Cockatiel Genetics

(or "What do you get when you mate a —")

Tony Barrett

Question: What do you get when you mate a —

–normal male and lutino hen?
Answer: All normals.
–pied male and cinnamon hen?
Answer: All normals.
–silver male and pearl hen?
Answer: All mormals.
–fallow male and pied-cinnamon hen?
Answer: All normals.

What's going on here? Can't cockatiels produce anything but normals? Well of course they can — when paired according to some basic genetic principles.

The purpose of this article is to introduce a simple, nontechnical method of computing offspring expectations when crossing mutations with normals or other mutations.

A simple listing of expectations is far from being practical. The possible pairings of normals, the six mutations, their splits and double splits total a tremendous number of possible combinations. Yields from some of the pairings are so diverse that memorization is next to impossible. Some pairings have a possibility of 32 (that's right, 32) genetically different offspring. (An example of this will be demonstrated at the end of this article.)

Besides the familiar normal (gray) cockatiel, to my knowledge there are six mutations: pied, lutino (commonly but erroneously called albino or white), pearl, cinnamon (or Isabel), silver, and fallow. I know of at least two others of which none have been released yet by their original breeders. Combinations of these mutations also exist. Those that I know of are pied-lutino, pied-pearl, pied-cinnamon, lutino-pearl, cinnamon-pearl, and pied-cinnamon-pearl. Others may exist, but I have not seen or heard of them.

Because this presentation will be nontechnical in nature, some liberties will be taken in descriptions and definitions. This may cause the competent biologist to have a heart attack or at least palpitations. If we must sacrifice a biologist or two for the sake of clear communication, then so be it.

Let's start out with a few definitions.

Genes are the controlling "chemicals" that direct an individual bird to look and act the way it does. They are inherited from the parents and passed on to the offspring thus establishing a pattern passed on from generation to generation. The only genes we are going to concern ourselves with here are those that affect color.

Mutations occur when there is a spontaneous alteration in the genetic code. This alteration took place for each one of the cockatiel color mutations we know.

Chromosomes are the "buckets" in which the genes are carried. The male's sperm and female's ovum both contain many chromosomes each carrying those mysterious genes. Chromosomes are friendly little creatures who detest loneliness. For this reason, they always travel in pairs.

Split is a term used to define a bird which carries the genes of a specific mutation yet does not display the color pattern of that mutation.

Genes for a mutation are inherited by one of two modes — "simple recesive" or "sex-linked".

Simple recessive mutations may be reproduced without regard for the sex of the mutant parent. Sex-linked mutations are carried on the male chromosome and offspring from pairings of mutation and normal or other mutation will differ according to which parent is the male and which is the female.

Here are the modes of inheritance for the basic mutations:

Simple Recessive	Sex-linked
Pied	Lutino
Silver	Pearl
Fallow	Cinnamon

Pied, silver and fallow are "recessive" to normal; or to put it another way, normal is dominant over these mutations. Hence, crossing a simple recessive with a normal will produce all normal appearing birds (split for the mutation).

Genes which ar responsible for transmitting parental characteristics to offspring are carried on a chromosome. Chromosomes travel in pairs. Conception requires one chromosome from the male parent's sperm and one from the female parent's ovum.

For simple recessive offspring prediction, let's use a capital "N" to denote a dominant normal chromosome and lower case letter for a recessive chromosome ("p" for pied, "s" for silver and "f" for fallow).

A normal which is not split for any mutation will have the chromosome pairing of NN; a pied - pp; silver - ss; and fallow - ff.

If we mate a normal (NN) with a pied (pp), all offspring will have one chromosome from each parent (one N and one p). Hence, all offspring will be Np — that is, half normal and half pied. However, since pied is recessive to normal, the offspring will be normal in appearance and split for pied. This may be diagrammed as:

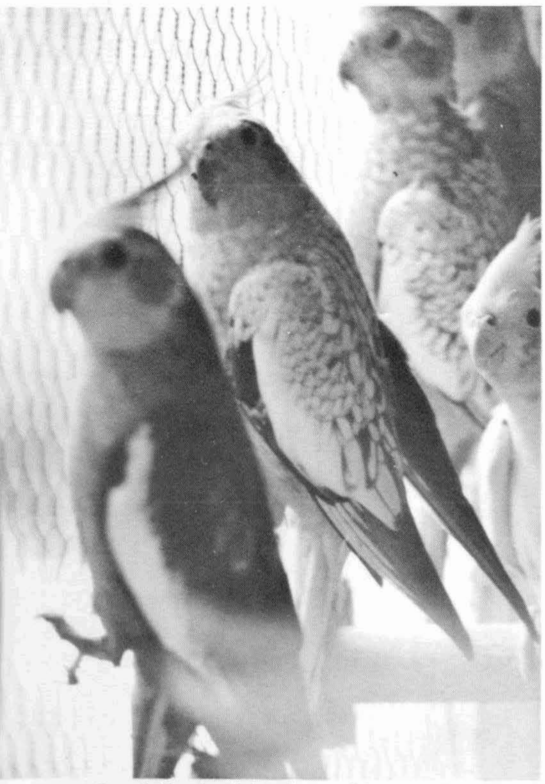
One parent's chromosome pair	The other parent's chromosome pair

Offspring chromosome pairing #1
Offspring chromosome pairing #2
Offspring chromosome pairing #3
Offspring chromosome pairing #4

-or-

$N_1 N_2$	$p_1 p_2$

$N_1 p_1$
$N_1 p_2$
$N_2 p_1$
$N_2 p_2$



Pearl Cockatiels about 11 months old. Female (right) retains lacing while male (left) looses wing lacing at maturity.

Subscript numbers are assigned to each unique letter only to show which parental chromosome paired with which. Also note that even though all offspring were Np (normal split for pied), there were four separate pairings of chromosomes.

Now let's mate a normal split for pied (Np) with a pied (pp) and see what we get.

$N p_1$	$p_2 p_3$

$N p_2$
$N p_3$
$p_1 p_2$
$p_1 p_3$

Result: an average of 50% normal split for pied (Np) and 50% pied (pp). How about pairing up two normals both of which are split for pied (Np)? Will we get any pied young? Let's see.

$N_1 p_1$	$N_2 p_2$

$N_1 N_2$
$N_1 p_2$
$p_1 N_2$
$p_1 p_2$

Yup. We got 25% pieds (pp). We also got 25% pure normal (NN) and 50% normal split for pied (Np and pN). A word of caution about averages is in order at this point. The above expectations are only accurate for a large sampling. One clutch of four young could be far from the calculated average.

If silver or fallow is substituted for pied in all the foregoing matings. the results are exactly the same.

Now let's have a look at the sex-linked mode of inheritance.

Male sperm and female ova have many pairs of chromosomes, each carrying genes which determine color, size, temperament, and all the other characteristics that make a bird look and act the way it does. However, there is a unique pair from each parent that determines the sex of the offspring. Sex-linked mutations are those mutations whose color pattern genes are passed along on the sex determining chromosomes.

For conception to take place, one of the male's sex chromosomes must pair with one of the hen's. A single chromosome referred to as "X" is a male chromosome; a single chromosome referred to as "Y" is a female chromosome. Female birds are conceived when an X (male) and Y (female) chromosome are paired; males when two X's are paired. Therefore, XX=male and XY=female.

Note that human males are XY and females XX. Be advised that human and avian sex chromosomes are exactly opposite.

All cockatiel sex-linked mutations are recessive and the mutant genes carried only on the X chromosome. The Y chromosome plays no part whatever in passing the mutant genes on to the next generation. Therefore, a female will take on the appearance of a given mutation with only the X being mutant because of the absence of another normal X to dominate the recessive mutant chromosome.

Unlike the simple recessive mode, pairings involving sex-linked mutations will produce offspring in a different assortment depending upon the sex of the mutant parent.

For the sex-linked mode, let's use this diagram:

Male parent chromosome pair	Female parent chromosome pair
Male offspring pairing #1	Female offspring pairing #1
Male offspring pairing #2	Female offspring pairing #2

-or-

$X_1 X_2$	$X_3 Y$
$X_1 X_3$	$X_1 Y$
$X_2 X_3$	$X_2 Y$

As in the simple recessive diagrams, the subscript numbers are used here only to show which X paired with which other chromosome. Note that there are only four possible pairings — two male and two female. Be sure to understand this diagram and how the offspring pairings were derived because subsequent diagrams will omit the subscripts to avoid clutter.

The exponent "N" will be use to identify a normal male chromosome (X^N); "L" for lutino (X^L); "P" for pearl (X^P); and "C" for cinnamon (X^C). Here are some examples: pearl male=$X^P X^P$; lutino female=X^L Y; normal male=$X^N X^N$; cinnamon female=X^C Y.

How about starting out with a mating of normal male & lutino hen:

$X^N X^N$	$X^L Y$
$X^N X^L$	$X^N Y$
$X^N X^L$	$X^N Y$

All the female offspring are normal (X^N Y); looks like the mutant lutino chromosome got lost in the shuffle. That's right, it did as far as the females are concerned. However, the male offspring chromosome

Photos by Tony Barrett

Pied-Pearl Hen. Note the degradation in lacing in the pied-pearl as compared with normal pearls.

pairs are half normal and half lutino ($X^N X^L$); or as we said before, normal in appearance but split for lutino. (The dominant normal masked the recessive lutino.)

If the sex of the parents is reversed so that the male is lutino and the hen normal, the offspring expectations change to:

$X^L X^L$	$X^N Y$
$X^L X^N$	$X^L Y$
$X^L X^N$	$X^L Y$

Son-of-a-gun. Now all the female offspring are lutino (X^L Y) instead of normal (X^N Y). However, the males are still normal split for lutino ($X^L X^N$).

Pairing a normal split for lutino male with a lutino hen will produce:

$X^N X^L$	$X^L Y$
$X^N X^L$	$X^N Y$
$X^L X^L$	$X^L Y$

Looks like 25% normal split for lutino males ($X^N X^L$); 25% lutino males ($X^L X^L$); 25% normal females (X^N Y); and 25% lutino females (X^L Y).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OK, so much for mutation × normal matings. Now let's look at mutation × mutation. A lutino male mated with a cinnamon hen looks like this:

$X^L X^L$	$X^C Y$
$X^L X^C$	$X^L Y$
$X^L X^C$	$X^L Y$

All female offspring are lutino but what are those males? One chromosome is

Pied Cockatiels. Young males displaying their wing color pattern.

lutino and one cinnamon — so what do they look like — lutino or cinnamon? Sorry, neither. They will be normal in appearance and split for both lutino and cinnamon. These males are called "double splits".

Going a step further, a double split male mated with a cinnamon hen produces:

$X^L X^C$	$X^C Y$
$X^L X^C$	$X^L Y$
$X^C X^C$	$X^C Y$

The yield is 25% normal males split for both lutino and cinnamon, 25% cinnamon males, 25% lutino females, and 25% cinnamon females.

By now, we should have the diagramming down pretty well, so let's take a crack at a mating involving all three sex-linked mutant chromosomes. Since we already have a double split male from the previous mating (split for lutino and cinnamon), let's pair him up with a pearl hen and see what we get.

$X^L X^C$	$X^P Y$
$X^L X^P$	$X^L Y$
$X^C X^P$	$X^C Y$

We produced all normal appearing males because none have both chromosomes of the same mutation. Half of the males are double split for lutino and pearl and the other half for cinnamon and pearl. Half of the female offspring are lutino and the other half cinnamon — no pearl.

Earlier, the pearl-lutino and cinnamon-pearl were mentioned. Try diagramming the combination to produce these sex-linked cross-mutations. What's that you say? Can't happen? You're right, it can't happen — with the usual pairing of chromosomes as demonstrated to this point. The closest you can come are double split males.

On rare occassion, the mutant gene carried on one X chromosome of a double split male can transfer over to the other X chromosome to combine both mutant genes on the same chromosome. When this happens, the donor X becomes void of the mutant gene and will produce young as a normal X^N chromosome.

For example, the sperm of a normal male double split for pearl and lutino would normally be expected to contain all $X^P X^L$ pairs. However, a very few unstable pairs could have kicked the L loose from its host X chromosome. The other X chromosome already containing P genes picks up the loose L. Hence, these unstable pairs now look like X^{PL} X instead of $X^P X^L$. This transferrence is termed "crossing over" of a mutant gene. Note that the reverse cross-over (where the P instead of the L is kicked loose) is equally possible (X X^{LP}).

If we are fortunate enough to have one of the crossed-over X^{PL} X pairs involved in conception, we could produce a lutino-pearl female or male split for lutino-pearl. However, every silver-lined cloud also has a black lining. There is an equal probability that the voided donor X could fertilize the ovum instead of the X^{PL}. In that case, all traces of both the pearl and lutino mutant genes are lost.

To demonstate this phenomenon, let's diagram a double split male (pearl and lutino) mated with a normal hen.

$X^P X^L$	$X^N Y$
$X^P X^N$	$X^P Y$
$X^L X^N$	$X^L Y$

— plus four more possibilities from crossed-over pairs —

$X^{PL} X^N$	$X^{PL} Y$
$X X^N$	$X Y$

Note that two of the cross-over possibilities result in just plain normal males and females (X X^N and X Y). However, two other possibilities result in pearl-lutino females (X^{PL} Y) and normal appearing males split for pearl-lutino ($X^{PL} X^N$) — not to be confused with split for pearl *and* lutino ($X^P X^L$).

Now that we have both a male split for pearl-lutino and a pearl-lutino hen, we can go to work and produce pearl-lutino males.

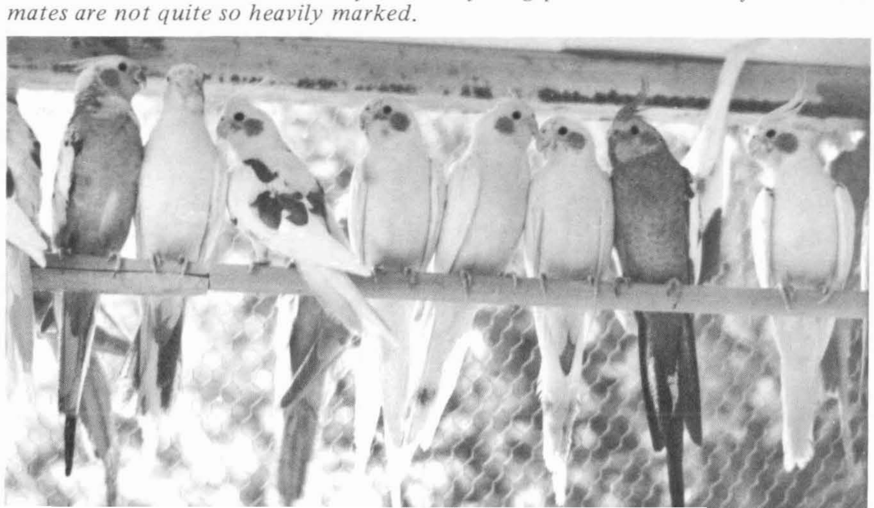
$X^{PL} X^N$	$X^{PL} Y$
$X^{PL} X^{PL}$	$X^{PL} Y$
$X^N X^{PL}$	$X^N Y$

From this we can see that our offspring expectations are:

25% pearl-lutino males ($X^{PL} X^{PL}$)
25% normal split for pearl-lutino males ($X^N X^{PL}$)
25% pearl-lutino females (X^{PL} Y)
25% plain old normal females (X^N Y)

Now that we are all smarted up and can handle simple recessive, sex-linked and cross-over diagramming, let's go for the biggie — a diagram involving all three of the above. Further, let's include all six of the mutations in addition to normal just to

Pied Cockatiels. With the exception of the 11 month old pearl male (second from right) and the very sparsely marked pied-pearl male (extreme left), all of these cockatiels are extra-heavily marked young pied males. Their female nest-mates are not quite so heavily marked.



Photos by Tony Barrett

make it interesting. Sounds complicated? Not so. It is really quite simple when taken in steps.

Earlier, it was stated that 32 genetically different offspring were possible from one mating. This is it. For this demonstration, we will use a normal male double split for pearl and lutino (sex-linked — $X^P X^L$) and further, split for silver (simple recessive — N_s). He will be mated with a cinnamon hen (sex-linked — $X^C Y$) split for both pied and fallow (simple recessive — pf).

Let's diagram this one step at a time. First the sex-linked possibilities —

$X^P X^L$	$X^C Y$
$X^P X^C$	$X^P Y$
$X^L X^C$	$X^L Y$

— and then the crossover possibilities —

$X^{PL} X^C$	$X^{PL} Y$
$X X^C$	$X Y$

— and now the simple recessive pairings —

Ns	pf
Np	
Nf	
sp	
sf	

The first male offspring in the sex-linked diagram (the $X^P X^C$) has four simple recessive possibilities — those shown in the simple recessive diagram. He can be

$X^P X^C$ - Np or
$X^P X^C$ - Nf or
$X^P X^C$ - sp or
$X^P X^C$ - sf

The other seven sex-linked offspring each have the same simple recessive possibilities just demonstrated for the first male offspring.

Now let's put the whole works together in one diagram:

$X^P X^L$ - Ns	$X^C Y$ -pf
$X^P X^C$ -Np	$X^P Y$ - Np
$X^P X^C$ - Nf	$X^P Y$ - Nf
$X^P X^C$ - sp	$X^P Y$ - sp
$X^P X^C$ - sf	$X^P Y$ - sf
$X^L X^C$ - Np	$X^L Y$ - Np
$X^L X^C$ - Nf	$X^L Y$ - Nf
$X^L X^C$ - sp	$X^L Y$ - sp
$X^L X^C$ - sf	$X^L Y$ - sf
$X^{PL} X^C$ - Np	$X^{PL} Y$ - Np
$X^{PL} X^C$ - Nf	$X^{PL} Y$ - Nf
$X^{PL} X^C$ - sp	$X^{PL} Y$ - sp
$X^{PL} X^C$ - sf	$X^{PL} Y$ - sf
$X X^C$ - Np	$X Y$ - Np
$X X^C$ - Nf	$X Y$ - Nf
$X X^C$ - sp	$X Y$ - sp
$X X^C$ - sf	$X Y$ - sf

Cinnamon vs. Normal Pearl. Cinnamon-pearl female (left-center background); normal-pearl female with rather limited lacing (right background). The two perched birds (left and right foreground) are young pied females.

This accounts for the 32 genetically different offspring. Simple, huh?

That's it; we are all through. You are now an expert at computing cockatiel offspring expectations. If you don't feel like an expert, then go back and re-read and practice a few simple recessive and sex-linked diagrams. When you feel comfortable with that, try a pairing or two to show crossover. (How do you get a cinnamon-pearl?) Then work on the steps necessary to combine a sex-linked and simple recessive mutation. (How many generations are required to come up with a pied-cinnamon-pearl when the first mating involves a cinnamon male and pearl hen?)

With enough practice, you will discover that at least the simpler pairings can be worked out mentally without ever touching a pencil.

Just think, now that you have the tools to work with you can start a program to come up with your very own pied-silver-fallow-lutino-pearl-cinnamon cockatiel. (I wonder what that would look like?) ■