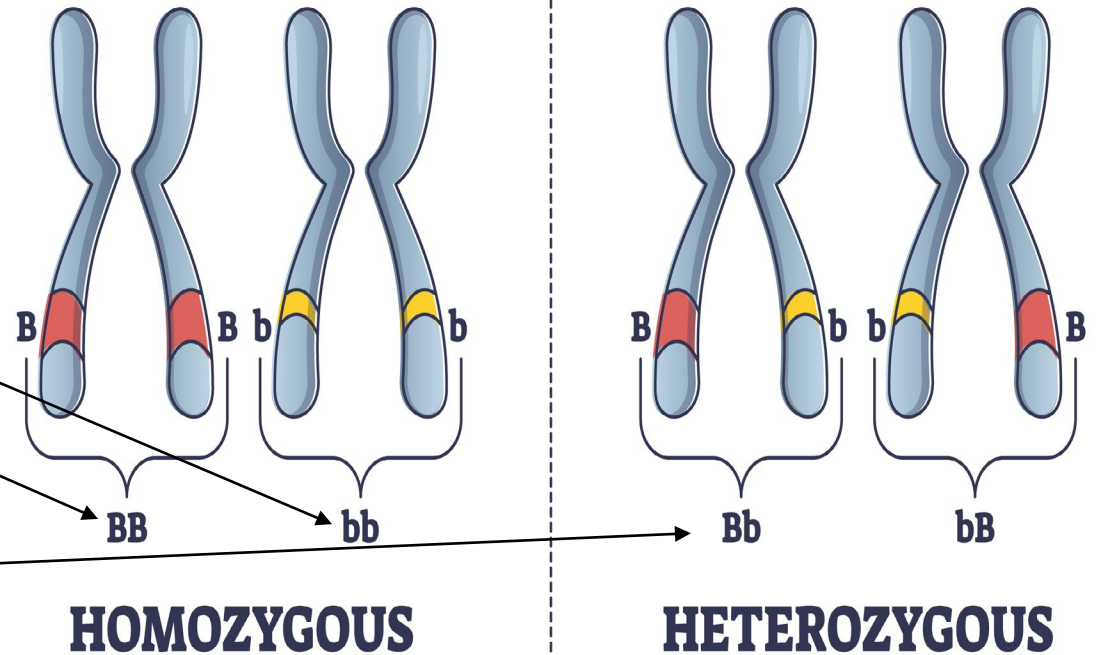
Terms, 2

- **Genes:** Chromosomal DNA which provides the blueprint for proteins; those contribute to traits or functions.
- **Locus:** Location of a gene on a chromosome (black or white bands)
- Every gene has multiple alleles though an individual normally only has 2 **alleles** (or versions) - one from each parent (A or a).
- **Alleles vary the trait or function;** e.g., if a gene is responsible for height, its alleles determine whether the height is tall or short



Terms, 3

- **Homozygous:** inherit the same allele of a gene from each parent (2 BB or 2 bb)
- **Heterozygous:** inherit a different allele of a gene from each parent (Bb or bB)



Terms, 4

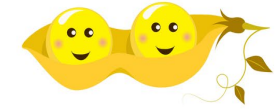
- **Dominant:** Only 1 copy of an allele is needed to express the phenotype. (G)
- **Recessive:** Two copies of an allele are needed to express the phenotype (g). A dominant allele will hide the other allele if the dog is heterozygous.

Mendel's Law of Dominance

Dominant trait = D
Peas are **green** in color



Recessive trait = d
Peas are **yellow** in color



Heterozygous green (Gg)





G

g

Heterozygous green (Gg)

G

g

Genotype GG Phenotype 	Genotype Gg Phenotype 
Genotype Gg Phenotype 	Genotype gg Phenotype 

Study of Color Traits in Bearded Collies

The BCCA has partnered with Embark Labs which currently tests for 9 color trait loci and is researching several others.

Data on frequency of coat color alleles were reported to BCCA in spring 2023; those are included in the slides on specific loci.

The coat color assigned is that seen at birth even though it changes with age (see last slides).

Canine Color Genetics

- Complex traits are determined by the interaction of allele/genes at different loci. For example, it's estimated that human height is influenced by a minimum of 400 alleles at different loci.
- At least 9 loci have a role in controlling color of dogs.

Loci Affecting Coat Color

Black is essentially the default for dogs if they don't inherit two copies of the alleles associated with any of the recessively inherited colors (e.g., brown, blue, fawn, tan points)

Loci Determining Base Color

LOCUS	EFFECT
E	Pigment Production Eumelanin (produces black in coat, paw pads, eyes, nose) Pheomelanin (produces reddish yellow pigment only in the coat)
K	Presence of black pigment
A	Distribution of pigments produced at E locus
B	Color of eumelanin (lightens black to brown)

Loci Modifying Base Color*

LOCUS	EFFECT
D	Dilutes color present (brown to fawn, black to blue). It does not cause progressive graying.
G	Graying ... a theoretical locus modifying intensity over time; the associated genetic variants are yet to be discovered.
Unnamed	Irish marking; it is possible that the small amount of white on paws, face, chest, and tail may be due to the Irish marking. More research is needed to identify loci responsible.
S	Location of pigment production. The insertion (addition) of a nucleotide near S turns off production of pigment. 2 copies of the insertion (ss) turn off pigment production in the coat and skin.

* Other loci not applicable to the Bearded Collie are M (merle) and H (harlequin)

Eumelanin Pigment

- Eumelanin gives your dog's coat a certain color; it also influences the coloration of a dog's eyes, skin and nose pigment.
 - A **black dog** has black skin and nose pigment and its eyes are brown or hazel.
 - A **brown dog** has chocolate brown skin and nose pigment and golden or amber eyes.
 - A **blue dog** has slate blue skin and nose pigment and a light amber or green eye color.
 - A **fawn dog** has pale brown skin and nose pigment and also light amber or green eyes.
- Even if you can't see any eumelanin in a dog's coat at all (e.g. in all-white, yellow, or red dogs), in most cases the eumelanin color can be determined by looking at the dog's nose pigmentation.

Nose Pigment



Blue



Fawn



Brown



Black

E Locus

- The **E allele** gives the ability to make eumelanin (black pigment). An E allele is dominant to an e allele (recessive red). An ee dog produces no dark hairs but various shades of red (deep copper, yellow, cream, white) that is controlled by multiple loci.
- **E locus** has 4 alleles with a hierarchical dominance pattern:
$$E_m > E_g > E > e_e$$
- **Em** (dark mask). Physical visibility of this and the Eg (grizzle) variant is dependent on genotypes at the K and A loci.
- **ee**: no dark hairs, only various shades of red (deep copper, yellow, cream, white) that are controlled by multiple loci
- Embark Beardies: Locus distribution: 88.8% EmEm, 11.1% EmE

K Locus

- The K locus affects eumelanin production and distribution
- The K locus has 2 reported alleles
 - **KB** and **ky**. KB is dominant to ky (only 1 copy of KB is needed for the coat color to be expressed and the A locus can be ignored regarding that dog's phenotype)
- **KB**: Solid black all over; it overrides the A locus
- **kyky**: The color is determined by the A locus
- Embark Beardies: Locus distribution: 64.4% KBKB; 31.6% Kbkky; 3.8% kyky

A Locus

- The A locus affects distribution of both eumelanin and pheomelanin
- The A locus has 4 alleles with a hierarchical pattern of dominance in most breeds: A_y (sable) > A_w (banded hairs) > A_t (tan points) > aa (recessive black - solid black with no red hair in coat)
- Embark Beardies: Locus distribution: 99.2% A_tA_t (this is only expressed if a dog's K locus is $kyky$ {previous slide})

B Locus

- The B locus affects the color of eumelanin in the coat, nose, paw pads, and eyes
- B is dominant to b
 - BB or Bb dogs produce normal black eumelanin
 - bb dogs produce liver eumelanin instead of black, lightening black to chocolate, liver or brown
- Embark Beardies: Locus distribution: 44.9% Bb; 33.8% BB; 21.0% bb

D Locus

- The D locus (dilution) affects the intensity of eumelanin in the coat, nose, paw pads, and eyes
- D is dominant to d
 - DD or Dd dogs produce normal black eumelanin
 - dd turns black to blue and brown to fawn
- Embark Beardies: Locus distribution: 46.6% Dd; 40.3% DD; 10.8% dd

S Locus

- The S locus controls where pigment is produced in a dog's coat and skin. An insertion (a type of mutation) near the S gene turns off pigment production in the coat and skin, resulting in white hair and/or pink skin.
- Dogs with 2 copies of the insertion (spsp) will likely have breed dependent white patterning. Dogs with 1 copy (Ssp) will likely have more limited white spotting.
- Embark Beardies: Locus distribution: 88.1% SS; 11.8% Ssp; no ss reported to date

G Locus

- **G locus (greying) affects how eumelanin in the coat keeps its intensity over time.**
- **At present this is a theoretical locus that has not been identified**

Impact of Genetics on Knowledge about Canine Color

- Phenotype (what is seen) can be produced by 1 or more genotypes
- Genetic study confirms what was previously observed
 - Black is dominant, meaning only 1 parent needs to have the trait
 - Brown is recessive, meaning both parents must have the trait
 - The diluted versions of black and brown are inherited from the D locus (dd) as recessives
 - Dilute black genotypes: BBdd, Bbdd
 - Dilute brown genotypes: bbdd

Impact of Genetics on Knowledge about Canine Color

- Study has demonstrated that color can be influenced by more than one genetic locus
- The K locus is dominant and controls when black color is present. 96% of Beardies are genotype KBKB or Kbky
 - If the K locus is recessive (kyky), then the A locus has a role: (A locus dominance hierarchy is Aw, Ay, At, a)
 - Although 99.2% of Bearded Collies are AtAt, only the 3.8% who have the recessive K (kyky) have tan points
 - Tan pointed dogs' base color is determined by the B locus
 - Black (BB or Bb); brown (bb) or their dilute counterparts

Impact of Genetics on Knowledge about Canine Color

- The S locus controls white spotting
 - 1 copy of a mutation near S (sp) causes limited white spotting (present in 11.8% of Bearded Collies; an example is white extending up the front of the hock)
 - 2 copies of the mutation (spsp) causes more white (possibly what is called a “mismark”). To date none have been reported in the Beardie
- The greying locus which governs intensity of eumelanin over time has not yet been identified

References

- [Dog Coat Colour Genetics](#)
- [Embark - coat color genetics 101](#)
- [Coats and Colors](#)
- [British Bearded Collie Connexion](#)



The following slides show color changes with age in Bearded Collies

Coat Color Change with Age



Black



6 weeks



1 year

Stay Black



2 months



7 months



20 months



7 years

Brown- bbDd KbKb atat SS



2 months



9 months



3 years



Brown Tri - bbDd kyky atat SS



2 months



~ 11 months



5 years



14 years

Blue



Young pup



Adult

Fawn - bbdd Ssp



Young pup



Adult

Rainbow Litter



Brown



Blue



From Top (2 Blue), small black, Fawn, Black, Brown, Black, Black, Brown



Fawn



Black

Rainbow Litter

Brown Puppy



4 weeks

8 weeks

2 days

Rainbow Litter

Fawn Puppy



8 weeks

Credits

Dr. Judith Leroy
Joanne Williamson
Dr. Casey Carl, Embark
Dr. Elsa Sell, author