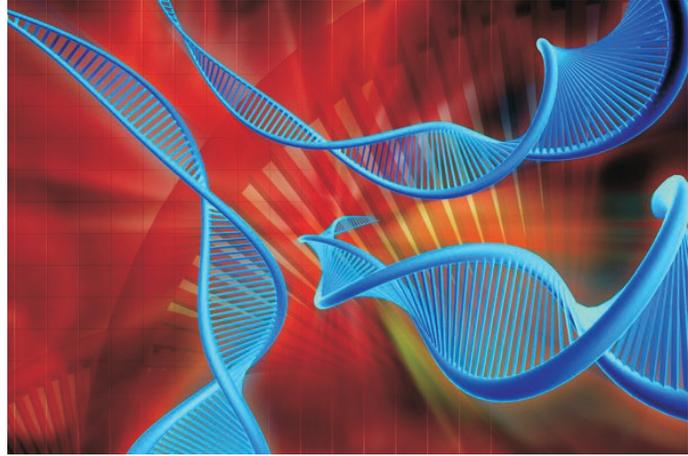


# Exploring Animal Genetics and Probability

**T**HE STUDY OF GENETICS is extremely valuable to several areas of science. From medical to agricultural applications, the development of new techniques in studying DNA has revolutionized genetics.



## Objective:



Explain the importance of genetics.

## Key Terms:



alleles	genetics	linkage
autosomes	genome	locus
chromosome	genotype	monohybrid cross
crossover	haploid	mutation
deoxyribonucleic acid	heredity	phenotype
dihybrid cross	heritability	probability
diploid	heritability estimate	Punnett square
dominant	heterozygous	qualitative traits
gamete	homologous chromosomes	quantitative traits
gene	homozygous	recessive
genetic code		sex chromosomes

## Animal Genetics

**Genetics** is the study of heredity. Gregor Mendel and Robert Bakewell were the first two individuals who gave insight into the study of genetics. Gregor Mendel discovered that traits are inherited through units called genes. A **gene** is any of the segments of a chromosome that contain the hereditary traits of an organism. Mendel further discovered that genes are found in

pairs and that half the inherited traits come from the father and half from the mother. This passing of traits from parents to offspring is called **heredity**. Robert Bakewell confirmed an offspring will express a certain trait if both parents excel and express the studied trait.

## CHROMOSOMES

Understanding chromosomes is fundamental to genetics. A **chromosome** is a tiny threadlike structure that contains the genetic material in a cell.

Chromosomes are found in the nucleus of a cell. The genetic material in the chromosomes is called the **genome** of the organism. When animals mate, the genome of the offspring is a combination of the traits from the mother and the father. All the cells within the animal are genetically identical. Each cell contains the same number of chromosomes. Different species express different numbers of chromosomes. Humans have a total of 46 chromosomes, which form 23 pairs. A pair of chromosomes is known as **homologous chromosomes**. Within normal individuals, the number of chromosomal pairs in body cells is constant.

An animal has one pair of sex chromosomes. These are the **X** and **Y** chromosomes. In some species, the male is **XY** and the female is **XX**. **Autosomes** are all the chromosomes in body cells other than sex chromosomes. Therefore, humans have 1 pair of sex chromosomes and 22 pairs of autosomes, for a total of 23 pairs of chromosomes.

A cell that contains the normal two sets of chromosomes (one from each parent) is said to have a **diploid** number ( $2n$ ) of chromosomes. A **gamete**, or sex cell, carries only a single set of chromosomes and is said to have a **haploid** number ( $1n$ ) of chromosomes.



FIGURE 1. The study of genetics benefits agriculture and other fields of science.

TABLE 1. Number of Chromosomes for Selected Animals

Species	Number of Chromosomes
Cat	38
Cattle	60
Chicken	78
Dog	78
Donkey	62
Horse	64
Human	46
Mule	63
Sheep	54
Swine	38

## DNA

Chromosomes are made of **deoxyribonucleic acid** (DNA), which is a protein-like nucleic acid that controls inheritance. Each offspring receives two genes that may code for the same trait or for two alternative traits. The particular location of a gene on a chromosome is referred to as the gene's **locus**.

When alternative forms of a gene occur, they are called **alleles**. Therefore, when two haploid gametes containing the same allele of a gene come together in fertilization to form a zygote (the zygote develops into an offspring), the zygote is said to be **homozygous**. When two haploid gametes containing different alleles come together, the zygote is said to be **heterozygous**.

Each DNA molecule consists of two strands shaped as a double helix or spiral structure. These strands are nucleotides bonded by pairs of nitrogen bases. The nucleotides are made up of sugar molecules held together by phosphates. There are four nitrogen bases found in DNA. They are cytosine, guanine, adenine, and thymine.

The **genetic code** is the sequence of nitrogen bases in the DNA molecule. This sequence is for amino acids and proteins. The ability of DNA to replicate itself allows for a molecule to pass genetic information from one cell generation to the next. Each species has a different genetic code.

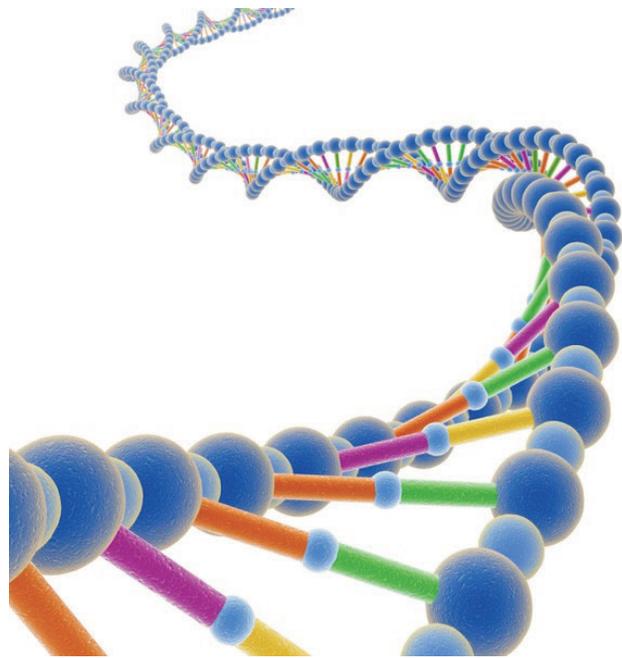
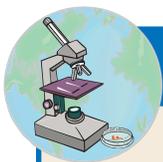


FIGURE 2. A DNA molecule.



## EXPLORING OUR WORLD...

### SCIENCE CONNECTION: Human Genome Project (HGP)

In October 1990, the Human Genome Project (HGP) started. Its goals were to determine the complete sequence of DNA subunits, identify all human genes, and allow for further study. The project came to completion in 2003. However, studies and further research have continued, not only with humans, but also with about 800 other organisms that have been sequenced in recent years. The importance of studying all DNA in every chromosome in humans will have numerous profound effects. Diseases usually have genetic components. Therefore, the knowledge of where specific genes are located will help in diagnosing, preventing, or treating diseases. In livestock, the location of genes will help in providing information for selecting superior breeding stock.

## GENOTYPE AND PHENOTYPE

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Just carrying a particular pair of alleles does not guarantee that the trait encoded by them will be expressed. Only the **dominant** allele (written as a capital letter) will express the trait. The corresponding **recessive** allele (written as a lowercase letter), though present, will not express the trait. For example, in Angus cattle, the black gene (**B**) is dominant to the red gene (**b**). Therefore, with two alleles (**B** and **b**), the possibility exists of having three genotypes (**BB**, **Bb**, and **bb**) and two phenotypes (two black and one red).

**Genotype** is the actual genetic code. Biologists often refer to the genotype as the totality of alleles that an individual contains. It controls physical and performance traits. The genotype of an organism cannot be changed by environmental factors.

**Phenotype** is an organism's physical or outward appearance. This is the part of the genotype the organism expresses. Phenotype is dependent on the genes the individual inherits. In some instances, phenotype may be altered by the organism's environment. For example, the color of coat may not be changed by the environment. However, a lamb may have a genotype to gain 1 pound per day. If the lamb receives a low-grade diet, then the lamb may gain only  $\frac{1}{2}$  pound per day. Therefore, the genetic potential of the lamb is hidden because of the environmental factor, the low-grade diet.

## QUALITATIVE AND QUANTITATIVE TRAITS

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**Qualitative traits** are traits controlled by only a single pair of genes and cannot be altered by the environment. Their phenotype is either one thing or the other. These traits most easily show how genes are inherited. An example is coat color.

**Quantitative traits** are traits controlled by several pairs of genes. These traits are expressed across a range. These traits can also be altered by environment. Examples are rate of gain, growth rate, and backfat depth.

## ESTIMATING HERITABILITY

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Estimating the inheritance of traits is based on probability. **Probability** is the likelihood or chance that a trait will occur. Mating animals that have particular traits does not guarantee that the traits will be expressed in the offspring. **Heritability** is the proportion of the total variation (genetic and environmental) that is due to additive gene effects. A **heritability estimate** expresses the likelihood of a trait being passed on from parent to offspring. If a trait has a high heritability, the offspring are more likely to express that trait.

### Punnett Square

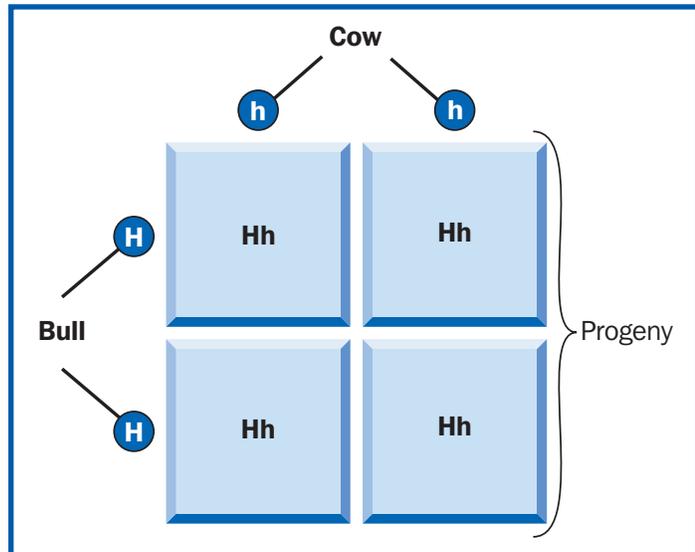
The **Punnett square** is a matrix that provides a technique for predicting genotype. It considers the dominant and recessive genes of both parents for one trait. The Punnett square is a useful tool to help determine both genotype and phenotype from animal crosses.

A Punnett square is created by drawing a 4-square ( $2 \times 2$ ) or a 16-square ( $4 \times 4$ ) box. Each parent is assigned a side of the box, and all possible offerings from that parent are written along the side, one offering per square.

Each parent is allowed to give one gene per trait. The dominant gene is represented by a capital letter, whereas the recessive gene is represented by a lowercase letter. By combining the gene from one parent with the corresponding gene from the other parent, the offspring is assigned a trait (e.g., eye color, polled or horned).

To determine the genotype and phenotype of the offspring, the parents' offerings are combined and written in the corresponding inner squares. For the offspring, similar letters are written next to each other to help sort the results. For example, when finding black coat color, the letter **B** is used for the dominant black, and the letter **b** is used for the recessive red. Handling the letters in this way causes less confusion when reporting genotype and phenotype. Labeling traits to letters within the title of a Punnett square is also helpful.

In calculating results, each possible offspring combination should be examined to determine both genotype and phenotype. A typical monohybrid heterozygous cross always yields a phenotype with a 3:1 ratio, whereas a typical dihybrid heterozygous cross always yields a phenotype with a 9:3:3:1 ratio.



**FIGURE 3.** A Punnett square predicts possible offspring when using known genotypes of the parents. In this example with cattle, H is horned, and h is polled (not horned). When a cow that is homozygous recessive (hh) for horns is mated to a bull that is homozygous dominant (HH) for horns, the probable outcome is revealed in this Punnett square.

## MONOHYBRID AND DIHYBRID

A **monohybrid cross** takes into account a single trait and is represented by a single set of letters. For example, black coat color is dominant in cattle over red, and the trait would be represented **Bb**. A Punnett square for a monohybrid heterozygous cross would have four inside squares.

A **dihybrid cross** takes into account two traits and would be represented by four letters instead of two. A dihybrid cross showing both eye color and hair color may be represented as **BbHh**. A Punnett square for a typical dihybrid heterozygous cross would have 16 inside squares.

## SEX DETERMINATION

**Sex chromosomes** determine the sex of a zygote. The process differs slightly among species.

Male sex chromosomes are either **X** or **Y** in mammals. A zygote that receives a **Y** chromosome from sperm will be male. A zygote that receives an **X** chromosome from sperm will be female. The male makes sex determination, as the egg from the female has an **X** chromosome. Therefore, a female zygote will have two **X** chromosomes (**XX**), whereas a male zygote will have one **X** chromosome and one **Y** chromosome (**XY**).

The female determines the sex of the offspring in poultry. The male carries two sex chromosomes (**ZZ**). The female carries only one sex chromosome (**ZW**). After meiosis, every sperm cell carries a **Z** chromosome. Only half the egg cells carry a **Z** chromosome; the other half carry a **W** chromosome.

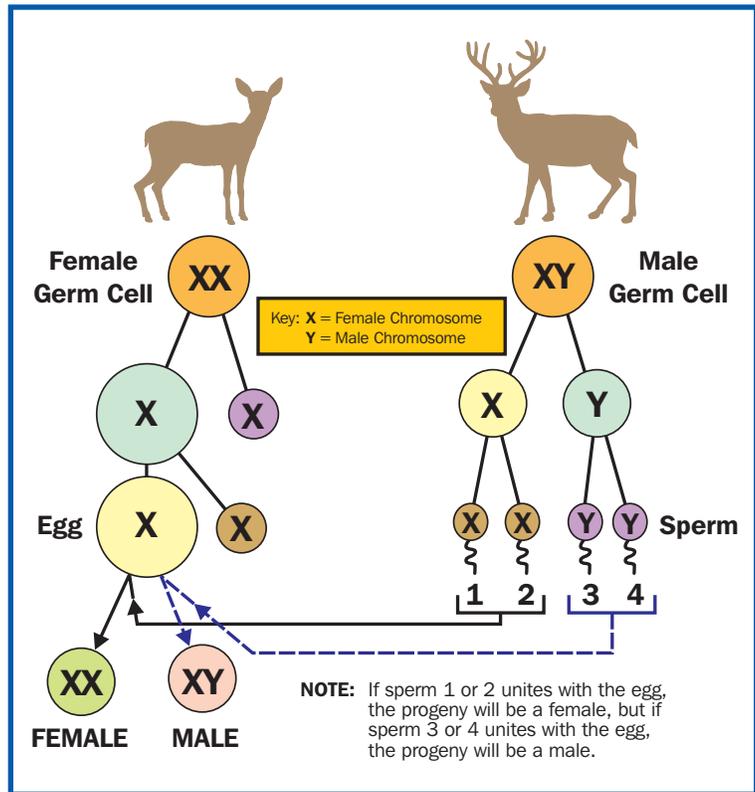


FIGURE 4. Sex determination.

## LINKED CHARACTERISTICS

The tendency for certain traits to appear in groups in the offspring is called **linkage**. Early studies in genetics were based on the idea that all genes are redistributed in each mating. It was found, however, that some groups of traits seemed to stay together in the offspring.

**Crossover** is the formation of new chromosomes resulting from the splitting and rejoining of the original chromosomes. This explains why the predicted results of a mating do not always happen. During one stage of meiosis, the chromosomes line up. They are very close to each other. Sometimes the chromosomes cross over one another and split. This forms new chromosomes with different combinations of genes.

**Mutation** is the appearance of a new trait in the offspring that did not exist in the genetic makeup of the parents. Mutations are of little value in improving livestock.

## Summary:



Innovations in studying DNA have revolutionized genetics. They have allowed biologists to develop and discover new drugs, vaccines, gene technology used in the treatment of genetic diseases, crops resistant to pesticides and pests, and commercially superior animals.

These developments have occurred because of the groundwork and research of Gregor Mendel, Robert Bakewell, and many other scientists. Research has shown

that the basis of genetics is in the understanding of chromosomes. Chromosomes are found in the nuclei of cells. The genetic material found in the chromosomes is called the genome of the organism. When animals mate, the genome of the offspring is a combination of traits from the mother and the father.

Not all traits passed from the mother and the father will be expressed in the offspring. Only one allele, the dominant one, will be expressed. The other allele, the recessive one, will be present but not expressed. The genotype of an individual reveals the genetic code, whereas the phenotype describes the outward appearance.

Some characteristics carried on to the next generation are sex linked. The genes for these traits are on the sex chromosomes. Knowledge about these genes and their location can assist producers and biologists in determining desirable traits of selected animals.

### Checking Your Knowledge:

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1. Why is it important to study genetics?
2. What are autosomes?
3. What is the difference between homozygous and heterozygous?
4. When does a recessive trait appear in an organism?
5. What are the genotype and phenotype ratios if a female that is heterozygous for horns (**Pp**) is mated to a horned bull (**pp**)?

### Expanding Your Knowledge:

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Polled (lack of having horns) is a dominant gene in Hereford cattle. Your herd consists of entirely polled cattle. During breeding and selection of bulls, you are careful to select polled sires. However, some calves that are born grow horns. You cull these calves and continue to ensure no horned cattle have entered your herd. Despite your efforts, more horned cattle are born the next year. What is the reason for the appearance of horned calves? How can you reach your goal of having entirely polled cattle? What should you do?

### Web Links:

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**Dolan DNA Learning Center**

<http://www.dnalc.org>

**Virtual Library on Genetics**

[http://www.ornl.gov/sci/techresources/Human\\_Genome/genetics.shtml](http://www.ornl.gov/sci/techresources/Human_Genome/genetics.shtml)

**Learn.Genetics**

<http://learn.genetics.utah.edu>

**Agricultural Career Profiles**

<http://www.mycart.com/career-profiles>