## Lesson 1:
## Importance of Genetics in Agriculture

There are many careers associated with animal genetics. This occupational area is expanding every day because of new methods of genetic advancement such as: cloning, AI (artificial insemination), and embryo transfer. Employment in livestock genetics is divided into two areas: (1) supplies and services and (2) production.

### Occupations Associated with Livestock Genetics

The supplies and services area usually requires a rigorous academic background and a strong agricultural background. The production area requires a very strong agricultural background, a good academic background, and extensive work experience to gain employment. These criteria also apply to independent producers.

Some occupations in the production area are: farm manager, animal breeder, dairy herd owner, horse rancher, cattle rancher, sheep rancher, swine producer, poultry producer, and specialty animal breeder.

In the supplies and services area, some occupations are: veterinarian, artificial breeding technician, veterinarian assistant, ova transplant specialist, breeding services representative, breed association employee, field sales representative for animal breeding products, artificial inseminator, cloning technician, and embryo technician. This is only a partial list of occupations.

### Economic Importance of Genetics

How can genetics influence the economic outcomes of livestock? Consider the case of a sow that produces 10 pigs per litter and another sow that produces eight pigs per litter. A good farm manager would pick the sow that produces 10 pigs per litter, because that sow will produce more income than the other sow.

How does genetics play a part in this? It is a fact that litter size is a 15% heritability trait. That means that the litter size of a sow is determined by 15% inheritance from parents and 85% from environment. So the boar used has an influence on how many pigs are produced, and this influences the amount of income produced from that sow.

Another example is the birth weight in beef cattle. Birth weight is a 40% heritability trait. That means that birth weight is determined from 40% inheritance and the other 60% is influenced by environment. How does the environment influence the birth weight in beef cattle? Consider if one cow has winter shelter during her pregnancy and another cow does not. Which cow will have a higher birth weight? A good farm manager would assume that the cow that had shelter would have a larger calf because she used fewer calories on body maintenance and utilized extra calories for her calf.

Heritability traits are broken down into three categories. The first category is called management traits. These traits are influenced by management techniques and decisions. For example, swine litter size at weaning is a management trait, because care of sows and facilities are management decisions.

The second category is known as physical traits. These traits are influenced by actual physical attributes of that animal. For example, the udder support in dairy cattle is a physical attribute of that specific animal.

The last category is production traits. These traits directly influence the quality of products and income received from the animal. For example, rate of gain is a production trait because it directly influences the income received from that animal. The less time a steer is in the feedlot, the less feed and money that is spent on that animal.

TABLE 1.1 - Heritability Traits in Beef Cattle

| Trait | Type | Inheritance to offspring (%) | Environmental influence (%) |
|---|---|---|---|
| Calving interval or fertility | Management | 10 | 90 |
| Birth weight | Management | 40 | 60 |
| Cow maternal ability | Management | 40 | 60 |
| Weaning weight | Production | 30 | 70 |
| Carcass grade | Production | 40 | 60 |
| Efficiency of gain | Production | 40 | 60 |
| Fat thickness | Production | 45 | 55 |
| Pasture gain | Production | 30 | 70 |
| Feedlot gain | Production | 45 | 55 |
| Final feedlot weight | Production | 60 | 40 |
| Tenderness | Production | 60 | 40 |
| Rib eye area | Production | 70 | 30 |
| Conformation score (at weaning) | Physical | 25 | 75 |
| Cancer eye susceptibility | Physical | 30 | 70 |

TABLE 1.2 - Heritability Traits in Dairy Cattle

| Trait | Type | Inheritance to offspring (%) | Environmental influence (%) |
|---|---|---|---|
| Milking speed | Production | 25 | 75 |
| Milk production | Production | 25 | 75 |
| Feed lot gain | Production | 45 | 55 |
| Percent of soluble nitrogen-free extracts | Production | 50 | 50 |
| Percent protein in milk | Production | 50 | 50 |
| Percent fat in milk | Production | 50 | 50 |
| Legs and feet | Physical | 15 | 85 |
| Udder support | Physical | 20 | 80 |
| Stature | Physical | 40 | 60 |

TABLE 1.2 - Heritability Traits in Dairy Cattle

| Trait | Type | Inheritance to offspring (%) | Environmental influence (%) |
|---|---|---|---|
| Fertility | Management | 5 | 95 |
| Birth weight | Management | 40 | 60 |
| Temperament | Management | 40 | 60 |

TABLE 1.3 - Heritability Traits in Sheep

| Trait | Type | Inheritance to offspring (%) | Environmental influence (%) |
|---|---|---|---|
| Multiple births | Management | 15 | 85 |
| Birth weight | Management | 30 | 70 |
| Type score for weanling | Physical | 10 | 90 |
| Wrinkles and skin folds | Physical | 40 | 60 |
| Yearling type score | Physical | 40 | 60 |
| Face covering | Physical | 56 | 44 |
| Carcass grade | Production | 12 | 88 |
| Carcass weight/day of age | Production | 22 | 78 |
| Carcass length | Production | 31 | 69 |
| Finish or condition at weaning | Production | 17 | 83 |
| 60-day weight | Production | 10 | 90 |
| 100-day weight | Production | 30 | 70 |
| Rate of gain | Production | 30 | 70 |
| Fleece grade | Production | 35 | 65 |
| Fat thickness over loin eye | Production | 35 | 65 |
| Staple length for weanling | Production | 39 | 61 |
| Fleece weight and grease weight | Production | 38 | 62 |
| Staple length for yearlings | Production | 47 | 53 |
| Loin eye area | Production | 53 | 47 |

TABLE 1.4 - Heritability Traits in Swine

| **Trait** | **Type** | **Inheritance to offspring (%)** | **Environmental influence (%)** |
|---|---|---|---|
| Birth weight | Management | 5 | 95 |
| Litter size at birth | Management | 15 | 85 |
| Litter size at weaning | Management | 12 | 88 |
| Litter weight at weaning | Production | 15 | 85 |
| Efficiency of feed utilization | Production | 30 | 70 |
| Days to 230 lbs. | Production | 35 | 65 |
| Back-fat thickness | Production | 40 | 60 |
| Daily rate of gain from weaning to market | Production | 40 | 60 |
| Percent lean cuts to offspring | Production | 50 | 50 |
| Muscle in loin area | Production | 50 | 50 |
| Predicted percent lean | Production | 58 | 42 |
| Carcass length | Production | 60 | 40 |
| Conformation | Physical | 29 | 71 |

**Genetic Selection**

Traditionally, animals were selected based on their physical traits. Since records were not available, animals were chosen by the type of individual, their pedigree, and by show-ring winnings. Now, there are an abundance of production, physical, and management records kept on animals, especially purebred and show animals. These records introduced production testing, which is the latest genetic selection method.

Today, animal selection is based on three types of testing: performance, progeny, and production. Performance testing is the practice of evaluating and selecting animals based on their merit or performance. For example, performance testing on a bull would include its 365-day weight.

Progeny testing is the practice of selecting animals based on the merit of their progeny (offspring). This testing was used more in the past, but today, more extensive records are kept. Progeny testing is used in selection of animals based on the performance of their offspring.

Production testing involves keeping accurate performance and progeny records, rather than casual observations. Production testing is the systematic measurement of differences in economically important traits and the *recording* of these differences for use in selection. Production testing is also used to compare animals that are handled alike (same lot, same feed, same amount of feed) to determine the better-performing animal. This method is not reliable in comparing different herds--just individuals. Finally, production testing is also used as a selection tool to increase the rate of genetic improvement in individual herds.

**Summary**

It is vital for livestock producers and others in livestock-related occupations to understand economic traits associated with genetics and to select livestock based on genetic improvement.

**Credits**

*Careers Unit for Ag Science I Core Curriculum* (Teacher's guide). University of Missouri-Columbia: Instructional Materials Laboratory, 1988.

Ensminger, M. E. *The Stockman's Handbook.* 7th ed. Danville, IL: Interstate Publishers, Inc., 1992.

## Lesson 2:
## Basic Building Blocks of Genetics

Cells are the basic, microscopic building units of all living things, and they reproduce through division. Cells are the beginning and the basis for every function within the body.

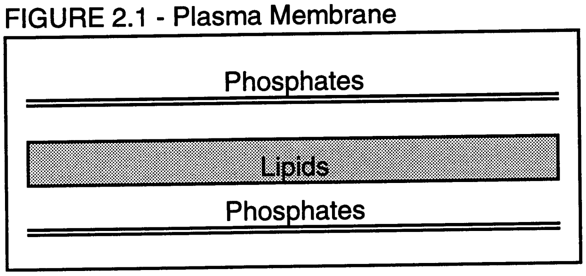
**How Cells Function**

Parts of the cell - Cells are complex systems that consist of several smaller structures within the cell. These smaller, membrane-bound structures are called organelles ("little organs"). The function of the cell depends on the organelles present in the cell. Therefore, the organelles determine the function of the cell.

The plasma membrane is the thin layer surrounding the cell. This very active part of the cell determines which molecules can enter or exit the cell.

The plasma membrane consists of two layers of molecules called phospholipids. Phospholipids are made up of a lipid and a phosphate group. Lipids are not soluble in water, but phosphates are. Phosphates sandwich the lipid layer in the plasma membrane. This allows certain molecules to enter and exit the cell, but not lipids. (See Figure 2.1.)

FIGURE 2.1 - Plasma Membrane




The spherical organelle that is located near the center of the cell is the cell nucleus. It controls the production of proteins in the cell. The nucleus also holds important information about the cell in DNA. The parts of the cell nucleus include the nuclear membrane, chromatin, chromosomes, and nucleolus.

The nuclear membrane separates the content of the nucleus from the rest of the cell. This membrane also allows substances to exit and enter the nucleus. The chromatin holds the necessary hereditary information about the cell so it can reproduce similar cells. The nucleolus is the darker part of the chromatin, which is involved in the production of ribosomes.

Cytoplasm is the gel-like substance that surrounds and suspends a cell's organelles.

Mitochondria are organelles that contain enzymes that release energy from food molecules during cellular respiration. The number of mitochondria in a cell depends on the function of the cell. An active muscle cell, such one found in the heart, contains more mitochondria because it requires more energy.

Ribosomes are tiny, round organelles that are involved in the protein synthesis. A majority of ribosomes attach themselves to long strands of membrane called endoplasmic reticulum. These attached ribosomes synthesize proteins that are released for use by other cells in the body. The ribosomes that float within the cytoplasm synthesize proteins used by the cell itself.

The two types of endoplasmic reticulum are smooth and rough. Rough endoplasmic reticulum contains ribosomes necessary for protein synthesis. Smooth endoplasmic reticulum does not contain ribosomes, so it is not involved with protein synthesis, but it does add structure to the cell.

Golgi bodies are flat, membrane-bound sacs that prepare proteins for secretion from the cell. Vesicles are tiny pieces of membrane pinched off the Golgi body that actually carry proteins to the plasma membrane. Golgi bodies catch proteins floating in the cytoplasm, and then vesicles carry these proteins to the plasma membrane.

Within the cytoplasm, there are membrane-bound, fluid-filled spaces called vacuoles. These vacuoles are usually filled with water and have their own membrane to separate them from the rest of the cell. Vacuoles provide shape and structure to the cell.

Proteins are actually digested by lysosomes. These organelles contain enzymes that break down proteins and recycle amino acids to make new proteins.

Cytoskeleton is the tiny internal support system found in cells. It is made up of many tiny protein strands called microtubules. The cytoskeleton resembles a fish net. Each strand in the net would be called a microtubule. The cytoskeleton provides shape and structure, but it also limits the movement of organelles within the cell.

The centriole is a cylindrical organelle that contains its own microtubules that lie near the cell nucleus. Most animal cells contain two centrioles. These pairs of centrioles are composed of nine sets of microtubules and play an important role in cell division.

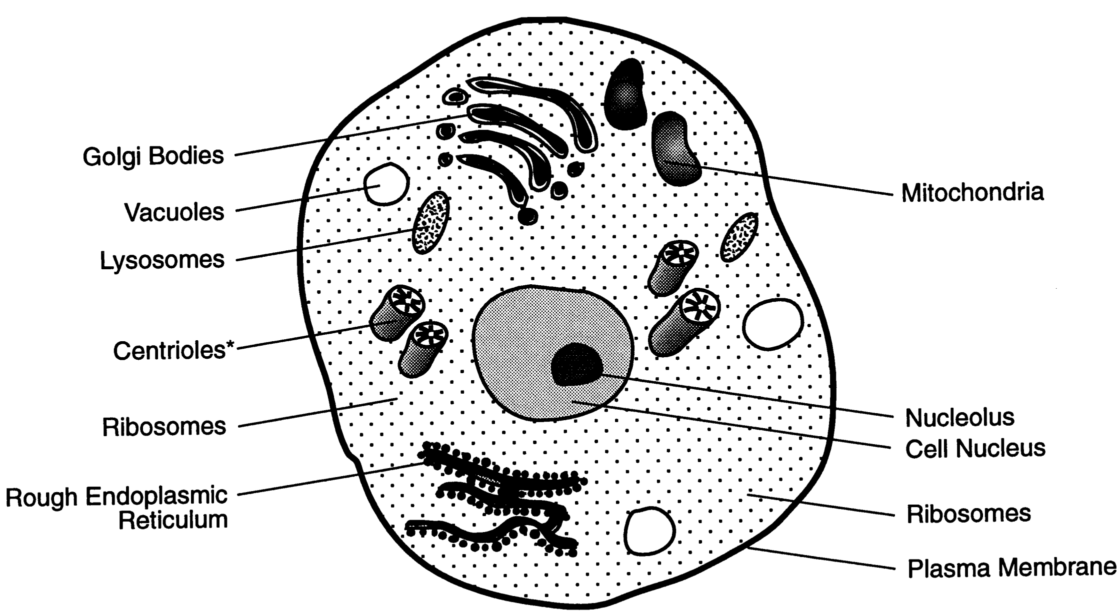
Types of cells - The two types of cells are eukaryotes and prokaryotes. Eukaryotes are cells that contain a membrane-bound cell nucleus. The eukaryote chromatin is held within a well-defined nucleus.

Not all organisms contain a nucleus. Prokaryotes are cells that do not contain a membrane-bound nucleus. The chromatin in prokaryotes is stretched out within the cytoplasm and not held within a nucleus. Bacteria are considered prokaryote because of the lack of a membrane-bound nucleus and other organelles. Prokaryotes lack organelles such as mitochondria and Golgi bodies.

Functions of cells - All active cells have four functions. The first function, nutrition, is the ability to manufacture their own food or obtain food from other environmental sources. The second function is cellular respiration, the process of changing the energy in food molecules into a usable form of energy. The third function, absorption, is the process of absorbing water, minerals, and other necessary elements from environmental sources. Biosynthesis is the fourth function. Biosynthesis is the process of synthesizing complex compounds from simpler compounds. A good example of biosynthesis is changing proteins into amino acids.

Differences between animal and plant cells - There are several differences between animal and plant cells. The first difference is the cell wall. Plant cells have a cell wall that surrounds the plasma membrane, while animal cells do not. When a cell is first formed, a primary cell wall surrounds the cell, and as the cell matures a secondary cell wall is formed inside the plasma membrane. The cell

FIGURE 2.2 - Animal Cell Components




*Found only in animal cells

wall does not determine what enters or exits the cell, but adds strength to the cell. Even when the plant cell dies, the cell wall remains (for example, as bark on trees).

The second difference is chloroplasts. In plant cells, chloroplasts provide green coloring. The third difference is chlorophyll. Plant chlorophyll uses sunlight to manufacture food for the plant.

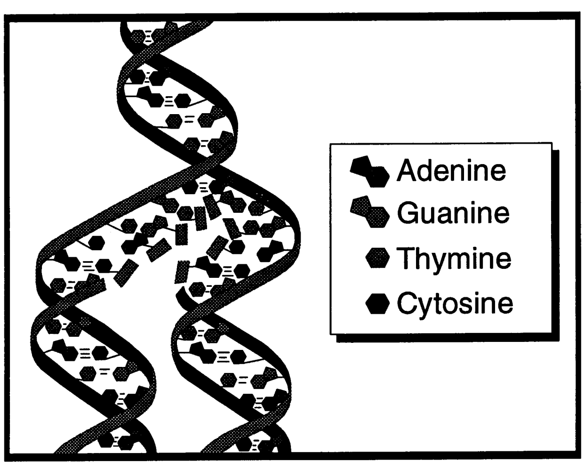
Plastids are the fourth difference. In plants, plastids are organelles capable of storing food for the cell. Animal cells use food just for the current needs of the cell; therefore, no storage of food is necessary.

The fifth difference is chromoplasts. Plant cells contain chromoplasts, which provide color for fruits and flowers. Chromoplasts make tomatoes red, roses yellow, and lettuce green.

**DNA's Effect on Genetics in Livestock**

Definitions of DNA and RNA - DNA (**d**eoxyribo-**n**ucleic **a**cid) is a nucleic acid molecule that controls the production of proteins. DNA is similar to a library in that it stores vital information about the cell. The DNA instructions are used repeatedly in cell division and protein synthesis. In eukaryotes, DNA is stored in the chromosomes in the nucleus. In prokaryotes, DNA is stored in circular strands that are located in the cytoplasm.

Structure of DNA - DNA is composed of nucleotides. Nucleotides are made up of three parts: a phosphate group, a nitrogen base, and a five-carbon sugar called deoxyribose.




| TABLE 2.1 - DNA strand | | |
|---|---|---|
| S ------ | GC | ------ S |
| P | | P |
| S ------ | CG | ------ S |
| P | | P |
| S ------ | AT | ------ S |
| P | | P |
| S ------ | TA | ------ S |
| P | | P |
| S ------ | GC | ------ S |
| P | | P |
| S ------ | CG | ------ S |
| P | | P |
| S ------ | AT | ------ S |
| P | | P |
| S ------ | TA | ------ S |
| P-Phosphate | | |
| S-Deoxyribose sugar | | |
| Nitrogen bases: | | |
| A-Adenine | | |
| T-Thymine | | |
| G-Guanine | | |
| C-Cytosine | | |

| TABLE 2.2 - RNA strand |
|---|
| R--G |
| P |
| R--A |
| P |
| R--U |
| P |
| R--C |
| P |
| R--G |
| P |
| R--A |
| P |
| R--U |
| P |
| R--C |
| R-Ribose sugar |
| P-Phosphate |
| Nitrogen bases: |
| G-Guanine |
| A-Adenine |
| U-Uracil |
| C-Cytosine |

A DNA nucleotide has one of four nitrogen bases. The four nitrogen bases are adenine, guanine, thymine, and cytosine. The "base pairing rule for DNA" is that adenine is always paired with thymine and guanine is always paired with cytosine. These nitrogen bases must be paired in this order to form a DNA strand. Then, these nitrogen pairs are attached to a phosphate and a deoxyribose.

The nitrogen-based pairs are sandwiched between a phosphate and a deoxyribose to form a DNA strand. These constructed DNA strands are then twisted into a spiral, like a spiral staircase. This spiral twist is called a double helix. Table 2.1 shows the structure of a DNA strand. A single DNA molecule can be millions of base pairs long. The order in which the nitrogen bases are arranged determines the function of the cell and the DNA's ability to run.

Formation of amino acids - Codons are three nitrogen bases attached together to form an amino acid. Any one of the triplets can form an amino acid. It does not take all the triplets to form an amino acid. In Table 2.3 is a list of codons that make up amino acids. Several codons represent the same amino acid. Since they have the same meaning, the redundant codons are like synonyms of words.

**RNA's Effect on Genetics in Livestock**

RNA (ribonucleic acid) is a nucleic acid that is shorter in length than DNA. RNA carries messages from DNA, transforms amino acids, and forms ribosome structures.

Structure of RNA - RNA nucleotides contain a phosphate group, a ribose sugar, and a nitrogen base. This is also determined by chemical analysis. RNA is made up of a ribose sugar instead of a deoxyribose found in DNA. Like DNA, RNA contains four nitrogen bases, but RNA contains uracil, which replaces thymine in DNA. Uracil acts in the same way as thymine. RNA usually has only one strand, instead of two like DNA. See Table 2.2.

Functions of RNA - There are three types of RNA--messenger RNA (m-RNA), transfer RNA (t-RNA), and ribosomal RNA (r-RNA). In eukaryotes, DNA never leaves the nucleus, so m-RNA (messenger RNA) carry messages from DNA to ribosomes. Ribosomes synthesize necessary proteins, but DNA decides which proteins need to be synthesized, and the m-RNA carry that assignment to ribosomes.

Transcription is the process of copying the DNA code to RNA strands. Transcription carries the necessary information to the ribosomes to form proteins. Getting all the necessary amino acids and lining them up in the right order to build a specific protein is the job of transfer RNA or (t-RNA). The cytoplasm contains all the amino acids necessary for building a specific protein. The t-RNA then gathers the proper amino acids in proper alignment and brings them to the ribosomes.

Translation is the process of assembling chains of amino acids according to the directions carried by the m-RNA and then translating the message into a particular protein. This assembly of t-RNA and m-RNA is done in the ribosome. The final function of RNA is to form ribosomes. The formation of the structure of ribosomes is done by r-RNA (ribosomal RNA). The r-RNA is made in the nucleolus of the cell.

Differences between DNA and RNA - As mentioned previously, RNA nucleotides contain a sugar, ribose, instead of the deoxyribose found in DNA. RNA contains a nitrogen base called uracil, which takes the place of thymine found in DNA. Uracil still forms a complementary pair with adenine, as in DNA. The DNA strand consists of two strands of a phosphate and a deoxyribose attached to a nitrogen base pair, but in an RNA strand there is only one strand of a phosphate and ribose attached to a nitrogen base pair. Remember, a DNA strand forms a double helix, but an RNA strand does not.

**Summary**

Cells, DNA and RNA are the starting points for all genetic occurrences in livestock. That is why it is so important to comprehend the functions and structures in cells.

**Credits**

McLaren, J.; L. Rotundo. *Heath Biology.* Lexington, MA: D. C. Heath and Company, 1985.

Oram, Raymond F. *Biology Living Systems.* 6th ed. Columbus, OH: Merrill Publishing Company, 1989.

TABLE 2.3 - The 20 Most Common Amino Acids

| Essential amino acids | Non-essential amino acids |
|---|---|
| Arginine (TCT, TCC, GCA, GCG, GCT, GCC) | Alanine (CGA, CGG, CGT, CGC) |
| Histidine (GTA, GTG) | Asparagine (TTA, TTG) |
| Isoleucine (TAA, TAG, TAT) | Aspartic acid (CTA, CTG) |
| Leucine (AAT, AAC, GAA, GAG, GAT, GAC) | Cysteine (ACA, ACG) |
| Lysine (TTT, TTC) | Glutamic acid (CTT, CTC) |
| Methionine (TAC) | Glutamine (GTT, GTC) |
| Phenylalanine (AAA, AAG) | Glycine (CCA, CCG, CCT, CCC) |
| Threonine (TGA, TGG, TGT, TGC) | Proline (GGA, GGG, GGT, GGC) |
| Tryptophan (ACC) | Serine (AGA, AGG, AGT, AGC, TCA, TCG) |
| Valine (CAA, CAG, CAT) | Tyrosine (ATA, ATG) |

# Lesson 3:
## Animal Cell Division

Each animal begins as one cell. This cell divides to make two cells. The cell continues to divide, and groups of cells form specialized tissues and organs in the animal's body. An animal's genetic traits are inherited from their parents through the transfer of genes through cell division.

### Genes and Chromosomes

Rod-shaped chromosomes within the cell nucleus act as carriers for genes, the basic units of heredity. Composed of DNA, each gene organizes itself on the chromosome in a position called a locus. An offspring receives one-half of its total genetic material from each parent. Therefore, the number of chromosomes in each body cell is said to be 2n (diploid). Chromosomes are diploid in number (exist in pairs) in all body cells, except sperm and egg cells. One chromosome of each pair comes from the father and one comes from the mother. The haploid number is "n" and represents the chromosome number found in the sex cells contributed by one parent:

1n (male) + 1n (female) = 2n new offspring

### Chromosomes in Common Livestock

Each species has a designated number of chromosomes. A human being has 46 chromosomes; a donkey has 64; and a bengal tiger has 38 in the 2n state. In diploid cells, chromosomes are paired. Each matched pair tends to resemble the other in size and shape, and they both carry genes affecting the same traits. Chromosomes in this relationship are said to be homologous (meaning alike or equal). Two genes located on the same locus on each homologue constitute a gene pair. One homologue contributes information from the female parent, while the other originates from the male parent.

**Credit:** ***Agriscience 332: Animal Science (Student Reference).*** Courtesy of Instructional Materials Service, Texas A & M University, College Station, Texas. Appreciation is extended to IMS for use of portions of the *Agriscience 332: Animal Science* instructional materials.

TABLE 3.1 - Characteristic Numbers of Chromosomes in Selected Animals

| Animal | Chromosome Number (2n) |
|---|---|
| Horse | 64 |
| Mule | 63 |
| Swine | 38 |
| Sheep | 54 |
| Cattle | 60 |
| Human | 46 |
| Dog | 78 |
| Domestic cat | 38 |
| Chicken | 78 |

Chromosomes contain millions of genes. It is because of the large number of genes and possible combinations of genes that very few animals are exactly alike.

### Cell Division by Mitosis

Through cell division, cells are able to increase in number. The two types of cell division are mitosis and meiosis. In mitosis, each cell divides and forms two "daughter cells," both with a complete set of chromosomes identical to those in the parent cell.

Animal growth is caused by cell division. As cells divide, the animal increases in size. A single cell divides into two cells; these two cells divide into four cells, and so on.

Mitosis is the exact duplication of cells in the body. As shown in Figure 3.1, mitosis involves several different phases.

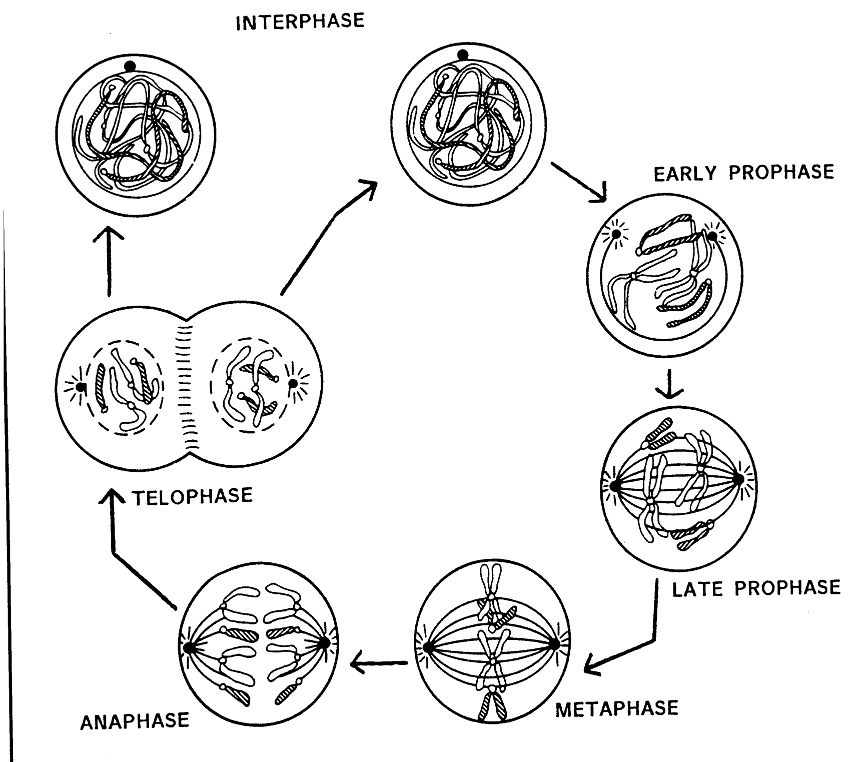
<u>Prophase</u> - The process of mitosis begins in prophase.

1. Early prophase: Chromosomes shorten, thicken, and appear as double strands of sister chromatids connected by a centromere.
2. Mid-prophase: The nuclear membrane disappears.
3. Late prophase: The centromere becomes attached to the newly formed spindle fibers.

<u>Metaphase</u> - The centrioles migrate to the poles, and the chromatids arrange themselves along the equator of the spindle fibers.

FIGURE 3.1 - Mitosis Phases

**Credit:** *Agriscience 332: Animal Science*




Anaphase - Each centromere separates into two centromeres, each with a chromatid. The centromere then moves toward the mitotic center, dragging its chromatid with it. The chromatids become the new chromosomes and are pulled to the centrioles at opposite ends of the cell.

Telophase - The nucleus reforms, and the nuclear membrane reappears around each mitotic center, resulting in two nuclei. The chromosomes grow longer and disperse into a network of fine threads. This phase of mitosis is completed when the cytoplasm. This division forms two new cells with the same chromosome makeup as the original mother cell.

Interphase - This is the resting period between the telophase of one cell division and the prophase of the next division.

**Cell Division by Meiosis**

Inheritance is determined by meiosis and in fertilization. In meiosis, the chromosome number of gametes or sex cells is reduced by one-half from the diploid (2n) number to the haploid (1n) number. When the egg and sperm unite in fertilization, the diploid number of chromosomes are restored to normal. This ensures that the progeny receives one-half of its chromosomes from each parent.

The stages of meiosis are organized into two sequential divisions called Meiosis I and Meiosis II. (See Figure 3.2.) Meiosis I begins with interphase, in which DNA replicates or reproduces itself so that by the beginning of Meiosis II, each chromosome will have two "sister chromatids" joined by a centromere. The stage after interphase is Prophase I, in which the chromatin or genetic material containing DNA appear as thin threads. Prophase of the first meiotic division is subdivided into five stages (Table 3.2).

TABLE 3.2 - Stages in Prophase of Meiosis I

| Stage | Features |
|---|---|
| 1. Leptotene | Chromosomes elongate, but appear single. |
| 2. Zygotene | Homologous chromosomes pair, forming n bivalents. |
| 3. Pachytene | Bivalents shorten. |
| 4. Diplotene | Homologues pull slightly apart, revealing separate chromatids. |
| 5. Diakinesis | Homologous centromeres move apart; chromatids shorten more. |

In the second stage of prophase, homologous chromosomes come together side by side in pairs called synapsis. The chromosomes then contract and thicken; each one splits lengthwise (except at the centromere). These synapsed pairs, known as tetrads, contain four strands called chromatids (two strands from the maternal parent and two from the paternal parent).

When the homologues are paired in this fashion, an event known as crossing over can occur. This involves the exchange of one portion of one chromosome for a corresponding portion of its homologue. This is one way that variation becomes introduced in the inheritance.

In metaphase, the next stage of Meiosis I, the nuclear membrane disappears and the homologues move toward the equatorial or mid-line of the cell. The centromere of each pair of homologues also becomes attached to the spindle--one above and the other below the equator.

During anaphase, homologues separate and are pulled to opposite poles of the cell by the spindle fibers. Thus separated, each homologue consists of two chromatids. Reduction division occurs in anaphase when the number of chromosomes moving toward each pole is only one-half the number of chromosomes in a 2n cell.

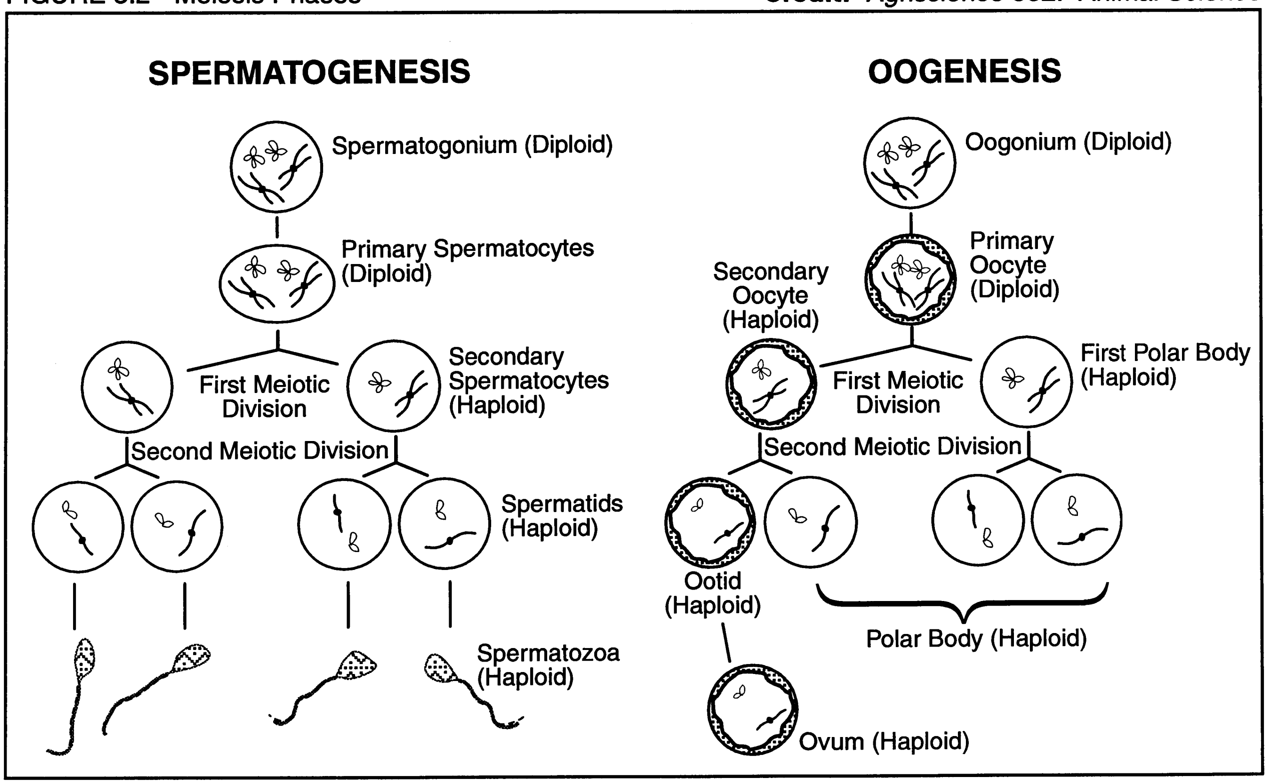
The first meiotic division ends with telophase. Here, the separated chromosomes disperse as the spindle fibers disappear and nuclear membranes form. The cytoplasm divides to create two "daughter cells," each with one-half he chromosomal material of the parent cell. There is a "resting stage" known as interkinesis that lies between Meiosis I and Meiosis II. Unlike interphase, no replication occurs at this time.

Meiosis II begins with Prophase II. During this stage, the genetic material condenses once more to form visible chromosomes. Recall that each chromosome is now composed of only two chromatids. Spindle fibers form as the nuclear membranes dissolve.

Chromosomes line up on the equatorial plane in Metaphase II. The centromere of the sister chromatids separate as the spindle fibers act to pull the new, individual chromatids to the opposing poles of each cell to complete Anaphase II.

Meiosis II ends in Telophase II where the chromosomes disperse, the spindle fibers are eliminated, and nuclear envelopes reform. The

FIGURE 3.2 - Meiosis Phases **Credit:** *Agriscience 332: Animal Science*



cytoplasm divides again. The end product results in four individual sex cells that contain a haploid number of genetic material in each. The process is more simply described in consecutive steps:

Step 1: Chromosomes begin to appear as thread-like strands. Each chromosome has already replicated during interphase.
Step 2: Each doubled chromosome lines up with another doubled chromosome of equal length.
Step 3: Each group of four chromosomes line up along the center of the cell. Fibers formed in the cell move the chromosomes to their correct positions.
Step 4: The groups of four chromosomes now separate. The original and its replication remain together. Those pairs are pulled toward one end of the cell. The other pair is pulled to the opposite end.
Step 5: The cell splits in half, forming two new cells. So far, the chromosome number of each new cell is the same as the number in the original cell.
Step 6: Once again, the chromosome pairs line up along the center of the cell. This time they line up in a direction different from Step 3.
Step 7: Chromosome pairs pull apart. An original moves toward one end of the cell, while a copy moves in the opposite direction.
Step 8: Each new cell now separates into two. A nuclear membrane begins to form around the chromosomes. Note that in Step 1 there was one cell containing four chromosomes before each replicated. Now there are four new sex cells, each with half the number of chromosomes that was present in the original cell.

Meiosis produces both sperm and egg cells. In the male, spermatogenesis produces four sperm cells from each cell. Each of these receives one-half the number of chromosomes of the original cell. In the female process of oogenesis, however, only one egg is produced; it has one-half of the chromosomes present in the original cell. The other three cells, called polar bodies, die in the process of egg formation.

Comparing mitosis and meiosis - Mitosis and meiosis are both forms of cell division, although they are not used for the same type of cells. Meiosis involves two separate divisions, while mitosis involves only one. For other differences, see Figure 3.3.

**Summary**

An animal's body is made up of millions of cells. Animals grow by cell division. The cell nucleus contains chromosomes, which are found in pairs. One chromosome of the pair comes from the father and one comes from the mother. Ordinary cell division is called mitosis, and each cell is exactly like the old cell. Reproductive cells are called gametes, which divide by meiosis.

**Credits**

*Agriscience 332: Animal Science (Student Reference).* Texas A & M University: Instructional Materials Service, 1989.

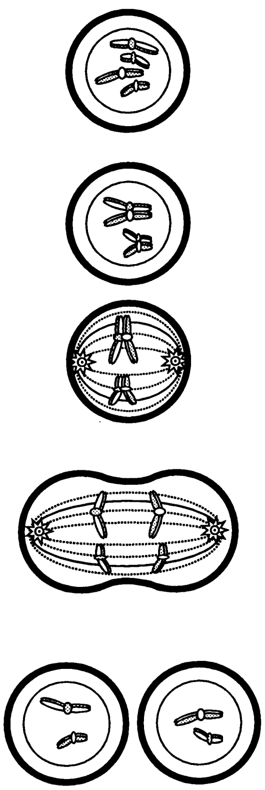
Gillespie, James R. *Modern Livestock and Poultry Production.* 4th ed. Albany, NY: Delmar Publishers, Inc., 1992.

Oram, Raymond F. *Biology Living Systems.* Columbus, OH: Merrill Publishing Company, 1989.

FIGURE 3.3 - Meiosis vs. Mitosis **Credit:** *Agriscience 332: Animal Science*

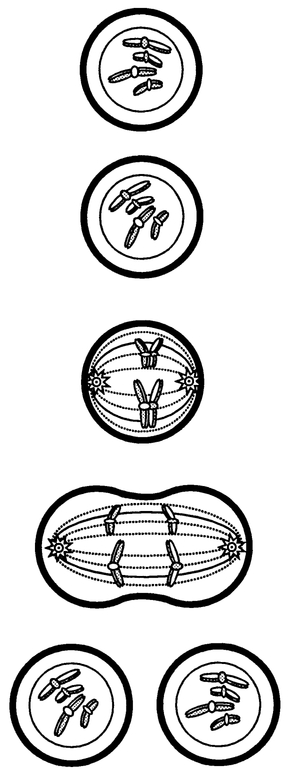
## MEIOSIS (First Division)

1. Two pairs of chromosomes in each cell. Each chromosome has two equal parts called chromatids.
2. The two members of each pair of chromosomes come together, forming a four-part chromosome called a tetrad.
3. Nuclear membrane disappears. Tetrads line up on the spindle. Spindle fibers are attached to the centromeres.
4. Each tetrad separates into two chromosomes. These chromosomes move in opposite directions. Each chromosome is still composed of two chromatids.
5. Two cells result. Each contains half the number chromosomes that were in the original cell. The chromosomes are still in the form of chromatids.



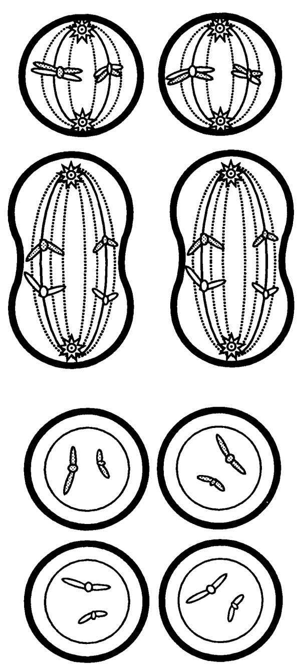
## MITOSIS

1. Two pairs of chromosomes in each cell. Each chromosome has two equal parts called chromatids.
2. No tetrad formation.
3. Nuclear membrane disappears. Chromosomes line up on the spindle. Spindle fibers are attached to the centromeres.
4. The chromatids separate from each other and pull apart. Matching chromatids go in opposite directions. The cell divides.
5. Two cells result. Each contains the same number of chromosomes as in the original cell. Each chromosome is now a single unit.



## MEIOSIS (Second Division)

6. Chromosomes line up on a spindle again. Each contains two chromatids.
7. This time the chromatids separate from each other and pull apart. The cells divide.
8. Four cells result. Each contains half the number of the chromosomes in the original cell. Each chromosome now consists of a single unit.



# Lesson 4:
## Basic Principles of Genetics

Each animal is made up of many different characteristics. Its color, size, being horned or polled, and carcass traits are only a few of the characteristics that are inherited from its parents. Genes control these traits and are the basic units of heredity. Even the word "genetics" originates from the word "gene."

### Roles of Genes and Alleles

Genes and alleles - Chromosomes within the cell nucleus act as carriers for genes. Composed of DNA, each gene organizes itself on the chromosome in a position called a locus (plural, loci). An offspring receives one-half of its total genetic material from each parent. Therefore, the number of chromosomes in each body cell of an organism is 2n or diploid. The haploid number is "n" and represents the chromosome number found in sex cells contributed by one parent.

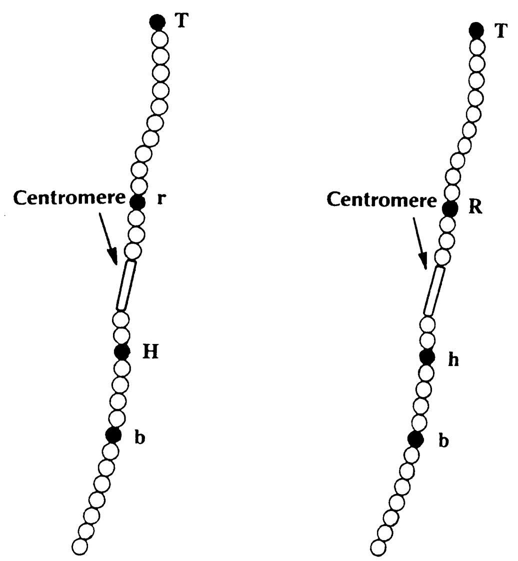
In diploid pairs, the chromosomes are paired. Each matched pair resembles each other in size and shape, and they both carry genes affecting the same traits. Chromosomes in this relationship are homologous. Two genes, which are located on the same loci on each homologue, form a gene pair. One homologue contributes information from the female parent, while the other originates from the male parent.

Each gene pair has two alleles. These two alleles interact to influence the character traits of an organism. A species may contain many different forms (multiple alleles) of the same gene. For example, a gene pair that codes for flower color may have several possible combinations. The allele "R" might represent an allele that codes for red, while "r" might code for blue flowers, and "y" might code for yellow. (See Figure 4.1.)

Additive and nonadditive gene action - An additive type of gene action refers to the situation when several individual genes each add to the phenotypic expression of a trait. Performance traits, with high heritability, such as rate of gain, feed efficiency, lactation, and egg laying are often affected by additive gene action. These types of traits might be affected by many pairs of genes.

FIGURE 4.1 - Homologous Chromosome Pair Diagram

**Credit:** ***Agriscience 332H: Animal Science (Student Reference).*** Courtesy of Instructional Materials Service, Texas A & M University, College Station, Texas. Appreciation is extended to IMS for use of portions of the *Agriscience 332H: Animal Science* instructional materials.




When additive gene action is involved, superiority for a trait depends on the number of desirable genes an individual possesses. Therefore, selection for additive gene action should be based primarily on the individual's merit.

TABLE 4.1 - Traits Controlled by a Single Pair of Genes

| Dominant | Recessive |
|---|---|
| Black-colored Holstein | Red-colored Holstein |
| Polled cattle | Horned cattle |
| White-wooled sheep | Black-wooled sheep |
| Mule-footed swine | Normal-footed swine |
| Black-colored Angus | Red-colored Angus |
| White-faced Herefords | Self-faced Angus |
| Black-colored horse | Chestnut horse |
| Dutch-belt pattern | No belting pattern |

Nonadditive genes control traits by the way gene pairs act in different combinations with one another. When combinations of gene pairs give good effects, the offspring will be better than either of its parents. This condition, called overdominance, exists when the heterozygote is phenotypically superior to either of the homozygous parents. This is often called heterosis or hybrid vigor.

**Genotypes and Phenotypes**

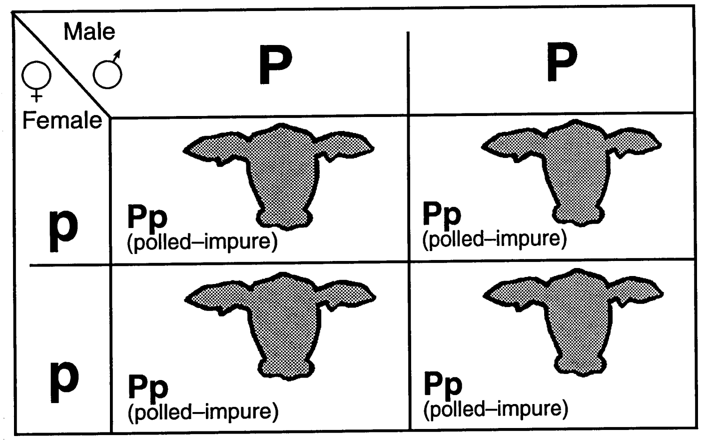
The genotype of an animal refers to the actual configuration of genes in the animal's cells. The phenotype refers to visible differences in the physical makeup of animals (color, weight, body structure, horned or polled, etc.). This makeup can be observed and is the result of the animal's genotype. Therefore, these phenotypic characteristics of animals, called traits, are controlled a pair of genes or several pairs of genes. Although the development of all traits is predetermined by the action of genes, some can be modified because of differences in the environment.

A square or a checkerboard diagram shows the probable results of breeding livestock. Normally, the male genotype is shown at the top, and the female genotype is indicated in the vertical margin. When crossing homozygous dominant parents (PP x PP), all offspring will be homozygous dominant polled individuals. Each of them can only produce a gamete with the dominant for the polled trait. The situation is the same when crossing homozygous recessive parents (pp x pp). All offspring will be horned. When crossing a homozygous dominant parent with a homozygous recessive parent (PP x pp), all offspring would be heterozygous and polled. This cross is illustrated in Figure 4.2.

When crossing a heterozygous parent with a homozygous dominant parent (Pp x PP), the expected offspring would occur in a 1:1 ratio of homozygous dominant to heterozygous individuals. Phenotypically, all offspring would be polled. If two heterozygous parents are crossed (Pp x Pp), one can expect an offspring genotypic ratio of 3:1 of the phenotypic expression of dominant pooled traits. Genotypically, there is a possibility of one homozygous dominant polled, one homozygous recessive horned, and two heterozygous polled offspring. The horned

FIGURE 4.2 - Homozygous Polled (PP) X Homozygous Horned (pp)

**Credit:** *Agriscience 332H: Animal Science*




individual produced from the cross will not carry a gene for the polled trait, although both parents were polled. This cross is shown in Figure 4.3.

To learn if a polled bull is homozygous for the polled trait (PP), the bull can be bred to homozygous recessive horned cows (pp). If he is homozygous for the polled trait, his offspring will all be polled. If this polled bull is mated to at least five horned cows with no resulting horned offspring, it is likely (95 percent probable) that the bull is homozygous for the polled trait. This test can determine whether animals are homozygous or heterozygous for other traits, as well.

FIGURE 4.3 - Heterozygous Polled (Pp) X Heterozygous (Pp)

**Credit:** *Agriscience 332H: Animal Science*

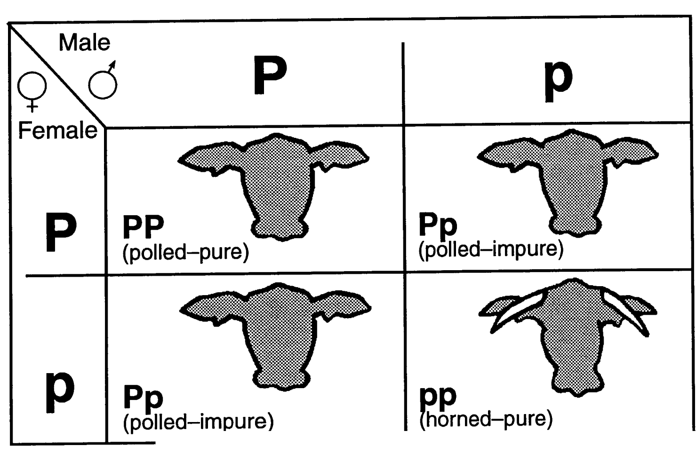


FIGURE 4.4 - Two Pairs of Heterozygous Genes, Each Affecting a Different Trait
**Credit:** *Agriscience 332H: Animal Science*

| Female ♀ \ Male ♂ | PW | Pw | pW | pw |
|---|---|---|---|---|
| **PW** | PPWW (polled whitefaced) | PPWw (polled whitefaced) | PpWW (polled whitefaced) | PpWw (polled whitefaced) |
| **Pw** | PPWw (polled whitefaced) | PPww (polled colored faced) | PpWw (polled whitefaced) | Ppww (polled colored faced) |
| **pW** | PpWW (polled whitefaced) | PpWw (polled whitefaced) | ppWW (horned whitefaced) | ppWw (horned whitefaced) |
| **pw** | PpWw (polled whitefaced) | Ppww (polled colored faced) | ppWw (horned whitefaced) | ppww (horned colored faced) |

Only single traits have been discussed up to this point. There are a number of traits to consider in any cross. One can expect a 3:1 ratio based on offspring appearance of a cross between individuals heterozygous for a dominant trait. With two pairs of heterozygous genes, each affecting a different trait, a 9:3:3:1 ration would be expected. (See Figure 4.4.) In the example, two individuals are mated that are heterozygous for the polled and white-faced traits. From this mating, the offspring phenotypically include nine polled white-faced, three polled colored-faced, three horned white-faced, and one horned colored-faced offspring.

### Dominant and Recessive Traits

A gene pair is homozygous if both alleles are identical. They may be either dominant or recessive for the particular trait they represent. While homozygous alleles influence the same trait similarly, heterozygous pairs influence the same trait in different ways.

All alleles do not influence traits equally. A dominant allele determines the phenotypic (visible) characteristics, even if only one chromosome of the pair carries that information. Dominant alleles are designated by capital letters, while recessive traits are shown by lower case letters.

For example, "T" represents tallness in cattle and "t" represents shortness. Possible combinations of these two alleles are:

TT - two dominant alleles (tall cattle)
Tt - one dominant allele, one recessive allele (tall cattle)
tt - two recessive alleles (short cattle)

In some situations, incomplete dominance may occur. If "R" encodes red hair in cattle, "W" encodes white hair, and both were equally dominant, neither color would be fully expressed in an RW genotype. The offspring would be roan, a combination of red and white.

**Homogenous and Heterogenous Traits**

Chromosomes illustrated in Figure 4.1 are homologous because they bear genes affecting the same traits. The circles represent individual genes composed of base sequences. The centromere is a region of the chromosome where spindle fibers become attached. The fibers are important in the movement of chromosomes during meiosis and mitosis (cell divisions).

Contrasting alleles "T" and "t" affect animal height: "T" specifying tallness and "t" specifying shortness. The contrasting alleles "R" and "r" affect resistance to a particular disease: "R" specifying resistance to disease and "r" specifying susceptibility. Contrasting alleles "H" and "h" determine horned of polled conditions: "H" specifying a horned condition and "h" specifying a polled condition. Contrasting alleles "B" and "b" affect hair color. "B" specifies black and "b" specifies red.

The gene pair of alleles "T" and "T," and the gene pair of alleles "b" and "b," are identical alleles. Therefore, this genotype is homozygous for the genes for height and coat color. The gene pair of alleles "R" and "r," and the gene pair of alleles "H" and "h," are contrasting alleles. Thus, this genotype is heterozygous for disease resistance and horn development.

**Basic Genetic Laws**

Incomplete dominance - The phenotypic expression of a trait can also be the result of a lack of dominance. The coat color of Shorthorn cattle is a typical example of a lack of dominance. The two allelic genes involved are R for red color and W for white color. If the genotype of a Shorthorn is RR, it will be red; if its genotype is WW, it will be white. However, if its genotype is RW, the Shorthorn will be roan or a mixture of red and white.

In Shorthorn coat color, there are three genotypes and three phenotypes that are easily distinguishable. Mating a red Shorthorn (RR) to a white one (WW) results in roan (RW) offspring.

FIGURE 4.5 - Epistasis Exhibited by the Coat Color in Rabbits

**Credit:** *Agriscience 332H: Animal Science*

| Female ♀ \ Male ♂ | CB | Cb | cB | cb |
|---|---|---|---|---|
| CB | CCBB (BLACK) | CCBb (BLACK) | CcBB (BLACK) | CcBb (BLACK) |
| Cb | CCBb (BLACK) | CCbb (CHOCOLATE) | CcBb (BLACK) | Ccbb (CHOCOLATE) |
| cB | CcBB (BLACK) | CcBb (BLACK) | ccBB (ALBINO) | ccBb (ALBINO) |
| cb | CcBb (BLACK) | Ccbb (CHOCOLATE) | ccBb (ALBINO) | ccbb (ALBINO) |

Epistasis - Epistasis is the interaction of two or more gene pairs that are not alleles, resulting in a phenotype that is different from the individual expression of the gene pairs. This type of inheritance is different from overdominance because overdominance results from the interaction of allelic genes. Epistasis affects animal phenotypes in different ways due to various interactions between nonallelic genes.

One example of epistasis is coat color in rabbits. Consider the possibilities of black, chocolate or albino (B=black, b=chocolate, C=color and c=albino). If a rabbit is homozygous for the gene for albino (cc), regardless of whether the individual carries genes for black or chocolate, it will be albino. However, if the offspring carries at least one gene for color (C), then the action of the other pair of genes is expressed. The gene for black (B) is dominant. Therefore, if an individual carries at least one black gene, it will be black. If the animal's genotype is bb and it has at least one gene for color, it will be chocolate. Figure 4.5 shows the possible outcomes if two rabbits that are heterozygous for both traits are mated. This is an example of a recessive epistatic gene greatly affecting all other genes for color.

There are various other combinations of epistatic genes, such as dominant epistatic, dominant and recessive epistatic, and pairs of recessive epistatic genes. Most species of animals have traits controlled by epistasis. The interaction between these gene pairs can be quite complicated, especially when many pairs of genes are involved.

Sex-linked traits - Some traits are sex-linked because they are carried on the X-chromosome that decides the sex of the animal. Remember, the female mammal has the genotype XX in the sex chromosome pair, while the male has an XY genotype. The X-chromosome is larger and longer than the Y-chromosome. Therefore, there is some portion of the X-chromosome that does not pair with genes on the Y-chromosome. There is also a certain portion of the Y-chromosome that does not link with the X-chromosome. Traits on this portion of the Y-chromosome are transmitted only from fathers to sons. Sex-linked traits are often recessive and are covered up in the female mammal by dominant genes.

Mutations - Genes can duplicate themselves. However, sometimes a mistake is made in duplication and a new gene called a mutation is born. This new gene will result in a change in the code sent by the mRNA to the protein formation process. Some mutations can cause a defect in animals, while others may be beneficial. Mutations are responsible for variations in coat color, size, shape, behavior, and other traits.

Law of segregation - As explained earlier, genes occur in pairs in the body cells. Because of the processes of meiosis and fertilization, an individual receives one gene from the father and one from the mother. Mendel's law of segregation and the recombination of genes shows that genes paired in body cells separate independently of each other. Therefore, there is a 50 percent probability that the offspring of an individual in the $F_1$ or first generation will possess a particular gene.

The probability that a particular gene will recombine during the fertilization process can also be predicted, provided no mutations or other chromosomal abnormalities occur. If two heterozygous individuals for a particular trait are mated (Aa x Aa), the probability that offspring will have certain genotypes is: AA (25 percent), Aa (50 percent), or aa (25 percent). As more genes become involved in a particular trait's heritability, the probability of selected genes recombining in offspring becomes more complex.

**Summary**

Much of the improvement in livestock results from using the principles of genetics. Genes control an animal's traits, and they are the basic units of heredity. Understanding the processes of gene action can assist in further genetic improvement in livestock.

**Credits**

*Agriscience 332H: Advanced Animal Science (Student Reference).* Texas A & M University: Instructional Materials Service, 1990.

*Livestock and Poultry Breeding (Student Manual).* 2nd ed. The Ohio State University: Agricultural Education Curriculum Materials Service, 1991.

Gillespie, James R. *Modern Livestock and Poultry Production.* 4th ed. Albany, NY: Delmar Publishers, Inc., 1992.

## Lesson 5: Tools for Genetic Improvement of Beef

Factors to consider when establishing a beef herd are: purebred or commercial, purebred or crossbred, price, adaptation, condition, age, longevity, health, herd size, and milking ability. Animal selection should be based on pedigree, individual performance and appearance, show-ring winnings, and performance testing.

**Sire and Female Selection**

Establishing a beef herd - There are several factors to consider before investing funds. There are two types of beef producers--the purebred operation and the commercial operator.

Purebred operators are a select few. They produce seed stock for commercial and other purebred operators. A higher investment is required to participate in a purebred operation because of the higher costs of breeding stock and facilities.

Commercial operators produce the majority of cattle in America. Their goal is to convert land, grass, and crops into a monetary form through traditional cow-calf operations, backgrounding, and feedlots. In commercial operations, crossbreeding is the most widely used breeding system. A commercial operator uses less capital to begin an operation than the purebred operator. The price of commercial breeding stock is comparable to market value or price.

The selection of a breed or deciding to use a cross is the next decision to make when establishing a beef herd. Purebred operators usually choose a breed based on personal preference or the breed with which they have had the greatest success.

This decision is difficult for commercial operators because of the increasing number of breeds and possible crosses. For instance, if there were 10 breeds of beef cattle, there would be 45 different single crosses and 360 possible three-way crosses from which to choose. But there are many more than 10 breeds of beef cattle (closer to 54 breeds). When establishing a beef herd, carefully research the decision on which breeds to use.

Consider milking ability when establishing a beef herd. The single most important factor in determining weaning weights is the ability of the mother to provide milk to her offspring. Remember, a lot of milk--a lot of calf, little milk--little calf!

A uniform herd is the goal of every purebred beef producer. Having the same size and color is essential for marketing in the purebred industry. If uniformity is lacking in a purebred operation, the life of that establishment will be short.

Uniformity is just as important in commercial operations as in purebred operations. Cattle buyers look for uniform size and muscling when buying cattle.

A beef producer must decide on the size of the herd. Several factors influence herd size. The first factor is the amount of labor needed to maintain the herd. An operator who runs a herd alone will probably have a smaller herd than one with three hired hands.

Quality is not determined by the size of the herd. Some of the finest beef stock are found on smaller operations. The cost of buying stock, cost of land, and the cost of facilities determine the size of herd.

No one wants breeding stock or market animals that are unhealthy. The purebred industry requires a certificate of health in the sale of an animal. Animals are tested for certain diseases before they are put up for sale. The health of beef animals is important to the future of the industry. When buying stock, remember to buy from operators and sale barns with strict health codes and reputations.

Consider the environmental conditions in the area, such as arid conditions of the southwest, the grain-producing Midwest, or the cold conditions of the northeast. Environmental conditions in certain areas are not suitable for certain breeds; this applies to both purebred and commercial industries.

When purchasing or selecting animals for breeding stock, always remember the importance of the animals' condition. Extremely thin or fat stock are detrimental to the herd because of low reproductive rates. Conditioning is a very important factor in selecting, purchasing, and managing stock in a herd.

Price is a very important factor because it will influence herd size and breed selection. The price of purebred animals is largely determined by the operator's reputation and the quality of stock.

Purebred animals bring more than market price because of the genetic superiority, extra costs associated with purebred operations, and the quality of stock. In the commercial industry, it is seldom necessary to pay more than market price for females, but it is beneficial to pay more for the sire to ensure genetic quality.

The final factors in establishing a beef herd are age and longevity of females. The longer a female can produce offspring that meets the standards set by the producer, the smaller the costs of buying replacement animals. Replacement animals are chosen based on price and the number of years remaining to produce quality offspring.

<u>Four bases of selection in beef cattle</u> - These bases are: (1) individuality and appearance, (2) production testing, (3) show-ring winnings, and (4) pedigree. Each method of selection has its own purpose, and it is up to the producer to emphasize one area of selection over another.

Selection based on appearance and individuality is completed using one of two methods--the traditional score card or the functional scoring system. The traditional score card lists individual body parts and gives them a numerical value. Body parts might include flank, rump, loin area, structure, head, and neck. A perfect score is 100 points. Each breed association has developed its own score card for the breed. This system is very valuable because looks can be deceiving.

The other individuality/appearance method is the functional scoring system. Here, the parts of the animal are divided into areas. Reproductive efficiency, muscling, size, freedom from waste, structural soundness, and breed type are the six areas in which the animal is divided. Numerical values are also given to each area for a maximum of 100 points.

Each area has economic importance. Reproductive efficiency is divided by gender. A female must have a long body, leanness, sound udder structure, smooth muscles, functional udder, and feminine characteristics to score 20 points. A male must possess masculine traits, muscling, well-developed genitalia, equal-sized testicles, and proper neck-to-scrotum length to score 20 points.

Muscling is also awarded 20 points. Muscles need to be smooth and round, not square, and must bulge and move when walking. Loin muscle must bulge on both sides to score well. Muscling applies more to bulls and steers than heifers.

Size is awarded 15 points. Animals must have adequate height at the hip and shoulder, adequate length of body, and leanness to score 15 points. Avoid early maturing bulls because they will lack growth spurts as they grow older.

Freedom of waste is also awarded 15 points. Trimness in both breeding and slaughter animals is very important. Fat animals have lower reproductive rates and lower carcass quality. As a producer, avoid loosely hided animals.

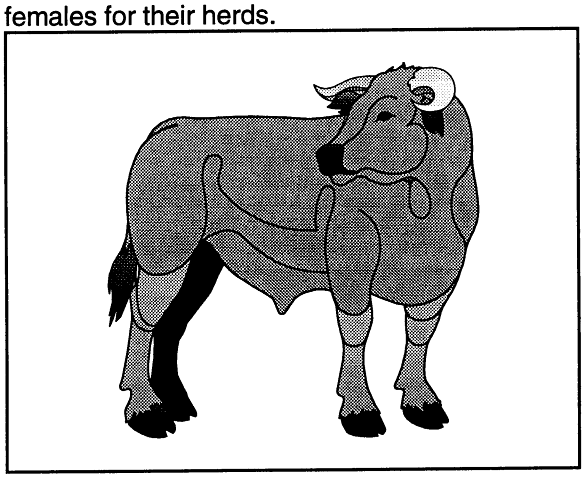
Structural soundness is also awarded 15 points. Animals must possess squarely set legs that are straight and true, squarely set toes and hocks, and equally sized toes to score 15 points. Avoid animals with hocks and joints that appear swollen.

Breed type is awarded 15 points. The animal must show signs of the breed, such as proper color; body markings, shape, and size; polled or horned; and proper shape of the head.

In general, selection based on performance testing can be described as the record keeping or data collection of the progressive stages of an animal. Data should be collected on birth weight, weaning weight, yearling weight, rate of gain, feed efficiency, pasture gain, feedlot gain, carcass traits, and conformation score. Collect data throughout different stages in the animal's life. This information is helpful when selecting animals because of the measurable traits.

Selection based on pedigree is used to judge future performance of offspring based on past performance of parents and ancestors. Selection based on pedigree is used more often in the purebred industry than in the commercial industry. Traits such as fertility, birth weight, weaning weight, rate of gain, and carcass traits all have economic importance and are transferred by inheritance. This demonstrates the importance of performance testing and pedigree selection.

Selection based on show-ring winnings is used often in the purebred industry. Animals that consistently win in the show-ring circuit are looked on favorably by producers in the purebred industry. Judges look for different characteristics each year when consumer needs change; that is why there is such an emphasis on show-ring winnings. Show-ring winners bring higher prices, though. Commercial producers also use the show-ring circuit to choose outstanding sires and females for their herds.



**Crossbreeding and Hybrid Vigor**

Crossbreeding is the breeding system that mates two or more different breeds to gain more quality traits. Crossbreeding is used for several different reasons. First, it increases productivity over purebred animals in the form of hybrid vigor. Second, it produces animals with a combination of desirable traits that are not found in any specific breed. Finally, crossbreeding produces foundation stock for new breeds.

Advantages - Crossbreeding introduces new and desirable genes quickly or at faster rate than selection within a breed. A good example is crossing a dairy breed to a beef breed to increase milking ability in the beef herd. Using a dairy sire to mate beef females will increase milking ability in one generation. If selecting from within a breed, it may take several generations to increase milking ability in the herd.

Another advantage is hybrid vigor or heterosis. Hybrid vigor is a biological phenomenon that causes crossbred offspring to outproduce the average of their parents. Hybrid vigor occurs because a dominant gene in a parent is usually more favorable than its recessive partner. When two separate gene pools are mixed together, the traits that may have been lacking now become superior with the mixture of genes. The example of crossing the dairy and beef animals explains the essence of hybrid vigor.

The use of complementary traits is another advantage of crossbreeding. Here, two or more characteristics complement or combine with each other. This results in the maximum desired traits in a cross. Each breed is known for certain desirable characteristics, and matching them with another breed that lacks those desired traits is referred to complementary crossing.

Types of crossbreeding - A two-breed cross mates a purebred sire to a purebred female of a different breed. Hybrid vigor only appears in the offspring, which is a limitation of this crossbreeding system. Another limitation is that the cross does not make use of a crossbred female.

A two-breed backcross or crisscross involves the use of a sire of breed A mated with a female of breed B. The offspring is then backcrossed to either breed A or B, resulting in a 1/4 to 3/4 breed. Mating a purebred Hereford sire to a purebred Angus female, then mating the offspring to a purebred Hereford or Angus sire, will result in a two-breed backcross or crisscross.

A three-breed rotational cross is another crossbreeding system. A rotational cross involves mating a purebred Beefmaster sire to a purebred Angus female, mating the offspring to a purebred Hereford sire, and then mating this offspring back to a purebred Angus sire, so that all three breeds had sired the offspring. Hybrid vigor will appear in all sets of offspring.

The last crossbreeding system is the three-breed fixed or static cross (terminal cross). This system mates a crossbred female (two-breed cross) to a third breed sire, which results in a three-breed fixed or static cross. In this system, all offspring are sold. When replacement females are needed, new females of the same two-way cross are purchased. A limitation of this system is buying the same quality of replacement females of the same cross. An example of a terminal cross is breeding a purebred Holstein sire to an Angus-Hereford cross female.

**EPDs and How They Are Used**

Expected Progeny Differences can be used to estimate how future progeny of the subject animal will compare to progeny of other animals within the breed. EPDs are designed to compare bulls based on estimated performance of the progeny, not to predict the performance of one or two progeny of a sire.

On the average, a bull with an EPD score of +50 lbs. yearling weight would be expected to sire calves 20 lbs. heavier than a bull with +30 lbs. yearling weight.

EPDs are used heavily in all phases of beef enterprises. Purebred and commercial herd owners use EPDs to select sires for different production traits.

Accuracy and reliability - The accuracy figure (ACC) is the reliability measure of the EPD. An accuracy of 1.00 is of the highest reliability. Accuracy is categorized as low (0.00 to .5), medium (.51 to .75), and high (.76 to 1.00). With low ACC, the possible change in pounds is high.

Reliability is increased as the number of progeny reported per sire increases (and decreases the amount of EPD change). For example, an ACC of .2 for weaning weight means that the EPD can change ±13.8. An ACC of .9 in the same trait and breed means weaning weight could change ±1.7 for that sire.

These numbers are examples of standards set up by breed associations. In Table 5.1, Bull A has an ACC figure of .91, which means a calf sired by Bull A will have a weaning weight of 22.2-25.6 pounds heavier than Bull B. Another example of ACC figures is that a .2 ACC for birth weight represents ±3.1 lbs.; a .9 ACC figure represents ±.4 lbs. This means a calf sired by Bull A will have a birth weight of 7.1-7.9 lbs. heavier than Bull B.

Table 5.1 shows an example of sire summary data for EPDs on four sires.

**Summary**

Application of sound selection methods and usage of EPDs are vital for beef producers to stay on the cutting edge of beef production.

**Credits**

Ensminger, M. E. *Animal Science Digest.* Danville, IL: Interstate Publishers Inc., 1991.

Ensminger, M. E. *The Stockman's Handbook.* 7th ed. Danville, IL: Interstate Publishers, Inc., 1992.

University of Missouri-Columbia Extension Division agricultural publication

a) GO2032: Understanding and Using Sire Summaries

TABLE 5.1 - Sample Sire Summary Data

| Sire | Birth weight | | Weaning weight | | Yearling weight | | Milk | |
|---|---|---|---|---|---|---|---|---|
| | EPD | ACC | EPD | ACC | EPD | ACC | EPD | ACC |
| Bull A | +7.7 | .93 | +29.6 | .91 | +42.3 | .78 | -20.3 | .85 |
| Bull B | +0.2 | .67 | +5.7 | .7 | +29.1 | .42 | +4.9 | .4 |
| Bull C | +6.5 | .89 | +39.3 | .85 | +62.0 | .72 | +16.5 | .72 |
| Bull D | +0.5 | .05 | +10.2 | .05 | +31.1 | .05 | +8 | .05 |

# Lesson 6:
## Selection Tools for Genetic Improvement of Dairy Cattle

Of all the species of livestock, dairy cattle are the most specialized in their performance area. They are expected to produce the most milk on the least amount of inputs. For this reason, genetic selection for optimal performance is an important factor when selecting individuals to be included in a dairy operation. (See Table 6.1.)

**Selecting Dairy Cows and Heifers**

Breed selection - The five common breeds of dairy cattle are Ayrshire, Brown Swiss, Guernsey, Holstein, and Jersey. Although there is no one best breed, there might be a particular breed that is favored by an individual dairy producer because it is better suited for certain farm conditions and market demands.

Selecting a breed of dairy cattle is like selecting any other item where an individual has a variety from which to choose. After considering all the advantages and disadvantages, personal preference may be the determining factor.

Consider each of these factors in selecting a dairy breed for an individual dairy operation.

1. The availability of breeding stock of the type and quality that is desired
2. The producer's markets for milk and butterfat
3. Availability of forage crops and pastures (since the larger and more rugged breeds require more roughage)
4. Climatic conditions, because breeds differ in ability to withstand temperature extremes
5. Age of maturity, since heifers of larger breeds do not usually mature and come into production as early as the smaller breeds
6. Local popularity of a breed (for marketing surplus stock and breeding stock availability)
7. The size and vigor of newborn calves, especially in relation to replacement prospects and for calving difficulties

Individual selection - Four factors are usually involved in selecting individual dairy animals: (a) type or physical appearance, (b) production records, (c) pedigrees, and (d) health and vigor.

Certain physical characteristics are associated with high milk production. Since type and production are closely related, it is important to become familiar with the correct or ideal dairy type. Understanding these characteristics makes it possible to judge the productive capacity of an animal before production records are available or when records are unavailable.

| | |
|---|---|
| Fat test | 50 |
| Protein test | 50 |
| Size | 50 |
| Birth weight | 45 |
| Weight | 35 |
| Gestation length | 35 |
| Fore and rear udder | 35 |
| General appearance | 33 |
| Type | 30 |
| Dairy character | 30 |
| Milk yields | 25 |
| Mastitis | 25 |
| Breed character | 25 |
| Milking ability | 24 |
| Body capacity | 23 |
| Udder depth | 22 |
| Teats, veins, and quality | 20 |
| Feet and legs | 18 |
| Longevity | 10 |
| Udder size and shape | 7 |
| Teat length | 5 |
| Reproductive performance | 3 |
| Service per conception | 3 |

The five major dairy breed associations in the U.S. have cooperated through the Purebred Cattle Association to develop a unified score card for dairy cows and bulls. This card indicates points to be considered in selecting dairy cattle and the emphasis to be placed on each area.

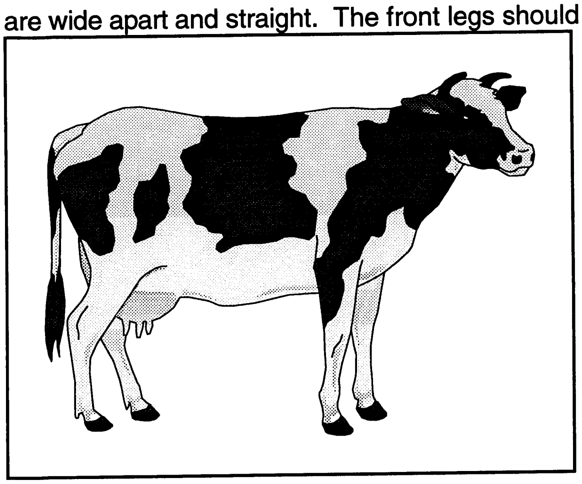
Dairy producers who use trait evaluation as a guide in selecting sires and mating cows find they can improve production, increase the number of profitable lactations, and reduce herd replacement numbers. This linear classification program measures precisely and uniformly all descriptive functional traits known to have a bearing on production of the animal.

*Form* includes stature, strength, body depth, and angularity. The classifier must study several features, such as the cow's measurement from the ground to the top of the withers, width and depth of the chest, muzzle width and substance of bone in the front end, depth of rib cage, rib openness, neck length, and sharpness and flatness of bone.

*Rump* evaluation includes angle, length, and width. Blending smoothly from the loin, the rump should appear long from the side and wide from the rear view. The distance between the hip and the pin bones determines the length of the rump. The thurl, or area between the hip and pin bones, should appear high, level, and full as viewed from the side, and both thurls should be wide apart as viewed from the rear. The tail head should blend neatly from the rump and set squarely between the pin bones.

The condition of the *legs and feet* is most important when evaluating general appearance. A cow must be correct on her feet and legs to endure the physical demands of milk production and to avoid lameness. Starting with the feet, the soles should be level to the ground and the hooves should be at a slight angle and evenly placed to avoid the toeing-out condition.

It is helpful when evaluating a cow's legs to see the cow walking. Regardless, the bones of the cow should appear flat, strong and smooth. The rear legs should be placed squarely under the body with only a slight curve to the hock as viewed from the side. A rear view should show legs that are wide apart and straight. The front legs should also be straight and square under the cow when viewed from the side. A front view should show legs that are wide apart, allowing for good width to the chest.



**Credit: *Agriscience 332: Animal Science (Student Reference).*** Courtesy of Instructional Materials Service, Texas A & M University, College Station, Texas. Appreciation is extended to IMS for use of portions of the *Agriscience 332: Animal Science* instructional materials.

Most dairy producers will agree that the *udder* is the cow's most important body part. Udders with defects or poor conformation can produce less milk or be more susceptible to infection and injury.

The udder should first be divided into sections for an evaluation, and then it should be evaluated as a whole. The fore udder should have moderate capacity. It should be long and curve smoothly into the cow's underline. The rear udder should extend high and wide. It should appear strong, have a well-defined cleft and attach smoothly in the rear. All four quarters of the udder should be rounded and balanced. The four teats should be convenient in size, spaced evenly at the corners of the udder and appear perpendicular to the floor of the udder. A prominent mammary vein is desired, but it is not as emphasized as it has been in the past. The udder tissue or secreting tissue is soft, pliable, and spongy to the touch. Any firm or fatty tissue is discriminated against.

<u>Production records</u> - Much of the guesswork is taken out of selecting dairy animals by production records. They show the productive capacity of the cow and give an indication of the possible production of the offspring. Since a purebred's production records and its ancestors are recorded on the pedigree, increasingly large numbers of dairy herds are being tested in dairy herd improvement association programs.

Dairy producers who keep production records usually keep one of the following types: (1) DHIA (Dairy Herd Improvement Association) or (2) Owner-Sampling Testing Records. Both of these types involve weighing the milk produced by each cow in the herd one day a month.

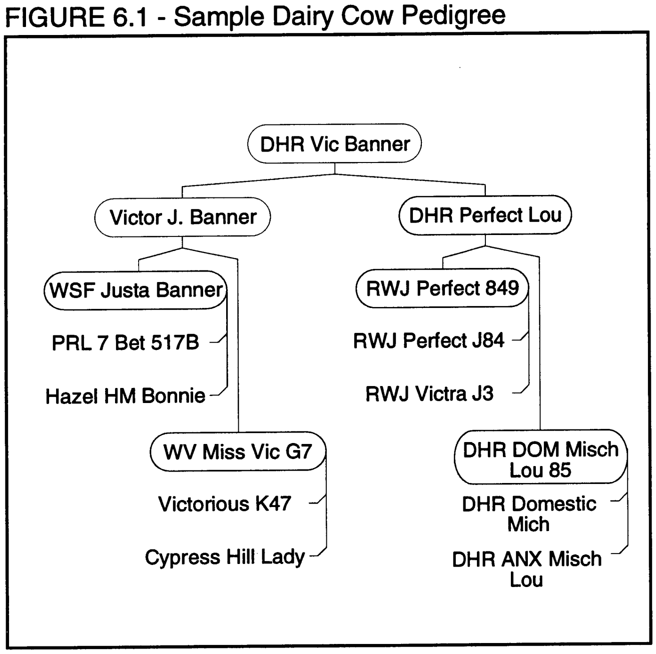
The DHIA, which is supervised by the USDA and the local DHIA Board of Directors, provides the most information on production and feeding for each cow in the herd. An approved tester does actual testing by visiting the dairy one day each month to weigh and sample milk, make butterfat tests, and calculate production and feed records. This information is sent to a data processing center for computation and summarization and is then returned to the dairy producer.

The report contains an individual cow's records, such as daily milk weights, butterfat percent, concentrates fed, reproductive status, value of milk produced, feed cost, and income-over-feed cost. It also has a herd summary for the test period.

Owner-sampler records are kept by dairy producers interested in a less expensive herd improvement and testing plan. Producers using this plan weigh and sample each cow's milk one day each month; a tester picks up the samples and calculates the results. Because dairy producers takes their own samples, this is not an official test.

Pedigrees - The pedigree lists the animal's ancestors and might also include production records and type classification of the animal and its ancestors. It might also carry summaries of any official production records made by the animals involved. Most pedigrees show three generations. (See example pedigree in Figure 6.1)

FIGURE 6.1 - Sample Dairy Cow Pedigree




Breeders of purebred cattle carefully study the pedigree of each animal before it is added to their herds. When using the pedigree as a basis of selection, the most consideration should be given to the sire and the dam because they contribute 50 percent to the animal's makeup. Other ancestors contribute the other 50 percent.

The more production records shown on the pedigree, the more reliable the information will be concerning the animal's possible production capacity. When comparing animals within a pedigree or comparing the pedigrees of different animals, the milking records should be equivalent as to the days and age; otherwise, the records should be adjusted so they are equivalent.

Health and vigor - The general health of the herd can be determined by the calving record of cows during the past year, the number of cows in production, stages of production, and the amount of milk being produced.

The most serious causes of health problems in dairy herds are sterility, mastitis and other related udder infections, Bang's disease (brucellosis), leptospirosis, and tuberculosis. It is desirable to buy animals only from herds that have been vaccinated or tested for Bang's disease and have been tested for tuberculosis and leptospirosis. If animals purchased have not been tested within the last 30 days for Bang's disease and tuberculosis, the animals should be tested before being purchased. To minimize health problems, one should select animals from a reputable breeder of a disease-free herd.

**Sire Evaluation Data**

Production of sires - The planned mating of superior cows and bulls can produce superior sires for artificial insemination. Cows which produce 4,000+ pounds of milk above herd mates and half-siblings producing 2,000-3,000+ pounds above herd mates are usually used for such matings. Also, take note of cow families for desirable conformation type, longevity, good temperament, and reproductive efficiency.

Mate the cow with a superior AI stud for high PD and repeatability. Semen collection from the offspring begins at 10-12 months of age. Then, in herds throughout the U.S., enough cows are mated with the young bull to obtain 50-100 production-tested daughters. The bull is placed "on the shelf" for 4-6 years until daughters mature and provide milk production records. Bulls with high PDs (Predicted Differences) are widely used.

Sire selection - Various indexes can be utilized to select a dairy sire.

1. Daughter average - selection based on the average production of the sire's daughters
2. Daughter-dam difference - considers the amount of increase or decrease in milk produced by a bull's daughters when compared to their dams
3. Equal-parent index - based on the premise that the sire and dam contribute equally to the inherent milk-producing ability of the progeny. It is equal to twice the average production of the daughters, minus the average production of dams.
4. Daughter-contemporary herd difference - substitutes the herd average for the dam's average in the daughter-dam difference index. The sire index is equal to the daughter's average minus the herd average.
5. Daughter-contemporary herd index - substitutes the herd average for the dam's average production in the equal parent index. The sire index is equal to twice the average production of daughters, minus the herd average.
6. Herd mate comparison - compares a sire's daughters with cows (herd mates) that freshen in the same herd during the same season of the same year. This index removes most environmental differences, such as the season of calving.
7. Adjusted herd mate average - adjusts each lactation of a sire's daughter for comparison with one another
8. Predicted Transmitting Ability (PTA) - an estimate of the amount of superiority (improvement) or inferiority an animal will transmit to its offspring. It is the most accurate measure available of an animal's genetic ability.

For herd improvement, a dairy producer should choose from the following: (1) bulls with the highest PTA, (2) bulls with high PTA values that also have high reliability values (narrow confidence intervals), (3) several bulls with high PTA values when the reliability value is below 75 percent, and (4) bulls with a low percentage of difficult births when breeding heifers.

**Summary**

When selecting for high-production dairy cattle, producers must evaluate the genetic potential for milk production, as well as visual selection for conformation. Production records help determine how long the cow will stay in the herd by providing information on good feet and legs, proper udder attachments, etc. Therefore, study the overall picture before making major decisions on replacement heifers/cows and sires.

**Credits**

*Advanced Dairy Unit.* University of Missouri-Columbia: Instructional Materials Laboratory, 1987.

*Agriscience 332H: Advanced Animal Science (Student Reference).* Texas A & M University: Instructional Materials Service, 1990.

Ensminger, M. E. *The Stockman's Handbook.* 7th ed. Danville, IL: Interstate Publishers, Inc., 1992.

# Lesson 7:
## Tools for Genetic Improvement of Sheep

### Factors to Consider When Establishing a Sheep Flock

The first decision to make before establishing a flock is the kind of stock to be used for breeding or foundation stock. The final selection (purebred, crossbred, or grade stock) is usually made based on personal preference or the amount of experience a producer has with the breed. Purebred operations usually demand much more experience with sheep production than either crossbred or grade stock. Most sheep producers elect to use a purebred ram and high-grade ewes for their operations. There are considerable price differences between purebred and crossbred stock.

After deciding the type of production desired, select a breed or breeds. This is usually done by personal preference, but some research needs to be done on types of traits desired. Breed selection is based on traits such as herding ability, long or fine wool, size, mutton or wool type, and adaption to environmental conditions in the area.

Environmental conditions are important in choosing native or western stock. Native ewes are sheep produced outside the western range area and are known for their mutton-type breeding. Native sheep are usually larger in size and usually cost more than western sheep. Western sheep are usually smaller in size and are less expensive to buy. Western sheep are parasite resistant, a vital characteristic in the western ranges of the U.S. Western sheep are usually a fine-wool by long-wool cross, which is also essential for range production.

Uniformity is the next important factor to consider when establishing a flock. It is essential to have uniform market lambs and have the same quality of wool when marketing these goods. Therefore, breeding stock should be selected by uniform size, conformation, and fleece quality.

The ram should be selected to match female stock (for ease of breeding) and for desirable traits.

The size of flock or band is the next factor to consider when establishing a flock. This is usually determined by the experience of the operator, capital, amount of land, and the method of management. Larger operations are usually commercial or grade flocks. Smaller flocks usually consist of purebred operations. A beginner can gain valuable experience through a small flock without subjecting a larger flock to this inexperience.

The most favorable time to begin a sheep operation is in the late summer when lambs are weaned and before the ewes are bred.

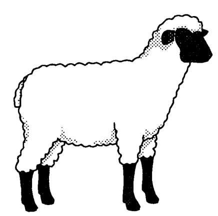
When establishing a sheep flock, healthy animals are critical to the herd's success and longevity. All breeding stock purchased or raised should be thrifty, vigorous, in good condition, and capable of producing healthy, strong offspring. If stock cannot produce under these conditions, they should be culled and replaced. Obtain health papers with purebred animals to ensure their health.

Age is an important factor to consider when purchasing sheep for a new flock. Older breeding stock is considered a poor investment in the sheep industry. Fleece can cover up problems that older breeding stock have; therefore, it is wise to invest capital in yearling ewes to avoid getting someone else's problems. Another plus with younger stock is that replacement costs should not appear for several years. Working with younger stock lets the operator see problems that might advance in several years.

Soundness of udder is an important factor to consider when selecting sheep to establish a flock. This requires the touch method and careful observation. Udders should be soft and pliable. There should be four working teats of equal size and shape. Any ewes that are missing teats or have meaty or abnormal teats should be rejected. Unsoundness of the udder will decrease production of the flock.

Price is the last factor to consider when establishing a flock or band. Cost is like any other livestock production operation--premiums will be paid for quality foundation stock. Price is usually based on the animal's ability to produce quality wool and offspring. The lower price of sheep should be considered when choosing a beginning livestock operation. Like other livestock operations, purebred stock is generally higher priced than crossbred or grade stock.

Selection methods - There are four criteria or methods used when selecting sheep for production and breeding stock. These four selection methods are based on: type and individuality, pedigree, show-ring winnings, and production testing.



With the presence of fleece, the selection based on type and individuality becomes difficult. Selection should not be based on observation only. Production records are very important when selecting stock for the flock. The "touch method" helps eliminate fleece-covering problems. The touch method helps determine economically important traits such as muscling, loin area, leg of lamb, and udder problems. This method is used in culling ewes, eliminating light-fleece animals, and removing wool-blinded animals.

Like cattle, sheep have a score card to use when evaluating them for type and individuality. Like cattle, the score card places numerical values on different parts of the animal. A perfect score is 100 points.

Without a doubt, selection based on pedigree carries less weight in sheep than in any other livestock selection. It is rare to find a commercial producer contemplating a purchase because of the pedigree. More pedigree emphasis is put on stud rams than ewes. However, blood lines do influence the price of purebred stock.

Selection based on show-ring winnings in sheep is like other livestock in that show-ring winnings dictate consumer wants and needs. Therefore, show-ring winners and their progeny are in great demand. Show-ring winners are usually a good investment if the producer is willing to pay premium prices, particularly in a purebred operation. Remember, show-ring winners represent other people's needs and demands, not necessarily the individual producer's.

As with other livestock, selection based on production/performance testing is emphasized a great deal by producers and sheep buyers. Unlike other livestock, sheep offer two products instead of one. Wool production is more prominent in the southwestern part of the U.S., and mutton production is more prominent where feed grain is more abundant.

Sheep production testing is divided into two areas: mutton and fleece production. Producers emphasize that production testing in sheep is a more accurate method of selection than any other method. Remember, production testing evaluates traits that have economic importance on the operation. Records are kept on traits such as multiple births, birth weight, weaning weight, rate of gain, fleece grade, and loin area.

**Crossbreeding Systems and Hybrid Vigor**

Crossbreeding is the mating of two animals of different breeds to combine the desirable traits of each animal. Crossbreeding helps produce two quality products, mutton and wool, from the same animal. Crossbreeding is also used because of the diverse conditions in which sheep are expected to produce. Hybrid vigor is a major factor in determining if a crossbreeding program will be used in a sheep production operation.

Advantages of crossbreeding - Hybrid vigor (heterosis) is a crossbreeding program benefit. Hybrid vigor is the biological phenomenon that causes crossbred offspring to outproduce the average of their parents. Another advantage to a crossbreeding program is introducing new, desired genes quickly or at a faster rate than simply selecting within a breed. Crossbreeding in sheep increases the yield of females at a much faster rate than same-breed breeding.

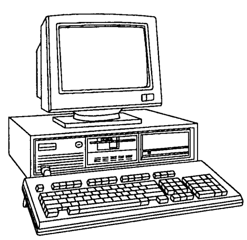
The last advantage of crossbreeding is the maximizing of desirable traits and the minimizing of undesirable traits. Complementary traits involve combining the most desired traits in one cross or generation. Since rams and ewes do not contribute equally in offspring, sheep are divided into ram breeds and ewe breeds.

Types of crossbreeding systems - A two-breed cross involves mating a purebred ram of breed A to a purebred or high-grade ewe of breed B. The offspring will have hybrid vigor as a result of this cross. A two-breed backcross or crisscross mates a purebred ram of breed A to a purebred or high-grade ewe of breed B, then mates the offspring back to a purebred ram of breed A or B. The offspring of both generations will have hybrid vigor as a result of this cross.

A three-breed cross mates a purebred ram of breed A to a purebred ewe of breed B, then mates the offspring to a purebred ram of breed C before mating the offspring back to a purebred ram of breed B. The offspring of all three generations will have hybrid vigor as a result of this cross.

**Using Performance Data**

The National Sheep Improvement Program or (NSIP) is a tool which helps sheep producers improve their efficiency in lamb and wool production. The program was solely developed for genetic improvement for sheep flocks. The NSIP is a computer-based program that provides output on the most accurate estimates of genetic merit for economically important traits for individual sheep anywhere in the U.S. This computer-based program can usually be found at any county extension office. For a producer to receive feedback from this program, the producer must first provide some input from the flock, although the NSIP also provides EPDs on other sheep for selection purposes.



Input needed for NSIP - First, there must be data collected on the ewes in the flock for each year, such as: the number of lambs born, the number of lambs reared, weights at birth, and weights at various days (30, 60, 90, 120, 240, or 365), gains between designated ages, ram days to lambing, fleece weight (as a yearling and annually thereafter), staple length, and fleece grade of the side and britch (hind quarter). (The micron count is optional.) Of the various day weights listed above, only three are needed.

There must also be data collected on individual sheep in the flock, such as: individual lamb identification (ID) number, sire ID number, dam ID number, type of birth, sex of lamb, type of rearing, date ewe was exposed to ram, date lamb was born, weights at birth, and weights at various days (30, 60, 90, 120, 240, 365), fleece weight, fleece grade of side and britch, micron count, and staple length. Of the various day weights listed above, only three are needed.

Other options for data collection are whether a birth was assisted or unassisted, face scores, wrinkle scores, shoulder height, and carcass merit. With the following information entered into the NSIP computer program, producers can evaluate their flocks.

Types of output from NSIP - The three types of available output are: flock genetic evaluation summary, ewe lifetime production summary, and flock management summary.

The flock genetic evaluation summary is considered the most important output. It provides accurate estimates of genetic merit for every ewe, ram, and lamb in the flock. Measurements are provided by the inputs previously taken on ewes and individuals in the flock.

The flock genetic evaluation summary also provides EPDs on sheep in the flock and other sheep across the country. An EPD (Expected Progeny Difference) is calculated the same way in sheep as it is in cattle. A ewe with a +3.2 for 90-day weight (See Table 7.1) should produce lambs that are +3.2 lbs. heavier than an average lamb in the flock. An average lamb has a 0 EPD rating. A ewe with -1.7 for 90-day weight (See Table 7.1) will produce lambs that are expected to be -1.7 lbs. lighter than an average lamb in the flock. EPDs are also available for rams.

The accuracy figure (ACC) indicates how much an EPD will change if additional progeny data is collected. A high value indicates that there will be little change when additional progeny data is collected. For example, an accuracy figure of a .90 indicates a higher degree of accuracy than a .72 accuracy figure.

A lifetime production summary is provided for each individual ewe in the flock. It contains the ewe's pedigree, performance as a lamb, lambing

TABLE 7.2 - Sample Ewe Summary Data

| Dam | 30-day weight | | 60-day weight | | 90-day weight | |
|---|---|---|---|---|---|---|
| | EPD | ACC | EPD | ACC | EPD | ACC |
| Ewe A | 0 | .80 | +1.2 | .86 | +3.2 | .90 |
| Ewe B | -.9 | .79 | -1.0 | .72 | -1.7 | .87 |
| Ewe C | +1.2 | .88 | +2.3 | .92 | +5.4 | .96 |

intervals, lambs born and weaned, and actual performance of every lamb to which she has given birth. This type of output is very useful for purebred producers to promote specific ewes and their progeny. This output also aids commercial producers in identifying truly outstanding ewes and deciding which progeny to purchase.

Flock management summary provides a summary of the average performance of the flock for the present production year and the previous year. The output provides distribution of lambing from the start of lambing season, age distribution of ewes, percent of single and multiple births for age groups, and reasons for culling and deaths. This output helps monitor flock performance and identify flock and management strengths and weaknesses.

Overall, the NSIP supplies the producer with an informative summary of the flock on both production and genetic traits. As said previously, the NSIP is a tool to aid producers in improving their efficiency in lamb and wool production. The producer must put forth some effort (data collection and data input) in order to receive the benefits from this program. With appropriate producer effort, benefits will be reaped ten-fold.

**Summary**

It is critical for sheep producers and those in related occupations to use available resources in sheep selection and flock improvement. These resources can be beneficial in genetically improving any flock.

**Credits**

Ensminger, M. E. *Animal Science Digest.* Danville, IL: Interstate Publishers Inc., 1991.

Thomas, D. "National Sheep Improvement Program: The Means to an End." *National Wool Grower* June 1989: 30-33.

# Lesson 8:
## Selection Tools for Genetic Improvement of Swine

Independent swine producers have either seed stock or commercial operations. In a commercial operation, hogs are produced and sold for slaughter. The slaughter animals are nearly always crossbred. Independent seed stock producers supply boars and/or gilts to be used as breeding stock in commercial herds. The animals can be purebred or crossbred. Seed stock producers also sell a part of their progeny for commercial slaughter. The breeding stock used by commercial producers is usually purchased from an individual seed stock producer or a corporate breeding company. Regardless of the type of operation, both producers keep alert for ways to genetically improve their herds.

**Breeding Stock Selection and Production**

Most swine breeding systems involve production and crossing of specialized sire and dam lines. These lines can be purebreds or composite lines. Eight major breeds are represented in the United States: Duroc, Yorkshire, Hampshire, Landrace, Chester White, Berkshire, Spot, and Poland China. Breed associations maintain registries for each of these breeds.

Commercial breeding companies and some large independent seed stock producers maintain composite lines. These homogeneous lines of animals have been developed from crosses among two or more breeds and subsequently closed to new animals. The composite lines are then managed much like a pure breed with all replacements selected from within the population.

<u>Performance testing</u> - For seed stock producers to remain competitive, they must make continued genetic improvement of their breeds or lines. A practice necessary for genetic improvement is *performance testing*. Performance testing is the practice of measuring the performance of the pigs in a herd for traits of economic importance.

Traits that are economically important to the swine producer include:

1. Litter size
2. Litter 21-day weight
3. Growth rate
4. Back-fat thickness
5. Loin eye area
6. Feed efficiency

Each trait impacts the producer's income. Litter size is usually considered the most important trait. It is relatively difficult to improve litter size through selection; however, it can be improved by good management practices and by using crossbred females of breeds with high reproductive rates. Litter 21-day weight indicates the female's reproductive rate, piglet survival, and milking ability of the dam. Heavy 21-day weights ensure pigs with a good start following weaning. Growth rate is important because rapidly growing pigs make efficient use of growing/finishing facilities.

Loin eye area and back-fat thickness help decide the slaughter hog price. Most pigs are now sold on some type of lean value program with price determined by a predicted percentage lean in the carcass. Greatest prices are commanded by pigs with a small amount of back-fat and large loin eye area.

Feed efficiency is related to the cost of production per unit. Feed efficiency is difficult to measure directly because it requires measurement of individual feed consumption. Fortunately, feed efficiency is closely related to the combination of back-fat thickness and growth rate. These two traits are easily measured and can contribute to improved feed efficiency.

For performance testing, pigs must be identified using a marking system, ear tags, or a standard pattern of ear notches. The performance of the pigs must be measured and recorded. The performance testing program can be as simple as recording litter size, the birth date of pigs, their date of slaughter and market weight. From these records, weight per day and days to slaughter can be calculated without even weighing a pig! However, since this information is only available on animals that are slaughtered, its use is limited to determining seasonal differences in performance, which might indicate need for management changes or progeny testing of sires in the herd.

Much genetic progress can be made by diligently measuring economically important traits and by using the information to make selection decisions.

Back-fat thickness - The next step up in complexity of performance testing involves weighing pigs and measuring back-fat thickness. A scale and back-fat probe are needed to take these measurements. These tools allow the calculation of 21-day litter weights, gains during the growing and finishing periods, and measurement of leanness.

Before records can be further processed, they must be adjusted to a common basis of comparison. Various factors, such as animals being reared in litters of different sizes, can affect their weight and can result in unfair comparisons if made on the raw data. Likewise, if ultrasonically measured for back-fat thickness, animals that are heavier at the time of measurement are at a disadvantage compared to lighter weight animals.

Adjustment factors have been calculated that help eliminate known sources of error. An example of this is shown in Table 8.1. The National Swine Improvement Federation produces publications that contain adjustment factors. Contact a local extension office or the state swine extension specialist for more information.

An alternative to adjusting records by hand involves using computer software such as "PigChamp," "PigTales," or other programs.

EPDs - At the highest level of performance testing, records are used to evaluate breeding values or expected progeny differences (EPD). These are statistically based combinations of information on one or more traits from an animal and its relatives. EPDs are the current state-of-the-art for estimating an animal's genetic merit.

The difference between EPDs for two boars is the expected average difference in performance of the boars' progeny for a particular trait. For example, if the boars' EPDs for days to market were -7 and -3 days, respectively, progeny of the first boar would be expected, on average, to reach market four days sooner than progeny of the second boar.

For maternal traits such as litter size and 21-day litter weight, the performance of the daughters of the two boars is compared. For example, if the EPDs of two boars for litter size were +1.5 and -1.1 pigs, respectively, daughters of the first boar would be expected to produce litters averaging 2.6 more pigs per litter.

**Heterosis and Crossbreeding**

Crossbreeding is a common swine production practice in Missouri and throughout the country. Approximately 95 percent of swine that are commercially slaughtered are crossbred. There are two reasons for crossbreeding in commercial production. For many production traits, heterosis

Table 8.1 - Calculating Adjusted Back-fat

Compare back-fat thickness of two boars. Boar 2-12 measured .72 inches when it weighed 223 pounds, and Boar 3-3 measured .80 inches when it weighed 245 pounds. For a fair comparison of leanness, the back-fat depths should be adjusted to a common weight at measurement. The National Swine Improvement Federation adjustment factor for back-fat thickness is:

$$\text{Adjusted back-fat} = \text{actual back-fat} + \frac{(\text{desired weight - actual weight}) \times \text{actual back-fat}}{\text{actual weight} - 25}$$

$$\text{Adjusted back-fat for Boar 2-12} = .72 + \frac{(230 - 223) \times .72}{223 - 25} = .75 \text{ inches}$$

$$\text{Adjusted back-fat for Boar 3-3} = .80 + \frac{(230 - 245) \times .80}{245 - 25} = .75 \text{ inches}$$

The adjusted values indicate that although Boar 2-12 had less back-fat when the two boars were probed, if they had been measured when their weights were equal, their back-fat would have been the same.

(hybrid vigor) is favorably expressed by the crossbred animal. Back-fat thickness is an exception; it tends to be greater in the crossbred offspring than the average of the purebred parents.

The second reason for using crossbreeding is to merge the desirable characteristics of two breeds into a single animal. The ability to combine specialized maternal or terminal characteristics of a breed is known as *breed complementation.* (Terminal lines refer to lines where all progeny are sold.)

Heterosis - In a crossbreeding system, individual heterosis is expressed by the crossbred progeny. Individual heterosis is measurable for traits such as growth rate and feed efficiency. Maternal heterosis is expressed by crossbred sows, affecting progeny performance for traits such as 21-day litter weight. Paternal heterosis is expressed by crossbred boars for traits such as sperm production and libido.

The amount of heterosis expressed in any cross is related to the common breed makeup of the parents and is described as a percentage. If the two parental breeds share no common breed makeup, heterosis is maximized at 100 percent. In a backcross, when a Hampshire x Duroc sow is mated to a purebred Hampshire boar, for example, heterosis in the offspring is 50 percent because the sire and dam share 50 percent breed composition. If individual heterosis for average daily gain was .2 pounds per day or 8 percent in a first cross, in a backcross yielding only 50 percent individual heterosis, the improvement in average daily gain would be expected to be 4 percent of the mean of the pure breeds.

Crossbreeding systems - A number of crossbreeding systems are used in swine production. They can be classified as rotational, terminal, and the combination rotaterminal systems. In general, rotational systems are easily managed and relatively inexpensive to operate. They suffer from less-than-maximum heterosis and no breed complementation. These systems are particularly well suited for medium- to small-sized operations.

Terminal systems require purchase of replacement females or their production in a separate component of the herd, either of which is relatively expensive. This is offset by the maximization of breed complementation and heterosis (individual and maternal). These systems are well suited to large operations of 100+ sows.

Rotaterminal crosses have some advantages of rotational and terminal systems. Replacement gilts are produced within a small component of the system. Breed complementation and individual heterosis are maximized in the terminal cross component. However, management of replacement female production and designing appropriate matings is complex in a rotaterminal crossbreeding system. More detail about each of these three systems follows.

Rotational systems - Traditionally, these systems have been used heavily in medium- to small-sized operations. In a rotational system, 2-4 lines of boars are rotated into the breeding herd, and replacement gilts are selected from among market hogs. Rotational system advantages are in easy management and relative low cost. Replacement females can be selected from among the market progeny with no special matings required. Production of replacement females on the farm reduces cost and the risk of disease introduction.

Unfortunately, rotational systems suffer two distinct disadvantages. All breeds that are incorporated into a system are used as sires; thus, no specialization of sire and dam lines is possible, and the system yields no advantage of breed complementation. Also, since breeds are used as sires on a rotating basis, the breed makeup of replacement females always shares a fraction of the breed of their mate, thus reducing heterosis.

Terminal systems - Terminal crossbreeding systems are currently very popular, especially in large commercial operations of 100+ sows. These systems are simple to manage since both replacement boars and gilts are purchased. These systems involve mating boars from a specific terminal line or a cross of two terminal lines to gilts from a specific maternal line or a cross of two maternal lines.

The boars and sows in a terminal crossbreeding system will always be from the same respective line. For example, in a three-breed terminal cross in which Duroc boars are mated to Yorkshire x Chester White sows, all boars will be Duroc and all sows will be Yorkshire x Chester White. All offspring are sold for slaughter.

Terminal system advantages include simple management, since any boar can be mated to any sow. Breed complementation is maximized since all sows can be from lines with excellent maternal characteristics and all boars from lines that are lean and efficient. Heterosis is also maximized in both the dam (if she is a line-cross) and the progeny.

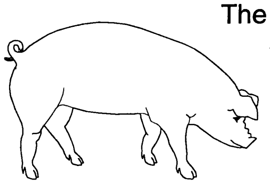
A disadvantage is that replacement females are purchased. Replacements can be costly, and there is risk of disease introduction into the breeding herd.

Combination rotaterminal systems - Rotaterminal systems involve a combination of the two previously described systems. Replacement gilts are produced in the herd and are of a rotation of two or more maternal type breeds. The females not needed for production of replacement females are mated to a terminal type boar, and all the progeny from this mating go to slaughter.

Rotaterminal crosses have some of the advantages of each system. Replacement females are produced from within the herd. Breed complementation and individual heterosis are maximized in the part of the herd involved in the terminal cross. Disadvantages include management complexity and less-than-maximum maternal heterosis.

**Other Tools Used in Swine Selection**

STAGES - For independent seed stock producers, an important breakthrough in evaluating genetic merit was the development of the Swine Testing and Genetic Evaluation System (STAGES) at Purdue University. The STAGES program is a computer package that evaluates expected progeny differences for traits of economic importance in swine production. The STAGES program operates through breed association offices. Performance records are sent to the associations for processing. The STAGES program estimates the genetic merit of animals relative to other animals in the breed. Other programs for evaluating genetic merit might also be available from state swine improvement organizations or for purchase from commercial companies.



Independent culling levels and selection indexes - In most selection programs, two or more traits must be considered simultaneously when making selection decisions. Two successful methods of simultaneously selecting for more than one trait are *independent culling levels* and *selection indexes.* Independent culling level refers to a method in which animals are culled if they perform below expectation for any trait considered important. The level of performance criteria must often be determined by experience.

An example of the use of independent culling levels for gilt selection might be to choose litter size, growth rate, and back-fat thickness are the traits of importance. Culling criteria might be set at litter size = 10, days to 230 pounds = 168, and back-fat thickness adjusted to 230 pounds = .85 inches. Gilts surpassing these criteria would then be examined for soundness. A small percentage in excess of the number needed for replacements would join the replacement pool.

Alternatively, a selection index that includes weightings for the three traits might be used. The appropriate weightings or multipliers have been determined for different conditions and are given in National Swine Improvement Federation materials; these should be available from a local extension specialist.

DNA testing - Direct evaluation of an animal's DNA might become a widely used method of evaluating genetic merit, although at present, its use is limited to a small number of traits that are influenced by single genes with large effect. In the future, DNA may be recognizable for many genes that have small influences on economically important traits. This technology is referred to as *marker-assisted selection.*

Anatomical defects of swine - Several physiological defects are occasionally observed in swine herds. One frequently discussed defect is porcine stress syndrome (PSS). It is a condition that can result in pigs with a recessive gene at a particular location on both copies of a chromosome pair. Porcine stress syndrome can be fatal to stressed pigs. In particular, it is likely to occur in finishing pigs and often is evident when loading and unloading. Signs of PSS include labored breathing, shaking, and a blotchy appearance on the skin. The gene that causes PSS also has an effect on animal performance, resulting in increased muscularity and possibly reduced reproductive performance.

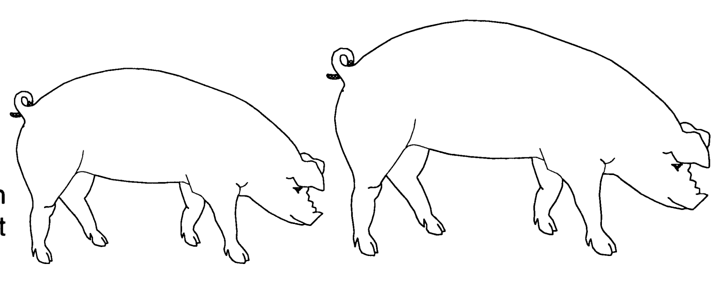
Not all animals with the genes that cause PSS will show symptoms. A DNA blood test is now available that can tell whether animals carry 0, 1, or 2 copies of the gene that results in PSS. This test has been a major breakthrough because it is now possible to identify animals that carry a single copy of the gene but do not show symptoms of the condition. Porcine stress syndrome is often linked to pale, soft, exudative pork (PSE), which causes meat to be watery and chewy. However, there is no direct correspondence between PSS and PSE. Porcine stress syndrome results in only about one-third of PSE cases.

Other defects - Rectal prolapse, umbilical and scrotal hernias, splayleg, and inverted nipples are other defects that occur in a swine herd. Rectal prolapse happens when the rectum becomes loose from its supporting connective tissue and protrudes through the anus. Often, this condition is associated with estrogenic compounds in the feed, an inflammation of the lower gut, and excessive piling or coughing among pigs.

Hernias result when abdominal organs protrude through the umbilical ring.

Splayleg is a condition of newborn pigs in which the rear legs extend outward to the side of the body and the pig is unable to stand properly. This condition frequently results from the sow's intake of moldy feed.

Inverted nipples do not extend outward from the body, and when palpated, tend to contract inward. A poorly inherited genetic component is often involved in causing inverted nipples; however, nipples that appear inverted in replacement gilts can become normal at farrowing.



Susceptibility to these conditions can result from the combination of several genes, particularly when aggravated by infection or excessive pressure. None of these conditions, however, result from a single gene, as does PSS.

Genetics is usually the cause if a defect shows up in a particular sire's progeny across multiple litters, but not in progeny produced by other sires. If a genetic cause is indicated, it can be corrected by culling daughters of the suspect sire and by breeding herd females to a boar unrelated to the one that is suspect.

**Summary**

In this increasingly competitive age, it is important to utilize all selection tools available in the swine industry today. Careful research must be done to ensure that the best choice is made.

**Credit**

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Lasley, John. *Genetics of Livestock Improvement.* 4th ed. Indianapolis: Prentice-Hall, 1986.