

Hidden Color: Wool Genetics in Columbia Sheep

Why two white Columbias can produce a natural-colored lamb — and what that means for your flock.

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1. White wool, dark lambs

Surprising lambs and what they're telling us

For most of the last century, commercial sheep production in North America has been built around white wool. White fleeces are straightforward to market and easy to dye, so white became the quiet default in most range and farm flocks. Yet nearly every shepherd can recall at least one dark or silver lamb born to two white-fleeced parents.

Those lambs are not accidents. They are visible evidence that genes for fleece color have been traveling inside our white flocks all along — masked, but never erased, by selection for white.

Columbia sheep are a clear example of that hidden variation. The breed's own founding story — told in full in the next section — explains exactly how those genes got there, and why decades of selecting for white never fully removed them.

Basic terms for wool color

Gene. A stretch of DNA that helps control a particular trait, such as fleece color, horn status, or growth rate. One instruction in the sheep's genetic code.

Allele. A specific version of a gene. At a wool-color gene, one allele might lead to white fleece and another to darker or patterned fleece. Every sheep carries two alleles for each gene — one from the sire, one from the dam.

Genotype. The combination of alleles an animal carries at a given gene, written as a pair of letters such as WW, Ww, or ww in a simple white-versus-colored

model. The genotype is the genetic recipe, whether or not its effect shows in the fleece.

Phenotype. What you actually see: white fleece, natural-colored fleece, badgerface pattern, solid black. Phenotype is the outward expression of the genotype, shaped by how different genes interact.

Dominant allele. An allele that shows its effect when at least one copy is present. If W is dominant for white and w is recessive for natural color, both WW and Ww sheep appear white, because one copy of W is enough.

Recessive allele. An allele that shows its effect only when both copies are the same. In the W/w example, only ww sheep are natural-colored. A single copy of w is masked by the dominant W.

Carrier. An animal with one dominant and one recessive allele (for example, Ww). Carriers look like the dominant type — here, a white Columbia — but can pass the recessive color allele to their lambs. This is why two white parents can produce a natural-colored lamb.

Locus (plural: loci). The address of a gene on a chromosome. Wool color in sheep is influenced by several key loci, including *Agouti*, which controls where pigment appears on the body; *Extension*, which can allow or block those patterns from showing; the black/brown locus; and spotting loci.

Homozygous / Heterozygous. Homozygous means the two alleles are the same (WW or ww). Heterozygous means they differ (Ww). A homozygous WW Columbia will always throw white at this locus, while a heterozygous Ww Columbia is a carrier that can produce natural-colored lambs when paired with another carrier.

In the sections that follow, we use these terms and a simple W/w model to show how Columbia's Lincoln-Rambouillet foundation still produces natural-colored lambs from two white parents.

2. Where the color came from

How breed history planted today's color genes

The Columbia was not imported. It was built. Beginning in 1912, USDA breeders at Laramie, Wyoming, set out to create a true-breeding range sheep that would replace routine crossbreeding, testing crosses of longwool rams on high-quality

Rambouillet ewes. The first-cross Lincoln-Rambouillet line proved the most promising of all the combinations tried, and the most desirable animals were bred within that developing population to fix a stable type ([Oklahoma State University breed profile](#)). The foundation flock was moved to the U.S. Sheep Experiment Station at Dubois, Idaho, in 1918, where selection continued; Columbia was one of three American breeds developed at that station, alongside Targhee and Polypay ([Ohio State University Sheep Team](#)). The goal throughout was a heavy, white, medium-wool fleece on a large, productive range sheep, and Columbia standards still call for a fleece that is white and free of colored fiber ([Columbia Sheep Breeders Association](#)).

That origin story matters for color, because of what the two founders brought with them.

Lincoln sheep are not genetically limited to white. “Lincolns may be white or colored, including shades of gray, silver, charcoal, and black,” notes the Livestock Conservancy, which also records that the British association does not register colored sheep while the National Lincoln Sheep Breeders Association in the United States registers colored Lincolns in a separate flock book ([Livestock Conservancy](#)). The recessive color alleles have plainly been part of the Lincoln gene pool all along, even where breeders emphasized white wool.

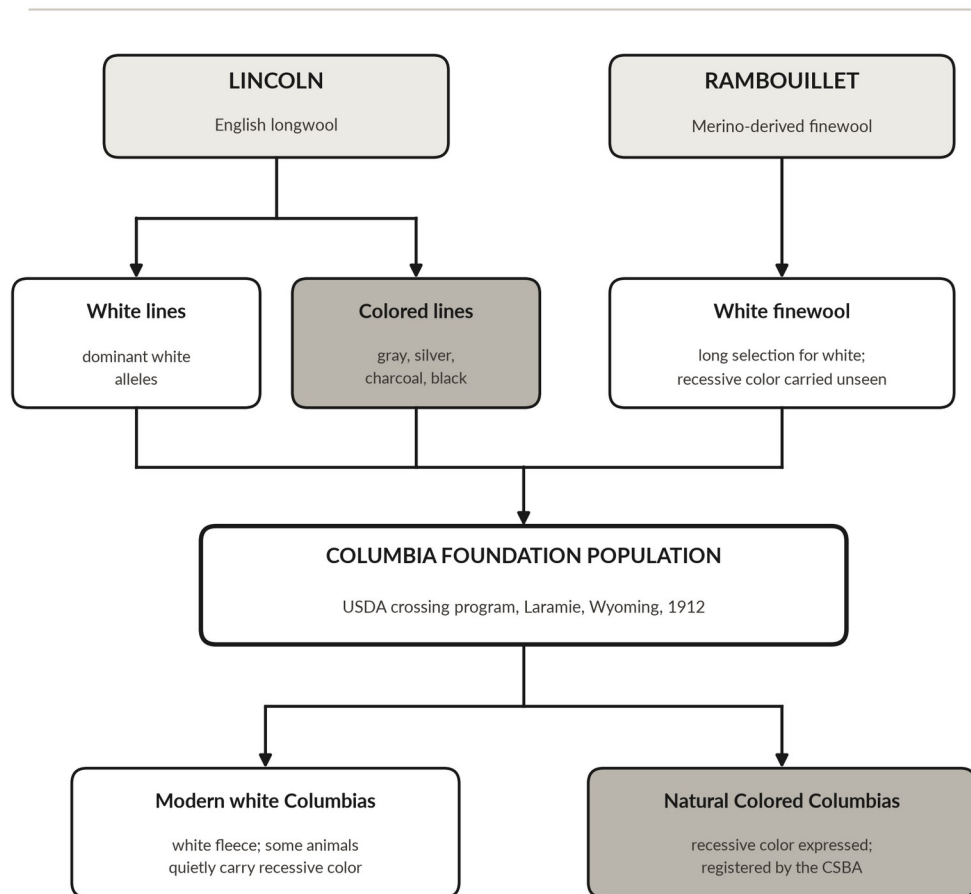
Rambouillet, meanwhile, is a white-wool breed, but white in sheep is a genetic state that can conceal pigment alleles rather than a guarantee that none are present — and coat-color research shows recessive pigment alleles can persist for many generations underneath a dominant white phenotype. When these two breeds were combined to found the Columbia, they brought more than fleece weight and body size. They brought dominant alleles that produce the desired white commercial fleece, and recessive alleles for solid dark, gray, brown, and patterned fleeces that can hide inside a white-coated animal.

Early Columbia breeders selected hard for white wool. That shifted the visible population strongly toward white, but it did not guarantee the removal of every recessive color allele. Because dominant white alleles at the *Agouti* region mask recessive self-color alleles, white Columbias from these lines could carry color quietly for generations.

Modern breed policy makes the legacy visible. The Columbia Sheep Breeders Association now registers Natural Colored Columbias, and sheep with any amount of natural coloring can be recorded as such, with a separate registration paper and number and with both sire and dam required to be registered

purebred Columbias ([Natural Colored Columbia proposal](#)). The existence of that category confirms that the founding color alleles are still segregating in the breed, even in flocks that have selected for white for decades.

Figure 1. Lincoln and Rambouillet contributions to Columbia color genetics



Both founding breeds contributed color alleles that still segregate in the breed today.

Figure 1. A simplified view of how Lincoln and Rambouillet contributed both white and colored alleles to the Columbia foundation. Lincoln longwools exist in white and naturally colored lines, while Rambouillet represents a finewool breed with a long history of selection for white but the capacity to carry recessive color. Those alleles were combined in the Columbia foundation and still segregate today in both white and Natural Colored Columbias.

3. The genes behind fleece color

Agouti, Extension, and friends

Wool color in sheep is not governed by a single color gene. Most of the visible variation traces to a small number of major loci that interact.

Agouti (the *A* locus, gene *ASIP*) controls the distribution and pattern of pigment on the body — white, tan, badgerface, the various gray patterns, or solid self-color. This is the locus that does most of the work in white breeds. Research on domestic sheep identified a 190-kilobase tandem duplication spanning the ovine *ASIP* coding region as the cause of white coat color in dominant white/tan sheep, with the extra copy driving *ASIP* expression throughout the body; by contrast, “a single copy *ASIP* gene with a silenced *ASIP* promoter occurs in recessive black sheep” (Norris and Whan, [Genome Research](#)). Later work has also linked small deletions and point mutations in *ASIP* to recessive black, and confirmed that a variable number of *ASIP* copies shapes color pattern in sheep (Kalds et al. [review, Archives Animal Breeding](#)).

Extension (the *E* locus, gene *MC1R*) controls whether dark pigment is produced at all, and can override the *Agouti* pattern. Classic work identified a two-allele series in sheep: a dominant black allele, E^D , and a wild type, E^+ , which lets the *Agouti* alleles do their job ([Archives Animal Breeding](#)).

The black/brown locus (gene *TYRP1*) determines whether the dark pigment is black or brown. Brown — moorit — is recessive to black, and loss-of-function alleles at *TYRP1* have been identified as the cause of brown fleece in sheep (Becker et al., [Animal Genetics](#)). A single-base substitution in *TYRP1* also explains the dark-versus-light polymorphism in the free-living Soay population ([Proceedings of the Royal Society B](#)).

Spotting loci add white patches on top of whatever the base color and pattern would otherwise be. Breeder-facing color guides commonly treat spotting as a separate gene series from base color and pattern, and as generally recessive (Icelandic Sheep Breeders of North America; [Black and Coloured Sheep Breeders' Association of New Zealand](#)).

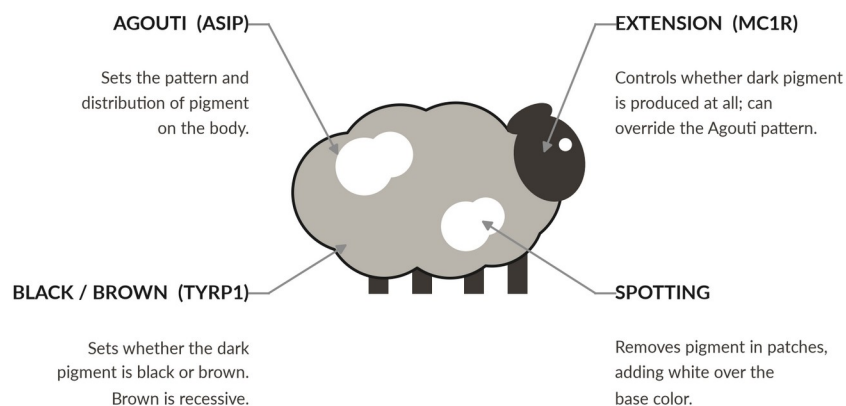
The practical message is that dominant alleles at these loci often produce white or patterned fleeces that suppress or rearrange pigment, while recessive alleles tend to produce solid, strongly pigmented color. A white sheep may be white because it is homozygous for a dominant white allele — or white only on the surface,

carrying recessive self-color alleles that reappear when it is bred to another carrier.

Why white doesn't mean "no color genes"

A useful way to say it: white is a phenotype, not a genotype. Two white Columbias can be genetically very different animals, and nothing in the fleece tells you which is which.

Figure 2. Key color loci that influence wool in sheep



These loci interact, which is why no single "color gene" can explain fleece color.

Figure 2. The major genes shaping wool color act at specific loci. Agouti determines the pattern and distribution of pigment. Extension controls whether dark pigment is produced and can block Agouti patterns from showing. The black/brown locus sets whether dark pigment is black or brown, with brown recessive. Additional spotting loci add white markings on top of the base color. Together these loci explain the range of colors and patterns seen in Columbia and its parent breeds.

4. What you can't see from the wool alone

Carriers, and what decades of white selection actually changed

Using the terms above, many white Columbias are heterozygous carriers for recessive color. If we simplify the whole system to one composite locus with a

dominant white allele (W) and a recessive color allele (w), three genotypes matter:

- **WW** — white, and true-breeding for white. Bred to another WW, it will never throw a colored lamb.
- **Ww** — white, but a carrier. It can produce colored lambs when mated to another carrier or to a colored animal.
- **ww** — natural-colored, expressing the underlying pigment pattern.

When breeders cull obvious colored lambs but keep productive natural color carriers, they change the visible color of the flock far faster than they remove alleles from the gene pool. Decades of selection for white altered what we see. It did not necessarily alter what is *there*.

Figure 3. Genotype and phenotype in a Columbia flock

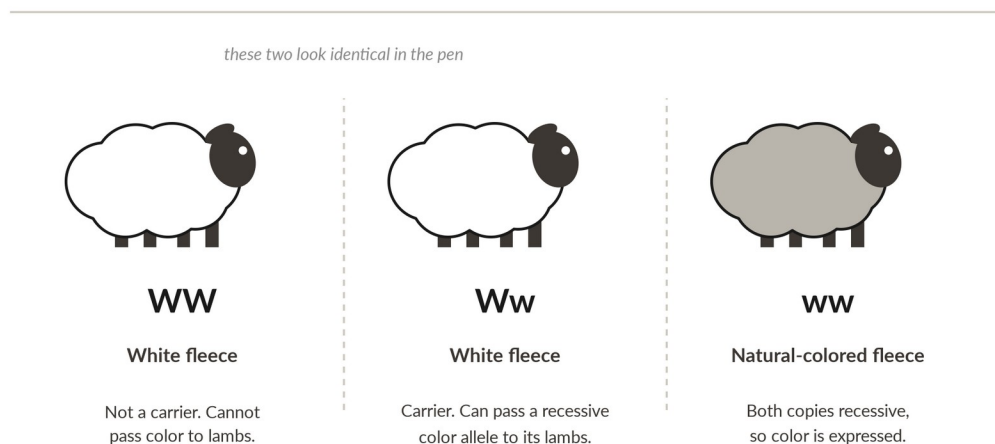


Figure 3. *The relationship between genotype — the pair of alleles a sheep carries — and phenotype, the wool color we see. Both WW and Ww Columbias appear white, but only Ww animals carry a recessive color allele they can pass to their lambs. Lambs with genotype ww grow natural-colored fleeces, revealing recessive alleles inherited from white parents.*

5. Running the numbers

A Punnett square for Columbias

Two natural color carriers bred together give the classic result. Over many lambs, a $Ww \times Ww$ mating is expected to produce one natural-colored lamb in four. Two other matings are worth memorizing:

- $Ww \times ww$ (natural color carrier bred to a natural-colored animal): about half the lambs colored, half natural color carriers.
- $WW \times Ww$ (true-breeding white bred to a carrier): all lambs white, but half of them carriers.

These are averages over many lambs, not promises about any single lamb crop. A carrier-by-carrier mating that produces four white lambs in a row has not disproven anything.

Punnett square for Columbia fleece color ($Ww \times Ww$)

A simple mating diagram showing how two white Columbia carriers produce white non-carriers, natural color carriers, and natural-colored lambs in predictable proportions.

	W (sire)	w (sire)
W (dam)	WW — white, not a carrier	Ww — natural color carrier
w (dam)	Ww — natural color carrier	ww — natural-colored

Counting the boxes: 25 percent WW (white, not carriers), 50 percent Ww (natural color carriers), 25 percent ww (natural-colored).

The same square in *Agouti* notation. If you prefer to name the actual locus rather than use a generic W/w, the same logic holds at *Agouti*, writing A^{wh} for the white allele and A^b for the recessive black allele. (In the scientific literature these same alleles are usually written A^{Wt} and A^a .)

	A^{wh} (sire)	A^b (sire)
A^{wh} (dam)	$A^{wh}A^{wh}$ — white	$A^{wh}A^b$ — natural color carrier
A^b (dam)	$A^{wh}A^b$ — natural color carrier	A^bA^b — black

Figure 4. Simple model of white and natural-colored fleece in Columbia sheep

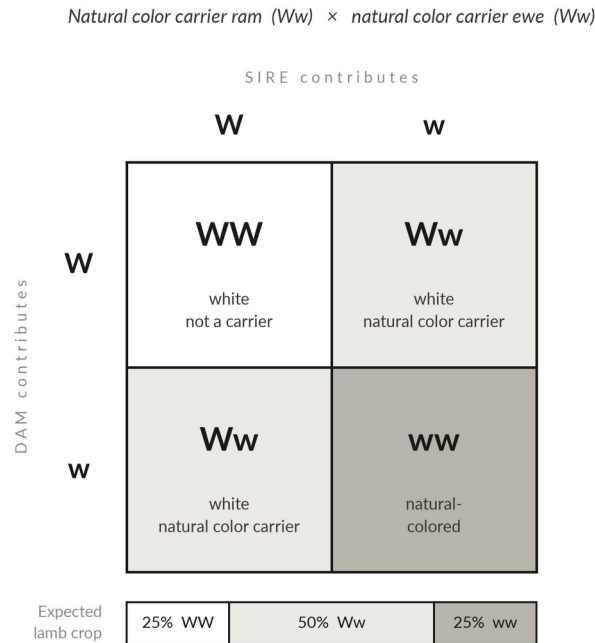


Figure 4. Simple one-gene model for Columbia fleece color. W represents a dominant allele for white wool and w a recessive allele for natural-colored wool. When two natural color carriers ($Ww \times Ww$) are mated, the expected genotypes in the lamb crop are 25 percent WW (white, not carriers), 50 percent Ww (natural color carriers), and 25 percent ww (natural-colored). Over many lambs, this explains how two white Columbias can produce natural-colored offspring.

6. Black, brown, and spotted

More than one layer of color

Two extra layers complicate the simple picture, and both matter to breeders working with colored Columbias.

Brown hides under black. Because brown is recessive to black at *TYRP1*, a black-appearing sheep can carry brown and pass it on (Becker et al.). A flock with black rams and black ewes can therefore produce a brown lamb, and a flock with no brown animal in sight can still be sitting on brown alleles.

Spotting sits on top of everything else. Base color and pattern genes determine what the fleece would look like if no spotting were present; spotting genes then remove pigment from patches of skin and wool. A sheep can be genetically black underneath and appear black-and-white. Breeder-based genetic guides treat spotting as generally recessive, so in a simple model where **S** is no spotting and **s** is spotting, an $Ss \times Ss$ mating gives roughly 25 percent non-spotted, 50 percent non-spotted carriers, and 25 percent spotted lambs ([Icelandic Sheep Breeders of North America](#)).

The catch is that the exact amount and placement of white are much harder to predict, because spotting appears to be influenced by additional modifier genes. Those modifiers affect whether a lamb gets a few white marks, broad body patches, head and leg markings, or the flecking and ticking that develops later. In short: you can often predict whether spotting may appear. You cannot predict what the pattern will look like.

7. Turning a “defect” into a fiber feature

Natural Colored Columbias

For white-wool markets, the standard is unambiguous. Columbia fleeces should contain no colored or medullated fiber, hair, or kemp, and any colored wool is a disqualification ([Columbia Sheep Breeders Association](#)).

But the association also now recognizes the color that the breed has carried since 1912. Sheep with any amount of natural coloring can be registered as Natural Colored, and to be exhibited a Natural Colored Columbia must be at least 35 percent colored on the body ([Columbia Sheep Breeders Association](#)). The program’s stated mission is to register and recognize Natural Colored Columbias within the CSBA purebred registry “for the purpose of tracking and preserving genetics in the Columbia breed,” with both sire and dam required to be registered purebred Columbias ([Natural Colored Columbia proposal](#)).

That recognition reflects an existing genetic reality rather than a new outside influence. It also opens real markets: handspinners, small-batch mills, and on-farm fiber sales all place a premium on natural-colored wool that needs no dye.

Is recessive black widespread in the breed?

The claim deserves care. The Lincoln-Rambouillet foundation, the demonstrated persistence of recessive black *ASIP* alleles under white coats, and the continued

existence of Natural Colored Columbias together make a strong case that recessive black is broadly distributed across Columbia lines. Proving that every Columbia carries it would require population-wide genotyping, and no such survey has been published. The defensible statement is that recessive black is probably present in many flocks even where it is not visible — which fits both the history of the breed and the way color inheritance works.

8. Practical strategies for your flock

Using simple tools, not lab tests

If your market demands white. Selection by appearance alone is imperfect, because white sheep hide recessive black and solid sheep hide spotting. Track pedigrees, segregate or cull known carriers, and select replacement stock from lines with a long white record. Remember the one piece of free information the flock gives you: whenever two white sheep produce a colored lamb, both parents are proven carriers. Write it down.

If you want to build natural-colored lines. Deliberately retain colored lambs and use known carriers. Record every mating and every outcome, including the lambs that came out white. Because brown is recessive to black, a flock with black rams and no brown ram can still produce brown lambs from black ewes that carry brown — worth planning for rather than being surprised by. Aim for consistency of shade and pattern, and keep the 35 percent body-color show threshold in mind when selecting animals you intend to exhibit.

For everyone. No affordable, breed-wide DNA color panel is going to make your records obsolete. A notebook, consistent ear tags, and the Punnett square above are enough for nearly every on-farm decision. Two white parents plus one colored lamb equals two proven carriers, and that single observation is worth more than any amount of guessing about a ewe's ancestry.

The history of the Columbia breed and the science of sheep color genetics point in the same direction. Columbia sheep were built from breeds that carried color, and the breed's white appearance never guaranteed those genes were gone. Black, gray, brown, and spotted Columbias are best understood not as contradictions of the breed's history, but as reminders of it.

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