The Pigeon Genetics Newsletter, News, Views & Comments.

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(Founded by Dr. Willard .F. Hollander)
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This Month : We take another look before we cross the street - The mysterious "CROSSOVER" in pigeon Genetics. The topic deserves another look as requested by Bill Greenslade of Canada.

How do we know when a **crossover** is necessary in order for a bird to inherit a specific genetic trait combination?

Here is **Paul Gibson's** description : In the meiosis , homologues chromosomes stick together in pairs.

The close association of homologous chromosomes allows segments of non-sister chromatids to trade places. This "recombination" of Maternal and Paternal genetic material is a key feature of meiosis , and this mechanism is known as a cross-over. (A portion of the first and a portion of the second reconnect).

When two or more genes reside on the same chromosome , they are said to be linked and do not assort independently, but in a cross-over , this becomes possible.

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Cross-Over V/S not. by **Jith Peter**.

For example, if the cocks mother was a dilute almond and his father was a non almond non dilute, then we can certainly say that the cock has both almond and dilute mutations in the same chromosome!. That is from (the) dam.
So in that case no need of crossover to get a dilute almond female from him...but we would need a cross over to get either just a dilute or just an almond female!

If the cocks dam is an almond and sire is a dilute , so that the cock is an almond split for dilute...that means the chromosome he got from his dam has the almond mutation and the chromosome he got from his sire has a copy of dilute....so both mutations are in diff
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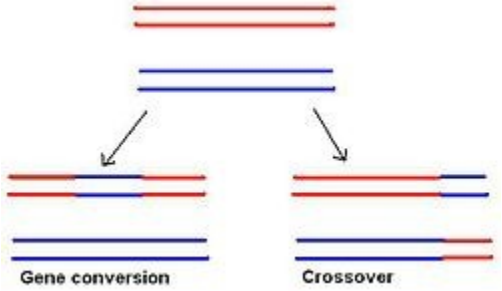
chromosomes...in this case a cross over needs to happened in order to produce a dilute almond female from him....



The difference between gene conversion and **chromosomal crossover**.

In most eukaryotes, a cell carries two versions of each gene, each referred to as an allele. Each parent passes on one allele to each offspring. An individual gamete inherits a complete haploid complement of alleles on chromosomes that are independently selected from each pair of chromatids lined up on the metaphase plate. Without recombination, all alleles for those genes linked together on the same chromosome would be inherited together. Meiotic recombination allows a more independent segregation between the two alleles that occupy the positions of single genes, as recombination shuffles the allele content between homologous chromosomes.

Recombination results in a new arrangement of maternal and paternal alleles on the same chromosome. Although the same genes appear in the same order, the alleles are different. In this way, it is theoretically possible to have any combination of parental alleles in an offspring, and the fact that two alleles appear together in one offspring does not have any influence on the statistical probability that another offspring will have the same combination. This theory of "independent assortment" of alleles is fundamental to genetic inheritance.[5] However, the frequency of recombination is actually not the same for all gene combinations. This leads to the notion of "genetic distance", which is a measure of recombination frequency averaged over a (suitably large) sample of pedigrees. Loosely speaking, one may say that this is because recombination is greatly influenced by the proximity of one gene to another. If two genes are located close together on a chromosome, the likelihood that a recombination event will separate these two genes is less than if they were farther apart. Genetic linkage describes the tendency of genes to be inherited together as a result of their location on the same chromosome. Linkage disequilibrium describes a situation in which some combinations of genes or genetic markers occur more or less frequently in a population than would be expected from their distances apart. This concept is applied when searching for a gene that may cause a particular disease. This is done by comparing the occurrence of a specific DNA sequence with the appearance of a disease. When a high correlation between the two is found, it is likely that the appropriate gene sequence is really closer.[6]

(one may say that this is because recombination is greatly influenced by the proximity of one gene to another. If two genes are located close together on a chromosome, the likelihood that a recombination event will separate these two genes is less than if they were farther apart.)

Genetic recombination happens as a result of the separation of **genes** that occurs during gamete formation in meiosis, the random uniting of these **genes** at fertilization, and the transfer of **genes** that takes place between chromosome pairs in a process known as **crossing over**.

Crossing over is the swapping of **genetic** material that occurs in the germ line. During the formation of egg and sperm cells, also known as **meiosis**, paired chromosomes from each parent align so that similar DNA sequences from the paired chromosomes **cross over** one another.

Crossing over is the exchange of genes between two chromosomes, resulting in non-identical chromatids that comprise the genetic material.

Each parent cell has pairs of homologous chromosomes, one homolog from the father and one from the mother. In meiosis, the maternal and paternal chromosomes can be shuffled into the daughter cells in many different combinations. This ensures genetic variation in sexually reproducing organisms. Further genetic variation comes from crossing over, which may occur during prophase I of meiosis.

Praveen Joy

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There you have three separate explanations of the process of a genetic "**Crossover**" .

You may have heard other terms such as (1) "Criss Cross", and (2) "Back Cross".

The first term simply describes the effect that takes place when a specific Sex-linked Trait of a female is dominant over its allele expressed by the male. All sons will resemble the female (dam) , and all daughters will be the same as the male (sire). A typical example would be a blue /Black cock mated to an Ash-Red hen:

(Blue/Black X Ash-Red = all sons will be ash red carrying blue black, all hens will be blue/Black)

The second term describes when an offspring is **bred back** to its respective parent. This may be a daughter bred back to her sire , or a son bred back to his dam. If we consider the pair above, we would have :

(Ash-Red son carrying blue/Black Back - crossed to his dam)

However if we want to show an example of a "CrossOver" , we need to add in another sex-linked trait, so let's use dilution. Only 'heterozygous birds can produce a crossover. Homozygous birds are dominant for the trait they express and do not carry a recessive allele.

Example (Blue Black Cock X Ash-Red hen that is also a dilute , thus an Ash Yellow.)

Offspring automatically will be a "criss-cross" : Ash-Red sons and blue/Black daughters but the sons will now carry dilution).
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To see the **crossover** effect we now must take one of the Sons and mate him to his dam "back-cross" or to any other ash-Yellow hen.

Example (Ash-Red carrying dilution {back cross} to his dam, or to any other ash yellow hen.)

The majority of offspring will still be expected to be Ash-Red with 25% blue/Black daughters BUT a very small number of the daughters will receive the colour gene from their sire's carried blue/Black, **now combined with** the dilution gene so that they will be silver/Duns.. indicating that a crossover had occurred in prophase 1 of meiosis .

In the case of a CROSSOVER, the birds do not have to be related or even of the same breed. The feature we are dealing with is "Linkage" of two specific traits on the Sex-Chromosome. It has been learned over the years that certain genetic traits are linked. This linkage can be broken by way of a "Crossover." The process can be rather rare, as explained by the gentlemen earlier in this Issue, the location proximity of the two specific linked traits determines the likelihood ratio of them being separated and recombined to individually express in the phenotype of the new offspring.

"Some examples of these ratios as listed in Axel Sell's Book - Pigeon Genetics - Applied Genetics in the Domestic Pigeon. are as follows: (1) The colour locus and dilution as reported by Cole & Kelly in 1919 is as low as 2%. (2) between Colour and the Stipple gene is about 3% , and between reduced and the dilution locus about 5% - Hollander 1983. "

The confusing part of this entire process is that some examples given on the net, and in Books , state that the final offspring is "THE CROSSOVER". The actual crossing over has taken place in the sperm and in the egg(zygote) and any offspring expressing the new trait combination is simply the result of fertilization., and is not the actual "cross over".

Multiple different crossovers can have taken place so that the more recessive sex-linked alleles we incorporate into our breeding stock the more complex the assortment can become. Phenotypically speaking the results also become extremely variable so that one cannot see typical results that they can rely upon when trying to follow the inheritance accurately. We often read where someone states that they have a definite crossover of several specific genes but the offspring look like a washed out specimen that could easily be just about any combination.

Accurately keeping track of the carried alleles is quite challenging especially when some alleles can be very similar to one another in phenotype.

Now we will show you a few photos of pairs that we will work with to allow a crossover created phenotype to be produced:

Pr. #1 This Cock is pure (homozygous) for intense phase base colour blue/Black. We will mate him with an Ash/Red hen that is pure (hemizygous) for her intense phase base colour allele. Their offspring will be in a reverse (criss-cross) order from that of their parents. All sons will be Ash/Red carrying blue/Black., and all daughters will be blue/Black. No "crossover" is involved . Photos are just for **colour** and may not actually be cock or hen as stated:

 X  =

 and 

So, with this above mating , you can see that the first three photos depict a range of Intense phase dominant ash/Red sons as far as base colour is concerned. All females will be intense phase blue/Black as it is dominant over the dam's dilution phase. All ash sons will carry dilution. For the sake of clarity all cock photos face left, and all hens face right for this demonstration of colour only.

We could raise young from <u>that pair</u> for their entire lives and not have a colour crossover take place.

Then we take Pr.#2, an Ash/Red son and back cross him to his dam.

 X 

If he was pure (homozygous) for ash, then he would not be carrying blue/Black or dilution, all young would be Intense phase ash/Reds regardless of sex, but in this case he is impure (heterozygous) for both blue/Black from his sire and dilution phase from his dam. Now when he fertilizes her eggs the sperm carries the crossover potential to produce a combination that normally would not happen. Along with intense blue/black daughters, Intense ash red and dilute ash cream daughters, there is a very low chance for a **<u>Silver/Dun</u>** daughter. The sons will be either Intense or dilute ash/Reds.

 and 

From this we can see that quite a few young must be raised to have that crossover reveal itself.

As I mentioned toward the beginning , there are many individual combinations and one pair may present MULTIPLE crossover possibilities. Keeping track of them in a pedigree is difficult but actually predicting them is impossible. Likewise you cannot look at a pair and tell if they have the potential for giving you a specimen that indicates a crossover had occurred. You just have to start with homozygous birds for a given trait or traits and then introduce the alleles to that or those traits. Eventually the hoped-for combination will surface.

In Jith's example above, he suggests a Cock that is not an Almond and is not dilute:

Blue series Intense phase cock X dilute (Dun) Almond hen.

 X  =

   and   

The above Intense blue/Black base **Almond sons all carry dilution from their dam** -- the daughters will all be non-almond blue series intense phase, any pattern, depicted here as blue bars.

 , if this cocks mother was a dilute almond and his father was a non-almond non-dilute, then we can certainly say that the cock has both almond and dilute mutations in the same chromosome!. That is from (the) dam.
So in that case no need of a crossover to get a dilute almond female from him...but we would need a cross over to get either **just a dilute** or **just an intense almond** female! (Jith P)

Then Jith went on to give another scenario whereby the genetics of the parents were somewhat reversed ;

"If the Son's dam is an intense almond and the sire is a dilute , so that the son is an almond split for dilute...which means the chromosome he got from his dam has the almond mutation and the

chromosome he got from his sire has a copy of dilute....so both mutations are in diff chromosomes, ...in this case a crossover needs to happened in order to produce a dilute almond female from him...."

Dilute blue/Black series cock X Intense phase blue/Black series almond hen =

and

Intense almond/ het dilution cocks and Intense blue/Black non-Almonds + dilute almond hens.

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Lastly , the traits do not have to be **sex-linked** although they may be easier to see. Autosomal genes may also be linked and may need a crossover to break that linkage . Spread factor and Pattern are linked. That is "Pattern" in the true sense of that term in pigeon jargon. Wing shield arrangement of smooth spread , Coarse spread and clumped pigments.

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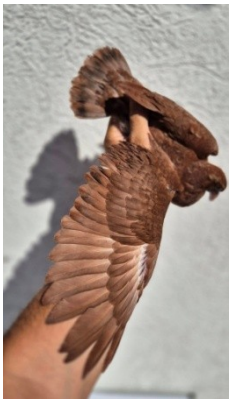
I hope that has helped clarify the topic of the crossover in Pigeon Genetics. -- Now a look at what you have been doing in your lofts over the past few years. The first two by **Porumbei Colorati** of Romania :

I have a question regarding this young bird. His mother is an extreme dilute brown. His father is believed to be ash red, heterozygous for blue, homozygous for reduced, and heterozygous for extreme dilute (with extreme dilute and ash red on the same chromosome). However, since I haven't tested his father, there's a possibility he could carry dilute instead of extreme dilute. The father is from a blue-based reduced hen and an ash red cock that is split for blue, heterozygous for dilute, heterozygous for extreme dilute, and heterozygous for reduced (with extreme dilute, reduced, and blue base color on the same chromosome).
If there was a crossover, it's possible that he could have passed down the dilute gene instead of the extreme dilute gene, along with reduced, to his son, which would be surprising but not entirely impossible.
Looking at the picture of his nephew, I can't definitively tell if he's homozygous for extreme dilute or if he's dilute heterozygous extreme dilute. However, I'm hoping that in the next round, I might get a hen that will help clarify things. What are your thoughts?

Exciting update from the aviary! I have a young male chick that seems to be a new genetic combination for me. I suspect he might be rubella hetero dilute, hetero extreme dilute. Hopefully, I'll be able to confirm this soon — the next clutch of chicks might give me the answers I need . The mother is rubella dilute . As for the father, I'm considering two possibilities: extreme dilute, hetero reduced, hetero rubella or reduced extreme dilute.

Below is a Reduced Dilute, Heterozygous Frill Stencil , Het. Brander Bronze, and a Spread factor blue/Black series Platinum Youngster. Posted by **Octavian Sarafolean** ~ Voiajori Colorati , Romania.

Then Special Brander Bronze youngsters , one Ember Brander Bronze and One brown Brander Bronze. These are part on an extensive study by **Octavian Sarafolean** into the workings of the Brander Bronze mutation and its interaction with many other mutations and colour modifiers.



Indigo x dominant opal., by **Hans Hergert**.
I have a few of these crosses in my shed and am intrigued by the wide variety of phenotypes.
This youngster catches the eye with such a soft colour. ASR.

Editor's note : Some Breeders refer to this phenotype as "Opalusian" when spread factor is involved. This bird is clearly dirty factor as shown in the beak and foot colour and may well be spread factor. It is not uncommon for Andalusians (spread factor Indigos) to express some bronzing and the Pattern may show in some instances. I have bred a number of birds with similar phenotypes . Usually the heads are darker due to the small feather tips not exposing so much basal region of each feather. That may increase in the adult feathering.

This is another youngster that **Hans** posted , Indigo plus Dominant Opal - the feet and dark head show Dirty factor (V). I think a T-Pattern as opposed to spread. This in my opinion would not be an Opalusian. Simply called Indigo Dominant Opal.

Jake Jones posted this question and photo on "Strictly Colour Genetics for Pigeons - "What's your guess on the color of this youngster? From a spread rubella cock and a het indigo velvet hen."

This drew one comment : from Archeopteryx Aviary

Looks like rubella, indigo, t-pattern. The banding on the tail makes me think rubella/indigo. Also the ticks behind the eyes says dirty female...

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Next two issues by **Hien VanGrouw** on the Doves , sorry I was unable to get anything on the colours of Senegal Doves as requested by one reader. Then I will finish out the year in December and regretfully that will be the end of the Hollander Newsletter. I have certainly enjoyed bringing it to you but it has come time to move on. Thanks for your support and encouragement !

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{Terminology not just for Pigeon Genetics} Certain atmospheric conditions can produce severe fire behavior reaching a point when the air temperature reading and the relative humidity reading will read the same (ie. Temp. 30° C , RH 30%), at this point a condition has been achieved called "CROSS OVER".}