"Crested Gecko, Foundation Genetics"... a living entity, in pursuit of knowledge

Updated: 5/01/21, v0.5

Why are we creating another morph guide?

This is not another morph guide. We are laying the foundation of genetics, for Crested Geckos, by addressing proper genetic terminology and tackling the complex world of combo morphs in the community. We have been incorrectly using genetic terminology for a long time. Gathering the information needed to properly understand what is happening, requires significant effort and it has never been gathered in a single place to reference and learn until now. This document contains years of research and information that we wish to share with the community. It will add clarity to what is happening with trait interactions. We are presenting the information in a way so readers can understand genetics by building off previous sections. Cresteds are a species that produce phenotypes that are made from multiple wild-type traits. Ball Pythons are at a stage where 3-8 gene combos create complex interactions and this guide will help with verbiage used to help explain trait interactions when we are all discussing genetics. Making sure we are using the same definition, when using genetic terms, is one of the most important things to help clear up confusion amongst breeders.

This is a long-overdue collaboration between breeders to classify and properly identify Crested gecko traits in the industry. We want to help enthusiasts understand the language when speaking about genetics and inheritance in groups along with providing this reference for clarification. This guide is endorsed by some of the most well know breeders, in the industry, including some that specialize in specific traits and bloodlines. We want this to be a living entity that continues to evolve as our understanding grows. The information gathered is reviewed and collaborated on by industry leaders to form a consensus in the classification of traits.

This document is a living guide. As we learn more, about specific traits, the guide will evolve. We always love to hear feedback from those who have data concerning classification, so please do not hesitate to reach out if you wish to collaborate with us and other industry professionals.

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How are morphs classified

Let us take a step back and look at this from a reptile community perspective. Currently, with crested geckos, we use lineage, having matriarchal and patriarchal visual examples, to try and predict breeding outcomes. In some cases, we have seen magnificent pairings flop. On occasion, we have animals that we would consider "standard," but pairing them can result in extravagant offspring. Why is this the case? This is easily replicable when breeding other species that are well understood. They are usually a result of recessive traits or traits that combine to make heterozygous forms from homozygous or super parents, and some of these normal-looking animals are considered powerhouse breeders. Crested Geckos are the only reptile to use a system of lineage tracking and purchasing animals based on what the parents look like we “bank” on the odds in hopes of traits developing or being recessive in nature. The larger reptile community uses Genetics to decide what to breed and how to pair animals. With this system, morphs can be classified based on a single trait, or multiple using just a single name to describe it, something you will find most prevalent in the Ball Python community.

Using the Mendelian system, we can test if a trait is recessive or dominant. When crossing those traits to others we can describe their interactions as either dominant, incomplete dominant, or codominant. Some of the more well-known species that follow this method of breeding are Ball Pythons, Leopard Geckos, Red Tail Boas, and Tegus. There is currently a shift in the Crested community, as more and more breeders begin to realize that certain types of breeding’s result in predictable odds, that follow Mendelian law, which can be predicted utilizing Punnett tables. In this system, taking a page from the Ball Python community, naming and classification of Crested traits will be the same as the wider Reptile community. The breeder that first produces and proves the trait is usually the one who names it. Names are usually extravagant, borrowed from other species, or named after the producer. Trait genetic inheritance will be agreed upon, by collaborators with experience, in breeding those traits over several generations. Finally, one thing to note... definitions within this guide relate to all animals. They will help to clear up how genes work and are defined within our community. This will help us gain a better understanding of Crested Gecko genetic inheritance.

A bit of history in the community

Crested Geckos were brought into the US through several expeditions by Philippe de Vosjoli, Allen Repashy, and Frank Fast in 1994-1997. Habitat, distribution, diet, and natural behavior were documented over several trips. A handful of animals were collected each trip and legally imported into the U.S. Several other animals were collected and adopted into Repashy's collection over subsequent years. Allen's collection is where many morphs and genes were developed over more than 10 years. Nearly all traits and phenotypes today were developed within Repashy’s collection and distributed to breeders around the world. Breeders have taken them and further developed and refined trait appearances and dominance. The “Rhacodactylus: The Complete Guide” book by Repashy, Frank Fast, and Philippe de Vosjoli was the first release discussing genetics and traits. Crested Geckos in Captivity by Robbie Hamper was also released. We have since had a huge gap, with many phenotypes coming to market, and little confirmed, genetically solved, information to help us understand Crested Gecko Genetics.

Due to the polymorphic nature of the wild-type population, it has proven difficult to define and isolate individual traits that contribute to the several morphotypes in the industry. Not having a simple fixed dominant wild-type phenotype, that can be used to easily prove a trait and its inheritance, has left the industry with a huge gap in understanding what is affecting or contributing to an animal’s appearance. The release of “The Rhacodactylus’’ book revealed some information about the morphs and gave them names. The details of inheritance was left up to the community

to develop and confirm. Misunderstanding Polymorphism has hindered our hopes on developing a foundation for traits. This page and the book currently in development by Tom Favazza @Geckological is a collaborative effort, between breeders, to help establish a baseline for the community and to begin to document and confirm results for traits. The fact that many traits have developed from just a few large collections is a blessing and a curse. In many species-specific communities, traits are identified and developed by breeders before being released to the general public. With how popular and prolific cresteds are, and being a fixed polymorphic species, breeding out individual traits is significantly more difficult than species with a fixed dominant trait, often referred to as a “normal”. Fixed polymorphic means that you can find more than one phenotype in the wild population living alongside each other. This is because several forms work well for camouflage and survivability and therefore do not get removed through natural selection. It does not mean that random mutations occur in a repeated sequence and can therefore “pop up” randomly, as some have come to believe. Now... on to the positive part about the morphs coming from a few large breeders!

The good thing is that if you establish a collection, of around 10 or more breeding adults, you should have several traits within your collection to begin to see how they interact to create different phenotypes. Extensive breeding colonies, of these animals, allowed 3-4 large breeders to refine morphs and develop on the expression of traits. Allen Repashy, Anthony Caponetto, and Matt Parks being some of the earliest pioneers. These breeders focused on unique traits, line breeding, and breeding the highest expression animals to one another, further developing traits, their expressions and Dominance. Eventually, a system of producing a line of animals, based on a single originating animal with a unique look, began to be the best method for producing high-end animals and developing greater expression. Breeders, over the years, began noticing patterns emerging with the phenotypes being produced. This started leading many to notice that the genetics, in these animals, followed a pattern and therefore were not as random as previously thought. Some have tried to bring this knowledge to the public with much resistance. After all, we have gone so far down the path, of not documenting what could be a trait, that the idea of trying to backtrack everything is like summiting Everest. Trying to convince the community that Polymorphism was not correctly understood became a challenge. Better Breeding practices have recently pushed the hobby knowledge further and the process is inspiring.

Line breeding usually starts from an originating animal that the breeder chooses to refine. The animal has a look that can contain several traits or just one. However, since we have not been relating the morphotypes in Crested Geckos to traits we instead began to use the animal’s name and the names of its relatives as the description for the Line or a look. Trying to remember 5-10 names of animals you do not own, for just a few traits that are visible, can be quite overwhelming let alone trying to build a family tree diagram. This system has resulted in several positive results in breeding and almost an equal number of negative results, sometimes extravagant pairings produce average-looking animals. The other side of the coin is we see normal-looking animals that produce excellent offspring. This is not an uncommon occurrence in the reptile community, for known species where the genetics have been confirmed. This practice of names has become misleading and we are moving towards the traditional system, to classify Crested Gecko traits, rather than gecko’s names. With so many new breeders interested in this species, we need to have a better system than recalling the great-great-great-grandparents and several relatives to hope for a result. With knowing what trait is contributing to the appearance we can begin to better choose pairings. This will allow us to add or remove traits and better refine what we are working with in our collections. This foundation will help by directly defining traits and establishing what traits are affecting different parts of the body and how they work with other traits.

Definition of Terms

Let us look at a few more definitions to understand what we will be talking about in the next section. This is where we will discuss how the multiple traits in cresteds contribute to their overall look and which ones are fixed wild-type, meaning that it is the normal gene and cannot be separated out. Which ones have been identified by looking at wild-type photo examples, and what we need to do to classify them, and how the inheritance works to create all examples of the phenotypes we breed. This will help deepen your understanding of genetics and assist with proving morphotypes. The following will be a simplified condensed version of terms that you would otherwise learn in an upper-division Biology class. It will help guide you in understanding how genes work in herpetology and how we use the terms when discussing morphs to help us evaluate phenotypes. All definitions apply to all animals including you and me with regards to genetics. They are not in alphabetical order, rather in order to build off each previous term.

Mendelian Genetics or Mendelian Inheritance: Patterns of inheritance that are characteristic of organisms that reproduce sexually. Mendelian inheritance is a type of biological inheritance that follows the principles originally proposed by Gregor Mende. These principles are referred to as Mendelian law. The three principles are the Law of Independent Assortment, the Law of Dominance, and the Law of Segregation.

Law of Independent Assortment
The law of independent assortment says that genes for different traits segregate independently of each other. It means that separate traits are separately inherited.

Law of Dominance
The law of dominance says that there are dominant and recessive traits. Dominant traits are defined as whichever phenotype is expressed in an organism that is heterozygous for the trait. See Heterozygous for the proper definition.

Law of Segregation
The law of segregation says that everyone has two versions (called alleles) for each trait—one from each parent—and that these alleles segregate randomly (see independent assortment) during meiosis.

A Brief Disclaimer:
Don't forget that Mendel's laws do not always work.

Mendel studied the results of crossing different traits in pea plants, which show relatively simple inheritance patterns. Luckily for Mendel, he didn't have to deal with things like incomplete dominance, sex-linked genes, or polygenic traits in his pea plants. Although Mendel's laws work, they don't perfectly apply in all situations. See non-Mendelian inheritance for more.

Non-Mendelian Genetics or Genetics: Genetics that fall outside of the simple rules of Mendelian Genetics. We can use Mendelian Genetics to describe individual traits, and determine inheritance and Dominance. However, when it comes to species with traits that are more complex, such as Crested Geckos who are polymorphic, or Ball Pythons, we use non-mendelian genetics. Traits that are incomplete dominant, codominant, polygenic, epistasis, or epigenetic are such that fall outside of Mendelian Genetics. Which means that the majority of the reptiles in the hobby should be evaluated by using non-mendelian genetic guidelines.

Line Breeding: This is the practice of breeding for a particular trait to enhance its appearance and/or increase its potential of being passed on to future offspring. This is accomplished by breeding animals that exhibit a similar trait that is compatible and produces offspring that display the trait either more frequently or with a high expression of the trait. When referring to a higher expression of the trait we may refer to it as “stacking”. Outcrossing these offspring and breeding back future generations back into the line is what is referred to as line breeding. Outcrossing and breeding back after several generations for the trait is considered responsible line-breeding practices. If a trait is

subtle at first line breeding can help the trait to express more like turning up the volume on your TV. More on this will be covered in further sections.

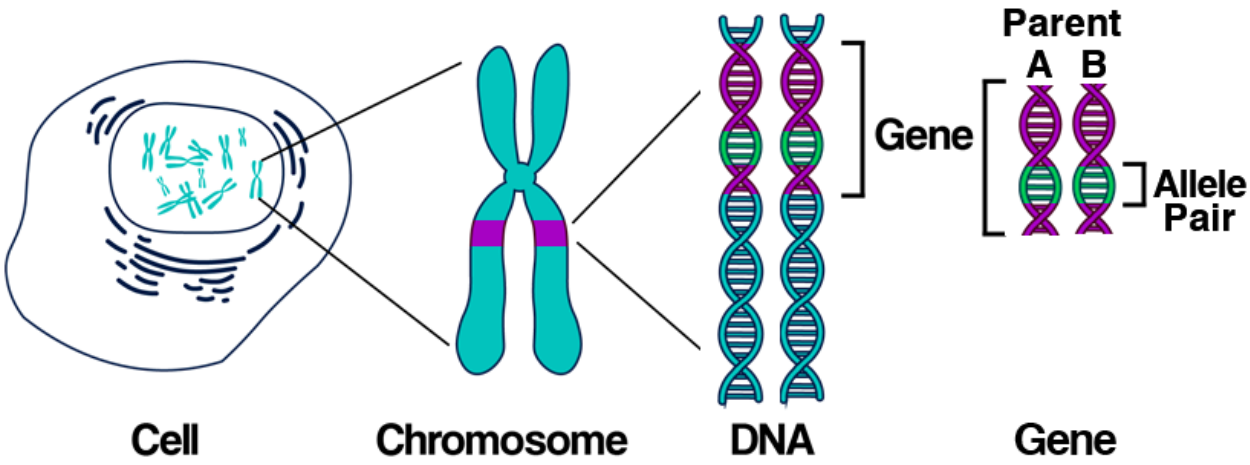
Line: A line is a group of animals that have been developed and refined by a specific breeder to refine a particular trait, morph, or look.

However: Often lines have been known to eventually define a trait and the Line becomes the trait name. For example, XXX (Pangea), started as a line and the lines turned out to be a trait. Although lines aren't always associated with a trait, they can develop animals with a tendency towards a particular look.

Example of a line: Betty White (Pangea), Harry Line (AC Reptiles), Cold Fusion (Geckological), Grunge (Lil Monsters)

Gene: A gene is a portion of DNA or a specific place in the chromosome that is responsible for a hereditary trait that can be passed on from parent to offspring and is responsible for a trait.

Example*:*



Allele: An allele is two or more forms of the same gene donated by each parent and located on a specific place in the chromosome called the locus (plural loci). In simple terms, an Allele is the "code" that contains the information for a specific morph or phenotype.

Example: Tan, Black, Red, Tangerine, Citrus, and Cream colors of a crested gecko's base color.

Allelic: Refers to an allele that is compatible with a particular trait located in the same locus. In short, the code that is used is different but located in the same spot in the gene. This makes different traits allelic. These traits can combine to form new morphs and can take quite a bit of trial and error to discover.

Morph: The term "Morph" is used to describe animals that have one or more than one visual trait that contributes to their appearance. In simple terms, if you have seen more than one gecko that has a specific trait or look then it is likely hereditary and can be passed on to offspring. This makes it a morph.

Example: Axanthic, Cold Fusion, Harlequin, Lilly White, Phantom, Pinstripe, or XXX. Even several of those expressed in one animal like Quad Stripe, Pandemonium, etc. are morphs.

Trait: A trait is a single characteristic of a morph that can be passed on from parent to offspring. A trait is a description of the gene responsible for the trait we are describing. This also includes the recessive traits (Hets).

Example: Axanthic, Cold Fusion, Harlequin, Lilly White, Phantom, or Patternless. Similar to the definition of a Morph (above) but none of those traits combined, that is the difference between the two.

Phenotype: A phenotype is a physical expression or outward appearance of a trait or multiple traits. The key here is that it is the outward appearance, of the trait, while a trait is the description of the gene responsible for the characteristic of a morph.

Example: Phantom, but not a Het Phantom. The term Phenotype can even be used to refer to a morph and the several types of offspring produced by parents. E.g., This pairing produces four different phenotypes.

Genotype: Refers to the type of information within the pair of alleles that express a trait. We use letters to help describe this information. Capital letters describe the information as Dominant, lower-case letters describe the information as Recessive. Using this system, we can predict the probability of traits and how they may pass on to offspring. This sounds technical but makes sense when we use Punnett Tables to predict offspring and inheritance. Genotyping in simple terms is just using letters to express what the information in the allele is doing Dominant or Recessive. This does not describe what the phenotype will look like. It must first be observed. For e.g., we know that an offspring might have some characteristics of two or three different traits being passed on, but we cannot predict what it will look like until we first produce that morph and observe the phenotype.

Heterozygous or (Het): An animal that has two different alleles for a gene, with only one being carried. The second allele will be a different trait. If it has 2 of the same alleles, then we use the next term below.

****NOTE:*** This term is often used incorrectly in the reptile community to try and describe Recessive traits by saying "Het non-visual". However Het is used to correctly describe incomplete dominant, and codominant not just traits that pass on in non-visual animals.

Homozygous or (Hzg): An animal that has both pairs of identical alleles. Also known as the Hzg form. The trait will be passed on 100% of the time because the animal must donate at least one of the two alleles to their offspring.

Morphotype groups and trait interactions

Morphotypes are different phenotypes of a species within a population of animals. Classifying different morphs into groups is useful to help identify how interactions can take place and assist the novice in learning where to look to identify the morph or trait. These groups are also part of what is used on Morph Market for gargoyle geckos. They were defined by us and in collaboration with other breeders. Much of this work is based on the framework in The Gargoyle Gecko book. Morphotype groups for cresteds are very similar and carry over, they are base, pattern, pattern color, structural, and iris. In the morph guide, we will outline this information and what category this falls under. We also want to address how we often see terms being used incorrectly to describe traits in the hobby. Additionally, we are adding a few new ways to use genetic terminology to describe different interactions between multiple traits when they are not allelic.

Genotype vs Phenotype

Genotype and Phenotype are similar but describe the difference between what we see with our eyes to describe a trait vs the genetic information for the trait that sits on the allele. Much of this verbiage will be used to put the puzzle together later and to describe trait interactions when we outline the morphs. When we refer to Genotyping, we are describing recessive and dominant interactions between Het and Hzg traits. We use this information in Punnett tables to predict the percentages of phenotypes that can potentially be produced. Shorthand is used with this, using 1-3 letters for individual traits, upper and lower case denote if the trait is dominant or recessive to its paired allele.

Phenotypes are the visual representation of genotypes, we use incomplete dominant, codominant, and dominant to describe the allelic interaction depending on what the phenotype looks like. With non-allelic traits, we can also use the same terms. However, since they are non-allelic, 99% of the time the trait is described as incomplete dominant. This leaves us with one word that describes two different, but similar, interactions. In short, we can have a recessive trait that is incomplete dominant to non-allelic traits. Recessive is the behavior when the trait is Het or Hzg. While incomplete dominant describes what it looks like when there are other traits present and create a mixture of the two and therefore making a new phenotype. This is where the phrases "behaves like" or "acts like" are most useful to explain what is happening on the animal's body, it is especially important when we are describing combo morphs. This language is becoming more and more important as we are seeing morphs with 3-8 gene combos and producing some of the most unique animals that we've ever seen in the hobby.

Heterozygous vs Homozygous

The first item we want to cover is correcting the mainstream use of “Het”. Het is probably one of the most widespread misuses of a genetic term, right up there with codominant, and polymorphic. Het simply means that the two alleles on a section of DNA (Loci), are different from one another, it does not imply anything else except that. Het does NOT mean recessive, which is how many people seem to try to use the term. When people are referring to a trait, we often see the phrase “it does not carry a Het” or “…the trait does carry a Het” and referring to it as “visual” or “non-visual”. The confusion seems to be that people use the word Het in conjunction with visual or non-visual to describe a recessive trait or incomplete dominant trait. Instead of using the word recessive to describe the behavior. This seems to be an attempt for hobbyists to simplify genetic terminology. This has only caused more confusion. Understanding and using the correct terminology will help people to know significantly more about a trait’s behavior. Incorrect use of the terminology makes trying to understand genetics VERY confusing. It is aggravating when a Google search of these terms does not align with the usage of the term being used on social media platforms and groups discussing genetics between knowledgeable breeders. For clarity Dominant, Incomplete Dominant, Codominant, and Recessive traits can all be Het or Hzg. Heterozygous just means that the animal only has one copy of the gene we are discussing, and the other allele is different. Homozygous means that the animal has two identical copies of the same gene, one donated by each parent. Now that we have some clarification with the Het and Hzg terms let’s investigate how they may differ from one another to produce different looking animals or phenotypes.

Since Het means the animal only has one copy of the gene, that gene can create different phenotypes depending on its dominance and interaction with the second allele. We confirm this information by observing the various phenotypes that the trait produces. Further on you will see some visual diagrams of what each one does. I used flowers to make the diagrams. It is easy to understand. and it is the most common example used when you look online to confirm the information in this guide. Recessive traits in Het form are dominated by the accompanying allele (usually normal), therefore, there is no visual difference in the animal. Some people refer to this as non-visual, but we should be saying Recessive (Het). When a Recessive trait is in the Hzg form (2 copies of the same trait) then it is visual because there is no longer any other allelic trait there to dominate it. All Recessive visual animals are Homozygous (Hzg) forms of the trait.

Recessive and Dominant

These two terms usually only describe the interaction between two different traits on the same allele. 99% of all online text will describe these terms on a single allele. This is where we use genotyping to describe if a trait is recessive to another or dominant over another. If the second allele is the same as the other, it is dominant. This is because there is no other allele present to dominate it or be recessive to. With that in mind, it is the simplest description of these terms and follows mendelian law when it comes to discussing genetics. Describing a trait as recessive just means the trait is dominated by the other paired allele and therefore only becomes visible when there are two copies of the gene in the animal. Recessive traits only have phenotypes when they are Hzg.

Dominant has a second use other than describing the interaction of Het animals. When we use the term dominant to describe a trait, we are saying the trait produces the same phenotype in Het and Hzg forms, and there is little to no visual difference in the look of the animal. A trait is considered dominant when it only yields a single phenotype between Het and Hzg forms. A Dominant trait will produce the same-looking animal regardless if it has one or two copies of the same gene. There is one slight difference in dominant traits between Het and Hzg form though, and it is with the offspring that it produces. The Het Dominant trait will pass on from the parent 50% of the time. A good example here is a Dalmatian parent and a clean no dalmatian parent passing on dalmatian to half the offspring due to only one parent having one copy of the gene, so 50% of the time it will not have spots. While the Hzg variant dalmatian will pass on dalmatian 100% of the time. That is the only difference and can be easily tested through breeding. This result has proven true for all our dalmatian animals, when crossing out, to other animals.

Incomplete dominant or Codominant

Now that we know how recessive, dominant, homozygous, and heterozygous function we can describe the other two terms in detail. All of these forms are confirmed by observing the animal or animals when they are produced. We refer to this as phenotyping. Genotyping an animal’s DNA and having the sequence does not reveal this information, we must produce visual forms first to determine the interaction.

The simplest way to describe Incomplete dominant is just like mixing crayons. Mixing Red and White makes Pink, this is how incomplete dominant traits work with color and pattern. When we have pattern though it can present differently. For example, horizontal pattern traits and vertical pattern traits can create hatch-like looking patterns or

breaks in the horizontal pattern, and cause blotches instead of stripes or dashes by breaking the pattern. Taking a tangent some things may not be a trait, but an attribute of multiple traits interacting to create a pattern that is confused by many to be a trait. So, if you read “attribute” then know it is something that usually happens due to multiple traits. An attribute is not a trait in itself, it is part of a trait or a result of trait interactions. Inc-dom represents around 80-99% of all traits in animals. The codominant phenotypes are extremely rare and so are recessive traits. In fact, combined likely make up less than 16% of all traits amongst all species. However, we can use the definition of these terms to describe how some traits behave in different ways. This is because they lose their strength or dominance in some areas of the animal. We say “behaves like” or “acts like” to describe this behavior. For ball pythons, this can happen on the belly or the headstamp. In cresteds, this happens with pinstripe and tiger, and walling traits. When the traits mix, sometimes they are less effective on the belly or the base of the tail. This especially happens with the Phantom trait in Cresteds. It loses strength by the base of the tail and on the laterals where other traits can push back in and be more visibly apparent. The pinstripe trait is one that becomes visible at the tail base. We can see this with a Phantom Lilly combo, Phantom loses dominance on the laterals and the Lilly gene acts or behaves codominantly and is less muted.

Let us discuss codominance, this is when the two different dominant traits create something that looks like a black and white cow, where sections of the animal show one trait, other section shows the other trait without mixing. Codominance means both traits on an allele are dominant, hence they are both visual. Each trait will occupy its own unique space on the animal’s body. The other reason these traits are so extremely rare is that the term specifically describes allelic trait interactions, not non-allelic interactions which are where many hobbyists get confused and the most commonly misused term. The most common occurrence of incomplete dominance is usually seen on the molecular level. Think human blood types for this. There are many videos on YouTube that will describe this. The flower example below illustrates visual manifestations of this term with red and white traits occupying unique areas on the flower without mixing to a pink. We also show two examples to show the variances of the trait.

Now that we have described how traits work, when they are on the same allele, we can also use the terms to describe what non-allelic traits do. We should be denoting this difference because breeders only use the visual effect of the trait and not its dominance. I want to use Ball Pythons as an example here and Dalmatians in crested geckos. The Ball Python Pinstripe trait is Dominant, Het and Hzg forms look the same, BUT, when breeding you either get 50% pins or 100%, as breeders we should try to represent that like we try to for inc-dom animals. For example, if you have a dalmatian that when paired to a clean animal makes 100% dals then that dalmatian is likely Hzg Dalmatian. If some Animals come out without spots, then the parent is Het Dal. This means all of the dalmatian babies are Het Dalmatian. We have been breeding dalmatians like this for over 10 years and this always holds true. We also use the term “Super” to describe traits that are incomplete-dominant to themselves which means the animal looks different when it has one copy and two copies of the same gene. The term Super means two things in the reptile world, one that there are two copies of the trait, this is the Hzg form, and two that it is incomplete-dominant.

So, in conclusion, we use genotyping to describe traits with text, their case describes if one is dominant or recessive. Having one copy or two copies denotes the animal as heterozygous or homozygous, respectively. Phenotypes must be observed to verify if a trait is Incomplete-dominant, codominant or dominant. Incomplete dominant makes up around 84% of all traits, 15% are recessive, and the rest are possibly codominant. Dominant can refer to two states where one allele is dominant over a recessive allele, the second is the trait only has one phenotype in Het or Hzg form. If the Hzg form produces a different phenotype then we can describe it as incomplete dominant. Incomplete dominant and codominant can also be used to describe non-allelic trait interactions that are attributes of multiple morphs and not part of a morph. We can say a trait “behaves like” or “acts like” to describe if the trait losses dominance in areas of the animal such as head, belly, tail base, etc.

Recessive: This is when an animal has a different pair of alleles. A recessive gene is only visible when both allele pairs are present, one allele donated by each parent. The Het version of the trait looks just like the animal would if it did not have the trait. Usually, the trait is dominated by the normal allele. The example below shows the “W” is the normal white color and dominant over the “r”. In the Hzg form, the flower turns Red because there is no longer any normal “W” allele to dominant it. Recessive traits are rare and constitute about 14% of all morphs, less in other species.

Example: Axanthic, Patternless, Phantom, and Red bases.

****NOTE:*** Occasionally with some traits, Het animals can display physical marks that reveal the animal may be Het for the trait, referred to as "Markers".

The example below shows how the phenotype is expressed only when both pairs of alleles are present, in this case, the "r".

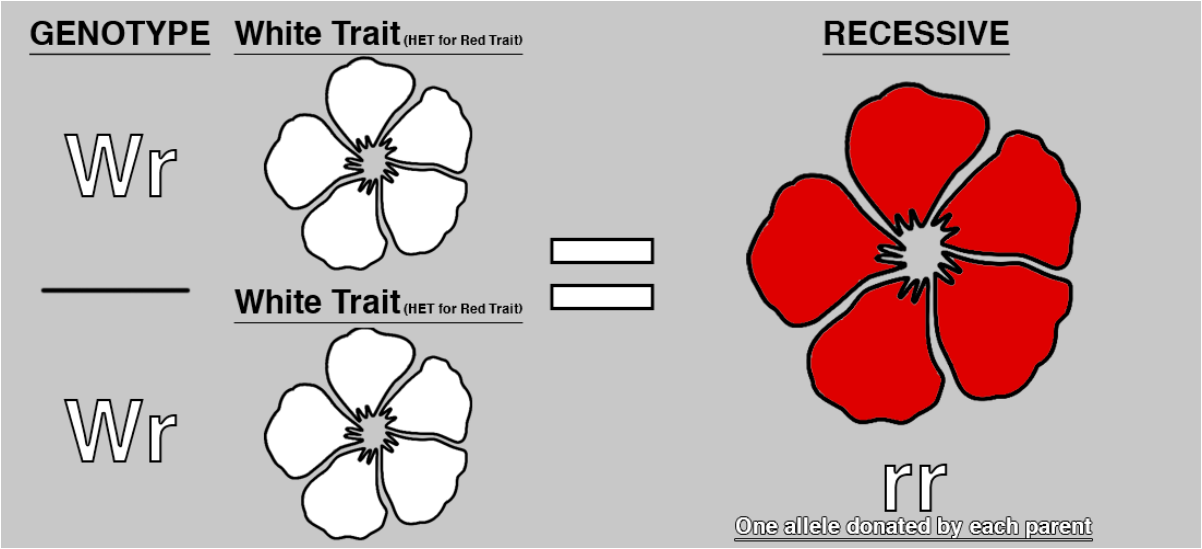


Diagram showing how a recessive trait works using the W (white) and r(red) genotype and describing the resultant offspring or phenotype.

Dominant: An allele that produces the same phenotype, whether its paired allele is identical or different. This term can also be used to describe the interaction between traits. If two different allelic traits are passed on but one is visually expressed and the other is not then that trait is dominant over the other, the other trait is referred to as recessive or non-dominant.

***NOTE:** This is where confusion can happen since the term can be used to describe two different behaviors. Dominant in that the trait only has one form regardless if it is Het or Hzg. While the other description Dominant being that it is visually expressed over another trait that is recessive to it.

***Example:** Images below represent two versions of dominance, if your breeder is Heterozygous Dominant there is a chance the trait will not pass on, such as Dalmatian spots in Crested Geckos, and can be proved by observing the phenotypes produced by the pair.

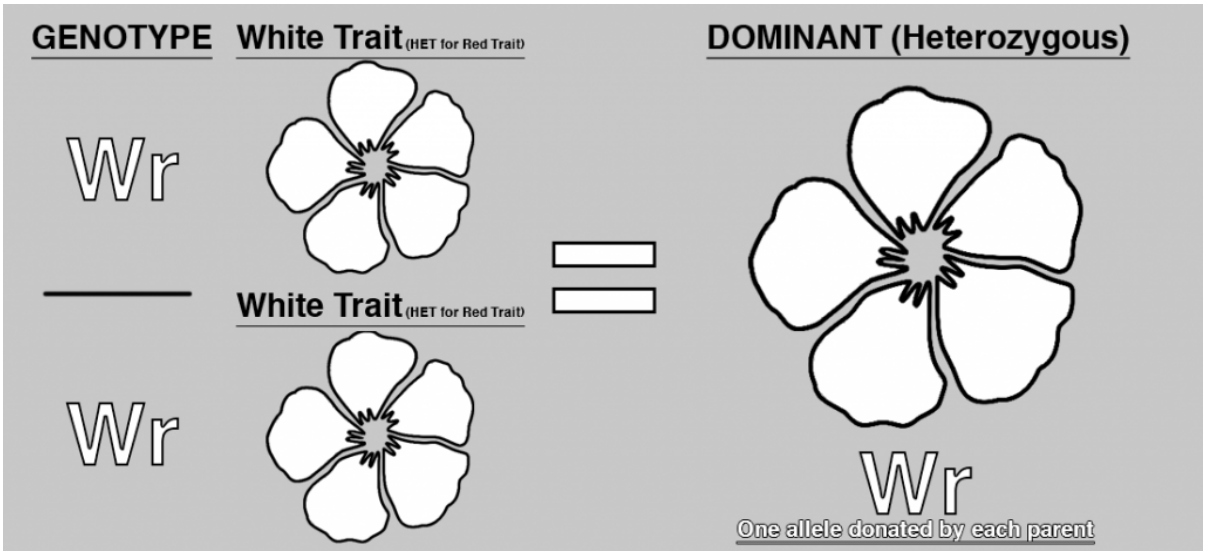


Diagram showing how recessive and dominant traits work using the W (white) and r(red) genotype, and describing the resultant offspring or phenotype.

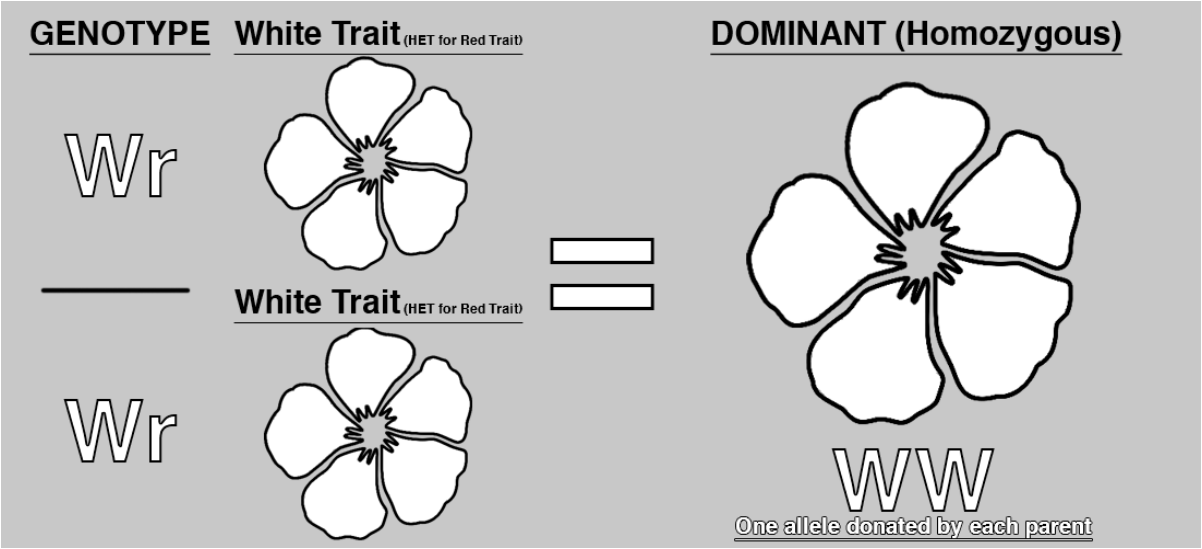


Diagram showing how recessive and dominant traits work using the W (white) and r(red) genotype, and describing the resultant offspring or phenotype in this case a Homozygous Dominant phenotype.

Incomplete Dominant: Describes when two traits are visible as a mixture of both. Think, mixing two crayons to make a new color, both are semi-dominant and combine to make a new color. This can happen with the same trait, different traits, allelic, or non-allelic. Some of these traits can produce "Super" forms or (Homozygous Incomplete Dominant). In many online texts, this term is described using allelic traits but can also be used to describe the behavior of multiple traits that are not allelic (think 6 gene ball pythons or red phantom Lilly white).

Example: Phantom and Lilly White combo morphs, even the lethal super Lilly White. XXX and Harlequin are other examples of an incomplete dominant combo.

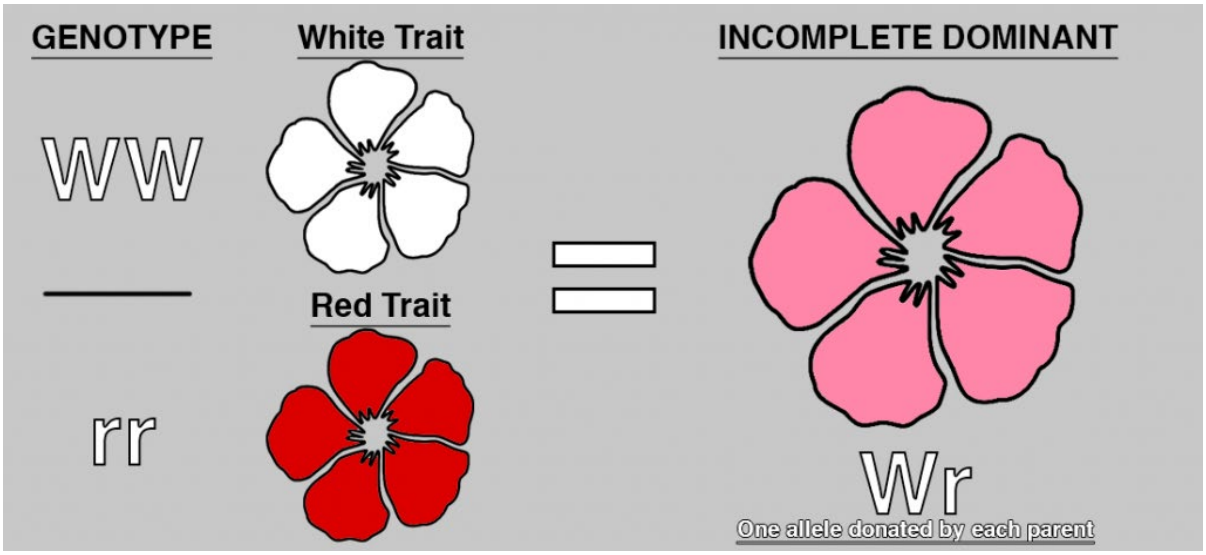


Diagram showing how an Incomplete Dominant phenotype would look like. Incomplete Dominant creates a new phenotype.

****NOTE:** This example also explains how non-allelic traits combine as a mixture of colors.

Codominant: A gene that is visible at the same time as another gene and they co-exist visually. In other words, localized groups of cells are colored with one trait while adjacent cells are colored with another trait. In this case, both traits are dominant visually observed at the same time. Co-dom morphs are extremely rare and constitute less than 1% of all morphs.

Example: Using a flower as an example, with two allelic traits one for Red and one for White. A codominant example is a Red flower with White blotches, hence codominance.

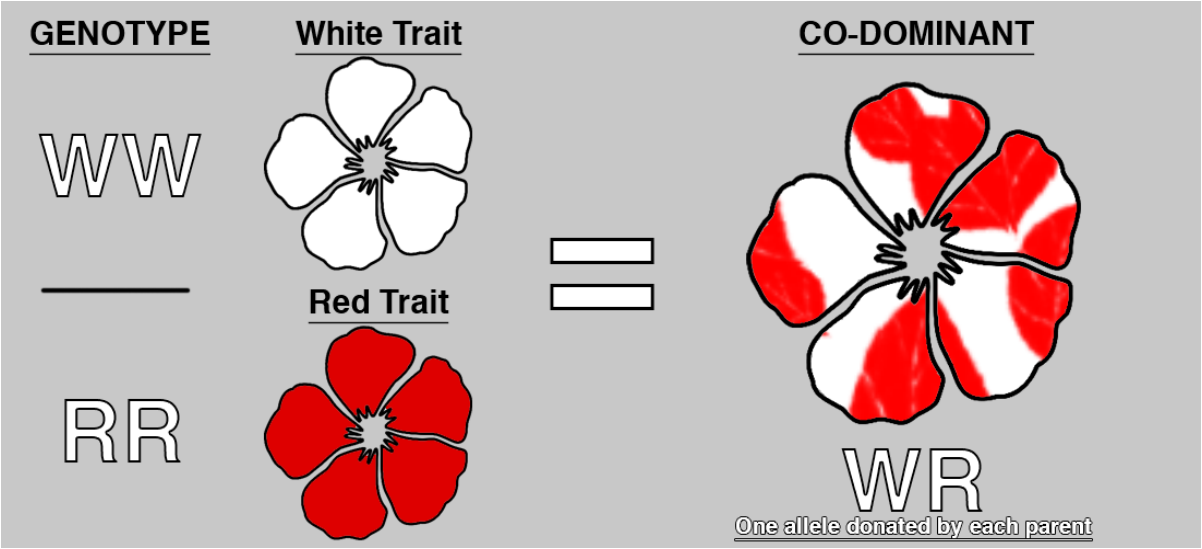


Diagram showing how codominant phenotypes would appear, showing each dominant trait sharing space on the offspring. Each trait is displayed at the same time, this is variant number one.

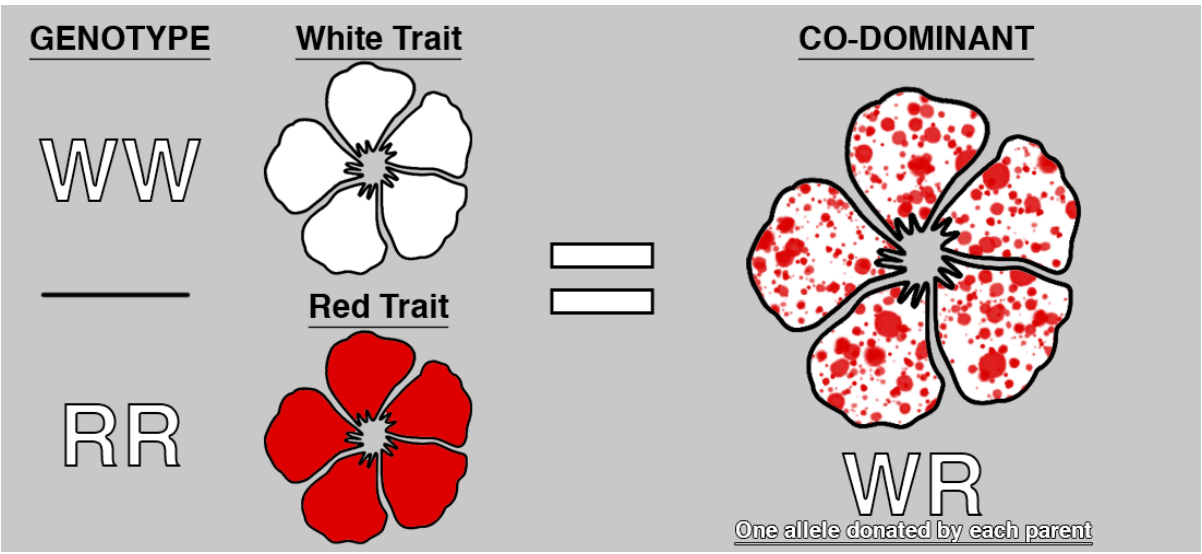


Diagram showing how codominant phenotypes would appear, showing each dominant trait sharing space on the offspring. Each trait is displayed at the same time, this is variant number two.

***NOTE:** This example also explains how non-allelic traits combine as blotches of color or pattern.

Super: The term "Super" in front of a morph name describes Incomplete-Dominant Traits ONLY and the animal is (Homozygous Incomplete Dominant). When both alleles of the same trait are present, they usually produce an extreme expression of the trait that is visually different from the heterozygous form.

***NOTE:** This term is only used in the reptile community and not in scholarly text. You will not find this in a genetics book. It is also confined to the same trait or allelic complexes of traits. *You can refer to the Ball Python Leucistic complexes for examples of this.

Stacking: This is a new term coined by Tom to describe how traits progress over time. Genetically this is caused by epigenetics that allow or restrict traits from expressing by tightening or relaxing on their suppression of the trait being transcribed in the genome. This is far outside the scope of what we need to know regarding genetics. So, the term Stack or stacking will be used instead as it perfectly describes and analogizes how we refine traits in the hobby by breeding for higher expression or lower expression.

Polymorphism: This is the foundation of all designer morphs that exist today. If an animal has more than one morph or comes in varying wild-type colors, that is polymorphism. Breaking down the term, Poly; more than one, morphism; morph, so we have a species that comes in varying colors but still belongs to the same genus.

***NOTE:** This term, along with the next, has brought a ton of confusion and misconception to the Crested Gecko Breeding community, especially in the early days.

Polymorphic: In biology, polymorphism is the occurrence of two or more clearly different morphs or forms, also referred to as alternative phenotypes, in the population of a species.

***NOTE:** This term has been used incorrectly by the Crested Gecko community for far too long. Several crested gecko breeders have not invested time into other species with established traits to learn how inheritance works and is transferred to offspring. Species like Leopard Geckos, Ball Pythons, Tegus, and Bearded Dragons are excellent learning beds for observing how genetic traits interact. Lacking this type of hands-on experience can lead to a misunderstanding of how traits interact to create the Polymorphic animals we love and breed.

Fixed Polymorphic: Fixed refers to when something in a population has reached a level of equilibrium, it is "fixed" in the population. This can be seen with Wolves or Rabbits having different color coats in the wild. As for Reptiles We have Spiny-Tail Iguanas, Leachianus, Gargoyle Geckos, etc. However, these animals still have genetic traits that are heritable and predictable. The reason this happens is that multiple forms work for the survivability of the species and have not been removed through natural selection.

***NOTE:** This is another common term used to incorrectly describe crested geckos as a sort of slot machine that randomly chooses when it will display a trait.

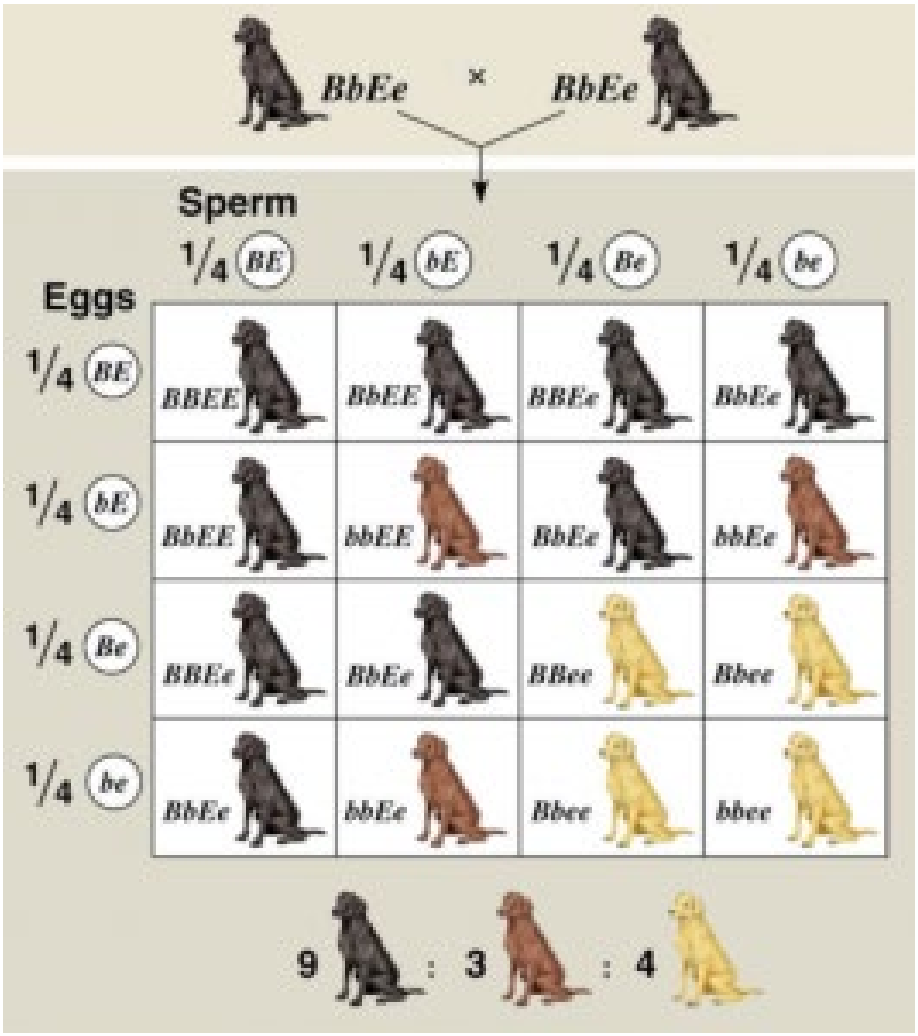
Fixed Dominant: Fixed dominant means that the wild-type population has a single phenotype. In the reptile world, we call this the Normal morph. All other mutations have not survived through natural selection and only one morph has managed to survive and is dominant in the population. A Normal Ball Python is a great example as it is the Fixed Dominant morph found in the wild

Polygene: A gene whose individual effect on a single phenotype is too small to be observed alone, but which act together with more than one gene to produce observable variations. This can be a bit on the controversial side but can explain why breeding for some traits is difficult. It is a term that we need to keep in mind when breeding and documenting as to not eliminate its potential behavior.

Polygenic: The term used to describe a trait relating to or determined by polygenes.

Epistasis: This is when one gene is responsible for controlling whether a gene is expressed or not. This can contribute to one or more than one phenotype and requires a lot of breeding to unfold.

Example: Labs make a great example of Epistasis and have been well documented. Black Labs, Brown Labs, and Yellow Labs are excellent examples of how a gene allows other genes to be visually expressed or not. Here is a chart to see how you need the recessive gene which turns coat color ON/OFF, to be expressed to create a yellow lab. Black, Brown, and Yellow labs and how the Epistasis works for these phenotypes. The GREY highlighted cells show Black Labs, the YELLOW highlighted cells are yellow labs, and the BROWN ones are brown labs. We also use the CAPS B to designate the Dominant Black the lower-case b to designate Brown and C or c as the dominant or recessive yellow gene.



A diagram showing the offspring when we are comparing epistasis.

How do geckos get their color?

Now that we know a bit more about what contributes to genetic inheritance and how things pass from parent to offspring. Let us look at what these genetic traits are physically doing that contribute to your animal's color, and how Chromatophore cells are affected by them. We will start with the individual colors produced by these cells. The bottom-most layer are melanophores which are responsible for dark pigment from browns to black hues and can travel between and into the other pigment cells. Xanthophores are the next layer up and responsible for yellow pigment, while erythrophores are what produce red pigment. In the third layer, we have iridophores which create dark iridescent color, and leucophores which make a white pearl-like color. These are the 3 layers responsible for color that make up the chromatophore in reptiles and fish. While two of these pigment-producing layers produce particular colors, the iridophores can modify how light is filtered, which is what can create interesting interactions by filtering light, like blue hues. Here is a great YouTube video that illustrates how scales can modify color using microscopic structures **VIDEO.** The way Iridophores function is different but this illustrates how structural morphs can take advantage of and manipulate light refraction in the chromatophore, some examples of this are Cold Fusion, Soft Scale, and Super Soft Scale.

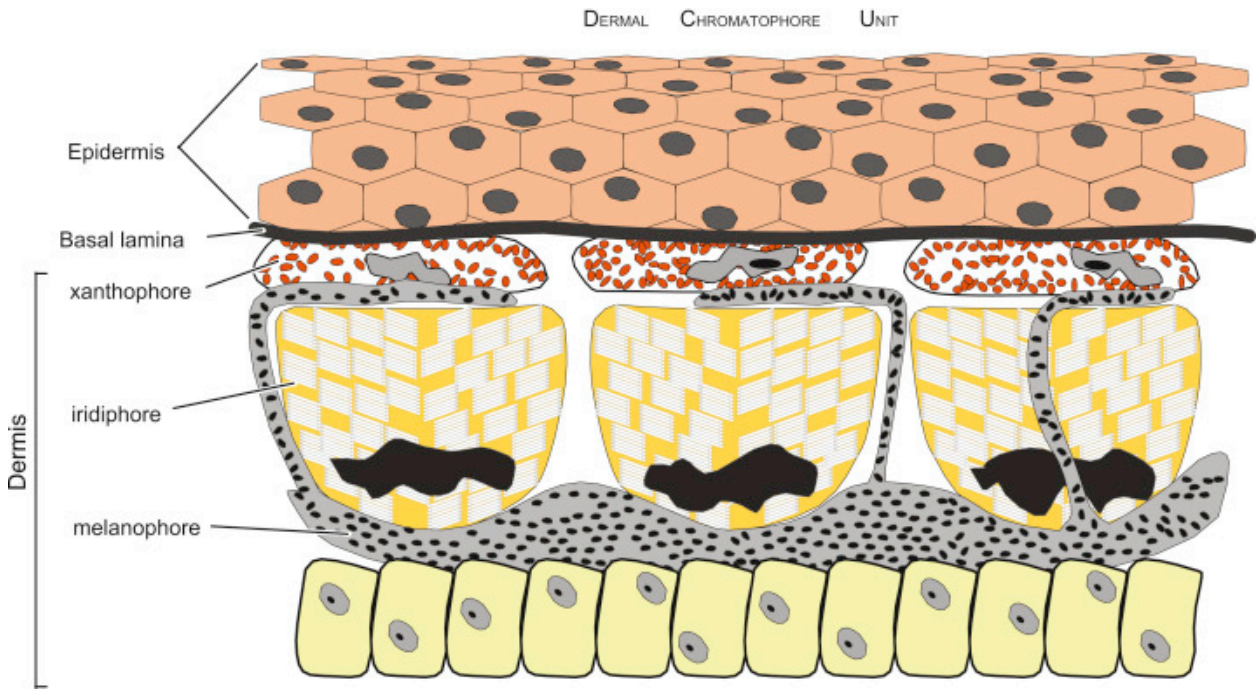
Have you ever wondered what is happening when your gecko fires up and fires down on the molecular level? It is the migration of melanin! Below you will see the 3 layers that constitute the chromatophore or the pigment inside your reptiles. This amazing mechanism is comprised of only 3 sections. From the bottom up we have Melanin, Xanthophores, and Leucophores. Combined these three cells make all the range of colors we see. Depending on the color that the layer is making we use different names to describe them. The Melanophore layer makes black to brown pigment and several hues in between all are referred to as melanin. The Xanthophore layer makes yellow and red pigment and many hues in between like orange. When the color granules made are orange or red, they are referred to as Erythrophores, it is all made in the same layer though. The highest layer are Iridophores which make rainbow blueish and greenish hues when refracting light. On occasion, the granules are pearl-colored instead of dark when they reflect light, so they are labeled Leucophores. This is what creates the bright paper white color. So, we have 3 layers, and six names, each name or type of color granule will reside in one of these three layers. In the definitions below we have grouped them for you to better find what layer a color resides in when referencing back to this guide.

In between all these cell layers are tubes that allow melanin to travel between and inside these layers. The melanin migrating between layers from the bottom to the top is what is happening when your animals fire up or down. In some reptiles this is autonomic meaning they do not directly control it and is a result of hormones. This happens as a response to stress, good or bad. Most geckos fire up when eating, mating, fighting, or as a response to light. These are all stress responses. One analogy I like to use is it is like when you get goosebumps, it can be to excitement or fear, but it is all a stress response.

That is it! There are 3 layers and depending on the color or hue they produce they can have different labels to describe what color they are producing. Since traits we breed directly affect these cells or the production of color granules in each cell, we sometimes label traits referencing the mechanism responsible for the color produced or removed by the trait. This leads us to a few more common terms used in the industry.

Chromataphore: A cell or plastid that contains pigment. Comprised of a mixture of 3 types of melanocytes: melanophores, xanthophores, and iridophores.

Example:



Dermal unit of the chromatophore, showing a lateral view if you cut through the top layer of skin, and through the chromatophore.

Melanin: Responsible for the brown or black pigment in animals.

Xanthophore and Erythrophores: When a chromatophore contains a large amount of yellow pigment it is labeled a Xanthophore, while if it is higher in orange or red, they are labeled Erythrophores. Both are contained in the same layer.

Iridophores and Leucophores: These cells reflect light and produce iridescent colors because of the diffraction of light. Leucophores are related cells that are more structured and produce reflective white hues instead of metallic colors.

Tyrosinase: This is an enzyme that is responsible for one of the mechanisms that are required to produce melanin in animals. It is actually the first step in the process of creating melanin. When this is interrupted or restricted, we can end up with various forms of albinism

Albino: Albinism is a lack of pigmentation, specifically melanin, in the eyes, skin, and/or hair. Albinism is an inherited condition usually resulting from the combination of recessive alleles passed from both parents of an individual.

Albino T-: This is an albino that has been labeled as lacking the Tyrosinase enzyme which means the animal has no melanin production.

Albino T+: This is an animal that appears Albino but still has some melanin production that is incomplete or reduced. The Tyrosinase enzyme hasn't been interrupted so the animal still starts to produce melanin. The method to determine this is with something called a Dopa test. Many breeders classify T+ or T- animals without doing this test and many are still unconfirmed as to what is causing the lack of melanin in the animal.

Leucisim / Leucistic: A condition in which there is a partial loss of pigmentation in an animal causing white, pale, or patchy coloration of skin, hair, feathers, scales, or cuticle. We refer to these morphs sometimes as BELs and result in Black or Blue eyes in some animals. Unlike Albinism the eye color is usually black or blue. Their acronym stands for Blue Eyed Lucy or Black-Eyed Lucy, these animals may also be completely white.

Melanistic: This is the increased development of the dark-colored pigment in the skin, hair, or scales. This produces very dark to black animals.

Hypomelanistic/Hypo: Is an animal that has reduced pigmentation, especially compared to the wild-type morph.

Axanthism/Axanthic: This is where the Xanthophore layer is being affected, the animal is lacking yellow and/or red pigmentation and in some cases completely lack xanthophores. These animals are usually Black and White or high in brown pigmentation and melanin is still produced.

Anerythrisic/Anery: This is used to denote specifically the lack or Red pigment. Although Axanthic covers both spectrums in the Reptile hobby we try to be specific in the color and this term is often used to denote the lack of red.

Xanthic/Xanthochromism: This is the opposite of Axanthism where there is an excess of yellow coloration.

Crested Gecko Genetics, let's start putting the puzzle together!

Now that we understand the genetic portion and have cleared up some of the misunderstandings in the community let's start discussing the Normal traits in the crested gecko. First, we will orient ourselves. When we refer to things being horizontal it is in the direction from the nose to the tail. Vertical refers to the animal from the center of the dorsal to the belly. The Interactive morph guide will follow this same logic. Cresteds in the wild have been identified as having multiple sets of traits and we can still see many of them in today's animals. At the bottom, we will show images of wild Crested Geckos from different trips and spanning 8 years or so. Once we reference the wild-type mutations in this guide we should have a firm foundation to be able to understand the Morph Guide that will follow on a new page.

Wild-Type Base Morphs

Wild-Type Melanin

Wild observed animals tend to display brown hues of melanin, observed especially on the head-stamp. This color is far from the black-based animals we tend to breed more for in the hobby. The brown coloration, originally referred to as "Buckskin," has been pulled out over the years but there are several animals in the hobby that still display the color. The headstamp is one of the areas that hold onto this coloration the most. Many generations are required to pull these brown tones out.

Tiger

Tiger or tigering is the lowest common denominator trait that cannot be isolated from a crested gecko's genes. Essentially it is Normal in them and fixed in the population. This is like spots on leopard geckos or the black pattern on Ball Pythons, often referred to as alien heads. However, a more direct comparison would be the BR (Banded/Reticulated) morph in Gargoyle Geckos. This contributes to banding and reticulation. As it is always there to some degree. The tigering in crested geckos contributes to how pattern breaks along the dorsal and the upper and lower laterals. This jagged pattern organizes and breaks pattern up vertically. The less horizontal pattern influence, the stronger the tigering will be and the more dominance it has over the direction of the animal's pattern. Tigering can be found significantly reduced showing small thin lines to freckles on solid-colored morphs to thick huge bands of pattern and breaks on dark base color. The variation comes from how much horizontal pattern there is. Pinstripe organizes pattern horizontally causing Tiger to reduce and get pushed to areas of the body. It can even

restrict where it can travel to. The variance here can be large, as small as freckles to as large as bands stretching up and through the dorsal.

Phantom

This trait is often referred to as “Phantom Pin,” however Phantom is NOT related to Pinstripe. They are often bred together as a combo though, so this is where the interpretation comes from for them being related. Phantom is recessive which means you need two copies of the gene to produce the morph. This means Pinstripe must be on a different allele since there are only two traits that can occupy a section of DNA. It is not a mutation that exists on the same allele as Pinstripe like many believe. The trait is often produced from animals that are not visually phantom as many breeders have observed. Pinstripe seems to be dominant and produces the same or similar phenotypes if there are one or two copies of the gene, although a Hzg Pinstripe might be what produces 98-100% pinstripe, depending on the strength of the trait with other traits like Tiger. Phantom is one of 2 traits confirmed as recessive with Crested Geckos. Phantom adds a significant amount of melanin which darkens the xanthophores and reduces the white coloration. The areas that Phantom loses dominance is by the base of the tail. You can see this with Lillies and pinstripes with white pattern. The other area is fringe and laterals where Portholes and Walls are found.

Flame/Harlequin

This morph is great and has been found in wild-type animals, primarily showing pattern on the dorsal, with minimal coloration on the legs and laterals. This is the morph that seems to be responsible for Harlequin, which is described as orange and white pattern, and has become very strong in animals these days depending on how stacked it is within the lineage. The two colors in the morphs seem to be allelic and incomplete dominant.

Colored Bases

The only colored bases we have been able to find from wild-type animals are a faded orange to yellowish-orange. Several of these forms seem to exist mostly with Phantom animals that further add to camouflage them, and another reason why these morphs exist and work for camouflaging animals.

Pinstripe

This morph was originally noticed as raised scales along the dorsal edge. Some wild-type animals that had flame and white patterning would have highlighted white color on the pinstriped raised scales. Stacking over generations and line-breeding has resulted in stronger white pattern and 100% white pinstripe and scales. Tigering described as the first trait mutes pinstripe coloration and raised scales when it travels through the dorsal edge and contributes to breaks.

Orange Spot

Crested Geckos originally were described as having lateral orange stripes toward the hind legs. The traits responsible for the orange spots might be what constrains pattern to lateral like portholes, walling, and quad striping after decades of developing and stacking genes.

Dalmatian

Dalmatian spots are a dominant mutation and the simplest to explain as black spots sized from small to large. The variance in this trait can be quite large and the difference between Het and Hzg forms seem to be more spots. We are unsure if it is incomplete dominant and there is a super form. There are MANY types of dalmatian that we will cover in the morph guide, but wild-type animals have been shown to have 5-20 spots of varying size.

Patternless?

This morph is difficult to discern in wild populations. It behaves like a recessive trait. It is also very similar in form to Phantom animals with little patterning. The difference is that phantom still shows the underlying pattern while patternless completely removes it. This has been revealed by breeding similar-looking animals that are Het for the different traits and observing the phenotypes. This is a common occurrence in the reptile world to be able to make combo morphs that resemble individual traits or traits that can combine to form similar-looking combos.

*NOTE: The photos above were taken from three different videos over 14 years apart from Geoff Cunningham's, Exo-Terra's, and Dāv Kaufman's visit to New Caledonia

Geoff Cunningham - VIDEO
Exo-Terra - VIDEO
Dāv Kaufman - VIDEO

What's NEXT?!

This is a four-part work, we will be releasing our work in stages as we complete them.

Part #1: Foundation Genetics Guide ✓

Part #2: We are working on the full Crested Gecko Morph Guide that outlines all the traits above and the traits in the community. The guide will discuss specific genetic traits, their inheritance, and what happens when they are combined with other traits to make the combos we see in the hobby.

Part #3: The Interactive Morph Guide, this will be a visual diagram to help you see what traits contribute to a Crested Gecko morph you can add and stack traits with this guide.

Part #4: The Crested Gecko Book and husbandry guide.

What's next for you, our readers

As for our readers... What is next for you, is to keep in mind that the majority of the current morphs and descriptions will be changing. The information in the morph guide is from the collections of Tom and Anthony's observations >2000 animals. We spent years sorting through phenotypes to extrapolate the individual morphs. We then took those phenotype results and further tested for individual traits to try and prove if it was dominant, or recessive. Tom and I both wrote genetic guides before we even knew each other. When we shared our results with each other we realized that we had both come to the same conclusions for the majority of what we wrote describing the base traits in the crested gecko. Using the results from other breeders in the industry only further confirmed that what we had found over the years was correct. The Foundation Genetic Guide is the 1-year result of Tom and I combining our efforts to lay out a plan to bring our work to the community.

With that in mind, we want you to challenge the results for yourself. Use the upcoming interactive morph guide to help you understand each trait and label what each trait is in your animal. When you produce offspring document the result of each using the 1-2 letters for the genotype section in the morph guide. You can then determine if your animals are Het or Hzg for those traits.

Provide feedback!

- Was something not well understood?
- Did you find anything confusing?
- Would a diagram for one of the definitions help you understand something better?

Let us know in the contact us section. This is a community resource and we plan to continue to update it, as new info is found. Thanks for reading and if you're still hungry for more we recommend the Gargoyle Book below.

Sources

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