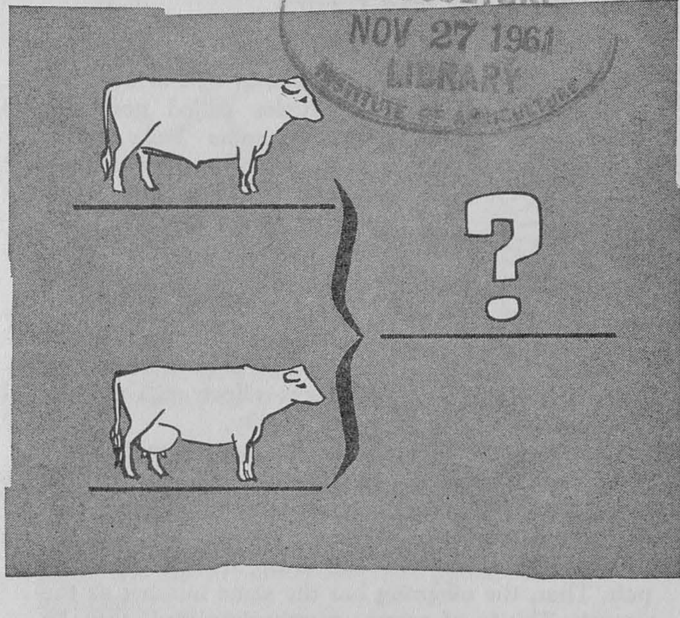
EXTENSION FOLDER 219 NOVEMBER 1961

genetics in dairy cattle breeding



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Animal breeding is more than an art. The successful dairy breeder of today also must be guided by the science of genetics.

A New Individual

Nature provides the means for all living things to reproduce. In most cases, life passes from one generation to the next through sex cells.

Before mating, the cow forms an ovum or egg. This is the female reproductive sex cell. At mating, the dairy sire deposits sperm or male reproductive cells in the cow's reproductive tract.

One sperm joins with the egg to begin a new individual. This united cell then divides. The two new cells form four cells, and growth continues in this way.

Chromosomes and Genes

In the center (nucleus) of the reproductive cells are chromosomes. These are made of disk or beadlike particles called genes. A chromosome looks much like a string of beads with each bead representing a gene (see figure 1).

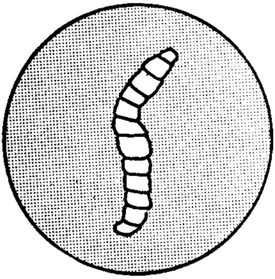


Fig. 1. A chromosome with genes.

The gene is the basic unit of inheritance. One gene pair may determine coat color, another if the animal will have horns, and others affect milk-producing ability.

Chromosomes always occur in pairs except in the sperm and egg. Only one member of each pair is found there. The process of sperm and egg formation is shown in figure 2.

When the sperm and egg unite, the chromosomes pair. Thus, the offspring has the same number as the parents. This is, of course, greatly simplified. Actually there are 30 pairs of chromosomes in dairy cattle and thousands of gene pairs.

How Characteristics Are Inherited

As an illustration let us see how the dwarf characteristic in cattle is inherited (see figure 3).

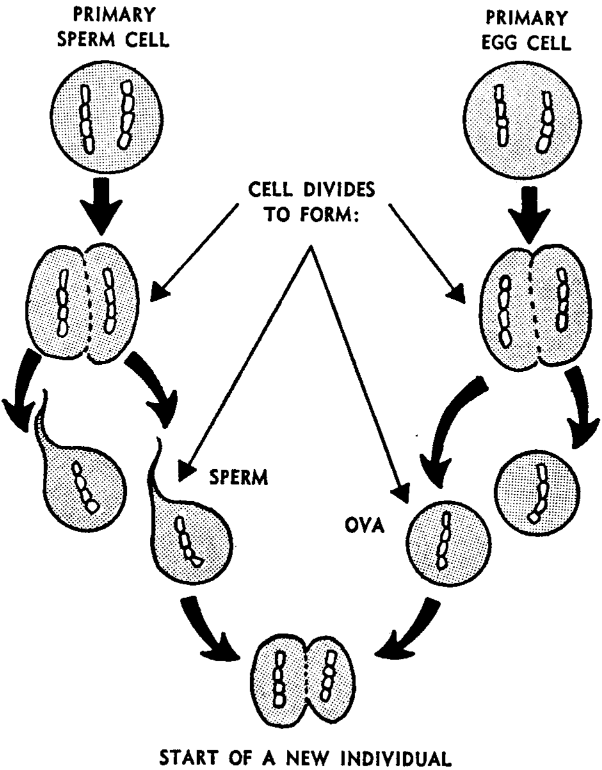


Fig. 2. Each reproductive cell goes through a process of reduction-division before fertilization takes place.

Step 1. A normal sire and dam.

Step 2. One gene pair is within the reproductive cell of each animal. In each cell the shaded gene indicates dominance for normal size. As long as it is there, the animal will be normal size. The other gene is recessive for dwarfism.

Dominant genes express their effect and, at the same time, cover up the effect of their recessive mates. Both parents carry the dwarf factor. However, its effect is masked by the dominant gene.

Step 3. The reproductive cells divide to form sperm and eggs.

Step 4. At mating, each parent contributes only one of each gene pair to the new offspring.

A. Each parent gave the shaded gene.

B. The sire gave his shaded gene and the dam her clear gene.

C. The dam gave her shaded gene and the sire his clear gene.

D. Both parents gave their clear genes.

The first three offspring appear normal. However, the second and third offspring carry the gene for dwarfism. But, the fourth offspring has both genes for dwarfism. Therefore, nothing prevents this characteristic from being expressed.

Only one offspring normally comes from each mating. Four offspring are shown to point out that chance alone determines how parental genes combine. Any one of the offspring could result from this sire and dam. If they mated four times, we would expect three normal offspring and one dwarf. Thus, the chances are 1 to 3 of getting a dwarf from carrier parents.

Sex is determined by a chromosome pair (see figure 4). In the male cell one chromosome is labelled X and the other Y. In the female cell there are only X chromosomes. In the process of cell division the male produces equal numbers of X- and Y-bearing sperm.

Thus, the sperm determine the sex of the offspring. Because X and Y sperm occur in equal numbers and have an equal chance of fertilizing the egg, an equal number of male and female offspring, on the average, are born.

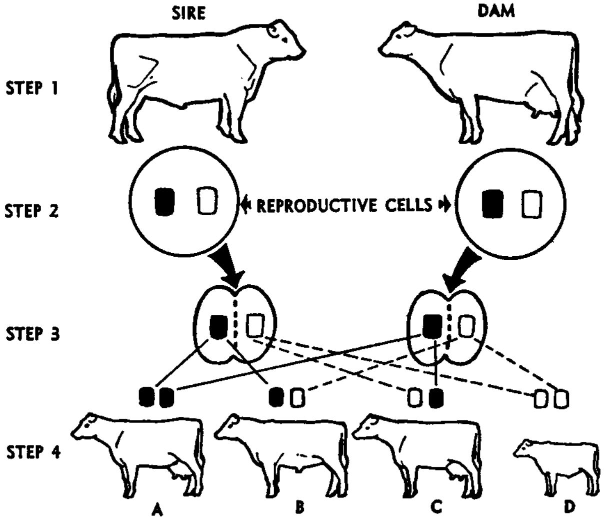
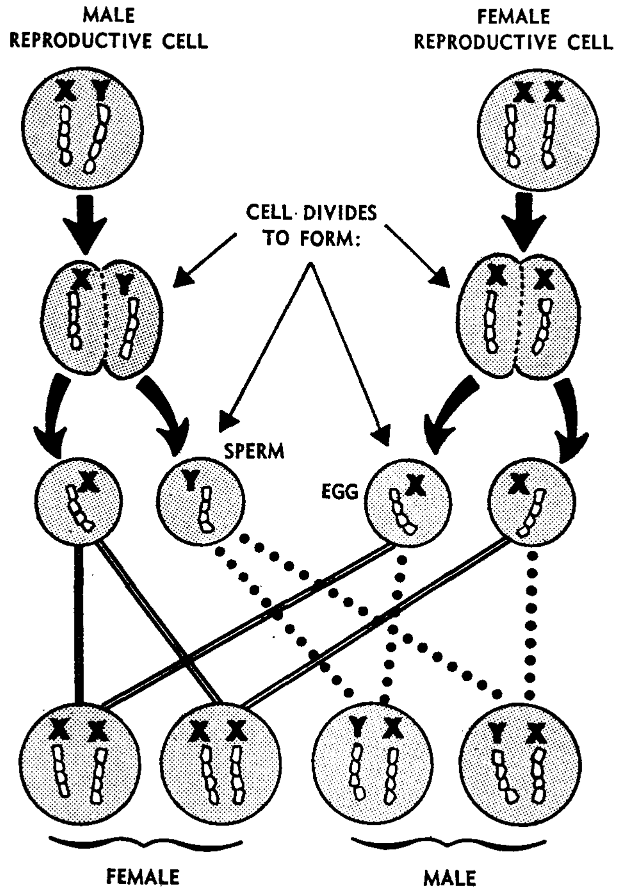


Fig. 3. Parents carrying the dwarfism factor will produce three normal to one dwarf offspring.



SPERM AND EGGS MAY COMBINE IN THESE WAYS TO GIVE A 50 TO 50 SEX RATIO

Fig. 4.

These are examples of simple inheritance. How we feed and care for the animal makes little difference in the expression of the trait. Inheritance for coat color, horns, and other characteristics are passed on in a similar manner.

Multiple Gene Inheritance

Inheritance for milk production, growth rate, and other characteristics are influenced by many gene pairs. Each gene makes a small contribution. The environment (care and feeding) plays a large role in the expression of these characteristics.

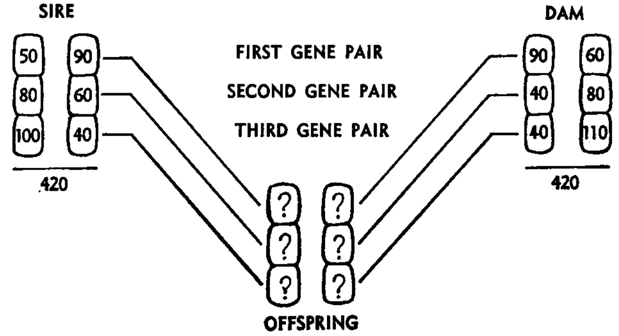


Fig. 5. Chance determines which member of each parental gene pair is transmitted to the offspring.

Figure 5 illustrates inheritance for milk production. Three gene pairs for each parent are shown. Each gene has a number representing its potential contribution in pounds of butterfat production. In both cases the total of the six genes equals 420. This means that the dam has the inborn ability to produce 420 pounds of butterfat in a normal lactation. Furthermore, both parents will on the average transmit to their offspring inheritance for butterfat production at the 420-pound level.

Even full sisters may differ considerably in their producing ability. The sire, in this illustration, may transmit the 50-pound gene from the first gene pair, the 60 from the second, and the 40 from the third. The dam may contribute the 60-pound gene from the first pair, the 40 from the second, and the 40 from the third. This offspring then has the potential for only 290 pounds of butterfat production (50+60+40 and 60+40+40).

On the other hand, if each parent contributes only the best gene of each pair, the offspring would have the inheritance for 550 pounds of butterfat production (90+80+100 and 90+80+110). This may be further illustrated by flipping a coin to determine which member of each gene pair in figure 5 will be transmitted. Chance alone determines what happens.

The offspring from this mating would range in production from 290 to 550 pounds. However, most offspring would produce near 420 pounds. This is essentially what happens in your dairy herd. Therefore, you may occasionally get offspring much better or much worse than their parents.

Of course, this illustration has been greatly simplified. It has been estimated that there are 20 to 400 gene pairs concerned with milk production. It is now impossible to know each gene and its effect in the multiple types of inheritance. How, then, can we hope to make progress in breeding for higher milk production?

Heritability Estimates

The expression of a trait such as milk production depends upon two major factors: (1) inheritance or ability to produce, and (2) environment or the opportunity to express the inborn ability.

Animal breeding scientists can measure the relative importance of inheritance and environment on a given trait. The term "heritability" describes the part inheritance plays. Heritability is 100 percent when the expression of the trait varies solely because of inheritance. A trait that varies solely because of environment has a heritability of zero. Variations in most traits are neither wholly environmental nor completely hereditary.

Table 1. Heritability estimates for some dairy cattle traits

Trait	Heritability percentage
Milk yield	25
Fat percentage	50
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Longevity (length of life)	5
Fraction of black or white color	95
Type (final rating)	20
Breeding efficiency	5
Milking rate	30
Solids not fat	50

Heritability of butterfat production is about 25 percent. What does this mean on a herd basis? Let us say that the herd averages 440 pounds of butterfat on a mature level. Then a young sire is selected that we estimate is capable of transmitting inheritance for 500 pounds of butterfat production. He is mated to cows in the herd with production records averaging 500 pounds of butterfat in normal 305-day lactation periods. What can be expected from the offspring?

Because heritability is 25 percent, we expect only one-fourth of the apparent superiority of the parents expressed in the offspring. The selected parents average 60 pounds of butterfat higher than the herd. One-fourth of 60 equals 15 pounds butterfat. Thus, the offspring would be expected to average 455 pounds of butterfat in this herd when given the same opportunity as the parents. The additional butterfat of the parents resulted from influences such as better feeding and management. This, of course, cannot be transmitted to the offspring.

Breed Wisely

The wise animal breeder will try to make improvements in both heredity and environment.

Heritability estimates can be valuable guides in planning a breeding program. Progress can probably be made in breeding for a given color, for example. But, there is little, if any, reward for doing so. Color does not influence milk-producing ability and has little market value.

The low heritability estimate for longevity suggests that little improvement can be expected through breeding. Feeding and care, more than inheritance, determine how long a cow will live. Therefore, little can be gained by including such things in a breeding program.

Progress through breeding accumulates slowly. Accurate records are needed to detect small differences. Nevertheless, small differences, accumulated over several generations, may account for substantial improvement.

Artificial insemination, along with recent advances in semen preservation, makes available a vast gene pool. This offers a wonderful opportunity and a real challenge to build inheritance for high and efficient production.

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Cooperative Extension Work in Agriculture and Home Economics, University of Minnesota, Agricultural Extension Service and United States Department of Agriculture Cooperating, Skuli Rutford, Director. Published in furtherance of Agricultural Extension Acts of May 8 and June 30, 1914. 10M—10-61