

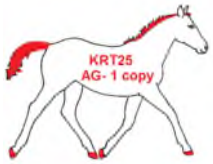
# Typical KRT25 and SP6 Crosses

## Legend:

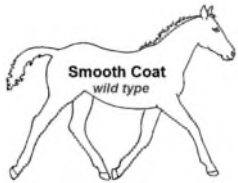
*Dr Mitch Wilkinson and Bunny Reveglia*



**(AA)** – homozygous for KRT25 – Damele, Native, Canadian, Fredell, WY Salt Wells Mustang and many Nevada mustang gene



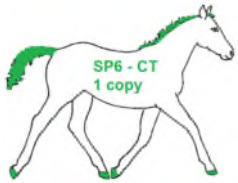
**(AG)** – heterozygous for KRT25 – Damele, Native, Canadian, Fredell, , WY Salt Wells Mustang and many Nevada mustang gene



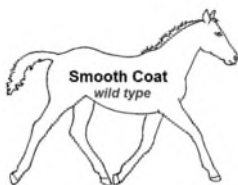
**(GG)** –wild type – no KRT25 mutation present



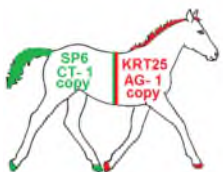
**(TT)** – homozygous for SP6 – Curly Jim gene



**(CT)**- heterozygous for SP6 – Curly Jim gene



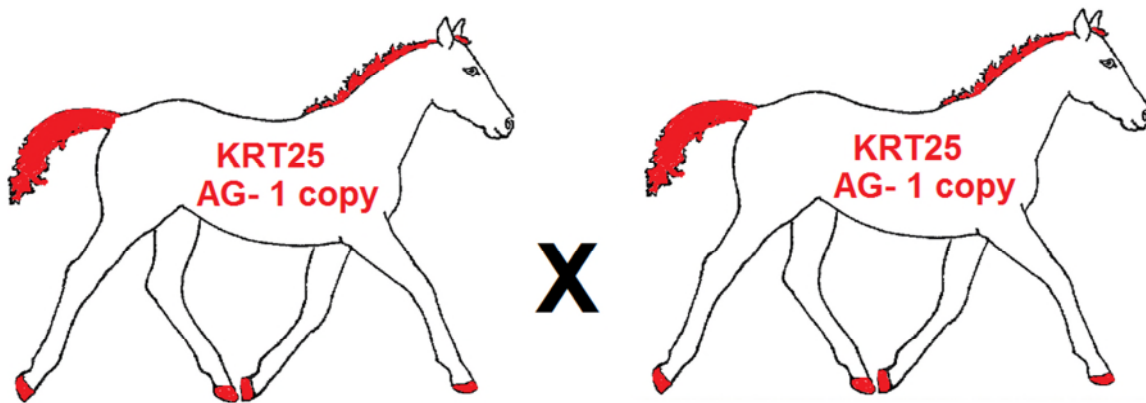
**(CC)** – wild type – no SP6 mutation present



**(AG-CT)** Heterozygous for KRT25 and SP6- Dual Genes

To use this document on typical breeding percentages, the user must know the KRT25 and SP6 status of the potential breeding pair. Hair follicle testing is available through the ICHO office. Once the KRT25 and SP6 status of the breeding pair is known, find the breeding cross that fits. The odds or potential percentages of breeding outcomes are found under each typical breeding scenario.

### KRT25 Cross- *heterozygous*



Using a **Punnett Square** to determine the percentages of a mating outcome. A simple cross of two heterozygous horses which have the **KRT25** gene mutation, but **do not** have the SP6.

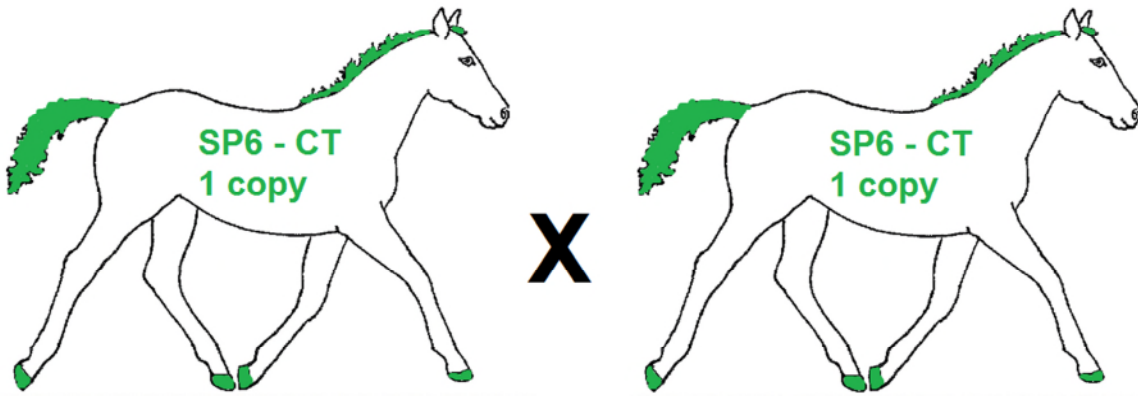
	A	G	
A	AA	AG	
G	AG	GG	
	25%	50%	25%
	AA	AG	GG

**1/4 odds** that the foal will be homozygous for KRT25 with scant mane and tail

**1/2 odds** that the foal will be heterozygous for KRT25 with mane and tail, but brittle hair

**1/4 odds** the foal will be born without a curly gene

## SP6 Cross- heterozygous



Another simple cross of two horses that are heterozygous for **SP6** (Curly Jim), but **do not** have KRT25 in their genetics.

	C	T
C	CC	CT
T	CT	TT
25%	50%	25%
TT	CT	CC

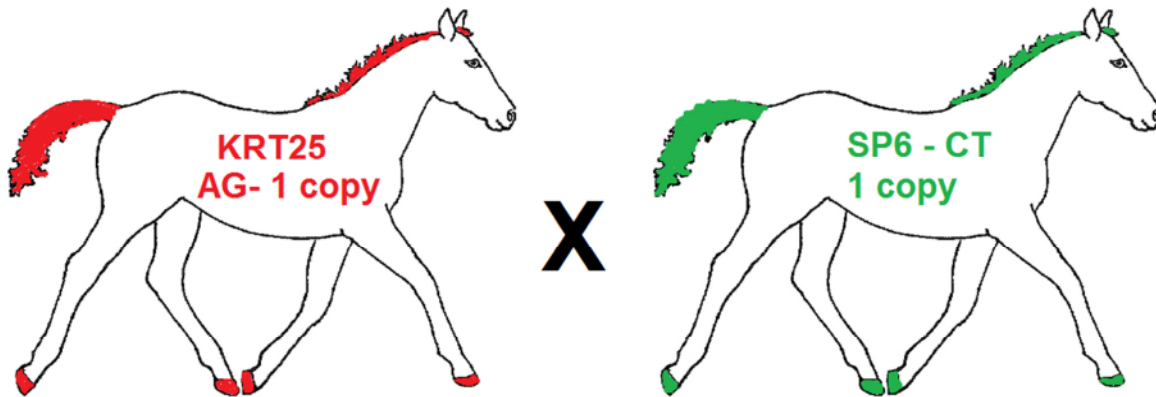
**1/4 odds** the foal will be homozygous for SP6

**1/2 odds** the foal will be heterozygous for SP6

**1/4 odds** the foal will not inherit a curly gene

**All results will produce a foal with normal strength hair and full mane and tail**

## Cross #1



The cross of two horses that are heterozygous for each gene: #1 Parent- KRT25 - AGCC which is crossed with #2 Parent- SP6 – GGCT. In this case, each parent only carries KRT25 or SP6, but does not carry both at the same time

Cross:  
AGCC × GGCT

	AC	AC	GC	GC
GC	AGCC	AGCC	GGCC	GGCC
GT	AGCT	AGCT	GGCT	GGCT
GC	AGCC	AGCC	GGCC	GGCC
GT	AGCT	AGCT	GGCT	GGCT

25%	25%	25%	25%
AG CC	AG CT	GG CT	GG CC

**Straight**

**3/4 odds** of producing curly foal --- **1/4 odds** of producing straight foal

**1/4 odds** for foal to be heterozygous for KRT25 but did not inherit SP6. Foal will have full mane and tail, but brittle hair.

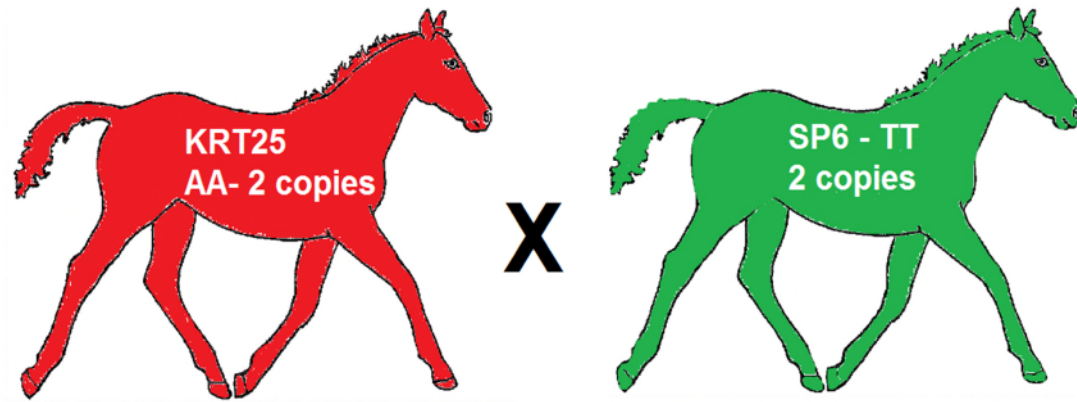
**1/4 odds** for foal to be heterozygous for SP6 but did not inherit KRT25. Foal will have full mane and tail and will not have brittle hair.

**1/4 odds** of foal carrying both KRT25 and SP6 - hetero for both – **dual gene**. The foal will have full mane and tail, but brittle hair.

**1/4 odds** of foal not having a curly gene and straight coated

**0% odds** of producing a foal with sparse mane and tail

## Cross #2



**#1 Homozygous KRT25 Parent crossed with #2 Homozygous SP6 Parent with each parent carrying 2 copies of KRT25 or SP6 curly genes**

**Parent #1 - AA CC (sparse mane and tail)**

**Parent #2 - GG TT (full mane and tail)**

Cross:  
AACC × GGTT

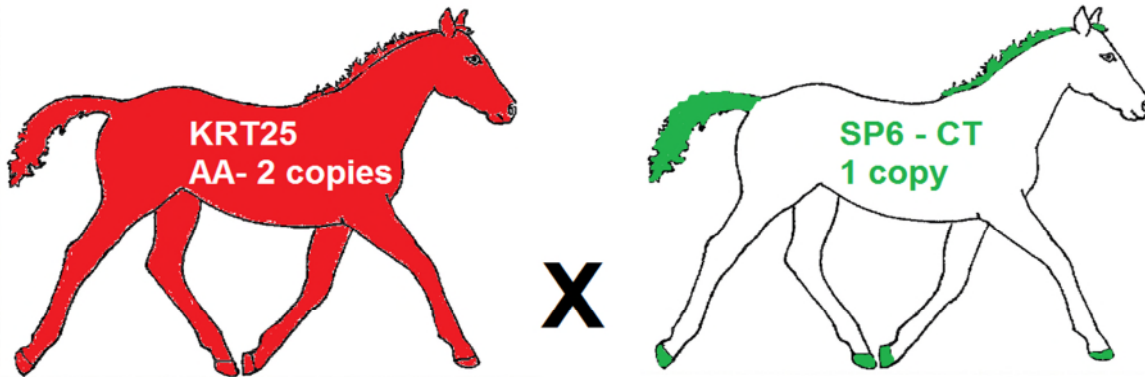
	AC	AC	AC	AC
GT	AGCT	AGCT	AGCT	AGCT
GT	AGCT	AGCT	AGCT	AGCT
GT	AGCT	AGCT	AGCT	AGCT
GT	AGCT	AGCT	AGCT	AGCT

**Offspring - 100% - AG CT – Dual Genes** - Good mane and tail, but possibly shorter with hair brittle

**0 % odds** of Straight

**0 % odds** of foal with sparse mane and tail

### Cross #3



### **#1 Parent Homozygous KRT25 (AACC) x #2 Parent Heterozygous SP6 (GGCT)**

Parent#1 AACC (sparse mane and tail)    Parent #2 GGCT (full mane and tail)

#### **Homozygous KRT25 x heterozygous SP6**

Cross:  
AACC × GGCT

	AC	AC	AC	AC
GC	AGCC	AGCC	AGCC	AGCC
GT	AGCT	AGCT	AGCT	AGCT
GC	AGCC	AGCC	AGCC	AGCC
GT	AGCT	AGCT	AGCT	AGCT

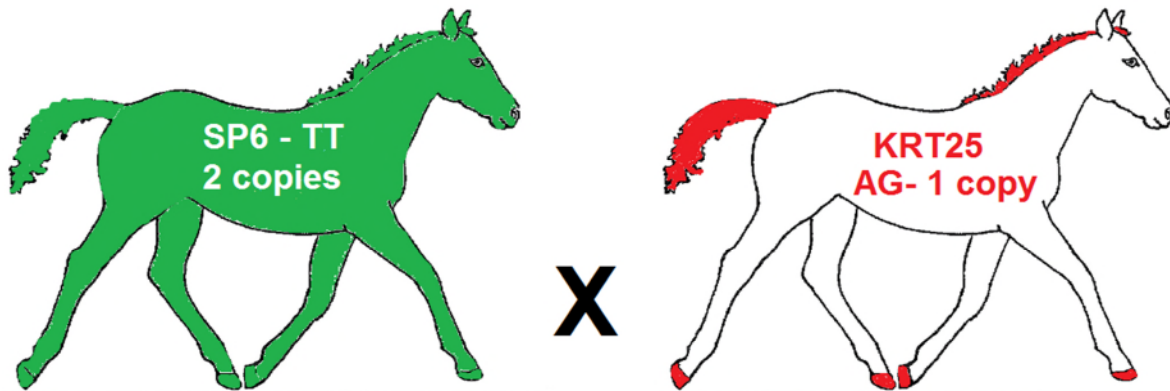
**50% heterozygous KRT25**  
**50% Dual Gened- heterozygous**  
**SP6 & KRT25**

**1/2 odds** that foal will be heterozygous for KRT25 – without inheriting the SP6 gene. The foal will have full mane and tail, but brittle hair

**1/2 odds** the foal will be have dual gene – The foal will be heterozygous for both KRT25 and SP6. It will have full mane and tail, but brittle hair

**0 % odds** of a straight foal

## Cross #4



**#1 Parent Homozygous SP6 (GGTT) x #2 Parent Heterozygous KRT25 (AGCC)**

**#1 Parent GGTT (Full mane and tail)**

**#2 Parent (medium mane and tail)**

**Homozygous SP6 x Heterozygous KRT25**

Cross:  
AGCC × GGTT

	AC	AC	GC	GC
GT	AGCT	AGCT	GGCT	GGCT
GT	AGCT	AGCT	GGCT	GGCT
GT	AGCT	AGCT	GGCT	GGCT
GT	AGCT	AGCT	GGCT	GGCT

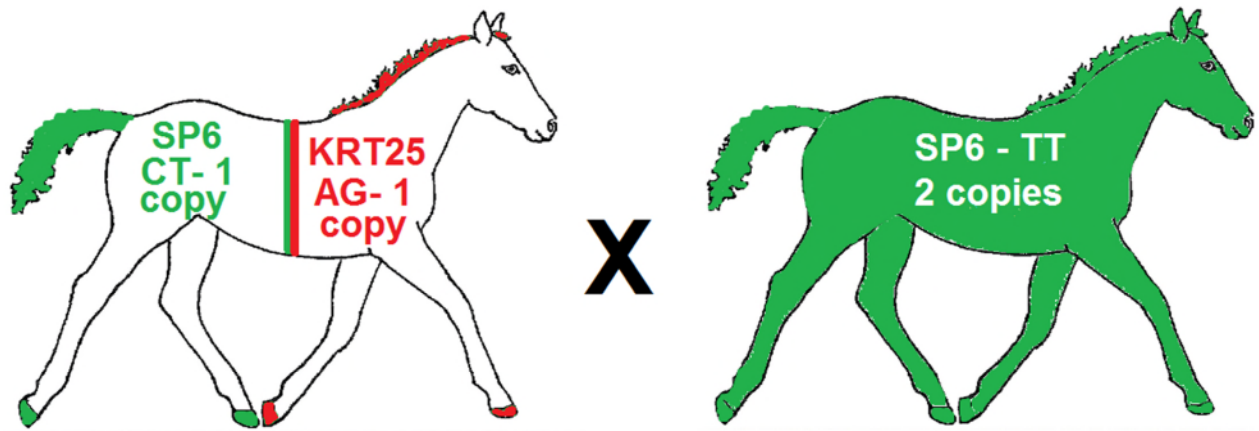
**50% Heterozygous SP6**  
**50% Dual Gened- Heterozygous**  
**SP6 & KRT25**

**1/2 odds** the foal will be heterozygous for SP6 with full mane and tail, and it will not inherit KRT25. This foal will not have brittle hair.

**1/2 odds** the foal will be have dual genes and will be heterozygous for KRT25 and SP6. Full mane and tail, but brittle hair

**0%** of having a straight foal

## Cross #5



**#1 Parent AG CT- Heterozygous for both genes (KRT25 & SP6) Dual Genes crossed with #2 Parent GG TT- Homozygous for SP6**

Cross:  
AGCT × GGTT

	AC	AT	GC	GT
GT	AGCT	AGTT	GGCT	GGTT
GT	AGCT	AGTT	GGCT	GGTT
GT	AGCT	AGTT	GGCT	GGTT
GT	AGCT	AGTT	GGCT	GGTT

**25%      25%      25%      25%** -- or 1/4 odds of each phenotype happening

**GG CT    GG TT    AG CT    AG TT**

**1/4 odds** for foal to be heterozygous for SP6 and did not inherit KRT25. Full mane and tail, but brittle hair

**1/4 odds** for foal to be homozygous for SP6 and did not inherit KRT25. Full mane and tail, no brittle hair

**1/4 odds** for foal to be heterozygous for both KRT25 and SP6 – **dual gene**. Full mane and tail, but brittle hair.

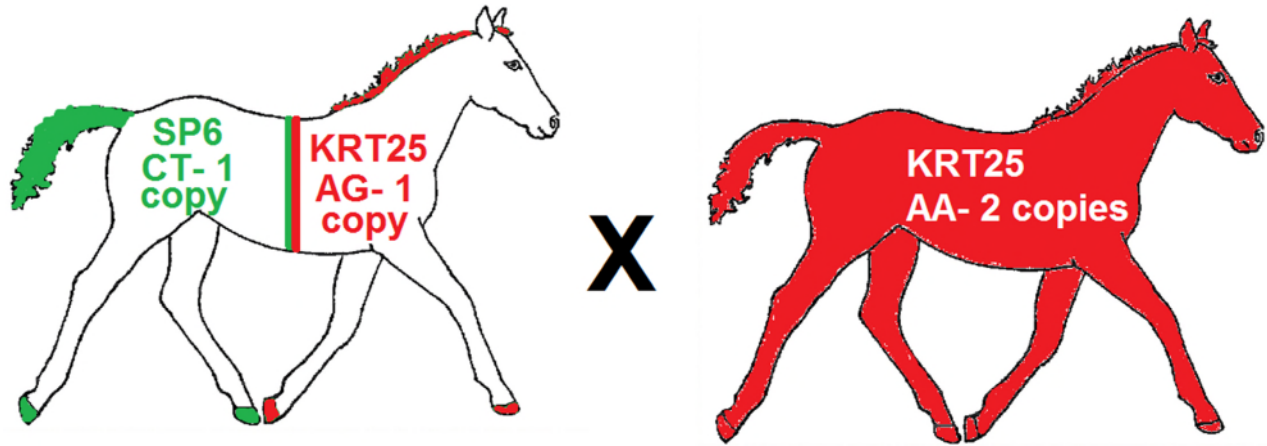
**1/4 odds** for foal to be heterozygous for Krt25 and homozygous for SP6- **dual gene**. Full mane and tail, but brittle hair

**0% odds**- straight offspring

**0% odds**- AA or horse with scant mane and tail



## Cross #6



**The Cross of #1 parent Dual genes AGCT x #2 parent KRT25 AACC homozygous**

Cross:  
AGCT × AACC

	AC	AT	GC	GT
AC	AACC	AATC	GACC	GATC
AC	AACC	AATC	GACC	GATC
AC	AACC	AATC	GACC	GATC
AC	AACC	AATC	GACC	GATC

25%  
AA CC

25%  
AA TC

25%  
AG CC

25%  
AG TC

**1/4 odds** the foal will be homozygous for KRT25 and did not inherit SP6 - scant mane and tail

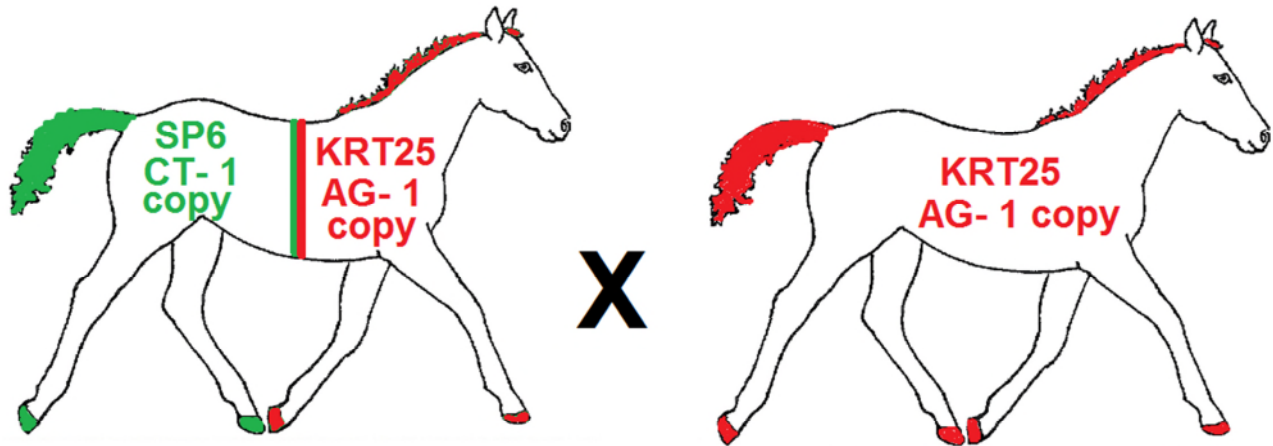
**1/4 odds** the foal will be homozygous for KRT25 and heterozygous for SP6 – **dual gene** - scant mane and tail

**1/4 odds** the foal will be heterozygous for KRT25 and did not inherit SP6 – full mane and tail but brittle hair

**1/4 odds** the foal will be heterozygous for both KRT25 and SP6 - **dual gene** – full mane and tail, but brittle hair

**0% odds** of straight foal

## Cross #7



**The cross of #1 Parent Dual Genes AGCT x #2 Parent Heterozygous KRT25 AGCC**

Cross:  
AGCT × AGCC

	AC	AT	GC	GT
AC	AACC	AATC	GACC	GATC
AC	AACC	AATC	GACC	GATC
GC	AGCC	AGTC	GGCC	GGTC
GC	AGCC	AGTC	GGCC	GGTC

<b>12.5%</b>	<b>12.5%</b>	<b>25%</b>	<b>12.5 %</b>	<b>25%</b>	<b>12.5%</b>
AA CC	AA TC	AG CC	GG TC	AG TC	GG CC

**1/8 odds** of AA CC – homozygous KRT25 but did not inherit SP6 - scant mane and tail

**1/8 odds** of AA TC - homozygous KRT25 and heterozygous for SP6 - scant mane and tail – **dual gene**

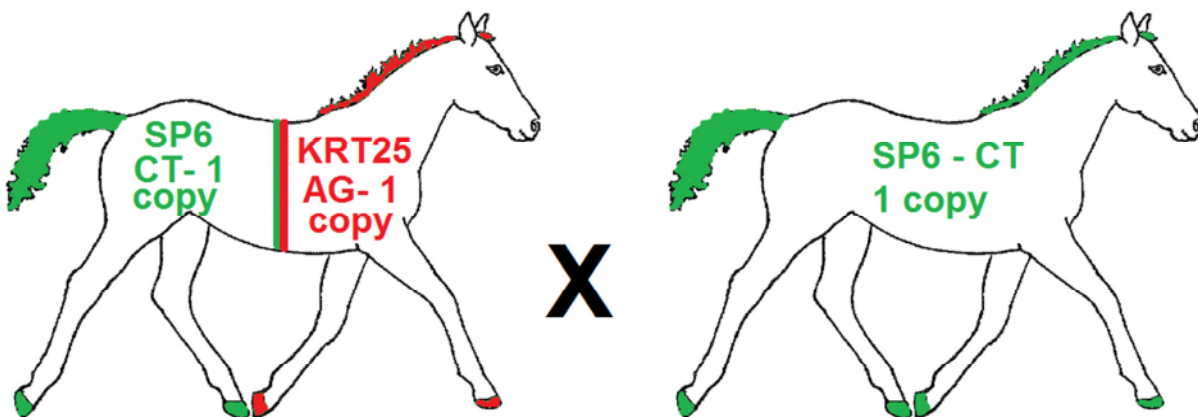
**1/4 odds** of AG CC – heterozygous KRT25 but did not inherit SP6 – full mane and tail – brittle hair

**1/8 odds** of GG TC – heterozygous SP6 but did not inherit KRT25 – full mane and tail with no brittle hair

**1/4 odds** of AG TC - heterozygous for both KRT25 and SP6 – brittle hair – **dual gene**

**1/8 odds** of GG CC - straight

## Cross #8



### Cross of #1 Parent AGCT Dual genes x #2 Parent Heterozygous SP6 GGCT

Cross:  
AGCT × GGCT

	AC	AT	GC	GT
GC	AGCC	AGTC	GGCC	GGTC
GT	AGCT	AGTT	GGCT	GGTT
GC	AGCC	AGTC	GGCC	GGTC
GT	AGCT	AGTT	GGCT	GGTT

12.5%	25%	12.5%	12.5%	25%	12.5%
AG CC	AG CT	AG TT	GG TT	GG TC	GG CC

**1/8 odds** of AG CC – heterozygous for KRT25 but did not inherit SP6 – full mane and tail –brittle hair

**1/4 odds** of AG CT – heterozygous for both KRT25 and SP6 – full mane and tail –brittle hair – **dual gene**

**1/8 odds** of AG TT - heterozygous for KRT25 and homozygous for SP6 – full mane and tail

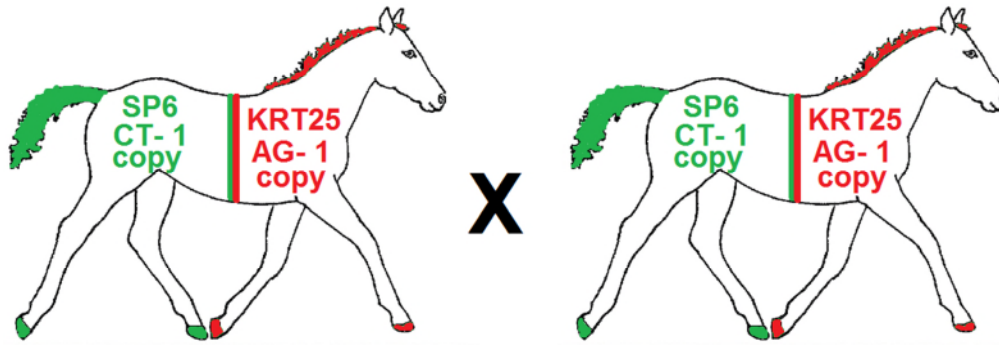
– brittle hair – **dual gene**

**1/8 odds** of GG TT – homozygous for SP6 but did not inherit KRT25 – full mane and tail

**1/4 odds** of GG TC – heterozygous for SP6 but did not inherit KRT25 – full mane and tail

**1/8 odds** of GG CC - straight

## Cross #9



### Cross of #1 Parent AGCT x #2 Parent AGCT

Cross:  
AGCT × AGCT

	AC	AT	GC	GT
AC	AACC	AATC	GACC	GATC
AT	AACT	AATT	GACT	GATT
GC	AGCC	AGTC	GGCC	GGTC
GT	AGCT	AGTT	GGCT	GGTT

The cross of two individuals that are heterozygous for both KRT25 and SP6 and carry both genes at the same time. Both Parents Dual Genes- Heterozygous- AGCT

25%	12.5%	12.5%	12.5%	12.5%	6.25%	6.25%	6.25%	6.25%
AG CT	AG CC	AA CT	AG TT	GG CT	AA CC	GG TT	AA TT	GG CC

**1/16 (6.25%) odds** of having a straight foal (GG CC)

**1/16 (6.25%) odds** of having a foal that is homozygous for both KRT25 and SP6 at the same time - **dual gene** – Sparse mane and tail

**1/4 (25%) odds** of having a foal with a scant mane and tail - AA or homozygous for KRT25

**1/4 (25%) odds** of having a foal that is heterozygous for both Krt25 and SP6 – **dual gene** – full mane and tail, but brittle hair

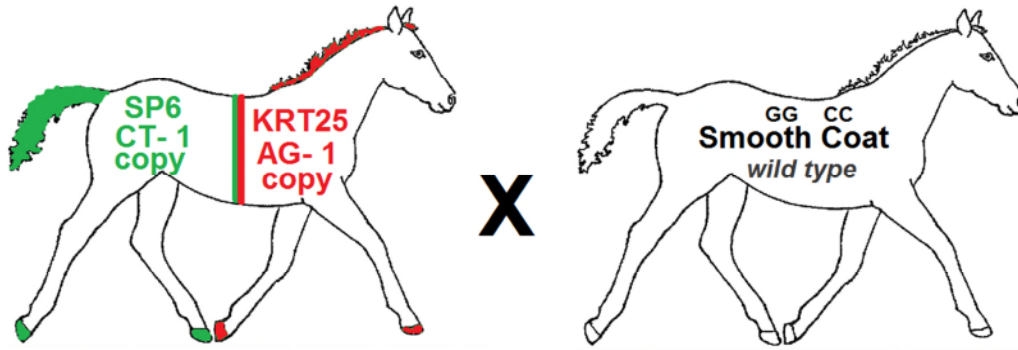
**1/8 (12.5%) odds** of having a foal that homozygous for KRT25 and heterozygous for SP6 – **dual gene** – sparse mane and tail

**1/16 (6.25%) odds** of having a homozygous SP6 that did not inherit KRT25 – full mane and tail, no brittle hair

**1/16 (6.25%) odds** of having a homozygous KRT25 foal that did not inherit SP6 – sparse mane and tail

**15/16 (93.75%) odds** of having a curly foal

## Cross #10



### Cross of #1 Parent AGCT x #2 Parent GGCC

The cross of a horse with two genes for curl (heterozygous for both KRT25 and SP6) and a horse with no curly genes- Wild Type- GG CC - No mutation (straight) or Smooth Coat.

Parent #1 – AG CT **Dual Genes**

Parent #2 - GG CC Straight or Smooth Coat

Cross:  
AGCT × GGCC

	AC	AT	GC	GT
GC	AGCC	AGTC	GGCC	GGTC
GC	AGCC	AGTC	GGCC	GGTC
GC	AGCC	AGTC	GGCC	GGTC
GC	AGCC	AGTC	GGCC	GGTC

(AGTC) with a totally straight mare (GGCC) **(AGTC) X (GGCC)** would produce the following genotypes:

**25%**  
**AG CC**

**25%**  
**AG TC**

**25%**  
**GG CT**

**25%**  
**GG CC**

So — 3/4 chance of having a curly and 1/4 chance of having a straight

**1/4 odds** of having a foal that is heterozygous for KRT25 but did not inherit SP6 – full mane and tail, but brittle hair

**1/4 odds** of having a foal that is heterozygous for both SP6 and KRT25 – **dual genes** – full mane and tail, but brittle hair

**1/4 odds** of having a foal that is heterozygous for SP6 and did not inherit KRT25 – full mane and tail with no brittle hair

**0% odds** of having a foal with the AA combination which produces sparse mane and tail

## Example of Cross #10

Parent #1 (AGCT)

X

Parent #2 (GGCC)



**\*Frostfire's Xequ**

(dual gene KRT25 & SP6 curly coated)



**Mariah**

( straight Peruvian Paso)

## Resulting Foal

**Foal (AGCC) KRT25**

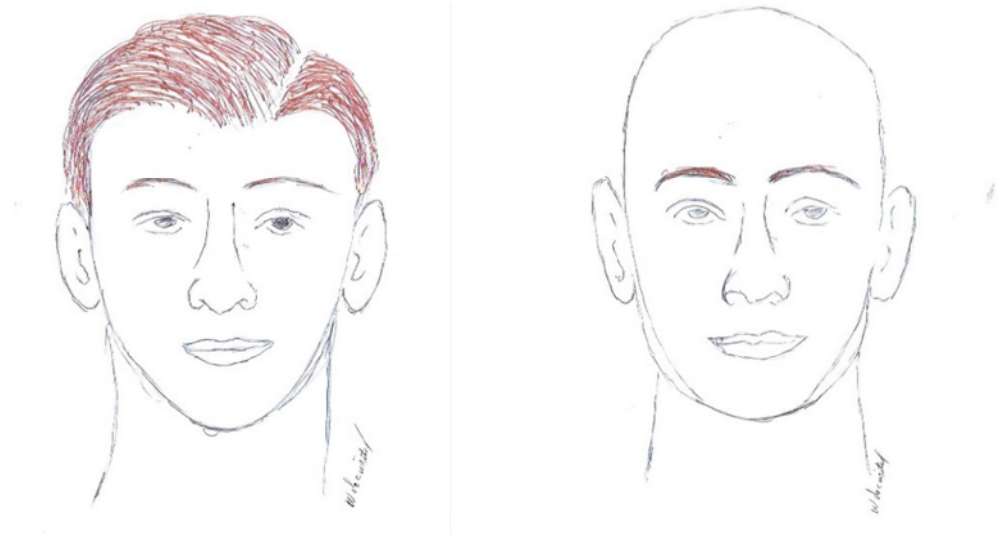


**\*Xarina**

**1/4 odds** the foal, Xarina, would be born heterozygous for KRT25, but did not inherit SP6. The coat is curly, but hair somewhat brittle. Full mane and tail.

# Epistatic Gene relationships

In classical genetics, if genes A and B are mutated, and each mutation by itself produces a unique phenotype but the two mutations together in the same individual show the same phenotype as the gene A mutation, then gene A is **epistatic** and gene B is **hypostatic**.



For example, the gene for total baldness is epistatic to the gene for red hair. It makes no difference if a person inherits the gene for red hair if he also inherits the gene for baldness. Baldness is epistatic to red hair. Baldness will always "mask" the effects of red hair.

Epistatic genes and hypostatic genes are two separate and independent gene mutations that interact on one aspect of the organism by chance. Epistasis is not **dominance**.

**Genetic dominance** is an interaction between alleles (two different versions of a gene) at the same gene locus (a specific gene location on a chromosome). Examples: The A allele is dominant over the G allele at the KRT25 locus. Likewise, the T allele is dominant over the C allele at the SP6 locus.

----- so, KRT25 and SP6 are two independent genes at different locations, but the effects of KRT25 mask the effects of SP6 like baldness masks the effects of a red hair gene.

In the case of the two curly genes isolated to date, KRT25 is epistatic (or masks to some extent) the effects of SP6.

## Hypotrichosis and Dysplastic Hair Shafts

Hypotrichosis (scant mane and tail) is a condition characterized by sparse hair or a coat that is not as thick or long as normally expected. It is also used to describe hair coats that have defects in the hair shaft or follicles (dysplastic) that lead to a sparser hair distribution compared to normal hair distribution for the species.

### KRT25

The missense mutation found in KRT25 is a mutation of a keratin gene which produces a type 1, inner root sheath – specific keratin protein that is essential in the assembly of keratin protein complexes required for the proper assembly of the hair shaft. The hair curl that is produced by KRT25 mutation is a consequence of the abnormal structure of the hair shaft itself. Along with curl, brittleness is also a consequence of the abnormal structure. The brittleness is thought to increase with UV light which is at its peak during the summer months.

Because KRT25 produces dysplastic hair shafts, it is epistatic to SP6 which produces normal hair shaft morphology.

### SP6

The missense mutation found in SP6 is a mutation which affects a transcription factor. SP6 produces a **transcription factor**. The transcription factor's role is to produce a protein which controls the initiation and speed of transcription of genetic information from the DNA molecule to the messenger RNA molecule, by binding to a specific DNA sequence. Much like a capitol letter is used to show the beginning of a sentence, the transcription factor protein shows the messenger RNA when, where, and how fast to begin reading that segment of the DNA chain. The function of transcription factors is to regulate - turn on and off - genes in order to make sure that they are expressed (produce critical proteins) at the right time and in the right amount to produce, in this case, a hair follicle.

The slight variation in SP6 from wild type to SP6 mutation produces an inner root sheath of the hair follicle which is ovoid shaped. The **inner root sheath** acts as a mold to form the shape of the growing hair shaft. Ovoid shaped hair shafts curl. Therefore, the hair shaft produced by the SP6 mutation is **not dysplastic**. It has a normal hair shaft anatomy and is not brittle, but instead has an ovoid shape which produces curl.

**Article and illustrations by Dr Mitch Wilkinson**

**Graphic's by Bunny Reveglia- ICHO**