



READING BETWEEN THE LINES

Learn how to decipher your horse's genetic testing results for insight about what lies beneath the surface.

By JESSICA HEIN

You've had your horse genetically tested, and now you're staring at a report card filled with alphabet soup ... what does all this mean in layman's terms anyhow?

Reading those results can seem complicated, but it's easier than you might think if you arm yourself with some basic information about the tests, how results are reported and how they might

interact on the palette that is your Paint Horse's coat. Read on as we help you break down test results from APHA's two approved testing labs in a way that's useful to the average horse owner.

COURTESY DORA SOCZE

THE REPORT CARD

Many genetic test results look similar to a report card—each test is like a class, followed by the outcome of your horse's DNA test for that "subject."

Basic information about your horse is also usually listed on the test, including his name, registration number, sire/dam information and the test ID number. Following this basic information are the genetic tests provided by the lab and your horse's results. Not all tests are performed on every horse—your horse's result medley depends on the testing package you ordered in most cases. Testing through APHA can include a package of six genetic health conditions, a package of 13 color and pattern tests, an all-inclusive test with both, or individual test results. Options depend on the lab you choose for testing.

Each test is specific for a certain gene, such as *HYPP* (hyperkalemic periodic paralysis) or *Cream* (which results in palominos, buckskins, smoky blacks and double dilutes). Each gene has two alleles, and a horse inherits one of those from each parent; so for each particular test, you'll see a result with two parts, often separated by a slash mark. The following charts on pages 37-39 detail the symbols you might see under the results column for each particular test:

Left:

Cowboyz Watch Out
Ee, aa, n/W20, n/SB1

The interaction of Sabino 1 and W20 on the coat of Cowboyz Watch Out might make him look gray, but he's actually a black (Ee,aa) overo, genetically.

Below:

Rise Above
Ee, AA, n/SW1, nd2/nd2

Rise Above is a bay overo gelding (Ee,AA)—his Paint markings are courtesy of one copy of Splash White 1. The nd2/nd2 note means he's unlikely to display any dun-like primitive markings, like countershading on the topline.

HEALTH

HYPP Hyperkalemic periodic paralysis	n/H (heterozygous, affected), H/H (homozygous, affected)
HERDA Hereditary equine regional dermal asthenia	n/HRD (carrier, unaffected); HRD/HRD (homozygous, affected)
GBED Glycogen branching enzyme deficiency	n/GBED (carrier, unaffected); GBED/GBED (homozygous, affected and will not survive)
MH Malignant hyperthermia	n/MH (heterozygous, affected); MH/MH (homozygous, affected)
PSSM1 Polysaccharide storage myopathy type 1	n/PSSM1 (heterozygous, affected), PSSM1/PSSM1 (homozygous, affected)
OLWS or LWO Overo lethal white syndrome	n/O (heterozygous Frame Overo, carrier, unaffected); O/O (homozygous, affected and will not survive) *Sometimes also noted as n/LWO on results.

These tests are part of the APHA genetic health panel. This panel is required for all breeding stallions, but is also useful for owners of mares and non-breeding animals.



UNIVERSITY OF CALIFORNIA, DAVIS
EQUINE DISEASE PANEL RESULTS

AMERICAN PAINT HORSE ASSOC.
P.O. BOX 961023
FORT WORTH, TX 76161-0023

Horse: **RISE ABOVE**
DOB: 2010 Sex: **Stallion** Breed: **Paint Horse**
Sire: **M.I. TIME FANCY** Reg: 00424796
Dam: **IN GOOD COMPANY** Reg: 00621963

GBED	N/N	HYPP - (Normal) - Does not possess the disease-causing GBED gene.
HERDA	N/N	HERDA - (Normal) - Does not possess the disease-causing HERDA gene.
HYPP	N/N	HYPP - (Normal) - Does not possess the disease-causing HYPP gene.
LWO	N/N	No copies of lethal white overo detected.
MH	N/N	MH - (Normal) - Does not possess the MH gene.
PSSM1	N/N	PSSM1 - (Normal) - Does not possess the PSSM1 gene.

Case#: _____ Date: _____ Print Date: _____ Report ID: _____

UNIVERSITY OF CALIFORNIA, DAVIS
APHA COAT COLOR PANEL TEST RESULTS

AMERICAN PAINT HORSE ASSOC.
P.O. BOX 961023
FORT WORTH, TX 76161-0023

Horse: **RISE ABOVE**
DOB: 2010 Sex: **Stallion** Breed: **Paint Horse**
Sire: **M.I. TIME FANCY** Reg: 00424796
Dam: **IN GOOD COMPANY** Reg: 00621963

AGOUTI	A/A	No black and red factors present.
CORONA	N/N	No copies of Corona gene detected.
BRAND	N/N	No copies of Brand gene detected.
IL LUTE	N/N	No copies of Il Lute gene detected.
LEATAL WHITE	N/N	No copies of Leatal White gene detected.
SABINO 1	N/N	No copies of Sabino 1 gene detected.
TORRADO	N/N	No copies of Torrado gene detected.
CLAMNIGHT	N/N	No copies of Clamnight gene detected.
SEALED WHITE	N/N	No copies of Sealed White gene detected.
CRACKLE WHITE	N/SW1	1 copy of SW1 detected.
GRAY	Absent	No copies of SW1 or SW2 detected.
DIRT	nd2/nd2	1 copy of nd2 detected.
SOFTLY WHITE	N/N	No copies of Softly White gene detected.
SPRINKLE	N/N	No copies of Sprinkle gene detected.

COURTESY SPIKE BREWER

It's important to note that recessive conditions—those like *HERDA*, *GBED* and *OLWS*—require two copies of the affected allele to develop the condition, one inherited from each parent. To sidestep these conditions 100 percent of the time, simply avoid breeding two carriers of a particular allele together.

Incomplete dominant conditions—like *HYPP*, *MH* and *PSSM1*—only require one copy to affect a horse, though animals that are homozygous for the condition are usually more severely affected. A horse's diet and exercise management can also affect many of these conditions, for better or worse.

COLORS

Extension/Red Factor	E/E (homozygous) or E/e (heterozygous) , each with the ability to produce both red and black pigment in the coat; e/e (can only produce red pigment)	<p>These tests are included on the APHA color/pattern panel, but you can also test for most of these individually.</p>
Agouti	A/A or A/a (regulates black pigment, if present, to the points of the horse); a/a (black pigment distributed uniformly)	
Cream	Cr/Cr (homozygous, creates double-dilute coat colors); n/Cr (heterozygous, creates single-dilute coat colors)	
Pearl	Pr1/Pr1 (homozygous, can create a pseudo-double dilute appearance); n/Pr1 (heterozygous and little effect, unless cream is also present—then, a pseudo-double dilute can occur)	
Silver	Z/Z (homozygous) or n/Z (heterozygous); in both cases, affects only black-based pigment	
Champagne	Ch/Ch (homozygous) or n/Ch (heterozygous); both affect coat color similarly	
Gray	G/G (homozygous) or n/G (heterozygous); both affect coat color similarly	
Dun	D/D (homozygous) or n/D (heterozygous); both affect coat color similarly Non-Dun 1 & 2 (nd1 , nd2) are also reported; nd1 can create countershading on the topline	
Roan	Rn/Rn (homozygous) or n/Rn (heterozygous); both affect coat color similarly	<p>Roan is not included on the APHA color/pattern panel, but you can order it as an individual color test through APHA for \$50.</p>



SMR DESIGNS

Half In Her Jeans

ee, Aa, n/Cr, nd1/nd2, n/W20, n/LWO, n/SW1

This palomino filly, *Half In Her Jeans*, is about 85 percent white, thanks to three white spotting patterns expressing on her coat: one copy of *Frame Overo*, one copy of *Splash White 1* and one copy of *W20*. Palomino is a result of red pigment only (ee) and one cream gene (n/Cr); the agouti result has no impact, since there's no black pigment to affect. She might also have countershading along the dorsal, thanks to nd1.



Genetic Profile Test Results

Horse: Mavis
Owner: Amanda Hollinger

Coat Color Results

Base				
Agouti	100%	ASP	A/a - One dominant Agouti allele detected; Inhibits the Black band to show up	More about A
Black/Red	100%	AKR	aa - No Black band detected and no Red	More about E
Modifier				
Brindle/SP	100%	BSKG	No Brindle/SP allele detected	More about IP
Gray	100%	STXTA	No Gray allele detected	More about G
Dilution				
Champagne	100%	SI C26A1	No Champagne allele detected	More about CH
Cream	100%	SI C45A2	CRn - One Cream allele detected	More about CR
Dun	100%	TBX2	n/ND2 (non-dun with possible primitive markings) One recessive Dun and one recessive non-dun allele - No Dun allele detected	More about DN
Pearl	100%	SI C45A2	No Pearl allele detected	More about PR
Silver	100%	PMEL17	No Silver allele detected	More about Z

N/N is one of the most common results you'll see on a test report—this means your horse doesn't carry any alleles associated with that particular test. If your horse does carry an allele for a particular gene, you'll see one of the designations noted previously.

Test reports from APHA partner lab University of California–Davis are usually a one-page document set up like a report card, with each test on the panel and the results noted. Next to the result box, there's a brief sentence about the results of the tests performed, noting whether the horse has one copy, two copies or no copies of that particular allele. The "Case" name at the upper right of the report will designate if your test was done through APHA, AQHA or privately.

Reports from Etalon Diagnostic, another APHA-approved lab, are longer—page one includes your horse's identifying information, page two is an overview of any specific alleles your horse carries, and it's followed by detailed results for each test and your horse's result. In addition to the color, pattern and health conditions noted above, Etalon also provides results for some additional tests. The "Pack" designation at the upper right on page 1 indicates if your test was done as part of the APHA package, which includes result reporting and recording with APHA.


With either lab, if the test was performed privately (not associated with APHA or AQHA), a \$40 DNA recording fee is required to log the results with APHA.

PATTERNS

Frame Overo	n/O (heterozygous Frame Overo, unaffected by related health condition); O/O (homozygous, health affected and will not survive) *Sometimes also noted as n/LWO on results	These tests are included on the APHA color/pattern panel, but you can also test for most of these individually.
Tobiano	TO/TO (homozygous) or n/TO (heterozygous)	
Sabino 1	SB1/SB1 (homozygous) or n/SB1 (heterozygous)	
Splash White	3 varieties in Paints: SW1/SW1 (homozygous) or n/SW1 (heterozygous) SW2/SW2 (homozygous) or n/SW2 (heterozygous) n/SW3 (heterozygous) *Horse can have multiple combinations of the gene options.	
Dominant White	More than 25 varieties; 3 are common in Paints: n/W5 (heterozygous) n/W10 (heterozygous) W20/W20 (homozygous) or n/W20 (heterozygous) *Horse can have multiple combinations of the gene options.	



COURTESY LAUREN BORK



Etalon
DIAGNOSTICS

Genetic Profile Test Results

Horse: Surprisingly Fancy
Owner: Lauren Bork

HORSE ID: 031518 006
PACK: 1

Coat Color Results, continued

White Patterns Results	Result	Gene	Description	More about
Recurrent White	+/+	RCT	W20 - One Dominant White 20 allele detected (DW1-21)	More about DW
Frame Overo (LWO)	0	EDNRB	No Frame Overo (LWO) allele detected	More about LWO
Leopard Complex Spotting (LP)	0	TRPM1	No Leopard Complex Spotting (LP) allele detected	More about LP
Pattern 1 (LP modification)	+/+	RPWD1	No Pattern 1 (LP modification) allele detected	More about PATH1
Splashed White (MTF)	+/+	MTF	SW10 - One Splashed White 1 allele detected	More about SW (MTF)
Splashed White (PAX3)	+/+	PAX3	No Splashed White 2 nor Splashed White 4 allele detected	More about SW (PAX3)
Sabino 1	0	RCT	No Sabino 1 allele detected	More about SB1
Tobiano	0	ECA1	No Tobiano allele detected	More about TO

Surprisingly Fancy

Ee, AA, n/W20, n/SW1

The bay mare (Ee, AA) Surprisingly Fancy has one copy each of Splash White 1 and W20, which might result in more white expression on her coat than a single pattern acting alone.

WORKING TOGETHER

When trying to predict a foal's color and pattern, you'll need to take the entire slate of color results into consideration to determine what the horse might look like—and even then, Mother Nature sometimes has funny ideas about outward expression.

Start with the horse's base color: red, black or bay. To do this, look at the results for **Extension/Red Factor** and **Agouti** on your horse's report. Extension is the horse's ability to produce red and black pigment in the hair shafts; agouti is like a light switch that "restricts" black pigmentation (if present) to certain areas of the body.

Black is dominant over red—if your horse has an "E" under Extension (note the capital letter), he's black-based. Red pigment is represented by the lowercase "e." A red-based horse (chestnut, sorrel, palomino, red dun, etc.) will always be ee in the Extension result—this means the horse can only produce red pigment in the hairs.

All horses have an agouti result (aa, Aa or AA), but it only comes into physical effect for bay- or black-based horses (Ee or EE). When that light switch is "on," with at least one capital "A" present in the results, the black pigment is restricted to the points of the horse: the mane, tail, legs and ears in most cases.

So why is this important? If you're aiming to breed for a specific color, among other things, these results can be useful. To guarantee a black foal, for example,

you'll want to consider a sire or dam that's homozygous for black at Extension (EE) and then make sure both parents are negative for Agouti (aa). That way, the homozygous EE parent will contribute at least one of those alleles to the foal—independent of what's contributed by the other parent—and both sire and dam will contribute their half of the aa combination to the foal, resulting in a baby with a black coat—not accounting for any other genes at play, of course.

Color-modifying alleles—cream, pearl, silver, champagne, gray, dun and roan—each impact a horse's base color to create vivid, eye-catching combinations like palomino, red dun, classic champagne and more. For each, at least one of the horse's parents must carry the allele in order to contribute it to the foal.



COURTESY BRANDON FENDER

Dare Tobe Dilute Ee, Aa, Cr/Cr, TO/TO

This stallion is genetically bay (Ee, Aa) but the addition of two cream genes (Cr/Cr) dilutes his coat to the beautiful perlino shade. Homozygous for cream and tobiano (TO/TO) means he's guaranteed to pass one copy of each to his foals, every time.

Cream: This dilution affects red pigment more than black, except when two copies of the cream allele are at play. One copy of cream dilutes a sorrel/chestnut coat to palomino, a bay to buckskin and a black to smoky black—though you probably won't be able to visually see smoky black on your horse's coat, since black remains a dominant color. Two copies of cream create a double-dilution—cremello (on sorrel/chestnut), perlino (on bay) or smoky cream (on black); these horses usually have very light-colored coats, manes and tails and blue eyes. The double-dilute coat colors are often tough to visually distinguish from one another without genetic testing.

Pearl: This color acts similar to cream. When present in combination with one cream allele, it creates a pseudo-double dilute appearance on the horse's coat.

Silver: This dilution affects black pigment, not red—you might notice a black or bay horse with a somewhat-lightened coat and a silver mane and tail.



Genetic Profile Test Results

Horse: Dare Tobe Dilute

Owner: Brandon Fender

HORSE ID: 06118014

PACK: APH4

Results Summary

Coat Color: Dare Tobe Dilute has one Red allele and one Black, indicating his base coat color appears Black. One copy of the Dominant Agouti allele was detected, invisible on a Red base, it pushes/restricts Black out to points, legs, ear tips, etc. appearing Bay. Two Cream alleles were detected which may dilute base coat color, possibly appearing Perlino on a Black base. Two Tobiano alleles were detected which may result in White markings. As a result of the allele count in each of the following, he has a minimum 50% chance of passing Red or Black, and 50% Dominant Agouti, and 100% Cream and Tobiano to any offspring.

Allele Summary: Aa, Ee, CR/CR, TO/TO, CC (Sprint Type)

Trails: Dare Tobe Dilute has not tested positive for any recessive disease alleles on this panel.

Please note: Your analysis is ongoing and may include some regions marked with an asterisk denoting the following.
* Discovery - This gene detection is in the early stages of discovery and will have varying reliability results.
** Inconclusive - Not a bad omen! Simply put, the gene of interest did not reveal itself (neither a positive nor a negative; no result, therefore unknown).



COURTESY PEGGY CUMMINGS

Catslittlesweetheart

Ee, AA, nd1/nd1, n/TO

Genetic testing shows Catslittlesweetheart is bay (Ee, AA) and Tobiano (n/TO), but it didn't test for her roan status—the mare is registered as a bay roan, given the intermixed white hairs in her coat and her pedigree, which includes a bay roan dam. Her nd1/nd1 status means she likely displays non-dun primitive markings, like countershading, and she'll always pass that to a foal since she's homozygous for the gene.



SMR DESIGNS

Investing In Onyx

Ee, aa, nd1/nd2, n/W20, n/LWO, n/GBED

A black-coated filly (Ee, aa), Investing In Onyx has two white patterns at play: W20 and Frame Overo. nd1 might create countershading, and though it would likely be hard to see on a black coat, she could pass that to future offspring. She's also a carrier of GBED—that has no ill effects on her health, but her owner should avoid breeding her to a fellow GBED-carrying stallion.

Champagne: Affecting both red and black pigment in the horse's coat, the champagne dilution often creates a gold, amber or bronze body color. Characteristics include lightly pigmented "pumpkin"-colored skin, mottled freckling around the eyes and muzzle and a lightened eye color. Gold champagne (on sorrel), amber champagne (on bay) and classic champagne (on black) are recognized by APHA.

Gray: The Gray allele is dominant; when present, the horse's hair color will transition from its original base color to gray or even white over time.

Dun: Whether your horse has one Dun allele or two, the outward appearance is basically the same—you'll know them as red dun (on sorrel), dun (on bay) or grulla (on black). Look for Dun's characteristic primitive markings: dark areas that create a dorsal stripe, shoulder stripe and leg barring, for instance. Some horses with *nd1*—non-dun 1, which is unrelated to Dun—might appear to have countershading along the topline, which can sometimes look like a dun's dorsal stripe. Non-dun 2 (*nd2*) has no effect on the horse's coat.

Roan: True roans often have dark heads and legs with lighter colored bodies due to intermixed white and colored hair. Red roan (on sorrel), bay roan and blue roan (on black) are the APHA-recognized variations, but it's possible for horses of other colors to showcase the roan gene, too—in those cases, owners select the closest appropriate color for APHA registration purposes.

GET COOKING

Think of a horse's coat color and pattern genetics like a recipe—you might start out with the same base ingredients, but the addition of a "secret" ingredient or two can change the expression entirely. And in the case of white patterns, even when the recipe stays the same, sometimes the cook (Mother Nature) gets a little crazy in the kitchen and the end result differs a bit from horse to horse ... but that's why we love Paints!

When you know your horse's genetic test results, you know what ingredients you're working with in your "kitchen." This might impact your management strategies, in the case of certain health conditions that can be better managed through conscientious diet and exercise, or it might impact your breeding decisions down the line. Either way, it starts with knowing your Paint from the inside out. **U**

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JESSICA HEIN

Norfleets Lucky Dee
ee, Aa, n/Cr, n/O, n/TO, nd1/nd2

The palomino tovero coat of Norfleets Lucky Dee is courtesy of several genetic "ingredients:" ee means she's sorrel (unable to produce black pigment); as such, her Aa status at agouti doesn't have any effect, since there's no black pigment to regulate. One copy of cream (Cr) dilutes her sorrel coat to palomino. And one copy each of Frame Overo (n/O) and Tobiano (n/TO) gives her an especially flashy amount of chrome. As nd1/nd2, she might display primitive markings like a countershaded dorsal stripe, but it's not caused by a Dun gene.

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HORSE COAT COLOR PANEL TEST RESULTS

		Case: NQ35427
		Date Received: 27-Mar-2017
		Print Date: 29-Mar-2017
		Report ID: 3097-6908-2881-6061
		<small>Verify report at www.vgl.ucdavis.edu/myglverify.html</small>
Horse: NORFLEETS LUCKY DEE		Reg: APHA #426283
DOB: 02/03/1999 Sex: Mare Breed: Paint Horse		
Sire: LUCKY BALLOU FLAME		Reg: APHA #201482
Dam: FLEET HONEY		Reg: APHA #126265

RED FACTOR	ee	Only red factor detected. Brown color is red in the absence of red/diluting gene	SPLASHED WHITE/PAJO (SW2, SW4)	N/N	No copies of PACE Splashed White detected
AGOUTI	A/a	1 copy of agouti. If present, black pigment is restricted to the points	LEOPARD	N/N	No copies of Leopard Complex detected
CREAM	N/Cr	1 copy of Cream dilution detected	PATTERN-1	N/N	No copies of PATTERN-1 detected.*
PEARL	N/N	No copies of Pearl dilution detected	GRAY	Absent	Gray gene is absent. Brown will not turn gray.
SILVER	N/N	No copies of Silver dilution detected	DUN	nd1/nd2	Have at least Dun dilute but may have primitive markings
LETHAL WHITE OVERO	N/O	1 copy of lethal white overo detected	DOMINANT WHITE (W5, W10, W20)	N/N	No copies of W5, W10 or W20 detected
SABINO-1	N/N	No copies of Sabino-1 detected			
TOBIANO	N/TO	1 copy of Tobiano detected			
CHAMPAGNE	N/N	No copies of Champagne dilution detected			
SPLASHED WHITE/MTF (SW1, SW5)	N/N	No copies of MTF Splashed White detected			

*Pattern-1 in order for high levels of white spotting to be visible on horses that inherit PATTERN-1, LP must also be present

For more detailed information on Horse Coat Color results, please visit:
www.vgl.ucdavis.edu/services/coatcolorhorse.php

Tests for Gray, Leopard/ Appaloosa, Lethal White Overo and Tobiano are performed under license