05 RAT GENETICS

As arguably one of the most daunting facets of breeding for an aspiring breeder, taking the time and putting in the effort to build a basic genetics knowledge is key to becoming the best breeder you can. It's intimidating to know where or how to even start with so many resources available. It's the goal of this guide to give an aspiring breeder, pet owner, or even existing breeder wanting to polish up their skills a solid starting line.

UNDERSTANDING STRUCTURE

For the purposes of this guide, we'll be starting the discussion on genetics structure at the chromosome.

Humans have a total of 23 pairs of chromosomes, but rats have a total of 21 pairs. On these chromosomes are specific, fixed positions where a particular type of gene lives, called a locus (plural: loci). Rats, like humans, are diploids. That means that each locus can host 2 copies of the specific gene that is meant to be at that locus. In order to visualize this, imagine a highway that is full of different coupe-style cars stalled at specific exits along the road. The highway is your chromosome; the cars themselves are acting as your loci. In a coupe, there are only 2 seats meant for passengers. These two seats inside the car are where you'll find the genes.

In the rat fancy, the gene that is responsible for what you'd see without mutation is known as wildtype. An example of wildtype is agouti fur coloring or black eyes. These genes have produced variants known as alleles. An example of an allele is black fur coloring or ruby eyes due to the red eye dilute gene. In most casual use cases among the fancy, you'll find both the terms genes and alleles being used interchangeably.

When an animal is said to have 2 copies of the same gene/allele at a locus, it is homozygous. When an animal is said to have different copies of the same gene/allele at a locus, it is heterozygous. To better visualize this, let's look at agouti vs black.

Agouti and black both exist on the A (agouti) locus. This is the base color locus for all rats, meaning that every rat will either have an agouti base or a black base. Agouti is considered wildtype and is a dominant gene. Black is the mutated allele found on the A locus and is recessive. A dominant gene only requires 1 copy of the specific gene to express, whereas a recessive gene needs 2 copies to express. The term express is

referring to what we can see, or the animal's phenotype. The genotype explains the animal's actual genes. Refer to the shorthand examples below. A phenotype is generally written like : Russian Blue Agouti

A genotype of that same animal could read like : Aa dd Mm indicating that the Russian Blue Agouti also carries mink.

Aa AA aa

When written down, agouti is referenced with a capital A and black is referenced with a lowercase a. Aa is a heterozygous animal because the A locus has 2 different variants of the gene present, but AA and aa are both homozygous due to the same variant is present in both gene slots.

In all but 2 instances, each locus has 2 options of genes to inherit: wildtype or the mutated allele. However, the C locus and the H locus are both multiallelic loci. This means that these loci contain three or more observed alleles. This includes wildtype plus at least 2 alleles. Keep in mind that each locus is still only able to hold 2 variants of the same gene. More about these loci later.

THE MODES OF INHERITANCE

Rats have a limited number of inheritance types for genes. They are as follows:

Dominant: A type of gene that expresses with 1 copy, suppressing any accompanying recessive gene on the same locus. When an animal has 2 copies of the same dominant gene, the animal visuallyis unchanged.
Ex: Agouti (Aa or AA)
Homozygous Lethal/Lethal Dominant: A subtype of a dominant gene where an animal who inherits a dominant copy of a gene from both parents is incompatible with life and is absorbed in utero.
Ex: Pearl (PePe)
Hypostatic Dominant: A subtype of a dominant gene where a dominant gene only expresses if certain terms have been met. When a hypostatic dominant does not have these requirements met, it's said to be unexpressed. It is still not carried.
Ex: Pearl requiring Mink (mm Pepe)
Incomplete Dominant: A subtype of a dominant gene where a 3rd phenotype arises when an animal has 2 copies of the dominant gene.
Ex: Double rex (ReRe) or Mendel's Pea Plant experiment
Recessive: A trait is not expressed when only one copy is present; requires 2 copies of an allele to express.
Ex: Chocolate (bb)

Rats do not currently have any known codominant genes discovered.

Recessives can be carried. Dominants cannot be carried. Hypostatic dominants may be unexpressed, but are still not carried.

UNDERSTANDING THE WRITTEN SHORTHAND

Each gene has a shorthand that can be written and referenced. Generally, a capital letter is referencing a dominant gene, and a lowercase letter is referencing a recessive gene for a specific locus. Unfortunately, learning which types of genes are recessive or dominant comes down to memory.

As was stated above, in the A locus, agouti (A) is dominant and black (a) is recessive. Other examples include the B (brown) locus.

B - wildtype, dominant b - mutated allele, recessive

The B locus controls whether a rat will be chocolate (black base) or Sienna (agouti base). An animal who is aa Bb is black (aa) carrying chocolate (Bb). Since chocolate is recessive, an animal needs 2 copies of the mutated allele (b) in order to express chocolate. However, an animal who is aa bb is called chocolate. Aa bb would be Sienna. Sienna carrying black could be said to include greater information.

PUNNETT SQUARES

Now that we understand the basics of inheritance, and how to write and read the basics of shorthand, we can learn about Punnett squares. For beginning genetics aficionados, a Punnett square can help you visualize how a specific gene may be passed down. A simple Punnett square may look like this:

	A	a
a	Aa	aa
a	Aa	aa

The aa along the left side is denoting the 2 types of genes at the A locus for Parent 1 where the Aa on the top is denoting the 2 types of genes at the A locus for Parent 2. From this, we can see that each pup has a 50% chance of being Agouti carrying black, and 50% of being black.

	Ab	Ab	ab	ab
AB	AABb	AABb	AaBb	AaBb
Ab	AAbb	AAbb	Aabb	Aabb
aB	AaBb	AaBb	aaBb	aaBb
ab	Aabb	Aabb	aabb	aabb

Punnett squares can become as complicated as you can imagine them. In a dihybrid Punnett square, you're using 2 different traits. For this example, we're pairing Sienna carrying black (Aa bb) to an Agouti carrying black and chocolate (Aa Bb).

From this example, you can see each pup has a:
12.5% chance of AA Bb (Homo Agouti carrying chocolate)
12.5% chance of AA bb (Sienna)
25% chance of Aa Bb (Agouti carrying black and chocolate)
25% chance of Aa bb (Sienna carrying black or just Sienna)
12.5% chance of aa Bb (black carrying chocolate)
12.5% chance of aa bb (chocolate)

Numerous Punnett square calculators exist across the web to help assist in the more complicated squares.

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COLOR LOCI

A rat's coat color is determined by the pigment in the hair. The two basic pigments are eumelanin, which causes black/brown color, and phaeomelanin, which causes yellow/red color. Genes found at their specific loci determine how these pigments express.

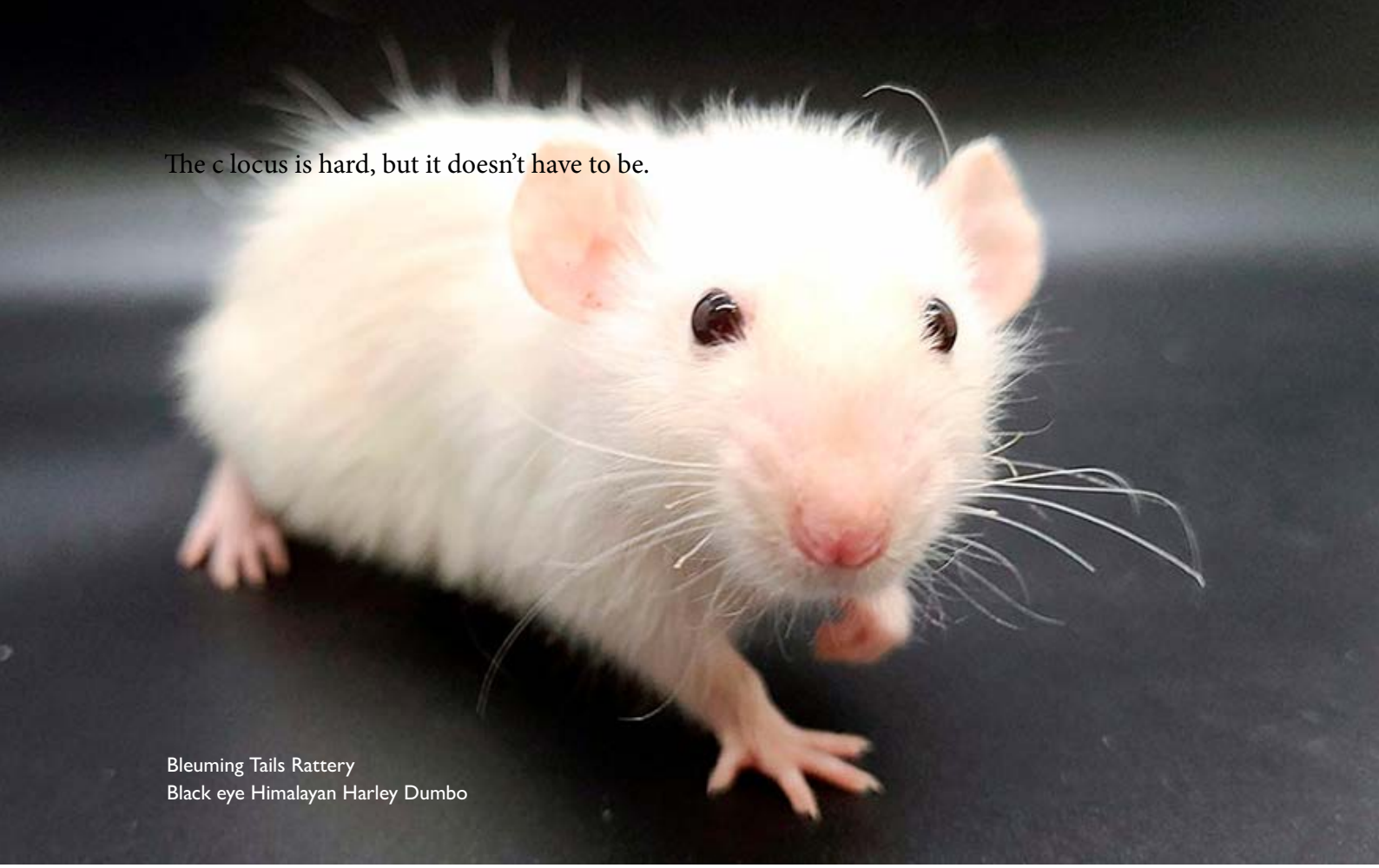
The fancy is constantly expanding, and new colorations are being explored and test bred. This list is not exhaustive of every color locus to exist, but does discuss the most common, and likely most available to aspiring breeders. Color loci can be combined to make almost indefinite combinations, some standardized by clubs and some are not. When a rat has two active color loci other than A locus, they're frequently called double dilutes. For rats with three active color loci other than A locus, they're referred to as triple dilutes. A good rule of thumb is that the more color dilutions that are present, the lighter the rat is likely to be when compared to its single dilution counterpart. For a more in-depth list with accompanying images, please visit the Rat Variety Guide by Igloo Rats.

RAT VARIETY GUIDE

COLOR LOCI CHART

Locus	Description	Alleles
A (Agouti) locus	The Agouti locus controls the distribution of yellow pigment throughout the coat. AA and Aa animals have a band of yellow near the top of each hair, giving the animal a ticked appearance. aa animals are black based and have hairs which are solid colored. Eyes should be black.	A–Banded hairs (Agouti, dominant) a–Solid hairs (Black, recessive)
B (Brown) Locus	This locus determines whether eumelanin is black or brown. B causes eumelanin pigment in an animal's coat to be black. We see this in the banding in Agouti and Black animals. Eyes should be black.	B–Black b–Chocolate (recessive)
D (Dilute) Locus	This locus causes black and yellow pigment to be lightened. Additionally, the pigment is clumped unevenly along the hair shafts, giving dilute rats a dark, heathering to the coat. dd animals, on a black background, is called Russian Blue. These animals are similar to Blue mice or Russian Blue cats. The D locus is often the only locus in other animals that causes a diluted "blue" coloration, but this is just 1 of 2. Eyes should be black.	D–No dilution d–Diluted color (Russian Blue, Recessive)
G (Gray) Locus	Like the D locus, the G locus seems to dilute black fur to a different type of blue, but leaves yellow pigment untouched. This is known as Blue or American Blue. While considered a fault, American blue frequently has light colored bases of the hair shafts, whereas Russian Blue does not. Additionally, American Blue lacks the dark heathering found in Russian Blue. This dilution is known to comes in three different shade ranges called (American) Blue, Sky Blue, and Powder Blue. Eyes should be black.	G–Full color (no dilution) g–Diluted color (American Blue, recessive)
Ma (Marble) Locus	While not exactly a color locus, Marble/Spotted Tabby acts as more of a color modifier. The base body color dilutes, and splotches of the original color show throughout the body. Unlike Merle, Marble can be seen on any color. Best spotting is shown on Black, Russian Blue, and Mink. Malocclusion is said to be in some lines of Marble.	Ma-Marble (dominant) ma-Full color

Locus	Description	Alleles
M (Mink) Locus	UK Mink (m) American Mink or Mock Mink (mo) Australian Mink (am) All three mink varieties are recessive, and have their own appearances. Additionally, they do not breed true to each other. Mock Mink is frequently seen to have eyes with a ruby sheen, without the presence of the red eye dilute. Aussie Mink goes through a rather dramatic color change between juvenile fur and adult fur. UK and Aussie Mink should have black eyes.	M, Mo, Am–Full color (no dilution) m, mo, am–Diluted color (UK Mink, American Mink, Australian Mink, recessive)
Me (Merle) Locus	It causes irregular blotches of dark color to appear on a lighter colored background. Merle is a hypostatic dominant that is reliant on the presence of 2 copies of the recessive mink. If an animal does not have 2 copies of the same type of mink, the Merle will not express. Best results are on a Pearl.	Me–Merle (hypostatic dominant) me–Non Merle
P (PED) Locus (Pink eye dilute)	This locus has an extremely strong dilution of eye color and black/brown pigment, creating pink eyes and a pale yellow color. It lightly affects yellow/red pigment. Despite the name, the range in which PED dilutes can vary. Eye color can range from a bright, true red to nearly translucent pink.	P-Black eyed (no dilution) p-Pink eyes (recessive)
Pe (Pearl) Locus	Pearl is a hypostatic homozygous lethal dominant where it causes most of each hair shaft to be white with just the tip being colored. In the fancy, poorer quality pearls are called Dark Phase Pearl. The standard Pearl is a very bright, icy white with that dark tipping. Like Merle, Pearl is reliant on the presence of the 2 copies of the same variant of mink. Homo lethality results in litters that may be 25% smaller than normal. No ethical issues arise from breeding Pearl x Pearl.	Pe–Pearl (hairs white with colored tip, hypostatic homozygous lethal dominant) pe–normal color (hairs have no white)
R (RED) Locus	This locus is very similar to P, but the dilution is not as severe. It dilutes eyes to ruby, lightens black/brown, and slightly affects red. Like PED, RED has a range in how much it dilutes the eyes and fur color. RED eyes can range from so dark ruby they appear black in most lights to dark, bright red.	R–Black eyed (no dilution) r–Ruby eyed (black/brown diluted)



The c locus is hard, but it doesn't have to be.

Bleuming Tails Rattery
Black eye Himalayan Harley Dumbo

C-COLOR LOCUS

You may have noticed we skipped the C locus in the logical place among the color loci listings. This is because this locus requires a more in depth look, as it's one of the multiallelic loci. This section will also include discussion about Burmese and the C locus Black Eye gene. Varieties from the C locus have naturally red to pink eyes without the use of RED or PED. The points found in the C locus are formed by temperature-sensitive tyrosinase. Pigment is darker in the cooler sections of the body such as nose, feet, ears, and the tail.
Among the C locus alleles, we have:

- C — no dilution, dominant over all other c-locus alleles
- c — albino (No pigment at all, so fur remains white, and eyes are bright pink.)
- c(h) — Himalayan (Acromelanistic pattern — pigment is color-sensitive, so the cooler parts of the animal are darker colored. These are called points and are found at the face, feet, ears, and tail. Eyes are red to ruby.)
- c(m) — Marten (Yellow pigment is almost entirely removed and becomes silver or very pale yellow. Black pigment is normal in babies, but fades to a dusty charcoal in adults. Eyes are pink to red. A common fault is marbling on the head.)
- c(t) — Tonkinese (Color point shaded variety where the body remains a rich brown that darkens to points. Ruby eyes. Renamed to Siamese Sable by the AFRMA, but the original founder of the variety (Kodachrome Rattery) named it Tonkinese.)

With a total of 5 genes found on the C locus, it can be quite tricky. An important note is that while the locus itself is recessive, meaning that you need 2 alleles that are not C present to express, the alleles themselves have varying levels of dominance that seem the closest to incomplete dominance. All C locus varieties have an underlying color such as Black, Russian Blue, Agouti, etc.

- cc — albino
- c/c(h) — Himalayan
- c(h)/c(h) — Siamese
- c(m)/c — Heterozygous Non-pointed Marten
- c(m)/c(h) — Pointed Marten
- c(m)/c(m) — Homozygous Marten
- c(t)/c, c(t)/c(h) — Tonkinese
- c(t)/c(m) — Marten Tonkinese
- c(t)/c(t) — Sable Tonkinese

In many instances, Siamese can be mistaken for Beige as a young juvenile, but a key sign to tell the difference is that, on an unmarked Siamese, you can see a darkening gradient towards the rump of the pup.

BURMESE

Burmese is a hypostatic incomplete dominant that relies on the C locus to express. Burmese, like Pearl or Merle, exists on its own locus separate from the C locus. The phenotype of the type of Burmese is dependent upon the base genetics found at the C locus. Like other incomplete dominants, 2 copies of Burmese create a 3rd phenotype known as Sable. Wheaten is the term given to Burmese when the animal has an Agouti base. Burmese can have any additional color recessives just like the traditional C locus genes. For example, a Burmese rat with 2 copies of Russian Blue is a "Russian Burmese." Unlike C locus genes, Burmese has naturally black eyes unrelated to the C locus black eye gene. Burmese can have any combination of C locus genes as the base, including Marten and Tonkinese. Below are Burmese combination with the traditional C locus genes.

Bleuming Tails Rattery
Ivory Dumbo

- Bu — Burmese
- bu — wildtype, no Burmese
-
- c(h)/c(h) BuBu or c(h)/c BuBu — Pointed Sable
- cc BuBu — Sable (no points)
- c(h)/c(h Bubu or c(h)/c Bubu — Pointed Burmese
- cc Bubu — Burmese (no points)
- A- c(h)/c(h) BuBu — Pointed Wheaten (Agouti) Sable Burmese
- A- cc BuBu — Wheaten (Agouti) Sable Burmese (no points)
- A- c(h)/c(h) Bubu or c(h)/c Bubu — Pointed Wheaten (Agouti) Burmese
- A- cc Bubu — Wheaten (Agouti) Burmese (no points)

C LOCUS BLACK EYE

Unrelated to wildtype, the C locus black eye is a hypostatic dominant that interacts with the C locus. This dominant causes the naturally red eyes of c locus varieties to become black. Like Burmese, this gene exists on its own locus, separate from the C locus.

- Be — C locus Black eye
- be — wildtype

IVORY

One of the options when disucssing black-eyed white is Ivory. This variety is created when an albino rat also has the C locus Black Eye allele.

DO I HAVE A SIAMESE OR A HIMALAYAN?

Generally, they cannot be truly told apart post molt. In a well-bred rat, a Himalayan should have a creamy color body with paler points and a Siamese should have a dark creamy body with robust, darker points. However, we often have himis and siams that start out too light in color, and a common rule of thumb in the fancy is that Himalayan and Albino both start out pure white and are indecipherable. As the animals age, the albino stays the same, but the Himalayan's points will darken and develop.

Himalayans darken into their points, and siamese lighten into their points. Markings can mask points.

COATS

Like the color loci, coats exist across a myriad of different loci. Each coat type is unique, and can be combined to create even more unique coat types. Being as this guide is meant as a jumping off point, these combo coat types will not be discussed. For more information on these, please visit the Rat Variety Guide by Igloo Rats. Coat types can come in any color.

bleuming tails rattery
Double rex dumbo

bleuming Tails Tattery
Russian Blue Variegated Dumbos

MARKINGS

Markings are a complicated facet of rat genetics. Like the C locus, the H (hooded) locus is a multiallelic locus. In addition to the marking alleles found on the H locus, other types of markings exist on their own loci that interact with the H locus.

Standard markings exist, but these are the ideal representation of the marking. Every kind of marking has over marked (too much white) and under marked (too much color) as non-standard variants, and multiple combos of genes can appear to make the same phenotype. Each allele restricts color from the animal in increasing increments in the following order: h(i)<h<h(n)<h(e)<H(re) (Torigoe et al., 2010). The alleles found on the H locus are as follows (Prinsloo, 2015):

- H — Wildtype, minimum/no white spotting
- h(e) — Extreme hooded, Superficial black eyes that glow dull red in bright light accompanied by extensive white spotting
- h(i) — Irish Hooded, Causes white spotting in the rat, but of a lesser grade than the hooded allele
- h — Hooded, extensive white spotting confined to the rear end of the animal
- H(re) — Restricted Hooded, extensive white spotting, homo lethal
- h(n) — Notched Hooded, Causes white spotting in the rat, but of a higher grade than the hooded allele
- H(ro) — Robert/Essex, homo lethal, slight dilution of color. Color on the back is darkest, evenly fading to lighter color down the sides. White spotting accompanies this color dilution. Pups are already identifiable due to fading.

These alleles all work together in varying combinations to create the phenotypes we know. Another important facet is the hooded modifier locus. This controls the length of the stripe on a hooded rat, as well as potentially effecting white spotting in other varieties.

- H(ml) — long dorsal hooded pattern. Necessary for hooded rats to have a stripe reaching right down to the tail.
- H(ms) — short dorsal hooded pattern. Necessary for barebacks.

OFF H-LOCUS MARKINGS

Coat	Description	Alleles
Roan/Husky Recessive	Born as a solid color, rats with the recessive ro fade to white as they age.	Ro-standard ro-Roan
Dalmatian Homo Lethal Dominant	Dalmatian acts as both a marking and a color modifier. It causes the base color to be diluted and heavily silvered. In a show quality dalmatian, they have spots of this silvered, diluted color all over their body in equal, even blotches. A dalmatian is NOT a variegated. It does not appear to be within the standard H locus that controls most other markings.	Dal-Dalmatian dal-standard
Downunder Homo Lethal Dominant	Downunder variety with a color on its belly that runs from the neck to the breech and appears to mirror the dorsal hooded marking. Downunder rats also exhibit anophthalmia or microphthalmia with incomplete penetrance. Downunder appears to be a homo lethal (Hieu et al., 2023).	Du-Downunder du-standard
Head spot Recessive	hs has the form of a white sport of variable size in the middle of the forehead just above the eyes, and can range in size from just a handful of white hairs to a full blaze. Recessive blazing cause by hs is not a DWS marking.	Hs-Standard hs-Head spot
Whiteside Recessive	Known for their "pants", whiteside have a band of white circling their belly.	Ws-Standard ws-Whiteside
Snowflake Recessive	Shows dappled white spots along the stomach area.	Sf-standard sf-snowflake

COAT CHART

Coat	Description	Alleles
Rex Incomplete Dominant	One of the most common rexoid genes in the fancy, it presents as a typical curly furred type. Whiskers can vary between long and wavy, and very short, curly and bent. The hairs of the coat should be short, but dense with as few guard hairs as possible. The fur should be coarser than standard or Velveteen, but not as coarse as Bristle. Bucks have the better rex coats than does, and tend to hold curl better as they age. Rex quality varies heavily and can present with patchy molts, generally thin fur, poor curl pattern, or even an almost non-existent curl pattern. Poor rex is indistinguishable from Velveteen and requires test breeding to see how it doubles. Rex is an incomplete dominant, and rex x rex can create double rex or "drex." A hallmark sign of drex is thin, patchy fur to completely hairless.	Re-Rex re-standard
Velveteen Incomplete Dominant	The other most common rexoid gene, Velveteen, is said to have lighter, softer waves than Rex while retaining its guard hairs. The fur quality should remain full, and the texture tends to be softer than Rex. The whiskers are typically long and curled forward. Velveteen is an incomplete dominant, and Velveteen x Velveteen creates double Velveteen or "dvelv." Unlike drex, dvelv does not molt out patchy in this form. Instead, the fur should remain full, but will be thick and dense similar to a shorn sheep.	Cu-Velveteen cu-standard
Bristle Dominant	Unlike Rex or Velveteen, a Bristle should feel similarly to a wire brush. The coat will be lightly waved as pups, but then straightens with age to a harsh, rough-looking, messy coat. Whiskers will be straight to curled on the ends.	Br-Bristle br-standard
Satin Recessive	Satin has a semi-long, shiny coat with a trademark mussed appearance. As pinkies, satins are easy to identify due to their "blown back" whiskers.	Sa-Standard sa-Satin
Lustrous Recessive	Lustrous will have a shiny (almost greasy), mussed coat. Whiskers on pinkies will be crimped and blown back.	Lt-Standard lt-Lustrous

Coat	Description	Alleles
Silvermane (D'Argente) Suspected Homo Lethal Dominant	A Silvermane is a fancy-favorite with their flashy fur type. To create the look, the hair shafts are hollow, silvering out and lightening the overall tone without the use of dilution genes. The rate at which they silver out depends on the line, but can be apparent as soon as fur begins to come in. Others take months to silver out, and some lose the silvering as they age. Silvermane is not the same as "silvering" as a fault or for "silvered" varieties. A tell-tale sign is the common "Silvermane mask" that appears as darker, non-silvered fur around the nose and eyes.	Sm-Silvermane sm-Standard
Harley Recessive	Harley is a long-haired variety with hallmark long thin wispy fur lacking undercoat. Baby coats can appear greasy. Like Satin and Lustrous, Harley can be noticed from birth by whiskers. Harley whiskers are often short and broken with a wave or curl. Some lines of Harley have been known to have sensitive skin issues, and some may have lactation issues. This is a variety that is ideally handled by experienced breeders. Harley does not have a standardized shorthand.	
Hairless Recessive	Hairless come in several varieties, all recessive, though it's unclear which one(s) is the most prominent in the fancy. The ethics of breeding hairless varies by region, but in the US it's considered ethical as long as the breeder is working toward bettering the variety. Common issues include agalactica, smothering litters, entropion, and delicate skin. Other concerns include temperature regulation. hr which is mostly hairless with a little short curly hair on the nose, feet and small amount on the lower legs and short curly whiskers. fz has a fuzzy body and short curly whiskers. nu lacks all forms of hair. Their body is complete nude and they lack whiskers.	Hr-Standard hr-Hairless Fz-Standard fz-Hairless Nu-Standard nu-Hairless
Patchwork/ Werewolf	The defining feature of werewolf is that the rat to continuously molts throughout its life in mostly symmetrical patterns over the body. It is often referred to as 'True' Patchwork in order to reduce confusion to the now incorrect nomenclature given to drex "patchwork."	Pw-Standard pw-Werewolf

Dominant White

SPOTTING

Erroneously known as high white or lethal white, DWS is a dominant marking trait. The traditional DWS markings are capped-stripe, collared, banded, split capped, and dominant blazing. Odd-eye is also a sign of DWS markings, but is not necessarily a DWS marking itself. However, DWS can also present in markings that resemble Berkshire and variegation. Roans are megacolon free. Other odd spine-centric markings with clear-cut edges also can be a sign of DWS.

What causes DWS markings? These interesting markings are caused when cell migration is delayed and the pigment cells, the cells that tell the color where to go, do not reach their final destination. During fetal development, these cells originate in the neural crest along the spine and travel throughout the rest of the embryo. If the cells do not make it to their final destination, it results in patches/patterns of colorless fur. The more the cells are delayed, the higher the white will be along the sides. These delayed cells also affect the head patterning and result in blazes or irregular head spots. Odd-eye can be caused by this delay. However, odd-eye is also suspected to have a genetic component outside DWS.

The neural crest cell delay can also cause problems within the colon where parts or the entirety lacks the ability to contract causing megacolon. Megacolon in rats is always fatal.

Markings such as dalmatian and variegated are not DWS genetics, despite a visual similarity. A defining characteristic is that DWS has very clean edges. DWS is a variety that is best handled by experienced breeders.

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