Discussion of Poultry Genetics

By Poultry Genetics for the Nonprofessional

The sex of your chicks
The sex of a chick is determined even before the egg is fertilized. Each pair of chromosomes in the fertilized egg has one chromosome from each parent. The father always contributes a long sex chromosome (the Z chromosome) to the fertilized egg.

Before the egg is fertilized, it has only those chromosomes from the mother. If the mother contributes a long sex chromosome, Z, to the unfertilized egg, the chick from that egg will be male because it will have two long sex chromosomes after fertilization, since it always gets a long sex chromosome from the father. If the mother contributes a short sex chromosome to the unfertilized egg, then the chick will be female because it will have one long and one short sex chromosome after fertilization. So, in this way the egg can be thought of as already having a sex (gender) even before it is fertilized.

The sex ratio of baby chicks
On the basis of extensive research, it is now accepted as fact that female chicks are equally probable as male chicks. There is no bias toward one sex or the other. Given good incubation techniques, one should hatch equal numbers of male and female chicks if a statistically valid (large enough) sample of eggs is incubated. However, it is believed that female embryos are preferentially killed by fluctuations in incubation conditions.

Feather sexing baby chicks
In order for rate of feathering to be an indicator of chick sex, the mothers of the chicks have to have a slow feathering gene (see the table) while the fathers have normal feathering or rapid feathering genes. A cross between these males and females will give pullets with rapid feathering and cockerels with slow feathering. This is a sex-linked trait that can be a sex-indicating trait in the same way that sex-linked barring can.

How to breed for a trait for sexing day-old chicks
In the gene table in Part III the first listing is a set of sex-linked genes. Some common sex-linked traits are Cuckoo barring, gold, silver, slow feathering and dwarfism. Gold, s+, and silver, S, are allelic, which means that they are found at the same locus (on the long, Z, sex chromosome). In order to breed for a trait that will useful for sexing day-old chicks, the trait must be visible in the hatchling. The brown eye trait is not a good choice because chickens don't get their final eye color until they reach sexual maturity.

To breed a trait that is present in male chicks and absent in female chicks, the trait must be dominant and on the Z sex chromosome (sex-linked), the female parent must have the trait and the male should be lacking the trait. Please see the sex-linked genes in the table in Part III. Any of the dominant sex-linked genes listed there can be exploited to give birds that are sexable at a very young age. The silver gene, S, is often exploited in varieties like Red Sex-Links for sexing day-old chicks. For example, we might choose to cross a red Rhode Island Red male (s+, s+) with a silver Delaware female (S, _) where this means that her long Z chromosome has the silver gene, S, and her short W chromosome is lacking that locus and is represented by an underscore or dash. The four possible gene combinations of the parent
genes from this cross are: \((S, s^+), (S, s+), (s^+,_), (s^+,_)\). Here the dominant gene is written first and any gene is written before the underscore.

In this example of the red male mated to the silver female, there are really only two unique gene combinations since two of the four gene combinations are identical to the other two. The 50% of the chicks that inherit the gene combination, \((S, s^+)\), are silver males (male because they inherited two copies of the long Z sex chromosome) and are essentially white birds with some possible coloration because silver can be a leaky gene. The other half of the chicks that inherit the \((s^+,_)\) genes are red females (female because she inherited the short W sex chromosome). So the pullets are red and the males are primarily white (yellow down). It is common that Delaware dams and Rhode Island Red sires are used in a cross like this to obtain a Red Sex-Link. This cross is sometimes called Sil-Go-Link for 'silver-gold-sex-link'. The silver gene used this way (the female parent having the dominant gene and the male parent having the recessive genes), will always give sons that have the dominant gene and daughters that do not.

If the cross is carried out the other way, a silver male on a red female, all the chicks will be essentially white if the male has two copies of the silver gene (homozygous for silver). In this case it is not possible to determine the sex of the day-old chicks by their color.

Any dominant sex-linked trait can be used in this way for the purpose of sexing day-old chicks so long as that trait is visible in the chicks. The slow feathering trait can be a good choice because it does not change the basic color or pattern characteristics of the birds (see Part III under Cuckoo barring) so that their appearance (phenotype) can be maintained.

**Auto-sexing breeds**

An auto-sexing breed is a breed in which the male and female day-old chicks can be distinguished. Some physical characteristic must be observable that is different in males than females. The important difference between a sex-link hybrid and an auto-sexing breed is that the auto-sexing breed is a pure, true-breeding strain and not a hybrid. Hybrids don't breed true in the sense that phenotypes of male individuals are similar to each other and female phenotypes are similar to each other.

An example of an auto-sexing breed is the Barred Plymouth Rock. In this breed, the auto-sexing property arises from the dose effect that the barring gene, \(B\), exhibits. The \(B\) gene is on the Z chromosome so the male Barred Rocks have two \(B\) genes while the females have one. The males and females hatch with white spots on top of their heads with the male spot being larger and less sharply defined. Also, the females tend to have darker shanks because the \(B\) gene is an efficient inhibitor of shank color. These two traits, based on the \(B\) gene dose effect, allow sexing of day-old chicks with a high accuracy rate.

**Lethal genes**

Some genes are lethal. A dominant gene that is lethal when a bird has only one of that gene (heterozygous for that gene) is immediately taken out of the gene pool, since no bird survives with it. Some dominant genes are lethal only when the bird has two copies of the gene. The creeper gene, \(Cp\) and the ear tuft gene, \(Et\), are lethal to a chicken with two copies (homozygous). I am aware of an exception to this in which someone claims to have a male with two ear tuft genes that has survived. This should be considered to be a rare exception. The short leg genes in other breeds are often lethal. Some traits, like frizzleness and rumplessness are known to reduce hatchability but are not explicitly lethal.
Genetics of ear lobe color
Most breeds have red ear lobes. The red color is due to the blood of the bird and is visible because the skin of the ear lobes, comb and wattles has a rich blood supply that is not masked in any way. These skin areas are so highly vascularized that squeezing a comb between your thumb and forefinger will more than likely squeeze out some of the birds blood onto your fingers. Mosquito bites often leave a small amount of dried blood on the comb. Breeds of the Mediterranean Class (Leghorn, Minorca and Spanish) have 'white' ear lobes.

The white ear lobe is due to the purine pigment which is controlled by a number of genes. The trait is said to be polygenic. The red ear lobe is due to the lack of the genes that invoke the purine pigmentation. Sometimes the white ear lobe can have a greenish or yellowish tinge. The number and location of the genes responsible for white ear lobes is not presently known.

Genetics of eggshell color
Brown eggshell color is a complex trait and as many as 13 genes have been proposed to account for the range in eggshell color. The white eggshell color is due to an absence of blue and brown, and perhaps some modifying factors (genes), since there are different shades of white. The blue eggshell gene, O, expresses if it is present which is why it is considered to be dominant. The gene symbol for the recessive, wild-type gene is o or o+. My understanding at present is that the locations of the brown eggshell genes are not known and it is not known how many brown modifying genes there are or where they are in relationship to the genes of known locations. Brown may itself be just an array of white modifiers. There is a recessive sex-linked gene, pr, that inhibits the expression of brown eggshell genes and can be used to help remove the brown tint from white eggs, for example.

The brown pigment, ooporphyrin, is deposited primarily on the outside of the eggshell and is a chemical compound resulting from hemoglobin metabolism. In fact, much of the brown pigment can bebuffed off with a common kitchen (plastic) scrubbing sponge and warm soapy water. The blue eggshell pigment, oocyanin, is a byproduct of bile formation and is present throughout the eggshell.

The eggshell color genes interact in the following way. The effect of the blue gene is dominant over white. The effect of the brown gene is dominant over white. When blue and brown genes are both present, both genes contribute to the eggshell color making the eggs appear green. In this case, the inside surface of the eggshell will be significantly less green and more blue than the outside surface, which is where most of the brown pigment is.

Since the blue and brown eggshell color genes should be at different locations, we need at least two pairs of genes to describe the genotypes of the blue, white, green and brown layers. For the purposes of this discussion, I use the fictitious symbol, Br, to indicate a brown eggshell color gene. I represent the complementary recessive gene that takes the place of Br when it is absent as "br" (lack of brown gene). We can represent the genotype of a blue eggshell layer as (O, O) with (br, br). Blue and white genes, (O, o) with (br, br) also yields a blue egg, but perhaps a lighter blue. The pair of eggshell color genes, (O, O) with (Br, Br), are the genes for producing a green egg, (o, o) with (Br, Br) produces a brown egg and (o, o) with (br, br) yields a white egg. Females having one blue gene and one or more brown genes will lay eggs having a greenish color. My personal experience with eggshell color makes me believe that this genetics picture of eggshell color is oversimplified (there are certainly more than one gene for brown eggshell color. In order to account for the wide range of shades of brown eggs we see in our Sil-Go-Link line, there must be a relatively large number of eggshell color modifying genes that are not yet known.
Most people accept a rule of thumb to the effect that a daughter will lay eggs that are a color between that of the parent lines.

To explore the genetics of eggshell color, let’s cross a green egg layer (faux-Araucana or Easter Egg Chicken) with a white egg layer (Leghorn). Here as before, I will use the fictitious symbol “Br” to represent brown eggshell genes. The genes of the green egg layer are (O, O) with (Br, Br) assuming the locations of the blue and brown genes are not the same. The Leghorn is (o, o) with (br, br) for eggshell color (white). In this example, the daughters will all have one gene for blue eggshell color and one gene for brown. They will all be green egg layers! My personal experience with eggshell color genetics leads me to believe it is more complex than this. There certainly must be a number of brown eggshell genes and once you have them, it is difficult to breed them out completely.

**Genetics of comb type**

Comb type in chickens is due to two genes, the rose comb gene, R, and the pea comb gene, P. These two genes are on different chromosomes. The lack of these genes is represented with lower-case letters, r and p. More correctly stated, r and p (or r+ and p+ to indicate they are the wild-type genes) are the genes that replace R and P when they are not present. A chicken with a single comb is lacking both R and P genes and so could be represented as (r, r) for rose comb and (p, p) for pea comb. Some authors will combine this ‘notation’ and write (rrpp) to represent the genes for single comb. I prefer the first way of writing the genes for the purposes of this text.

A chicken with a rose comb will have one of the gene combinations: (R, R) with (p, p), or (R, r) with (p, p).

A bird with a pea comb will have (r, r) with (P, P), or (r, r) with (P, p). Since one copy of the rose or pea gene is sufficient for that comb type, these genes can be thought of as dominant. However, they act together to create the walnut comb when both rose and pea comb genes are present.

Poultry with a walnut comb have at least one copy of both the rose comb gene and the pea comb gene. The gene combinations that give walnut comb are: (R, R) with (P, P), (R, r) with (P, P), (R, R) with (P, p) and (R, r) with (P, p).

To explore the genetics of comb type, let’s cross a pea comb chicken, (r, r) with (P, p), and a rose comb chicken, (R, r) with (p, p). Because two genes on different chromosomes are involved, there is more bookkeeping than if there were only one gene involved, but the principle is the same and no more difficult. We first have to consider the combinations of the rose comb genes of the two parents, then the combinations of the pea comb genes of the two parents. Then we realize that each of the rose comb combinations can occur with each of the pea comb combinations. In the end there are 16 combinations in all.

The four possible combinations for the rose comb genes from the two parents are: (R, r), (R, r), (r, r) and (r, r). The four combinations for the pea comb genes from the two parents are: (P, p), (P, p), (p, p) and (p, p). Since each of the four rose comb combinations can occur with any of the pea comb combinations, we now have to consider each of the rose comb combinations with each of the pea comb combinations (16).

The figure above shows how to make a helpful drawing. Make a list (column) of the four rose comb gene combinations on one side and the pea comb genes on the other side. The combinations of the first rose comb gene pair with all the pea comb gene pairs is shown in the figure by the connecting arrows.
Considering the (A, a) of the drawing to be (R, r), the possible combinations of the first rose comb gene pair with the pea comb gene pairs are: (R, r) with (P, p) twice [we get this combination twice], and (R, r) with (p, p) twice. The second rose comb gene pair with the pea comb genes gives the same combinations: (R, r) with (P, p) twice and (R, r) with (p, p) twice. The third rose comb gene pair with the pea comb gene pairs gives: (r, r) with (P, p) twice and (r, r) with (p, p) twice. The last rose comb gene pair with the pea comb gene pairs gives the same: (r, r) with (P, p) twice and (r, r) with (p, p) twice.

So, of the 16 possibilities, four of them are (R, r) with (P, p) and is walnut comb, four are (R, r) with (p, p) and is rose comb, four are (r, r) with (P, p) and is pea comb, and four are (r, r) with (p, p) which is single comb. We have four out of 16 chances (25% chance) to get a walnut comb from this cross, four out of 16 chances to get rose comb, four out of 16 chances to get pea comb and four out of 16 chances to get single comb.

**Genetics of shank/feet color**

The shank/feet color is controlled by genes that affect the skin at different depths. The visible color is due to the combined effect of the different colors of the dermis and the epidermis. So, the shank/feet colors are a combination of upper skin and deeper skin pigmentation. The following table gives the shank/feet colors that result from the major gene combinations (the bird has two copies of each gene). It is important to remember that other genes can modify shank and foot color. For example, the sex-linked barring gene, B, is a potent inhibitor of dermal melanin. The Barred Plymouth Rocks, for example, would not have light shanks and feet if it were not for the fact that they have sex-linked barring. The female Barred Rocks tend to have darker shanks due to the dose effect of the barring gene. The following table is intended as a guide but should not be considered to be absolute, since (as mentioned) other genes, such as sex-linked barring, can modify shank/foot color.

<table>
<thead>
<tr>
<th>Shank/Foot Color</th>
<th>Genes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Near black with white soles</td>
<td>W+, Id, E</td>
</tr>
<tr>
<td>White shanks and feet</td>
<td>W+, Id, e+</td>
</tr>
<tr>
<td>Black shanks, white soles</td>
<td>W+, id+, E</td>
</tr>
<tr>
<td>Blue shanks, white soles</td>
<td>W+, id+, e+</td>
</tr>
<tr>
<td>Near black with yellow soles</td>
<td>w, Id, E</td>
</tr>
<tr>
<td>Yellow shanks and feet</td>
<td>w, Id, e+</td>
</tr>
<tr>
<td>Black shanks with yellow soles</td>
<td>w, id+, E</td>
</tr>
<tr>
<td>Green shanks with yellow soles</td>
<td>w, id+, e+</td>
</tr>
</tbody>
</table>
**Genetics of dark skin color**

The hypermelanic condition of some breeds, such as the Silkie breed, is due to a pigment cell activator, which was named by F. Hutt as "fibromelanosis" to emphasize the fact that the gene causes pigmentation of connective tissue. The inheritance of the dark skin phenotype involves the fibromelanosis gene, Fm, as well as dermal melanin inhibitors, such as the sex-linked Id dermal melanin inhibiting mutation. The fowl with Fm and wild-type dermal melanin, id+, will have darkly pigmented skin and connective tissue. The combination of Fm and Id gives a bird that has little or no observable skin pigmentation. There are other dermal melanin inhibitors that may have an influence on the degree of melanization due to Fm (or the degree of expression of Fm). Some genes influencing plumage color have an effect on dermal melanin, such as the E-locus alleles, which may influence the expression of Fm. However, fibromelanotic Silkies exist with black, white, blue and partridge patterns.

**Genetics of feather color**

The genetics of feather color and patterns is an active topic of poultry science research. Much of the work that was done prior to the late 1980s is now considered out of date. Because a number of genes interact to determine feather colors and patterns, it might seem to be too involved for the average enthusiast. I don’t believe that this is the case, however, the topic of feather color and patterns may be beyond the interest and motivation of some enthusiasts.

White is actually all the colors combined and black is the lack of reflection of light in the visible range, so one might argue that black and white are not really ‘colors’ technically. However, if we count black and white as colors, chickens have only three basic colors: black, white and red (gold).

The colors of chickens are achieved by diluting and enhancing or masking black and red (gold). For example, Rhode Island Reds have the gold gene with the dominant mahogany (red enhancing) gene. A blue chicken is a black bird that has the blue gene which dilutes black. Two copies of the blue gene give a splash effect. A white chicken can be achieved in a number of ways by inhibiting black and red pigmentation with combinations of genes (dominant white, recessive white, silver, Columbian, Cuckoo barring).

Some perceived colors of feathers are due to the structure of the feather and not any pigmentation. The purple and the ‘beetle’ green sheen that can be seen in some poultry is due to the way the feather structure reflects light rather than the presence of a pigment.

First, we need to define a couple of terms. In poultry there are primary and secondary color patterns. Perhaps it is better to define secondary patterns first. A secondary pattern is a pattern that appears on individual feathers. These are patterns like single and double lace, mottle, and so on. Primary patterns are color patterns that involve the entire body of the bird. An example is the silver Columbian pattern. In the Columbian bird, black is restricted to the hackles, wing bow and tail. The silver Columbian is a white bird with some black in the neck, wing and tail areas. Because this pattern is not manifest on individual feathers, it is a primary pattern.

To ‘construct’ a chicken having a particular color scheme, one begins with the ‘background’ or the E-locus gene(s). The other color and (secondary) pattern genes essentially modify this ‘background’. Please refer to the table at the end and the pattern table below to see the choices and comments (other E-genes have been proposed but they are not yet well accepted). Some of these are: E, extended black or nigrum; ER, birchen; eW, dominant wheaten; e+, wild type; brown, eb; speckled, es; butternut, etc; and ey, recessive wheaten. These genes cause recognizable chick down color and influence the adult
feather color, sometimes male and female feather colors are influenced differently. For photographs of chicks with an assortment of E-genes the interested reader is directed to Poultry Breeding and Genetics, R.D. Crawford, ed., Elsevier, 1990 pages 115-117.

As an elementary exercise, let’s ‘build’ a white chicken. We can start with wild-type background, e+, and require our bird to have two copies of this gene. We can suppress the red in the chicken by adding the silver gene, S, which has the effect of changing red to white. Black is suppressed (changed to white) by the dominant white gene, I, however this gene is ‘leaky’ (see the table for comments) and allows black specks through. A good ‘helper’ gene in this situation is the Columbian gene, Co, since it is a restrictor of black. Although this set of genes is not the only set that will yield a white chicken, it is one of the ways a white chicken can be obtained.

**The influence of one versus two genes for a color trait**

Feather color genes often display a ‘dosing’ effect: “Two genes are stronger than one.” For example, since the locus of the sex-linked barring gene is on the Z sex chromosome, females that have Cuckoo or sex-linked barring (the barring that Barred Rocks have) can have only one barring gene and have barring that is less well defined than the barring of males that have two barring genes. Also, Sil-Go-Link males that have only one silver gene (silver inhibits red) often have some red color on their wings. So, in the Sil-Go-Link male, the one silver gene does not completely inhibit the red pigment. The silver gene is dominant but still some red is visible when only one silver gene is present. This ‘dose effect’ in which two genes for a trait reinforce or strengthen the expression of a trait is common in poultry.

**Genetics of patterns**

New research has indicated that several major patterns in chickens are not due to independent genes as previous believed. The single lace, double lace, autosomal barring (horizontal penciling) and spangling are now thought to be due to interactions with the Pg gene (pattern gene). For a review of the original literature, see W.C. Carefoot in Crawford’s volume. Single lace pattern can be obtained with the genes: Ml (melanotic), Pg (pattern gene) and Co (Columbian) on either eb, ey or eWh background genes. Double lace pattern is obtained from the single lace pattern by removing the Co gene. Spangling is obtained with Db (dark brown), Ml (melanotic), Pg (pattern gene) on either the E or eb background. Penciling is obtained with the Pg gene on the eb or e+ background. Autosomal barring (sometimes called horizontal penciling) is obtained with the Db and Pg genes. The table below, originally constructed by Brian Reeder, is intended to serve as a guide to the patterns seen in chicken plumage. A similar table is found in Poultry Breeding and Genetics, R.D. Crawford, ed., Table 5.3, page 127.

**Chicken Poultry Patterns**

<table>
<thead>
<tr>
<th>Pattern</th>
<th>Pg</th>
<th>Ml</th>
<th>Co</th>
<th>Db</th>
<th>E-locus</th>
<th>Hf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partridge (or pencilled)</td>
<td>x</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td>e⁺</td>
<td>/</td>
</tr>
<tr>
<td>Salmon-breasted pencilled (female)</td>
<td>x</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td>e⁺</td>
<td>/</td>
</tr>
<tr>
<td>Autosomal barring - Hamburg</td>
<td>x</td>
<td>/</td>
<td>/</td>
<td>x</td>
<td>e⁺</td>
<td>/</td>
</tr>
<tr>
<td>Autosomal barring - Fayoumi</td>
<td>x</td>
<td>/</td>
<td>x</td>
<td>x</td>
<td>E⁺</td>
<td>/</td>
</tr>
<tr>
<td>Autosomal barring - Buttercup</td>
<td>x</td>
<td>/</td>
<td>/</td>
<td>x</td>
<td>e⁺</td>
<td>/</td>
</tr>
<tr>
<td>Single Lace (as in Wyandotte)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>/</td>
<td>e⁺</td>
<td>/</td>
</tr>
<tr>
<td>Pattern</td>
<td>Pg</td>
<td>MI</td>
<td>Co</td>
<td>Db</td>
<td>E-locus</td>
<td>Hf</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>---------------</td>
<td>--------</td>
</tr>
<tr>
<td>Single Lace (as in Polish)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>E(^R) (or E)</td>
<td>/</td>
</tr>
<tr>
<td>Single Lace (as in Seabright)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>E(^R) (or E)</td>
<td>x</td>
</tr>
<tr>
<td>Single Lace (as in Andalusian)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>/</td>
<td>E(^R) (or E)</td>
<td>/</td>
</tr>
<tr>
<td>Double Lace (as in Dark Cornish)</td>
<td>x</td>
<td>x</td>
<td>/</td>
<td>/</td>
<td>e(^Wh), e(^b), e(^v)</td>
<td>/</td>
</tr>
<tr>
<td>Spangling (as in Hamburg)</td>
<td>x</td>
<td>x</td>
<td>/</td>
<td>x</td>
<td>E(^R) (or E)</td>
<td>sometimes</td>
</tr>
</tbody>
</table>

**Genetic of Eye Color**

The genetic basis of eye color has not been extensively studied as have other aspects of phenotype. However, some things are accurately known. First of all, the wild-type eye is characterized by the Light Brown Leghorn. Eye color is a result of pigmentation of a number of structures within the eye (iris, retina, uveal tract, ciliary).

The bay-color eye (various shades of reddish brown) is due to carotenoid pigments and the blood supply of the iris. Brown eyes are increasingly melanized with the darkest eye color due to the fibromelanotic gene characterized by heavy eumelanin deposits throughout the eye. Little is known about pearl eye and Smyth has speculated that it has the same eumelanin distribution as the bay but without the carotenoids.

Eye color is modified by a number of genes that are known to be associated with shank and plumage color. The sex-linked dermal melanin genes, id\(^+\) and id\(^M\) enhance dermal shank and eye pigmentation. The inhibitor of shank dermal melanin, Id, also inhibits eye pigmentation. Smyth hypothesized that the id\(^M\) gene together with extended black, E, is responsible for dark brown eyes. id\(^M\) also darkens the eye on the e\(^+\) background.

A dominant sex-linked inhibitor of eye pigmentation is known, Br. This trait is not useful for developing sexable day-old chicks because chickens do not get their final eye color until they reach sexual maturity.

In the absence of other melanin inhibitors, the E-locus alleles, E (extended black) and E\(^R\), birchen, result in a brownish eye with the E allele making the darker eye. Sex-linked barring, B, and eumelanin inhibitors at the E-locus, like e\(^Wh\) have an effect on eye color. Recessive white seems to have no effect on eye color and dominant white, I, has a strong ability to inhibit eye pigmentation. The genetics of pearl are not known, however, it is known that the white skin gene, W, is not the genetic basis of pearl eye, since Cornish have yellow skin and can also have pearl eye.

**Genetics of Chick Down Color**

Virtually everyone who hatches their own baby chicks wants to know what the chick down color tells them about the genes of that individual chick. This section is an effort to give some guidance in this direction.

<table>
<thead>
<tr>
<th>Some Basic Chick Down Color Genetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chick Down</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>E, Extended Black</td>
<td>Basically black down. Variation includes gray and cream bellies. The cream can invade the head and face. Often Australorps have cream in their faces and heads although the adults are standard black color. Sex-linked barring puts the cream head spot on the black down. Recessive mottling (mo) makes these chicks look like penguins.</td>
</tr>
<tr>
<td>e^Wh, Dominant Wheaten</td>
<td>Without colombian (Co) Wheaten down is a light cream for both sex-linked silver and gold. One cannot distinguish silver from gold with any accuracy on dominant wheaten. Heterozygotes can have varying amounts of striping. Some New Hamps have light reddish stripes on their backs at hatch. This may be due to heterozygosity or some other modifiers in these lines. With Co wheaten downs are easily sexable. There is a high degree of difference between silver and gold wheaten down when colombian is present. This is why commercial white-tailed reds have dominant wheaten and colombian.</td>
</tr>
<tr>
<td>e^+, Wild-type</td>
<td>The dark eye stripe is characteristic of wild-type. The wild-type is often referred to as the 'chipmunk' look. The buff color of the face and back stripes are affected by sex-linked silver and gold. You can easily tell Silver Duckwing chicks from Light Brown Leghorns, but you tend to have trouble in crosses, involving Ss heterozygotes, so there are probably modifiers that affect the gold color of the pure line chicks.</td>
</tr>
<tr>
<td>e^b, Brown</td>
<td>Can range from a solid dark mink brown to light brown with stripes. The most accurate typing for e^b is that they have brown heads with no stripes on the head like e^b.</td>
</tr>
<tr>
<td>e^bc, Buttercup</td>
<td>More yellow than e^+. This dilution may be due to e^bc or Db that seems to be in all the crosses and pictures involving this allele. Adult females are like eb females and do not have salmon breasts.</td>
</tr>
<tr>
<td>e^y, Recessive Wheaten</td>
<td>Sometimes pictured as being yellow but more brown than e^Wh. Both are said to be cream in color. Recessive wheatens are often called dark wheatens because the adult females have more stippling on their backs than dominant wheaten females usually have.</td>
</tr>
<tr>
<td>e^b, Co</td>
<td>Chicks having sex-linked silver in addition to the above genes are cream colored with varying amounts of gray on their backs. Their backs can be nearly black. Sex-linked gold chicks show buff on their flanks and faces and cream bellies with the same varying amount of gray on their backs. The less gray the more buff on the backs of sex-linked gold chicks.</td>
</tr>
<tr>
<td>e^b, Co, Db</td>
<td>Mostly light (yellow) body with brown head and back stripe. Buff breeds may have wheaten, Co, and Db.</td>
</tr>
</tbody>
</table>

Some additional genes that affect chick down color are: Dominant and recessive white with extended black at the E-locus gives yellow chick down. If black spots leak through it is usually because the chick is heterozygous for dominant white. Dark brown, Db, makes the black down of extended black to be a reddish brown. Blue or grey chicks can be extended black and Bl (blue) heterozygotes. These chicks can also look black. Chicks that are homozygous for recessive lavender are blue / grey.

**A Fun Exercise**
It is fun to consider the genetic make up of some popular breeds. From what we know at this point about poultry genetics, we can make some judgments about the genes that birds have to have in order to look the way they do.
Let’s consider Rhode Island Red as an example. With respect to feather color, the Rhode Island Red (RIR) has gold (on the sex chromosome), s+ (sometimes called G), and the mahogany (red enhancing) gene, Mh (see the tables below). A Rhode Island Red without any black in her hackle or tail may have a black suppressing gene such as dominant white, I, and Columbian, Co, serves as an additional black suppressing influence. She will have no black extending genes, such as nigrum, which would change her to a black bird. Rhode Island Reds come in both single and rose comb types so she may have at least one copy of the rose comb gene. The single comb RIRs have neither the pea comb nor rose comb genes. RIRs have yellow skin, shanks and feet, which requires two copies each of the w, Id, e’ genes. RIRs can have either one or two genes (hetero- or homozygous) for eggshell color giving the brown egg.

White Leghorns are white chickens that lay white eggs. The white could be achieved in a number of ways. The task at hand is to effectively inhibit both black and red. We construct a Leghorn by having two dominant white genes, I, which are black inhibitors, but the dominant white gene allows some black flecks through (see the table at the end) and needs help. Sex-linked barring, B, acts as a black inhibitor in white birds and is used as such in Leghorns. The red inhibitors in Leghorns are the silver gene, S and birchen gene, E\textsuperscript{b}, or nigrum, E. To get the single comb, the Leghorn has (r, r) and (p, p) for comb genes and she needs (o, o) for eggshell color genes for the white eggs. The Leghorn has yellow skin, shanks and feet which requires two copies each of the w, Id, e’ genes.

**Genotypes of Common Interest.**

Below is a table of partial genotypes for breeds of common interest. There may be other genotypes and so I do not claim that any given breed must be exactly the genotype specified. If a gene does not appear in the table, it is intended that wild-type be assumed although sometimes wild-type genes are listed for emphasis. I continue to collect information to update this table....

<table>
<thead>
<tr>
<th>Breed</th>
<th>Autosomal Genes</th>
<th>Sex-Linked Genes</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australorp, Black</td>
<td>W/W, E/E, co\textsuperscript{+}/co\textsuperscript{+}, db\textsuperscript{+}/db\textsuperscript{+}, (MI/MI), i\textsuperscript{+}/i\textsuperscript{+},(Pg)</td>
<td>S, Id</td>
<td>Evidence of unknown black enhancers and the pattern gene have been observed in Black Australorps.</td>
</tr>
<tr>
<td>Silver Spangled Hamburg</td>
<td>E\textsuperscript{b}/E\textsuperscript{b}, Co/Co, Db/Db, MI/MI, pg\textsuperscript{+}/pg\textsuperscript{+}</td>
<td>S, Id\textsuperscript{+}</td>
<td>The combination of dark brown and melanotic may be responsible for the white undercolor.</td>
</tr>
<tr>
<td>Silver Laced Wyandotte</td>
<td>e\textsuperscript{b}/e\textsuperscript{b}, Co/Co, db\textsuperscript{+}/db\textsuperscript{+}, MI/MI, Pg/Pg</td>
<td>S, Id</td>
<td>Yellow legged blacks are usually based on the e\textsuperscript{b} E-locus allele.</td>
</tr>
<tr>
<td>New Hampshire</td>
<td>e\textsuperscript{wh}/e\textsuperscript{wh}, Co/Co, Mh/Mh, w/w</td>
<td>s\textsuperscript{+}, Id</td>
<td>With polygenes for red ear lobe and brown eggshell color. A primary difference between New Hampshire and Rhode Island Red is the wheaten allele at the E locus in the New Hamps.</td>
</tr>
<tr>
<td>Rhode Island</td>
<td>e\textsuperscript{+}/e\textsuperscript{+}, Co/Co,</td>
<td>s\textsuperscript{+}, Id</td>
<td>With polygenes for red ear lobe and brown eggshell color.</td>
</tr>
<tr>
<td>Breed</td>
<td>Autosomal Genes</td>
<td>Sex-Linked Genes</td>
<td>Comments</td>
</tr>
<tr>
<td>---------------------</td>
<td>--------------------------</td>
<td>------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Red</td>
<td>Mh/Mh, w/w, Db?</td>
<td>K, S, B, Id</td>
<td>With polygenes for red ear lobe and brown eggshell color. The slow feathering gene, K, is believed to aid in obtaining a cleaner barring. Barred Rocks have yellow shanks because of the dermal melanin inhibiting property of Cuckoo barring. Without this, the breed would have near black shanks with yellow soles.</td>
</tr>
<tr>
<td>Barred Plymouth Rock</td>
<td>E/E, Co/Co, w/w</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White Leghorn</td>
<td>Homozygous for either E, E^r or e^b, I/I, w/w, o/o</td>
<td>B, S, Id</td>
<td>Lines of Leghorns have been found with different alleles at the E locus.</td>
</tr>
<tr>
<td>Delaware</td>
<td>e^b/e^b, Co/Co, w/w</td>
<td>B, S, Id</td>
<td>With polygenes for red ear lobe and brown eggshell color. Delawares have Barred Rock and New Hampshire genetics.</td>
</tr>
</tbody>
</table>

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