

Two tiny cells are the only links of inheritance an animal has with its parents. A sperm cell from the sire and an egg cell from the dam unite and grow into the new animal.

We know, therefore, that any characteristics inherited from the parents must come from these two cells. With good care and good nutrition, the material in the sperm and egg will determine almost everything about the developing animal - its size, its shape, its color, even is intelligence.

The study of how characteristics are passed from parents to offspring is the science of genetics. It's easy to see why genetics is important to horse breeders. In trying to understand the mysteries of inheritance, geneticists learn things which help to produce better horses.

## GENES AND CHROMOSOMES

Inside the cells of animals are certain complex chemical compounds. These substances are the carriers of inheritance. They are called genes and chromosomes.

Chromosomes are long, thread-like structures made of complex protein. They can be seen with a microscope. In all body cells except the sperm and the egg, chromosomes exist in pairs.

Each cell contains a certain number of chromosome pairs, depending upon the animal. Man has 23 pairs of chromosomes in each of his cells. Here are the number of chromosome pairs for farm animals.

Horses	33	Pigs	19
Cattle	30	Sheep	27
Goats	30	Chickens	6

Strung along the chromosomes, somewhat like beads on a string are genes. Genes consist of complex molecules. They are chemically

linked to the protein of the chromosome. Genes are too small to be seen with a microscope. But other research methods tell us they are there.

Genes are the units of inheritance. Characteristics are passed from parents to offspring through genes. Genes are the "brains" of the cell. They determine what the cell will be like. This, in turn, determines what the body will be like.

Since chromosomes come in pairs, so do genes. Two genes exist side by side, each on one of the chromosomes in the pair. The total number of genes on a chromosome is not known, but they are many. And different chromosomes have different numbers of genes.

The unique thing about genes and chromosomes is that they are able to reproduce themselves.

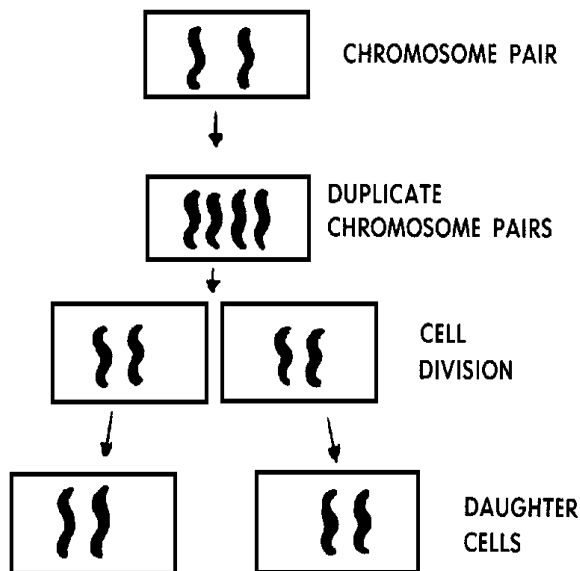
As an animal grows, cells divide and form two. Before the cell divides, each chromosome duplicates itself. When the cell divides one of the duplicates moves into each of the two new cells. So the two new cells have exactly the same kind and number of chromosomes. This type of cell division is called mitosis.

## CHROMOSOMES IN SEX CELLS

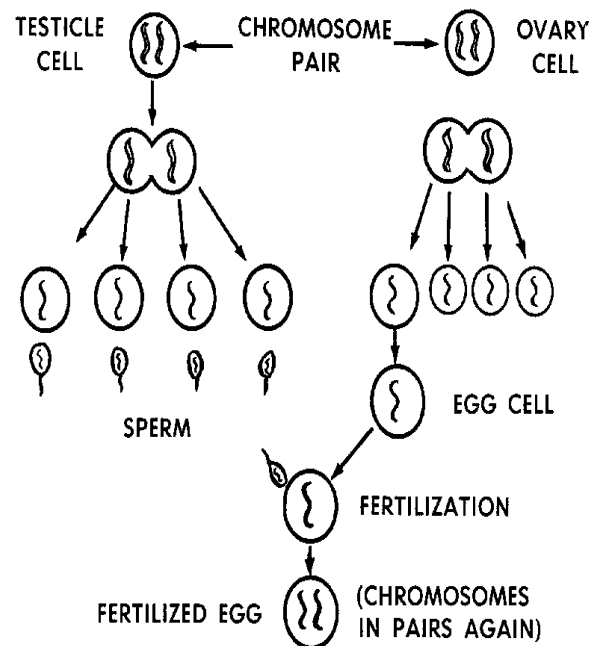
Genes and chromosomes act somewhat differently when sperm cells and egg cells are formed. In the testes of the male and in the ovaries of the female, cell division happens another way.

The chromosome pairs separate, one member of each pair going to one new cell and the other member going to the other new cell. As these cells divide again, the single chromosomes form duplicates which go into each of the new cells. This makes the sperm or the egg contain only a single chromosome of each original pair of chromosomes. This type of division is called meiosis.

### NORMAL CELL DIVISION (MITOSIS)



### SEX CELL DIVISION (MEIOSIS)



In horses, the sperm from the stallion and the egg from the mare each contain 33 single chromosomes instead of 33 pairs. Because of the way chromosomes separate at meiosis, millions of different kinds of sex cells can be produced by one animal.

When fertilization occurs, the single chromosomes from the sperm join the single chromosomes in the egg. Once again pairs are formed. So the fertilized egg contains the same number of chromosome pairs as the cells of the parents.

This fertilized egg develops into a new individual, resembling each parent in some ways, yet different from them both. And probably different from any other individual in the world, since the slightest difference in gene make-up would make a difference in the animal.

### Dominant and Recessive Genes

Most characteristics are determined by several pairs of genes. For this reason it is impossible to tell exactly what an unborn animal will look like.

A few characteristics, however, are determined by only one pair of genes. Black and red coat color in horses is one example. By studying characteristics such as this, we can learn something about how inheritance works.

One pair of genes causes the coat to be either black or red, depending on which particular combination of the two genes is present. There is one gene for black and a corresponding gene (allele) for red. The horse will be black if he has two black genes or if he has one black gene and one red gene. This is because the black gene is dominant. The horse will be red only if he has two red genes.

Here's how the genes combine. Let the capital B represent the black gene. We use the capital because black is dominant. Let the

small b represent the red gene. Since genes come in pairs, a horse could have two black genes (BB), one black and one red gene (Bb), or two red genes (bb). A black horse could have either BB or Bb genotype. (Genotype means genetic makeup.) A red horse would have bb genotype. The gene for red (b) is recessive to the dominant gene for black (B).

Consider this problem: A red (chestnut) mare (bb) is bred to a truly black stallion (BB). What color will the foal be?

As the genes and chromosomes divide in the mare's ovaries, the bb genes separate. Each egg contains one b gene. Likewise, each sperm from the stallion contains one B gene.

When the sperm and egg unite, two genes influencing coat color are again present. The genotype of the foal will be Bb. Since the B gene for black dominates the b gene for red, the foal will be black.

His phenotype (outward appearance) will resemble the stallion. Both would be black. But their genotypes are different. The foal is Bb and the stallion is BB.

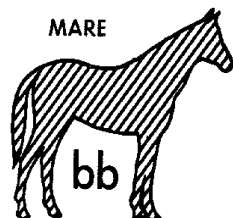
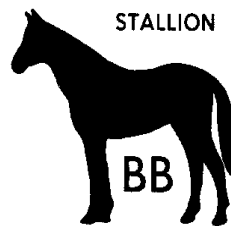
What then would happen if a black stallion that had a Bb genotype were bred to a red (bb) mare?

Two possible kinds of sperm would be produced by the Bb stallion. Half of the sperm would have the B gene and half would have the b gene.

It would be a 50:50 chance whether the B sperm or the b sperm united with the b egg from the mare. The genotype of the foal would be either Bb or bb. Thus half the foals from such a mating would be black and half would be red.

Suppose a Bb stallion were mated to a Bb mare. Both the mare and the stallion would be black, but both would carry a recessive gene (b) for red. Half the sperm would carry the B gene. Half the sperm would carry the b gene. The same would be true for the eggs.

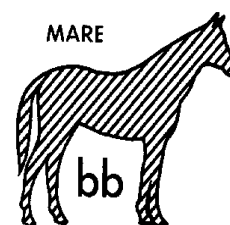
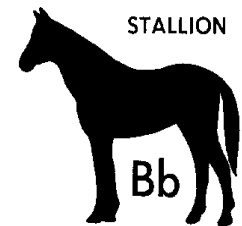
MATING OF  
BLACK  
STALLION (BB)  
TO RED MARE (bb)



Bb	Bb
Bb	Bb

ALL FOALS WOULD BE BLACK WITH A  
RECESSIVE GENE FOR RED (Bb)

MATING OF  
BLACK  
STALLION (Bb)  
TO RED MARE (bb)



Bb	bb
Bb	bb

HALF THE FOALS WOULD BE RED (bb)  
AND HALF WOULD BE BLACK (Bb)

Chances are 25 percent that the foal would have the BB genotype, 50 percent that it would have the Bb genotype, and 25 percent that it would carry the bb genotype.

Theoretically, of 100 such matings were made, 75 of the foals would be black. Twenty-five would be red. Of the 75 black foals only 25 would be truly black (BB) and 50 would carry a recessive red gene.

What would happen if a red (chestnut) stallion were bred to a red (chestnut) mare? In this case all the eggs and all the sperm would carry the b gene. All foals from such matings would be red.

There are also several other pairs of genes that control other coat colors in horses. The many possible combinations of these genes cause the many different color patterns we see.

### INHERITANCE OF SEX

We can use a similar analysis to show how the sex of a foal is determined.

In horses, there is one pair of chromosomes which does not exactly match. One is called the x chromosome and the other, the y chromosome. Stallions have one x and one y chromosome. Their sex genotype is xy. Mares have two x chromosomes. Their genotype is xx. (The small letters x and y do not indicate that either is dominant or recessive.)

In reduction division in the stallion, half the sperm contain an x chromosome and half contain a y chromosome. In the mare all egg cells contain x chromosomes.

If a sperm carrying an x chromosome fertilizes the egg, the foal will have xx genotype. It would develop as a female. If a sperm

carrying a y chromosome happens to fertilize the egg, the foal would be xy. It would be a stallion.

The chances are 50:50 for the foal to be male or female.

### COMPLICATIONS

So far we have seen how inheritance works in its simplest form. This basic system forms the pattern for all inheritance. Complications arise where characteristics are influenced by more than one pair of genes.

Most of the important traits in horses, such as conformation, temperament, physical performance, size, muscularity, and longevity, are influenced by many genes. With 33 pairs of chromosomes and hundreds of genes involved, it is impossible to know a horse's complete genotype.

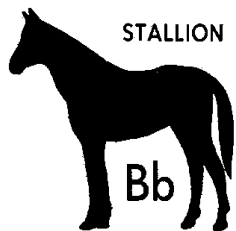
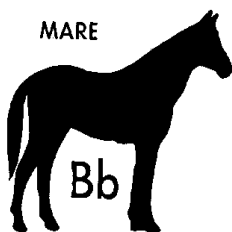
Furthermore, all gene pairs do not work as completely dominant and recessive. We see this in certain kinds of flowers. When the red flowering plants pollinate a white flowering plant, the flowers on the new plant are pink instead of red or white. In horses, the palomino color pattern is similar to this.

Finally, many things besides the genetic make-up affect a horse. He may have the genes for running fast, but unless he is fed properly, well-trained, and protected from injuries he may never win a race.

A horse with genes for just average temperament that is properly cared for may have a better disposition than one with good genes that is treated badly.

Much remains to be learned about inheritance in horses. The present-day popularity of horses should provide the incentive for further scientific study in this field.

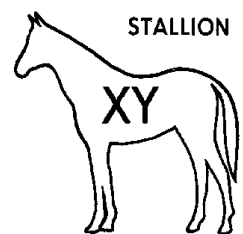
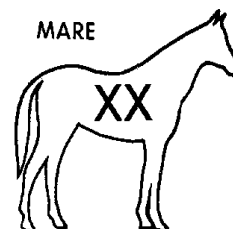
MATING OF  
BLACK  
STALLION (Bb)  
TO BLACK MARE (Bb)



BB	Bb
Bb	bb

ONE-FOURTH OF THE FOALS WOULD BE PURE BLACK (BB). ONE FOURTH WOULD BE RED (bb). HALF WOULD APPEAR BLACK BUT CARRY THE RECESSIVE GENE FOR RED (Bb)

HOW SEX IS  
DETERMINED



X X	X Y
X X	X Y

ONE-HALF OF THE OFFSPRING WOULD BE FEMALE AND ONE-HALF WOULD BE MALE