Genetics principles of cattle breeding

Review and application of mendelian genetics

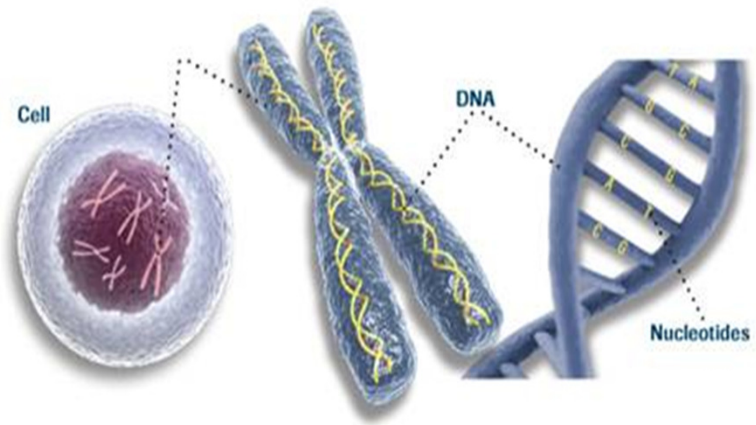
What is genetics?

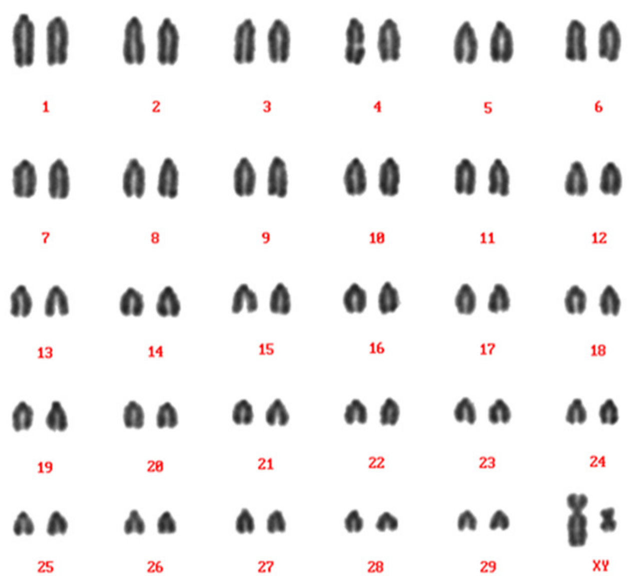
- William Bateson, who named the field of study in 1906, wrote
- «Genetics is the science dealing with heredity and variation seeking to discover laws governing similarities and differences in individuals related by descent»

The key words are heredity,

the transmissions of genetic metarial from one generation to the next, and variation, the vide range of values seen in such traits as milk production.

Transmission of genetic material from parent to progeny





All living matter consist of cells
Each cell has in its nucleus a complete copy of the genetic material of the animal.
Genetic material is contained on chromosomes, which are long, slender threadlike structures found in the nucleus. These chromosomes are paired although the pairs are not exact duplicates of the genetic material. Each cow has 30 pairs of chromosomes.

Along the chromosomes are lokated the genes

The genes correspond to chemical structures along the chromosome. Since the chromosomes are paired, the genes also paired but the pairs may or may not be identical. Nonidentical genes located at the same place along the chromosomes are called alleles.

Transmission of genetic material

- Knowledge of how genes are transmitted from parent to offspring is necesarry for an understanding of how genetics can be applied to dairy cattle breeding.
- Germ cells (sperm or ova) are formed that contain only one pair of each chromosome and gene.

Assume, an animal carried the gene for polled (no horns), P; and the gene for horns, p. The pair of genes at the location for horns are not identical for this animal. Each cell of the animal contains both P and p allels-P on one chromosome and p on the paired chromosome

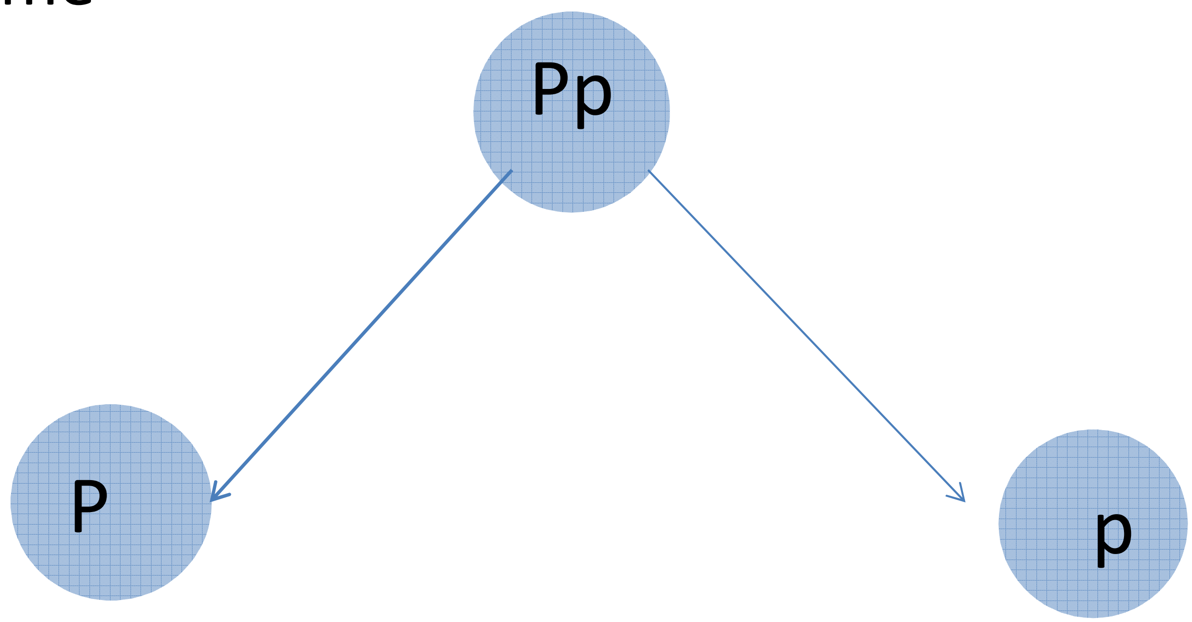


Figure 1.

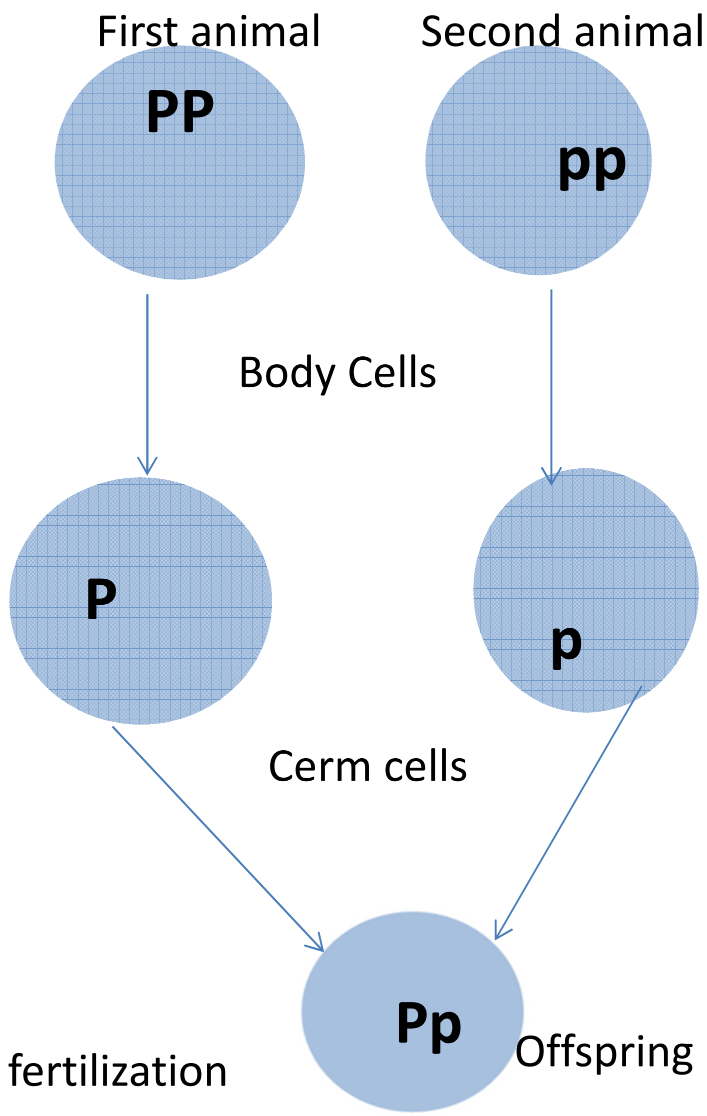


Figure 2.

With respect to P or p, two kinds of sperm or ova can be formed in equal numbers. The same pattern holds true for all other gene pairs that control other traits. The other parent provides germ cells in the same way. When fertilization (union of a sperm and an ovum) occurs, genes are again paired. For example, suppose that an animal that is PP is mated to another that is pp. .

Genotypic frequencies

If the parents can form from different kinds of germ cells, the genes of the offspring are determined by chance union of one germ cell from each parent.

A simple method for determining the expected or average fraction of different types of offspring is to write the allels from each parrent, together with their frequency;

Let the parents are Pp and Pp:
Expected frequencies of the offspring from mating
Pp X Pp
F X M

$({}_{1/2}P + {}_{1/2}p) \text{ X } ({}_{1/2}P + {}_{1/2}p) = {}_{1/4}PP + {}_{1/4}Pp + {}_{1/4}pP + {}_{1/4}pp$

This formula is not complicated as it appear.

if you look at the figure 3.

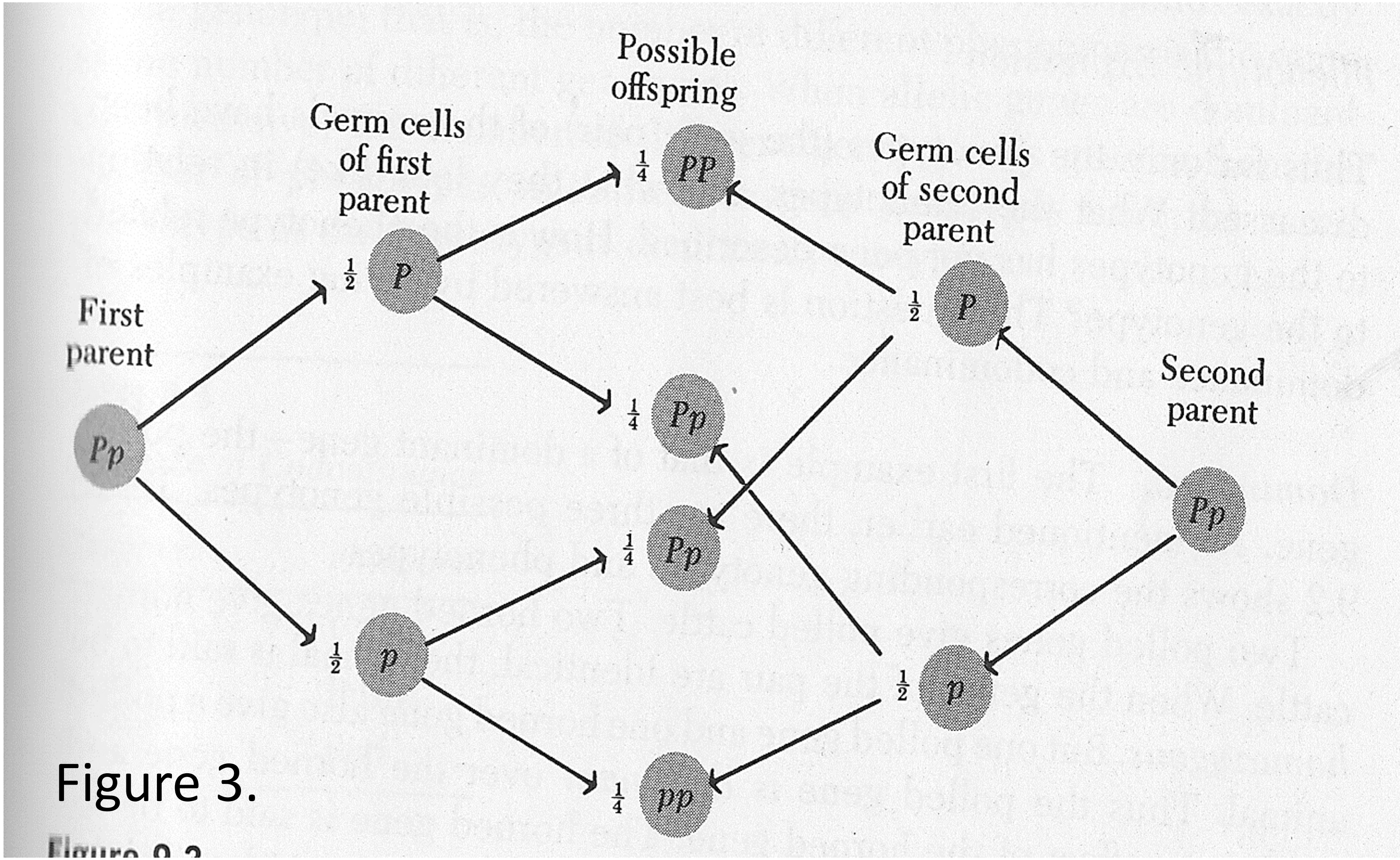


Figure 3.

When there are two possible alleles at a locus there are six possible types of mating

Table 1. Six possible Matings for two Alleles at One Locus

First Parent		Second Parent	Expected frequencies of offspring
PP	**X**	**PP**	**All PP**
PP	**X**	**Pp**	**½ PP + ½ Pp**
PP	**X**	**pp**	**All Pp**
Pp	**X**	**Pp**	**¼ PP + ½ Pp + ¼ pp**
Pp	**X**	**pp**	**½ Pp + ½ pp**
pp	**X**	**pp**	**All pp**

The expected proportions of offspring from the various matings are expected fractions of the possible kinds of offspring if many such matings are made. Any particular mating might give considerably different proportions.

For example, suppose that a mating is Pp X Pp.

If only two-offspring are obtained, some two-offspring families will be all PP, some will be all pp, some will be all Pp, and others will have various proportions of the three types, all by chance. The average proportions for a large number of offspring will however, be close to the expected proportions, ¼ PP + ½ Pp + ¼ pp.

Phenotypic Expression

Up to now, we have discussed only genotypes (the gene pair) of the animals.

What the phenotypes are?, what they look like in relation to the genotypes?

How is the phenotype related to the genotype?

Dominance and codominance

First example is that of a dominant gene-the polled gene. There are three possible genotypes.

Table 2. Example of Dominant gene action

Gene pair (genotype)	What is seen (phenotype)
P and P	Polled (no horns)
P and p or p and P	Polled
P and p	Horned

We have seen that

Two polled genes give polled cattle.

Two horned genes give horned cattle.

When the genes of the pair are identical, the animal is said to be **homozygous.**

But one polled gene and one horned gene also give a polled animal.

That means polled gene is **dominant** over the horned gene and masks any effect of horned gene.

The horned gene is **recessive** to the polled gene.

When the genes of a pair are not identical the animal is said to be **heterozygous** at that locus.

Another dominant gene is the one for black in Holsteins and Angus cattle, which is dominant to red.

The curly coat in Ayrshires is dominant to a slick coat.

Codominance

The second situation, the heterozygote is different from either of the homozygotes.

Roan color of shorthorns.

Let W be gene for white, and w be the gene for red.

Table 3. example of codominance

Genptype	Phenotype
WW	White
Ww	Roan
ww	Red

When allelic genes are codominant, the phenotype corresponds exactly to the genotype; that is, the number of the different phenotypes is the same as the number of different genotypes.

When allelic genes are dominant and recessive, the number of different genotypes is greater than the number of phenotypes since heterozygous genotypes have the same phenotype as homozygous dominant genotype.

Combination of the traits

Independent loci

If the phenotype of each trait is dtermined separately by allelic genes and if genes determining one trait are independet of the genes for other traits,

another rule: to be independent, the genotype at one locus must not affect the axpression of the genotype at another locus.

independence of loci, the expected results at one locus are multiplied by the expected results at the other locus.

Independent loci

Example: Consider mating a roan Shorthorn that is heterozygous for polled to a roan horned Shorthorn;

Ww Pp X Ww pp

Expected results for the color locus:

(½W + ½w) X (½W + ½w) = ¼WW + ½Ww + ¼ ww

Expected results for the polled locus are:

(½P+ ½ p) X (1p)= ½ Pp + + ½ pp

The joint results are

¼ WW + ½ Ww + ¼ ww) X (½Pp+ ½pp)

= 1/8WWPp + 1/8 WWpp + ¼ WwPp + ¼ Wwpp

+ 1/8wwPp + 1/8wwpp

Expected frequencies of the six different joint genotypes.

The expected frequencies of the joint phenotypes can be found by adding together the frequencies of genotypes that look alike.

In this exmple the phenotypic frequencies are same as the genotypic frequencies.

Epistasis

The joint phenotypic frequencies may also differ from the joint genotypic frequencies if the genes at one locus affect the expression of the genes at another locus .

Example: recessive gene for albino, which, when homozygous, prevents any color expression.

Suppose C allows color and c is the albino gene.

Crossing two Holsteins heterozgous both for black and white and for albino gene

Genotypic frequencies

(Bb X Bb) black and white	(Cc X Cc) Albino
(½B + ½ b) X (½B + ½ b)	(½ C + ½ c) X (½ C + ½ c)
= ¼ BB + ½ Bb + ¼ bb	= ¼ CC + ½ Cc + ¼ cc
= 1/16 BBCC + 1/8 BBCc + 1/16 BBcc + 1/8 BbCC + ¼ BbCc + 1/8 Bbcc + 1/16 bbCC + 1/8 bbCc + 1/16 bbcc	

Phenotypic frequencies

(1/16 BBCC + 1/8 BBCc + 1/8 BbCC + 1/4 BbCc	**= 9/16 Black and white**
(1/16 bbCC + 1/8 bbCc)	= 3/16 red and white
(1/16 BBcc + 1/8 Bbcc+ 1/16 bbcc)	4/16 albino