Poultry Genetics For Small and Backyard Flocks: An Introduction

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If you breed poultry or are considering breeding poultry, a basic knowledge of poultry genetics is important. In particular, it is useful to understand the key elements of genetics and to know why certain traits exist in certain chickens.

A basic knowledge of poultry genetics begins with understanding the following key terms:

- DNA (short for deoxyribonucleic acid)—The material containing the genetic instructions used in development and function of an organism. DNA is arranged in double helix–shaped strands.
- Gene—A segment of DNA that carries a blueprint for the function of a cell and, ultimately, a particular characteristic of an organism.
- Chromosome—A structure containing a complete strand of DNA. Chromosomes function in the transmission of hereditary material from one generation to the next. Chromosomes typically come in pairs, with one set donated from the mother and one from the father. Humans have 23 pairs of chromosomes. Chickens have 39 pairs.
- Genotype—The genetic makeup of an organism.
- Phenotype—The observable physical or biochemical characteristics of an organism resulting from its genotype. Examples of aspects of a chicken's phenotype include body shape, feather color, eye color, comb type, and so on.

The two categories of chromosomes are sex chromosomes and autosomes. The sex chromosomes carry the genetic material that determines the sex of an offspring. In humans, the sex chromosomes are referred to as X and Y. A human having the sex chromosomes XX is female, and a human having the sex chromosomes XY is male. In chickens, the sex chromosomes are referred to as Z and W. A chicken having the sex chromosomes ZW is female, and a chicken having the sex chromosomes ZZ is male. The sex chromosomes of mammals and birds are illustrated in Figure 1. Autosomes are all the chromosomes except the sex chromosomes.

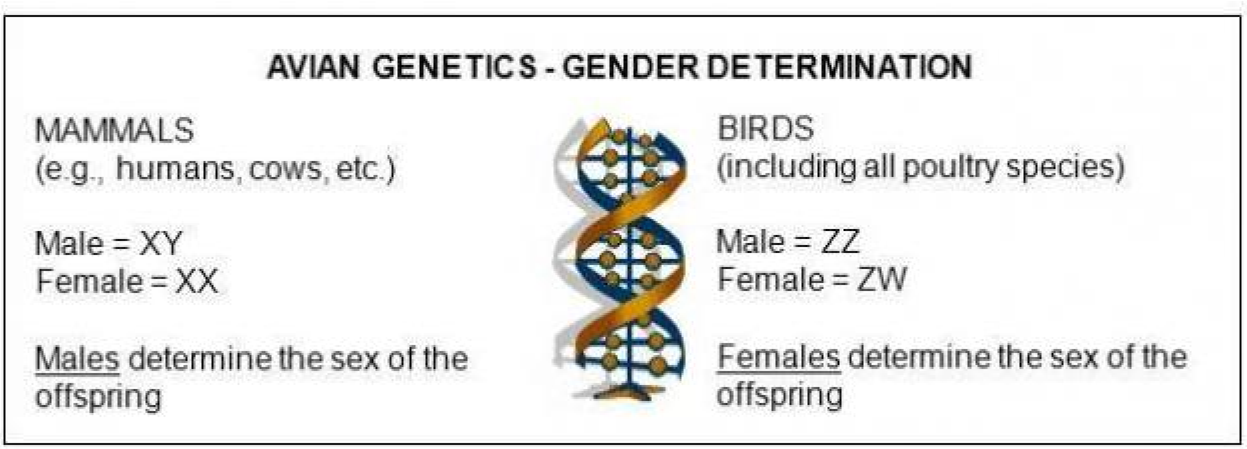

Fig. 1. Sex chromosomes of mammals and birds.

Because chromosomes come in pairs, genes also come in pairs. Each parent contributes one gene in each pair of genes. The phenotype for a specific trait in a chicken depends on the makeup of the gene pair for that trait. If the genes are the same, the genetic state is referred to as **homozygous**. If the genes are different, the genetic state is referred to as **heterozygous**. A gene that can express itself in the homozygous state or the heterozygous state is referred to as a **dominant factor**. A gene that can express itself only in the homozygous state is referred to as a **recessive factor**. When dealing with a trait for which there is a dominant gene and a recessive gene, three conditions (combinations of the genes in the gene pair) can occur. The homozygous dominant condition occurs when both genes present are the dominant gene. The homozygous recessive condition occurs when both genes present are the recessive gene. The heterozygous condition occurs when one gene present is the dominant gene and the other is the recessive gene. (The two variant forms of the gene in such a gene pair are called alleles.)

Typically, in the heterozygous condition, the dominant gene is expressed over the recessive gene. In some gene pairs, however, each gene is capable of some degree of expression in the heterozygous condition. This phenomenon is referred to as codominance. The contribution from each gene in the pair can be equal, or the contribution can be dominated more by one gene than the other.

To confuse things further, not every trait is controlled by a single pair of genes. A particular trait can be controlled by numerous gene pairs. Such traits are called **quantitative traits**. Brown shell color in eggs, for example, is controlled by as many as 13 genes. The result is the range of brown color observed in eggs laid by different breeds of chickens.

Genetics of Significant Observable Traits in Chickens

When breeding chickens, it is helpful to understand why certain significant observable traits exist in certain chickens. These traits include comb type, feather color, shank/foot color, and skin color.

Genetics of Comb Type

Chickens have a variety of comb types, as shown in Figure 2. The genetics of comb type of chickens is historically significant. Gregory Johann Mendel is considered the father of genetics. His work with peas resulted in the idea that genes control different physical characteristics. Building on this idea, William Bateson used comb type of chickens to show that genetics apply to animals as well.

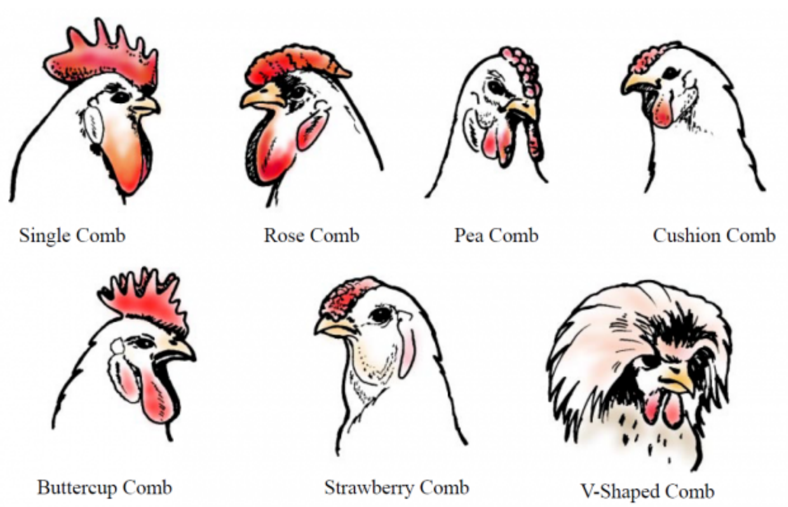

Fig. 2. Types of chicken combs. Source: University of Illinois. Used with permission.

Comb type in chickens basically is controlled by two different genes on two different chromosomes. One is the rose comb gene (represented by the letter *R*), and the other is the pea comb gene (represented by the letter *P*). A presence of the gene is represented by the uppercase letter; an absence of the gene is represented by the lowercase letter. Both the rose comb gene and the pea comb gene can express themselves in the heterozygous state. That is, only one copy of the rose comb gene or the pea comb gene is sufficient for that type of comb to occur. Therefore, both genes can be thought of as dominant genes.

- When at least one copy of the rose comb gene is present and the pea comb gene is absent, the result is a rose comb. In other words, a chicken with a rose comb has one of two possible gene combinations: RRpp or Rrpp.
- When at least one copy of the pea comb gene is present and the rose comb gene is absent, the result is a pea comb. A chicken with a pea comb has one of two possible gene combinations: rrPP or rrPp.
- When at least one copy of each gene is present, the result is a walnut comb. A chicken with a walnut comb has one of four possible gene combinations: RRPP, RrPP, RRPp, or RrPp.
- When both genes are absent, the result is a single comb. A chicken with a single comb has the only possible gene combination: rrpp.

To further understand the genetics of comb type, consider the results of breeding certain chickens. For example, what happens if a chicken that breeds true for pea comb (that is, a chicken that has the gene combination rrPP) is crossed with a chicken that breeds true for rose comb (that is, a chicken that has the gene combination RRpp)? Considering that each parent contributes to the offspring one each of the two genes that control comb type, the only possible gene pair that the parent that breeds true for rose comb can donate is Rp. Similarly, the only possible gene pair that the parent that breeds true for pea comb can donate is rP. Consequently, as shown in Figure 3, all offspring from such a mating would have the heterozygous state for both genes (that is, RrPp) and would thus have walnut combs. The offspring, however, would not breed true for walnut combs; that is, birds with walnut combs bred to birds with walnut combs could produce offspring with other comb types.

	Rp	Rp
rP	RrPp	RrPp
rP	RrPp	RrPp

Fig. 3. Gene combinations resulting from mating a chicken that breeds true for pea comb with one that breeds true for rose comb.

Exploring further, if two of the offspring depicted in Figure 3 are crossed, the number of possible combinations of genes increases. Each parent could contribute one of four possible gene combinations, resulting in 16 genetic combinations in the offspring. By considering the phenotype associated with each different genotype combination, you can calculate the odds of a particular comb occurring in the offspring. As shown in Figure 4, there would be a 9/16 chance for a walnut comb, a 3/16 chance for a rose comb, a 3/16 chance for a pea comb, and a 1/16 chance for a single comb.

	RP	Rp	rP	rp
RP	RRPP Walnut	RRPp Walnut	RrPP Walnut	RrPp Walnut
Rp	RRPp Walnut	RRpp Rose comb	RrPp Walnut	Rrpp Rose comb
rP	RrPP Walnut	RrPp Walnut	rrPP Pea comb	rrPp Pea comb
rp	RrPp Walnut	Rrpp Rose comb	rrPp Pea comb	Rrpp Single comb

Fig. 4. Gene combinations resulting from mating offspring of the cross depicted in Figure 3.

Genetics of Feather Color

To understand the genetics of feather color, it is necessary to understand how the different colors of poultry are achieved. In poultry, there are secondary and primary color patterns. A secondary pattern is a color pattern that appears on individual feathers. Single and double lacing, mottled, and so on are secondary patterns. Primary patterns are color patterns that involve the entire body of the chicken. An example is the Silver Columbian pattern. The Silver Columbian is a white chicken with some black in the neck, wing, and tail areas. Because the pattern does not manifest on individual feathers, it is referred to as a primary pattern.

To breed a chicken having a particular color scheme, one begins with the background color, which is controlled by the E-locus gene. The other color and (secondary) pattern genes essentially modify this background. Several different genes interact to determine feather colors and patterns. Considering white and black to be colors, there are three basic feather colors: black, white, and red (gold). (Technically, white and black are not colors: white is actually the result of all the colors combined, and black is the lack of reflection of light in the visible range.) The colors of chicken feathers are achieved by diluting and enhancing or masking black and red. For example, Rhode Island Reds have the gold gene with the dominant mahogany (red-enhancing) gene. A blue feathering is produced when a black-feathered chicken has the blue gene, which dilutes the black color. Two copies of the blue gene result in the splash effect. A white chicken can be achieved in a number of ways by inhibiting black and red pigmentation with combinations of genes (such as dominant white, recessive white, silver, Columbian, and Cuckoo barring).

Some perceived feather colors actually are due to the structure of the feather rather than to pigmentation. That is, the purple and beetle green sheens seen in some poultry are due to the way the feather structures reflect light rather than to the presence of pigments.

Genetics of Shank/Foot Color

The visible color in the shanks/feet of chickens is the result of a combination of colors in the upper skin and deeper skin. Shank/foot color basically is controlled by three genes, one of which is sex-linked and located on the Z sex chromosome. Table 1 shows the shank/foot colors that result from the major gene combinations. Remember that each chicken has two copies of each gene. The table is only a guide because other genes affect shank/foot color as well. For example, the sex-linked barring gene, B, is located on the Z sex chromosome and is a strong inhibitor of melanin pigment in the skin.

Barred Plymouth Rock chickens would not have light shanks if not for the fact that they have the sex-linked barring gene. Female Barred Plymouth Rocks (having the sex chromosomes ZW) tend to have darker shanks than the males (having the sex chromosomes ZZ) due to the dose effect of the barring gene in the male.

Table 1. The genetics of shank/foot color

Shank/Foot color	**Genes**
Near black with white soles	W^+, Id, E
White shanks and feet	W^+, Id, e^+
Black shanks, white soles	W^+, id^+, E
Blue shanks, white soles	W^+, id^+, e^+
Near black with yellow soles	w, Id, E
Yellow shanks and feet	w, Id, e^+
Black shanks with yellow soles	w, Id, E
Green shanks with yellow soles	w, id^+, e^+

Genetics of Dark Skin Color

The silkie chicken, shown in Figure 5, is known for its dark skin color. The dark skin results from higher than normal levels of melanin. A pigment cell activator called fibromelanosis causes pigmentation of connective tissue. The inheritance of the dark skin phenotype is controlled by the fibromelanosis gene, Fm, as well as dermal melanin inhibitors, such as the sex-linked Id dermal melanin–inhibiting mutation. Chickens having the Fm gene but not the Id gene have dark skin and connective tissue. The combination of the Fm gene and the Id mutation results in a chicken with no visible skin pigmentation. Other dermal melanin inhibitors also may have an influence on the degree of melanization (pigmentation) caused by the Fm gene (or the degree of expression of the Fm gene). Moreover, some genes influencing plumage color also have an effect on skin color, such as the E-locus alleles, which may influence the expression of the Fm gene. However, fibromelanotic silkies exist with black, white, blue, and partridge feather patterns.

Fig. 5. Black silkie chicken. Source: Jacquie Jacob, University of Kentucky.