

Genetics for the Novice

by Carol Barbee

Wait! Don't leave yet. I know that for many breeders any article with the word genetics in the title causes an immediate negative reaction. Either they quickly turn the page and pretend they didn't see it, or they drop the magazine and flee from the room in terror. But this article is written especially for those people. It is for you - the one who always thought that genetics was too complicated, too full of big words and funny symbols for the average person to understand. Anyone who is serious about breeding a better cat needs a basic knowledge of genetics. The key word, though, is basic. It may be interesting to know all of the ins and outs of genetics and to be able to rattle off a whole page of symbols to describe your cat. But unless you are going to work on developing a new breed it really isn't necessary. The purpose of this article, then, is to present the fundamentals of genetics in layman language without any more of the big words and symbols than are absolutely necessary. Ready? Take a deep breath and let's begin.

Every living body, including a cat's, is made up of a bunch of cells. Each one of those cells contains the chemical code for all of the characteristics in the whole body - every characteristic from eye color to liver size to number of toes. Inside of each cell are some long wormy looking things called chromosomes. At certain times you can see these chromosomes inside of the cell by using a microscope. All individuals of a particular group of animals have the same number of chromosomes in their cells. All humans have 46 chromosomes; all crayfish have 200; all domestic cats have 38. Each characteristic which an individual possesses has its own chemical code which is contained in a unit called a gene. There is a gene for coat color, a gene for tail length, a gene for intestine length, a gene for every one of the thousands of intricate characteristics which make up an individual animal. The genes are located on the chromosomes. A chromosome carries many different genes on it and a particular gene is always located in the same place on the same chromosome.

All of the chromosomes in a cell are arranged in pairs. The two chromosomes in a pair have genes on them for the same characteristics. Therefore, every cat has two genes for every characteristic that he possesses. For example, a cat has two genes which each control hair length. One of these genes may be a chemical code which makes the hair long; the other may be a code which makes the hair short. Or, they could both be for long hair or both be for short hair. Obviously, both genes cannot operate and control a characteristic if they are different. One of them must be stronger than the other and produce the characteristic according to its code. In the majority of cases this is exactly what happens. The strongest gene is called dominant; the weaker gene is called recessive. In cats, the gene for short hair is dominant over the gene for long hair. Therefore, a cat which has one gene on the chromosome pair for long hair and the other gene for short hair will have short hair. In order for a cat to have long hair it must possess both genes for long hair. There must be two recessive genes present for a recessive characteristic to show. A great many genes with which we have to deal in cat breeding are either dominant or recessive to the other gene in the pair. Occasionally, however, we run into something called incomplete dominance. In this case, neither gene in the pair is strong enough to be completely dominant over the other. When this happens the characteristic appears as something different than either gene would have made it alone. For example, in cattle, a cow may have one gene for white coat color and one gene for red coat color. Neither of these genes is completely dominant and the cow will have red and white hairs mixed in the coat. An example of this in cats is the mink color in Tonkinese and other breeds. Mink color is produced when the cat has one gene for siamese pattern and one gene for burmese pattern. Neither gene is dominant and an in between color appears.

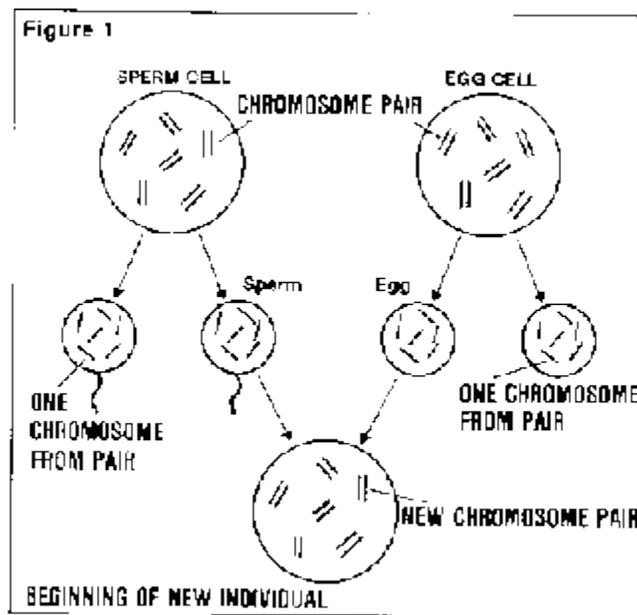
Now then. You are probably wondering about the characteristics which have more than two different ways of appearing, and many characteristics do. We have learned that a gene for a particular characteristic is always located in the same place on the same chromosome. And we have learned that, because of the fact of chromosome pairs, there are always two genes present for each characteristic - no more and no less. All of the genes which produce alternate forms of the same characteristic are called alleles. If there are more than two gene alleles for one characteristic it is called an allele series. However, no matter how many alleles there are in an allele series, only two of them can be present at the same time. Let's take an example. There is an allele series which controls the distribution of color pigment in a hair of the cat. The genes in this series are as follows: full color, burmese, siamese, albino. It is only possible for a cat to have two of these alleles at one time. If the full color gene is present it will be

dominant over any of the others. If the albino gene is present it will be recessive to any of the other alleles. If, however, the siamese gene is present it will be recessive to the full color gene but dominant over the albino. Remember, of these four genes, no more than two can be present in one cat because they are all located in the same place on the same chromosome pair.

How do you know whether a gene is dominant or recessive to another gene? How do you know how many gene there are in an allele series? All of this is found out by doing experimental breedings. It takes a long time and a whole lot of breedings to find out for sure about a gene. If you flip a coin five times it may come up heads every time and you may be tempted to say that the coin has two heads. But if you flip it one hundred times you will get very close to fifty per cent heads and fifty per cent tails. The same is true in cats. It takes a lot of kittens to make a definite statement about a gene. Most breeders are content to get their information from books or from more experienced breeders.

Now you know a little about genes and chromosomes and how they determine which characteristics a certain cat will possess. But in cat breeding we are concerned with the characteristics that a cat passes on to its offspring.

All of the cells in a cat's body are capable of reproducing themselves. When an ordinary cell, say one in the cat's ear, is ready to reproduce itself each one of the chromosomes in the cell makes an exact copy of itself. For a short time the cell contains two complete sets of chromosomes. Then the cell splits in half and one complete set of chromosomes goes into each half. When the split is finished you have two identical cells. However, the cells which make the sperm in the male and the egg in the female do not reproduce in this manner. (See figure I) When a cell which will eventually be a sperm or an egg is ready to divide to make two cells it does not duplicate its chromosomes first. Instead, one chromosome from each pair stays in the old cell. The two cells produced from this division each have only one half of a complete set of chromosomes. Remember that this happens with both the sperm cells and the egg cells. When a sperm joins with an egg to make the first cell in a new kitten embryo, the half set of chromosomes from the egg and the half set of chromosomes from the sperm make a complete set again. The new cell will have a complete set of chromosomes, half obtained from its mother and half obtained from its father, which it will duplicate to make the billions of cells necessary to produce a living kitten. The chemical code carried by the genes on those chromosomes will be what determines the characteristics possessed by the new kitten.



We have learned, in talking about dominant and recessive genes, that a cat may have a gene in its genetic makeup which does not show in its physical makeup. A short hair cat can have a recessive gene on the other chromosome in the pair for long hair. Therefore, a cat can pass on a characteristic to its offspring which in itself does not physically possess. Let us suppose, for example, that we have a male short hair cat who carries the recessive gene for long hair.

When a cell from his body splits to make two sperm, one of these sperm will have the gene for short hair and the other sperm will have the gene for long hair. If the sperm with the long hair gene should join with an egg that also carries long hair then a long hair kitten will be produced. Which sperm gets which gene and which sperm joins with which egg is strictly a matter of chance. If a sperm carrying short hair joins with an egg carrying short hair then a short hair kitten will result which will never have a long hair offspring, since it carries no gene for long hair. A cat cannot pass on a characteristic which it does not possess in its genetic makeup. Bear in mind, however, that a recessive gene can be passed along for many generations and until it meets another recessive like it that characteristic will not show up physically. In order for you to be certain that a particular cat does not carry a particular recessive gene you must mate it to a cat which you know does carry that recessive gene. If, after several litters, that characteristic has not shown up, you can assume that the cat does not carry it.

The kitten pictured in figure 2 is the result of a cross between a Siamese and a Cornish Rex. This kitten carries the gene for the Siamese pattern and a gene for the Rex coat. However, since both of these genes are recessive, neither characteristic is visible. With the proper breeding this kitten will produce both Siamese patterned and Rex coated kittens.

Figure 2



It was said before that the two chromosomes in a chromosome pair are identical to each other. There is exception to this rule - the chromosome pair which determines the sex of an individual. In this pair there can be different types of chromosomes. One chromosome is normal in appearance and is designated as the X chromosome. The other is short and crooked and is designated as the Y chromosome. If an individual has two X chromosomes it will be a female. If it has one X and one Y it will be a male. It is obviously impossible for an individual to have two Y chromosomes since one chromosome comes from each parent and the mother can only give an X.

The sex chromosomes carry genes for determining various body characteristics just as the other chromosomes do. However, since the Y chromosome is abnormal in shape, its genes do not completely match those on the X chromosome.

Characteristics which are controlled by genes located on the X and Y chromosomes are called sex linked. In cats, color is sex linked. The gene for red or black pigment is located on the X chromosome and there is no color gene on the Y chromosome. If a cat has one X with the gene for black pigment and one X with the gene for red pigment she will be a tortoiseshell. A special mechanism controls which color each cell will produce when both are present. A male cannot be tortoiseshell because his X chromosome will carry either the red or the black gene, not both, and the other allele is not present on the Y chromosome.

Occasionally a tortoiseshell cat with male characteristics is reported. These cats usually have an extra X chromosome in addition to the usual X and Y. This extra chromosome could carry the other color; it also would almost always make the cat sterile.

Obviously, then, things do sometimes happen with genetics which don't follow the rules. Even though you may know all that is possible about your line, a kitten may suddenly appear with a new characteristic, or with a characteristic in combination with another that has not occurred before. There are a number of causes for this. Sometimes a piece of a chromosome breaks off and is lost or attaches itself to another chromosome. Sometimes

there is a mistake when the cell splits and the chromosomes don't all go in the proper place. Sometimes the chemical code in a gene changes spontaneously. This last occurrence is called a mutation and is the most well known of genetic changes. An example of a mutation in cats is the Rex. Mutations are permanent and breed true. Most mutations, however, do not produce results as dramatic as that of the Rex mutation.

It should be kept in mind that a great many characteristics are produced by several genes working together. A blue smoke cat, for example, must have one gene to make black pigment, another gene to change the black pigment to make it appear as blue, and another gene to make the pigment occur only in the upper part of the hair. If any one of these genes is not present the cat will not be a blue smoke.

Genetics is not yet an exact science and there is still much to learn about it, even though geneticists are learning more each day. The areas covered here, however, have been long tested and proven reliable. By studying basic genetics and using it in your breeding program you should be able to develop the characteristic you want in your cats

GENETICS GLOSSARY

Allele: One of a series of genes which are alternative to each other because they are situated at the same locus. Each chromosome normally carries only one allele of the series.

Autosome: Any chromosome other than a sex chromosome (X or Y).

Crossing over: The exchange of parts between homologous chromosomes leading to the separation of linked genes. Causes unexpected results in the offspring.

Dominant: Having a visible effect in single dose (i.e. when heterozygous)

Epistatic: A gene is epistatic over another non-allelic gene when it masks its visible effects.

F1: The offspring resulting from crossing members of the parental generation.

F2: The offspring resulting from intercrossing members of the F1 generation.

Feral: Referring especially to wild forms of domesticated species.

Genome: Sets of chromosomes, with respect particularly to genetic information contained therein.

Genotype: The genetic makeup of an organism .

Heterozygous: The two alleles at a particular locus are different.(ex Aa)

Homozygous: The two alleles at a particular locus are the same.(ex. AA)

Linkage: Genes are on the same chromosome and therefore stay together during cell division unless separated by crossing over.

Locus: The place on a particular chromosome where the gene under consideration is located.

Monogenic: Under the control of a single gene.

Phenotype: The appearance of an organism with respect to the characteristics under consideration. Animals of the same phenotype may have different genotypes.

Polygenic: Many genes, each producing a small effect, work together to produce a characteristic.

Recessive: Without a visible effect unless homozygous.

Wild type: The normal form of an organism or gene, typical of the species in the wild. The wild type allele at any locus can be denoted by +.

Zygote: A fertilized egg.

This glossary taken, in part, from Comparative Genetics of Coat Colour in Mammals, Searle, A.G., 1968, Logos Press, London