W 891

EQUINE GENETICS
BASIC COAT COLOR INHERITANCE

Kelly Melvin, Graduate Research Assistant, Department of Animal Science
Jennie Ivey, PhD, PAS, Assistant Professor and Extension Equine Specialist, Department of Animal Science
Lacey Johnston, MS, PAS, Equine Lecturer, Department of Animal Science

Special Credit: **Victoria Alphen** and **Erin Roberts**, created in part for ANSC 496 Equine Industries

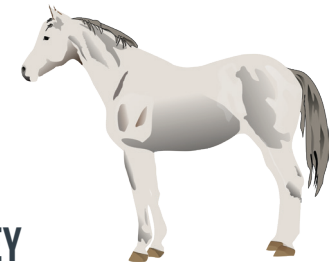
Horses come in many colors, all of which are controlled by genetic variation in one or more genes within the horse's genetic makeup. Properly identifying coat colors and knowing how each of these genes influence coat color is important to consider when breeding responsibly. Knowing and applying a horse's coat color genetics in combination with other genetic factors when selecting breeding stock can help decrease certain diseases, overpopulation and unwanted horses, while ultimately improving the foal's conformation, use and longevity. The focus of this publication is to review basic coat color descriptions and associated genes that are responsible for producing each color.

COAT COLOR DESCRIPTIONS

Properly identifying a horse's coat color through visual evaluation is an initial step to determine the potential genetic makeup of an individual. Use the guide and images below to assess basic coat colors common among most horse breeds.

WHITE

Absence of pigment in the skin and hair. Generally, white horses have pink skin; a white coat, mane and tail; and light hooves. White horses most likely have dark brown eyes but may have blue eyes.



GREY

Grey horses will have dark pigmented skin and can be born displaying any other coat color, except white. Grey colored horses will permanently fade to gray over time. Fleabitten greys maintain tiny areas of the original coat color amongst grey coat hairs.

BLACK

Black horses have black pigmentation and will not bleach in the sun.

CHESTNUT

Chestnut horses have red pigmentation which can vary from light (sorrel) to very dark (liver) in color. Chestnut colored horse's mane and tail may be similar to the body color, or vary to lighter or darker shades.

BAY

Bay horses have a brown body, which can vary in shades, and black points including the ears, legs, muzzle, mane and tail.

DUN

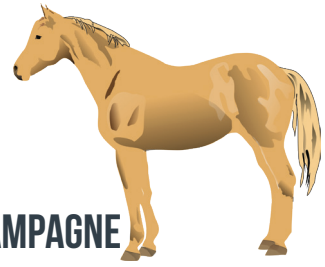
The dun color alters the horse's base body color to display primitive markings on legs and shoulders, such as leg barring, shoulder striping, cobwebbing throughout the coat and a dorsal stripe. The dun gene can produce a bay dun (pictured, bay base color), red dun (chestnut base color) or grulla (black base color).

PALOMINO

Palomino horses will display a light (flaxen) mane and tail with varying shades of golden body hair, resulting from a dilution of the chestnut body color.

BUCKSKIN

Horses with buckskin coloration will display black points on the mane, tail, ears and legs, and a golden coat that can vary in shade. Buckskin color results from a dilution of a bay body color base.



CHAMPAGNE

Depending on base color, champagne colored horses can range from gold (above) to dark tan, and tend to have amber eyes. A dilution of a black body base results in classic champagne color, while chestnut base horses dilute to a gold champagne, and bay horses dilute to amber champagne.

ROAN

Roan horse coats have a mixture of 50 percent white hairs and 50 percent any base color. A red or strawberry roan (pictured above) will have a chestnut base. Roaning over a black base is called a blue roan, and over a bay base is a bay roan.

WORDS TO KNOW

Gene: A unit of heredity which is transferred from a parent to offspring and determines a characteristic of the offspring

Allele: A variant form of a gene

Locus: A fixed position on a chromosome where a gene is located

Heterozygous: Has two different alleles of a gene

Homozygous: Has two of the same alleles of a gene

Genotype: The genetic makeup of an individual, created by the combination of alleles unique to each individual

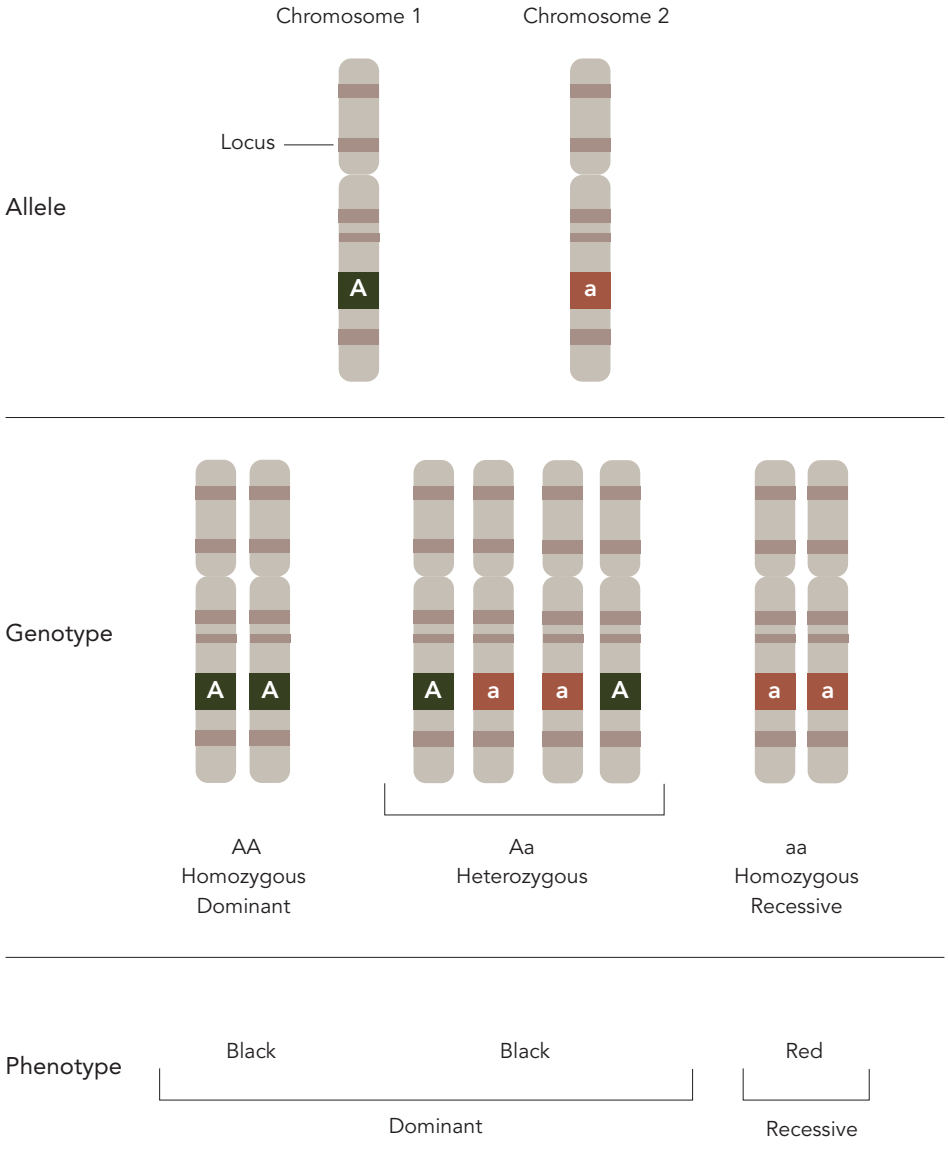
Phenotype: The observable or physical characteristics an individual displays as a result of their genotype

Dominant: The result of a dominant allele expressed over other alleles within a phenotype

Recessive: An allele that can be masked by a dominant allele; In order for a recessive allele to be expressed in a phenotype, there must be two recessive alleles inherited

Incomplete dominance: An intermediate form of inheritance in which a heterozygous genotype displays a mixture of phenotypic traits encoded by each allele

Epistatic: The interaction between different genes in which a dominant gene can mask the phenotypic expression of other genes



BASE COAT COLORS AND LACK OF PIGMENT

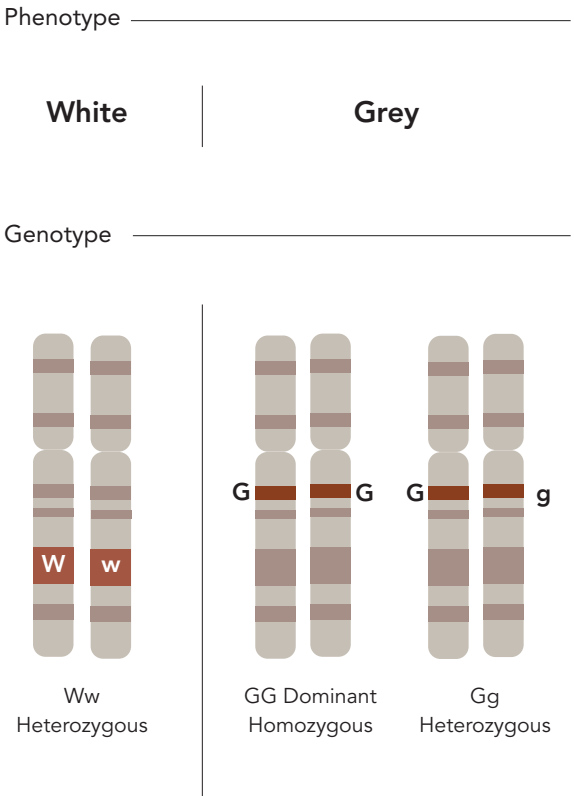
Two main pigments create all equine coat colors. No matter the coat color that is seen, all horses start with a base of either red or black. Horses with base black pigment, or eumelanin, will display either a black or bay coat color. Horses with red base color display the pigment pheomelanin, will have no eumelanin, and thus display a red coat color. Other coat colors are due to lack of pigmentation, dilutions or other patterning genes and their expression.

WHITE-BASED COLORS

There are two white-base colors: white and grey. Both the white and grey genes are called epistatic, meaning a dominant allele for either gene will mask other phenotypes, or coat colors.

White: White horses lack any pigmentation in the skin and hair. White horses will display pink skin; a white hair coat, mane, tail and hooves; and darker brown eyes. White is a dominant trait, W, at the white locus. The genotype for white horses must be heterozygous dominant, Ww, as homozygous dominant, WW, is thought to cause early embryonic loss.

Grey: Grey horses can be born any color other than white, and as they age grey hairs will appear and lighten. Grey coat color is due to the presence of the dominant allele, G, at the grey locus. The genotype of a horse with this allele present will be either GG or Gg. All non-grey horses are gg.



EXTENSION AND AGOUTI

The most basic horse colors are controlled by two loci, Extension (E) and Agouti (A). Every non-white horse is going to have either a black or red base coat color. These loci control the black, bay and chestnut coloration.

Extension, "Black'" gene (E):

Extension has two alleles, E and e, that encode for black or red pigments.

Black Genotype: can be either EE or Ee

Bay Genotype: can be either EE or Ee

Chestnut Genotype: ee

Agouti Gene (A):

The Agouti loci controls the distribution of black pigment on the horse. The dominant allele, A, restricts black pigmentation to points on the horse's body to tips of ears, legs, mane and tail. The recessive allele, a, allows black pigment to be expressed throughout the body. In chestnut horses, it is difficult to determine which alleles the horse possesses, unless the genotype of the parents is known, since they do not possess black pigmentation.

Black Agouti Genotype: aa

Bay Agouti Genotype: AA or Aa

Chestnut Agouti Genotype: AA, Aa, or aa

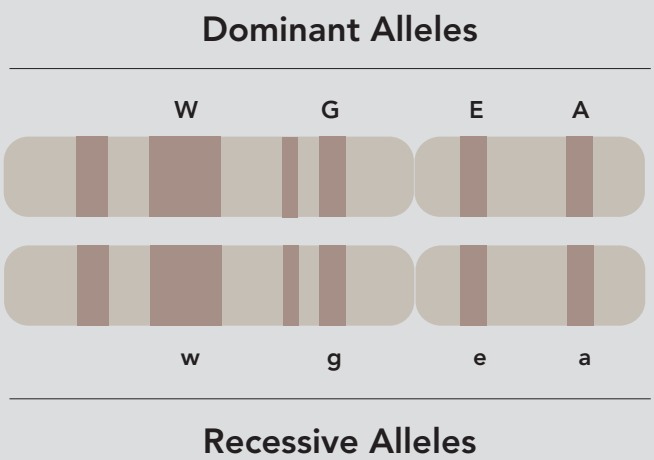
ALLELE ABBREVIATIONS

White: W is the dominant white allele
w is the recessive white allele

Grey: G is the dominant grey allele
g is the recessive grey allele

Extension: E is the dominant extension allele
e is the recessive extension allele

Agouti: A is the dominant agouti allele
a is the recessive agouti allele



BASE COLOR VARIATIONS: DILUTION AND ROANING

CREAM DILUTIONS: An allele of the C gene, named C^{Cr}, dilutes the coat color through incomplete dominance. A horse with no dilution would have a genotype of CC. Horses with only one cream dilution allele (CC^{Cr}) include palomino (chestnut base), buckskin (bay base) or smoky black (black base). Horses with two cream dilution alleles (CcrCcr) include cremello (chestnut base), perlino (bay base) and smoky cream (black base).

Palomino horses possess one cream gene, and will display a lighter (flaxen) mane and tail with varying shades of golden body hair. Horses that have a chestnut base coat with two copies of the cream allele ($C^{Cr}C^{Cr}$) are called **cremello**. They will have cream-colored, diluted body hair which can sometimes be mistaken as white, pink skin and blue eyes.

Buckskin horses also have one cream allele diluting the bay base coat. Buckskins retain their black points on the mane, tail and legs while exhibiting a dark golden body that can vary in shades. A bay horse with two copies of the cream allele are called **perlino**. The perlino body hair is best described as ivory.

Horses that have a **black** base color with one cream allele are called **smoky black**. Two cream alleles will produce a **smoky cream** coat. In some cases, cream dilution will have a very minor impact on black pigment, so it can be difficult to determine if the cream dilution allele is present.

DUN DILUTION: The dominant allele, D, dilutes black and red pigmentation and leaves the points unaffected. Both genotypes of DD and Dd will produce dun horses, whereas dd, the homozygous recessive gene, will produce non-dun horses. Dun horses will have primitive markings, such as a dorsal stripe and leg barring, shoulder striping, cobwebbing throughout the coat and a dorsal stripe. The dun gene can produce a bay dun, red dun or Grulla. A homozygous dominant dun (DD) does not display an enhanced effect as seen with cream dilution.

Roan: The allele Rn produces Roan horses with a mixture of 50 percent white hairs, with the remaining 50 percent being any base color. The head, mane, tail and lower legs can be solid in color and still be roan. All Roan horses produce a genotype of Rnrn or RnRn, while all non-roan horses are rnrn.

Champagne Dilution: Controlled by the dominant allele, Ch, at the champagne locus, it dilutes the body and the points. These horses will have a golden coat with a range of shades depending on the original base coat color. They will have pink skin that freckles with age as well as blue eyes that turn to amber as they age.

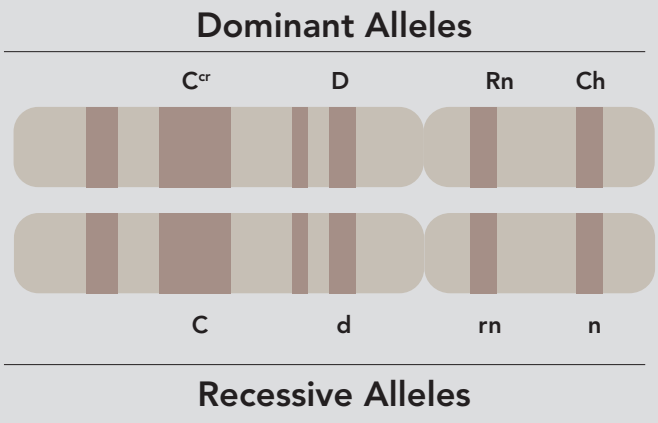
ALLELE ABBREVIATIONS:

Cream: C^{Cr} is the dominant cream allele
C is the recessive cream allele

Dun: D is the dominant dun allele
d is the recessive dun allele

Roan: Rn is the dominant roan allele
rn is the recessive roan allele

Champagne: Ch is the dominant champagne allele
n is the recessive champagne allele



READING GENOTYPES

When talking about coat color genetics, it is important to be able to read and identify the genotype of a coat color. When written out, the genotype is structured in a specific order as certain genes will mask others. In order, the genotype should be written, White (W), Grey (G), Extension (E), Agouti (A), Cream Dilution (C/C^{Cr}), Dun (D) and Roan (Rn).

For example, if a horse is white, Ww, then it masks the expression of other genes making the rest of the genotype difficult to determine. The examples below illustrate the genetic code possibilities for each gene discussed in this publication.

COAT COLOR EXAMPLES

Chestnut Genotype

Not white:	ww
Not grey:	gg
Not black:	ee
Agouti:	AA, Aa, or aa
Not cream:	CC
Not dun:	dd
Not roan:	rnrn
Genotype:	ww, gg, ee, AA, Aa, or aa, CC, dd, rnrn

Bay Dun Genotype

Not white:	ww
Not grey:	gg
Not chestnut:	Ee or EE
Agouti:	AA or Aa
Not Cream:	CC
Dun:	DD or Dd
Not roan:	rnrn
Genotype:	ww, gg, EE or Ee, AA or Aa, CC, DD or Dd, rnrn

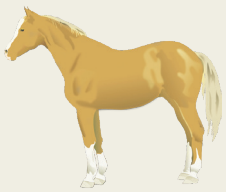
Red Roan Genotype

Not white:	ww
Not grey:	gg
Not Black:	ee
Agouti:	AA, Aa, or aa
Not cream:	CC
Not dun:	dd
Roan:	RnRn or Rnrn
Genotype:	ww, gg, ee, AA, Aa, or aa, CC, dd, RnRn or Rnrn

CREAM GENE DILUTION EXAMPLES

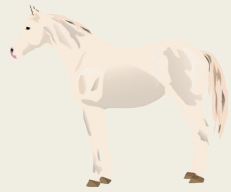
Chestnut Genotype

Not white:	ww
Not grey:	gg
Not black:	ee
Agouti:	AA, Aa, or aa
Not cream:	CC
Not dun:	dd
Not roan:	rnrn
Genotype:	ww, gg, ee, AA, Aa, or aa, CC, dd, rnrn



Palomino Genotype

Not white:	ww
Not grey:	gg
Not black:	ee
Agouti:	AA, Aa, or aa
Cream:	CC^{Cr}
Not dun:	dd
Not roan:	rnrn
Genotype:	ww, gg, ee, AA, Aa, or aa, CC^{Cr}, dd, rnrn

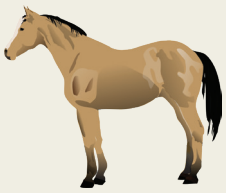


Cremello Genotype

Not white:	ww
Not grey:	gg
Not black:	ee
Agouti:	AA, Aa, or aa
Cream:	$C^{Cr}C^{Cr}$
Not dun:	dd
Not roan:	rnrn
Genotype:	ww, gg, ee, AA, Aa, or aa, $C^{Cr}C^{Cr}$, dd, rnrn

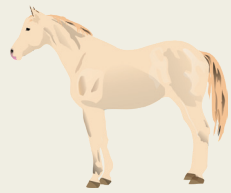
Bay Genotype

Not white:	ww
Not grey:	gg
Not chestnut:	Ee or EE
Agouti:	AA or Aa
Not cream:	CC
Not dun:	dd
Not roan:	rnrn
Genotype:	ww, gg, EE or Ee, AA or Aa, CC, dd, rnrn



Buckskin Genotype

Not white:	ww
Not grey:	gg
Not chestnut:	Ee or EE
Agouti:	AA or Aa
Cream:	CC^{Cr}
Not dun:	dd
Not roan:	rnrn
Genotype:	ww, gg, EE or Ee, AA or Aa, CC^{Cr}, dd, rnrn



Perlino Genotype

Not white:	ww
Not grey:	gg
Not chestnut:	Ee or EE
Agouti:	AA or Aa
Cream:	$C^{Cr}C^{Cr}$
Not dun:	dd
Not roan:	rnrn
Genotype:	ww, gg, EE or Ee, AA or Aa, $C^{Cr}C^{Cr}$, dd, rnrn

COAT COLOR OUTCOMES FOR SELECTIVE BREEDING EXAMPLES

When breeding two horses, a Punnett square can display the probability of potential color outcomes, provided the horse's genotype is known. The examples below show how to use a Punnett square to determine the probability of getting a specific color outcome based on particular breeding combinations.

EXAMPLE 1

One Gene

Using the extension gene, what genotypic outcomes are possible when crossing a black stallion with the genotype of Ee and a chestnut mare with the genotype of ee?

Stallion **E e** **Black Coat**

	E	**e**
e	 **E e** **Black Horse**	 **e e** **Chestnut Horse**
e	 **E e** **Black Horse**	 **e e** **Chestnut Horse**

Mare

e e

Chestnut Coat

Track the color of each allele from the stallion and mare to their respective locations within the punnett square. Each parent can contribute only one copy of each gene to the potential offspring. This mating could produce a 50 percent change of heterozygous Ee genotype with a black coat color, and 50 percent chance of homozygous recessive ee genotype with a chestnut coat color.

OUTCOME

50% change of heterozygous Ee genotype with a black coat color

50% chance of homozygous recessive ee genotype with a chestnut coat color

EXAMPLE 2

Two Genes

Using the Extension and Agouti genes, what genotypic and phenotypic outcomes are possible when crossing a black stallion (genotype:Eeaa) to a bay mare (genoype:EeAa)?

Stallion E e a a Black Coat

Mare

E e A a

Bay Coat

	E a	E a	e a	e a
E A	E E A a Bay Horse	E E A a Bay Horse	E e A a Bay Horse	E e A a Bay Horse
E a	E E a a Black Horse	E E a a Black Horse	E e a a Black Horse	E e a a Black Horse
e A	E e A a Bay Horse	E e A a Bay Horse	e e A a Chestnut Horse	e e A a Chestnut Horse
e a	E e a a Black Horse	E e a a Black Horse	e e a a Chestnut Horse	e e a a Chestnut Horse

Following each allele from the mare and stallion for each gene, this cross would produce 25 percent chance of chestnut (eeAa and eeaa genotypes), 25 percent chance of bay (EEAa and EeAa genotypes) and 50 percent chance of black (EEaa and Eeaa genotypes) coat colors, respectively.

25% chance of chestnut
(eeAa and eeaa genotypes)

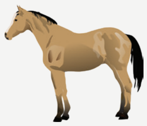
25% chance of bay
(EEAa and EeAa genotypes)

50% chance of black
(EEaa and Eeaa genotypes)

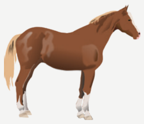
EXAMPLE 3

Three Genes

Building upon examples 1 and 2, adding the cream gene in combination to the extension and agouti genes will show the cross between a buckskin stallion (genotype: EeAaCC^{cr}) and a chestnut mare (genotype: eeAaCC).



Stallion E e A a C C^{cr} **Buckskin Coat**



Mare e e A a C C

Chestnut Coat

Mare \ Stallion	E A C	E A C^{cr}	e A C	e A C^{cr}	E a C	E a C^{cr}	e a C	e a C^{cr}
e A C	E e A A C C Bay	E e A A C C^{cr} Buckskin	e e A A C C Chestnut	e e A A C C^{cr} Palomino	E e A a C C Bay	E e A a C C^{cr} Buckskin	e e A a C C Chestnut	e e A a C C^{cr} Palomino
e A C	E e A A C C Bay	E e A A C C^{cr} Buckskin	e e A A C C Chestnut	e e A A C C^{cr} Palomino	E e A a C C Bay	E e A a C C^{cr} Buckskin	e e A a C C Chestnut	e e A a C C^{cr} Palomino
e A C	E e A A C C Bay	E e A A C C^{cr} Buckskin	e e A A C C Chestnut	e e A A C C^{cr} Palomino	E e A a C C Bay	E e A a C C^{cr} Buckskin	e e A a C C Chestnut	e e A a C C^{cr} Palomino
e A C	E e A A C C Bay	E e A A C C^{cr} Buckskin	e e A A C C Chestnut	e e A A C C^{cr} Palomino	E e A a C C Bay	E e A a C C^{cr} Buckskin	e e A a C C Chestnut	e e A a C C^{cr} Palomino
e a C	E e A a C C Bay	E e A a C C^{cr} Buckskin	e e A a C C Chestnut	e e A a C C^{cr} Palomino	E e a a C C Black	E e a a C C^{cr} Smoky Black	e e a a C C Chestnut	e e a a C C^{cr} Palomino
e a C	E e A a C C Bay	E e A a C C^{cr} Buckskin	e e A a C C Chestnut	e e A a C C^{cr} Palomino	E e a a C C Black	E e a a C C^{cr} Smoky Black	e e a a C C Chestnut	e e a a C C^{cr} Palomino
e a C	E e A a C C Bay	E e A a C C^{cr} Buckskin	e e A a C C Chestnut	e e A a C C^{cr} Palomino	E e a a C C Black	E e a a C C^{cr} Smoky Black	e e a a C C Chestnut	e e a a C C^{cr} Palomino
e a C	E e A a C C Bay	E e A a C C^{cr} Buckskin	e e A a C C Chestnut	e e A a C C^{cr} Palomino	E e a a C C Black	E e a a C C^{cr} Smoky Black	e e a a C C Chestnut	e e a a C C^{cr} Palomino

19% chance of bay	19% chance of buckskin	25% chance of chestnut	25% chance of palomino	6% chance of black 6% chance of smoky black

CONCLUSION

In conclusion, there are many aspects to consider prior to selecting a breeding pair. The conformation of the sire and dam, the ability to fit breed standard and registration requirements, the foal's use (form to function) and genetic disease testing should all be considered before breeding for color. Genetic testing is important for breed registrations, reproduction and decreasing the prevalence of genetic diseases. When breeding for specific colors or single traits, genetic testing can help to increase the chance of getting the desired outcome while decreasing undesirable consequences. By breeding responsibly, you can help decrease the unwanted horse population within the United States while increasing the foal's health, use and value.

If you have any questions or would like further information, please contact your local county Extension office, equine Extension specialist, or visit UTHorse.com.

REFERENCES:

Thiruvenkaden, A., Kandasamy, N., & Panneerselvam, S. (2008). Coat colour inheritance in horses. Livestock Science, 117(2-3), 109-129.

Lumpa, M., Coleman, R., & Coleman, S. (2017). A horse of a different color: Comparing coat color genotypes of American Quarter Horses with their registered phenotypes. Journal of Equine Veterinary Science, 52, 75. doi:10.1016/j.jevs.2017.03.218

Pixabay.com images.

UC Davis Veterinary Genetics Laboratory . (n.d.). Introduction to Coat Color Genetics. Retrieved from US Davis Veterinary Genetics Laboratory : https://www.vgl.ucdavis.edu/services/coatcolor.php