10-4005-S

STUDENT REFERENCE

Animal SCIENCE

IML

ANIMAL SCIENCE

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FOREWORD

Development of this *Animal Science* unit is the result of MVATA Teaching Aids Committee suggestions. The unit was developed to enhance curriculum for 11th and 12th grade agriculture students. Depending on local need, an Animal Science course could replace traditional advanced production course(s).

This instructor guide and the corresponding student reference contain 30 lessons grouped into four units: Nutrition, Genetics, Reproduction, and Animal Health. Transparency masters and activity sheets have been included where appropriate. Check the Table of Contents for a detailed listing of lessons. Additional student reference copies can be purchased separately.

In an effort to provide challenging test questions that reduce guesswork, multiple-choice questions with multiple answers have been included in some of the lesson evaluations. When scoring this type of question, each possible response can be worth one point. Of course, it is the teacher's option to increase the weight of a question, if desired.

During the summer of 1981, the Missouri State Board of Education formally adopted the concept of "Instructional Management Systems" (IMS) as a priority for the 1981-82 school year. The Missouri Commissioner of Education described the IMS concept as a practical way of "organizing for excellence" in education. To meet the demand for greater productivity and accountability, the director of Vocational Education applied the elements of IMS to form the Vocational Instructional Management System (VIMS). The VIMS process provides a framework to use in planning and organizing to assure excellence in Missouri's vocational education system by focusing greater attention on the management of teaching and learning.

This guide incorporates the needed component parts to aid agriculture teachers in the implementation of VIMS. For ease of use, performance objectives and competencies have been included at the beginning of the guide, as well as incorporated within each lesson. A competency profile has been provided in the front of the guide for convenient record keeping.

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Lesson 1:
Importance of Animal Nutrition to Agriculture

Agriculture is the largest industry in the United States. The total assets of agriculture exceed one trillion dollars, which is equal to approximately 70% of the capital assets of all U.S. manufacturing corporations. The production of livestock is an important part of the total agricultural industry. About one-half of farm cash receipts come from the sale of livestock and livestock products. The cost of feed represents from one-half to more than three-fourths of the total cost of raising livestock. Careful attention to animal nutrition can help reduce feed costs and thus increase the potential profit from livestock.

Careers in Animal Nutrition

More than 20% of the U.S. labor force works in an agriculture-related occupation. Approximately 540,000 are employed in the meat, poultry, and dairy production industry. Careers associated with nutrition are many, and may be directly or indirectly related to nutrition. Careers include: agricultural instructors, livestock producers/farmers, nutrition specialists, feedlot managers/employees, feed sales reps, horse trainers, feed store managers, veterinarians, and nutrition researchers.

Most occupations require a college degree or years of experience. More and more areas are requiring a Master's degree or other advanced degree. Today, most feed sales reps are required to have a college degree.

Nutrition Guidelines

The work of research scientists in agriculture has resulted in greatly improved methods of feeding livestock. Many U.S. Agriculture Experiment Stations conduct feeding trials. Results of these experiments relate to the value of feeds and rations under controlled feeding conditions.

The National Research Council of the National Academy of Sciences in Washington, D.C. develops the requirements for different livestock species. The respective sets of requirements are available in publications specific to each species, such as *Nutrient Requirements of Dairy Cattle.* Sub-committees on each species are formed to review the requirements that were set through years of experimentation. The National Research Council (NRC) revises and/or reviews its requirements every several years to keep up with new information discovered through continuing research.

Feed Tags

Before evaluating feed tags, remember one thing--feed tags do not tell the whole story. Investigate the reputation of the feed company before buying any of their products. Companies that have gained the trust of consumers and stood the test of time are good indications of a quality product. When crude protein percentages are given on a tag, a consumer has no idea what type of protein was used. (State regulations do not require this information.) These proteins could be rapidly soluble, slowly soluble, or bound. Find out as much as you can about a product before buying.

Individual states generally regulate the manufacturing and sale of feeds. However, regulations relating to feed additives are made by the federal government. The Association of the American Feed Control Officials has published the "Uniform State Feed Bill," which is followed by many states when preparing their regulations of feed manufacture and sale. This results in a fairly of uniform state regulations.

Major provisions of most state feed laws, rules and regulations include (1) registration of feed manufacturers; (2) labeling requirements; (3) prohibited acts; (4) definitions of misbranding and adulterations of feed; (5) a schedule of inspection fees and reports; (6) inspection, sampling and analysis procedures, and (7) penalties for violations.

The feed tag found on a bag of commercial feed is important to the livestock producer. It contains information about the content of the feed and its proper use. The format and content of the feed tag are regulated by state laws.

FIGURE 1.1 - Sample Feed Tag

NET WEIGHT 50 LBS.

SUPER COW
16% TEXTURED

GUARANTEED ANALYSIS
Crude Protein, not less than 16.0%
Crude Fat, not less than 3.0%
Crude Fiber, not more than 7.5%

INGREDIENTS
Grain Products, Processed Grain By-Products, Plant Protein Products, Animal Protein Products, Cane Molasses, Salt, Calcium Carbonate, Dicalcium Phosphate, Manganese Oxide, Ferrous Sulfate, Copper Sulfate, Magnesium Oxide, Potassium Chloride, Cobalt Carbonate, Zinc Oxide, Ethylenediamine Dihydriodide, Sodium Selenite, Lignin Sulfonate and Sodium Bentonite (pellet binders), Vitamin A Acetate, D-Activated Animal Sterol (source of Vitamin D-3), Vitamin E Supplement, Niacin Supplement, Dried Lactobacillus Acidophilus Fermentation Products, Zinc Methionine.

FEEDING DIRECTIONS
Feed Super Cow 16% Textured as a high-energy supplement to excellent legume hay or haylage or lush legume-grass pasture when used as the only source of roughage for the lactating cow. Feed 1 lb. of this feed for each 2-3 lbs. of milk produced.

Manufactured by
MFA INCORPORATED
Columbia, MO 65201

378X1F   1WR56244   **5624**

Generally, the tag contains the following information:

1. Net weight
2. Product name and brand name
3. Guaranteed analysis of the feed
   • Minimum percentage of crude protein
   • Maximum or minimum percentage of equivalent protein from nonprotein nitrogen
   • Minimum percentage of crude fat
   • Maximum percentage of crude fiber
   • Minimum and maximum percentages of calcium and salt
   • Minimum percentage of phosphorus
   • Other minerals
   • Vitamin content
4. When drugs are used as an additive:
   • The word "medicated" must be on the label.
   • The medication's purpose must be stated.
   • Directions for use and precautionary statements must be included.
   • A list of active drug ingredients must be given.

Certain exemptions on labeling are common.

1. No mineral guarantee is needed *if* no label claims concerning minerals are made, *and* the total mineral content is less than 6.5% of the total contents.
2. Vitamin information is exempted when the feed contains no claims concerning vitamins or is not being sold as a vitamin supplement.
3. Crude protein, crude fat and crude fiber guarantees are exempted if the feed is not intended to furnish these substances or if they are a minor part of the total ingredients, i.e., in drug premixes, mineral or vitamin supplements, and molasses.

This general description of feed tag labeling is not intended to be a specific guide for a given state. Instead, the Department of Agriculture in each state establishes committees to set state standards. The feed laws, rules and regulations of each state should be considered to determine specific requirements for that state.

Economic Importance of Understanding Nutrition

As was stated before, agriculture is big business in the United States. About one-half of farm cash receipts come from the sale of livestock and livestock products.

The cost of feed is 50-75% of the total cost of raising livestock. Careful attention to animal nutrition can help reduce feed costs and thus increase the potential profit from livestock. However, the lowest cost feed ration may not be the most profitable. Feeding efficiency and

nutrition value must also be considered when selecting rations.

It is estimated that 65-80 percent of the total cost of production in a swine operation is for feed. Poultry feed costs range from 55 percent (layers) to 65 percent (broilers and turkeys) of the total cost. Dairy feed costs range from 50-60 percent of the total cost of milk production. Feed costs for a cattle finishing operation are approximately 70 percent of the total cost of feeding cattle. Feeder lamb feed represents about 50 percent of the total cost of production.

General Functions of Nutrients

An animal uses feed for several purposes. Some are basic to all animals, and some are specific to the purpose of the animal. Basic uses include maintenance, growth, and reproduction. Uses reflecting the purpose of the animal include finishing, fitting for show, production, and work.

Maintenance - A maintenance ration is one that maintains basic life processes without any work or production being done. A maintenance ration must supply (1) heat to maintain body temperature; (2) energy for vital functions and a minimum amount of movement, and (3) small amounts of protein, minerals and vitamins.

Oxidation of food in the digestive tract and of nutrients in the muscles and other tissues produces heat. The rate of oxidation is relatively constant and occurs at a low temperature. An animal at rest must still maintain activity in such vital organs as the heart and lungs, as well as other internal organs. Animals that are standing require a higher rate of oxidation of nutrients than those lying down (because of the muscle tension needed to remain standing). Even more energy is needed when an animal moves around. Maintenance rations for mature animals, except swine and poultry, can be mostly roughages that yield enough heat but are relatively low in energy value.

An animal's maintenance requirement is relative to its body surface and its weight. Some protein is required in the maintenance ration because there is some breakdown of protein in body tissues each day. There is also daily loss of calcium and phosphorus from the body of an animal. For this reason, a small amount of protein in the maintenance ration replaces the loss. Salt and a small amount of vitamins A and D are also needed in maintenance rations for most species of livestock.

Growth (assimilation of tissue) - During the growth period, there is a substantial increase in the size of muscles, bones, internal organs, and other body parts. Animals need nutrients to grow properly so that they will be efficient producers when mature. The full genetic potential of an animal cannot be reached if it is not fed a well-balanced ration during the growing period.

Young, growing animals have more nutritional needs than do mature animals. A shortage of digestible nutrients or net energy during growth will result in slower growth or smaller size when animals mature.

Reproduction - If the livestock producer is to make a profit, animals must reproduce. Poor nutrition is a major contributing factor to reproductive failure. The production of sperm and the quality of semen is influenced by the ration's quality. Males that are too fat may become temporarily or permanently sterile. Rations balanced with the proper nutrients improve fertility.

Finishing - Animals such as beef, swine, lambs, and broilers that are fed for meat need nutrients above the maintenance requirements for fattening. Nutrients for fattening animals come mainly from carbohydrates and lipids in the ration. Unneeded protein may also be converted into body fat.

Fitting for show - Animals being fitted for show purposes are fed a liberal supply of carbohydrates and fats, usually through the addition of more grain in the ration. Mature animals being fitted for show need little additional protein, minerals, and vitamins above the maintenance requirements. However, young and growing animals must be fed more liberal amounts to reach the desired level of finish for show purposes.

Production - The production of milk requires a liberal supply of energy, protein, minerals, and vitamins in the ration. For milk production, the

quantity of milk and its fat content influence the amount of nutrients needed above the maintenance level. Wool and mohair have high protein content; therefore, rations for sheep and goats must contain an adequate protein level to meet this production need.

Work - The production of work is limited mainly to horses. Riding and racing require additional nutrients for efficient production. As the amount of work increases, so does the animal's energy requirements. Animals require additional nutrients in relation to the kind of terrain they are on, and whether or not they are in confinement feeding. Also, when animals are on pastures, the distance to feed and water influences the amount of nutrients needed.

Summary

Producers are rarely interested in just maintaining animals, yet the maintenance requirements must be met before animals will provide any productivity. Because of the great impact that nutrition has on the overall success of a livestock operation, it is important to have a basic understanding of animal nutrition.

Credits

Cullison, Arthur Edison. *Feeds and Feeding.* 4th ed. Reston, VA: Reston Publishing Co., 1987.

Gillespie, James R. *Animal Nutrition and Feeding.* 4th ed. Albany, NY: Delmar Publishers, Incorporated, 1987.

Lesson 2:
Livestock Digestive Systems

Livestock digestive systems fall into four basic types: ruminant, nonruminant, modified nonruminant, and avian. A ruminant animal has a four-compartment stomach that aids in digestion of roughages. The nonruminant digestive system is very similar to the human digestive system. It is considered a simple stomach system, which is unable to digest roughage effectively. A modified non-ruminant digestive system is also a simple stomach system, but it has an active cecum that helps digest roughages. The avian digestive system does not have a true stomach; it uses several organs to aid in concentrate digestion.

Digestive Parts and Functions of Ruminants, Nonruminants and Modified Nonruminants

Oral region - The oral region includes the mouth, teeth, and tongue. Three physical processes take place here. Prehension is the process of bringing food into the mouth, which can occur in several ways. Humans use their fore limbs to bring food into their mouth. Livestock take in feed through the mouth, tongue, lips, and teeth.

The second process is mastication--the chewing of food once it enters the mouth. Mastication begins by physically tearing and grinding the food into smaller particles. Saliva is also added to food during mastication.

The third process is called deglutition, or swallowing the food, which occurs after saliva is mixed and chewing has taken place. These three physical processes occur in all digestive systems, except the avian's.

Esophageal region - This region includes the esophagus, pharynx, and the larynx. The esophageal region applies to all classes of livestock. At the top of the esophagus is the pharynx, which controls the passage of food, water, and air. When deglutition occurs, the

FIGURE 2.1 - Digestive System Parts of a Ruminant
NOTE: Drawing does not show exact anatomical placement.
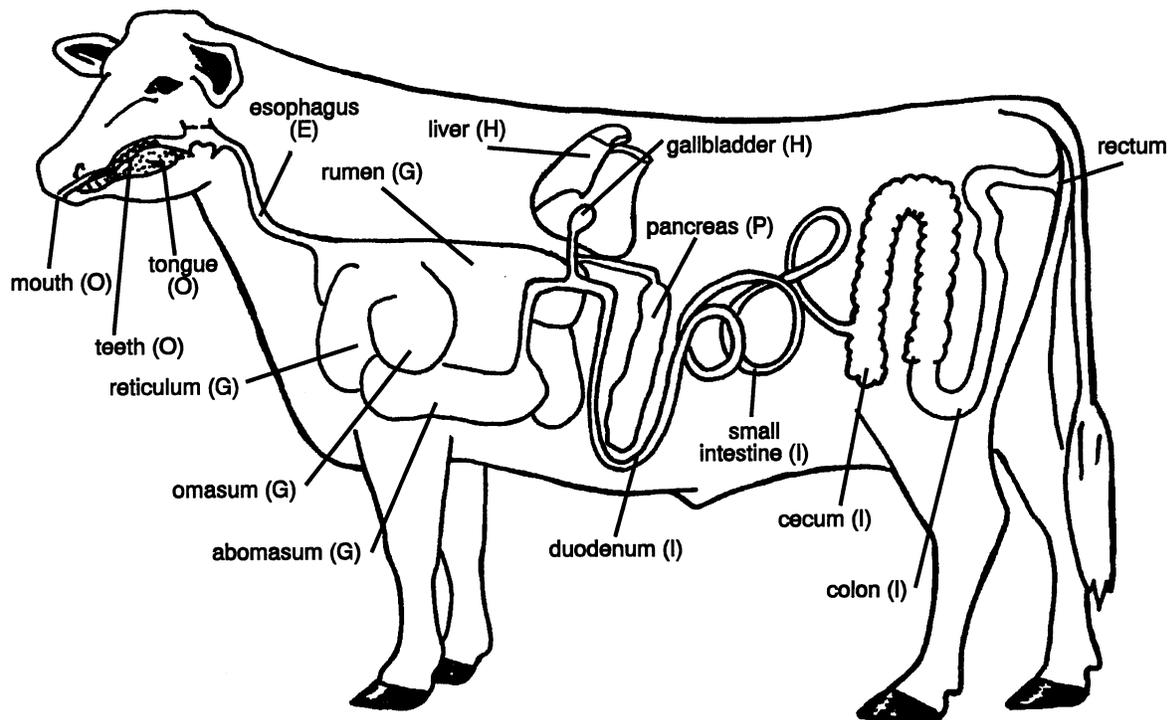
larynx closes. This allows the feed to go into the esophagus--not into the respiratory tract. The muscular tube that extends from the mouth to the stomach is called the esophagus.

Peristalsis is the coordinated contraction and relaxation of smooth muscles. This process creates a unidirectional movement, which pushes food through the digestive system. For further digestion of food, peristalsis is reversed in ruminants through belching or vomiting. Reverse peristalsis is considered an abnormal function in other digestive systems.

Gastric region - The gastric region in ruminant animals consists of four compartments: the rumen, reticulum, omasum, and abomasum. In the rumen and reticulum area, bacteria and protozoa are present to aid in digestion. These microorganisms digest carbohydrates, and produce carbon dioxide and volatile fatty acids. The fatty acids are then absorbed as a source of energy. Carbon dioxide is released through

belching. Once food enters the gastric region, the food is mixed and stirred with water through muscular action in the rumen. Vitamins K, C, and B complex are synthesized in the rumen. Since the vitamins are synthesized, there is no need to supplement these vitamins in the diet if quality feedstuffs are provided in the diet.

The major function of the omasum is to grind the partially digested food further. The omasum also absorbs a small percentage of water from the partially digested food. Finally, the omasum absorbs some of the volatile fatty acids as food passes through the digestive tract.

The abomasum is considered the "true stomach" of the ruminant animal. In the abomasum, digestive juices are added, which contain acids and enzymes that increase the moisture content of the feed. This mixture becomes acidic in nature because of the added acids. This also occurs in nonruminant and modified nonruminant

FIGURE 2.2 - Digestive System Parts of a Nonruminant
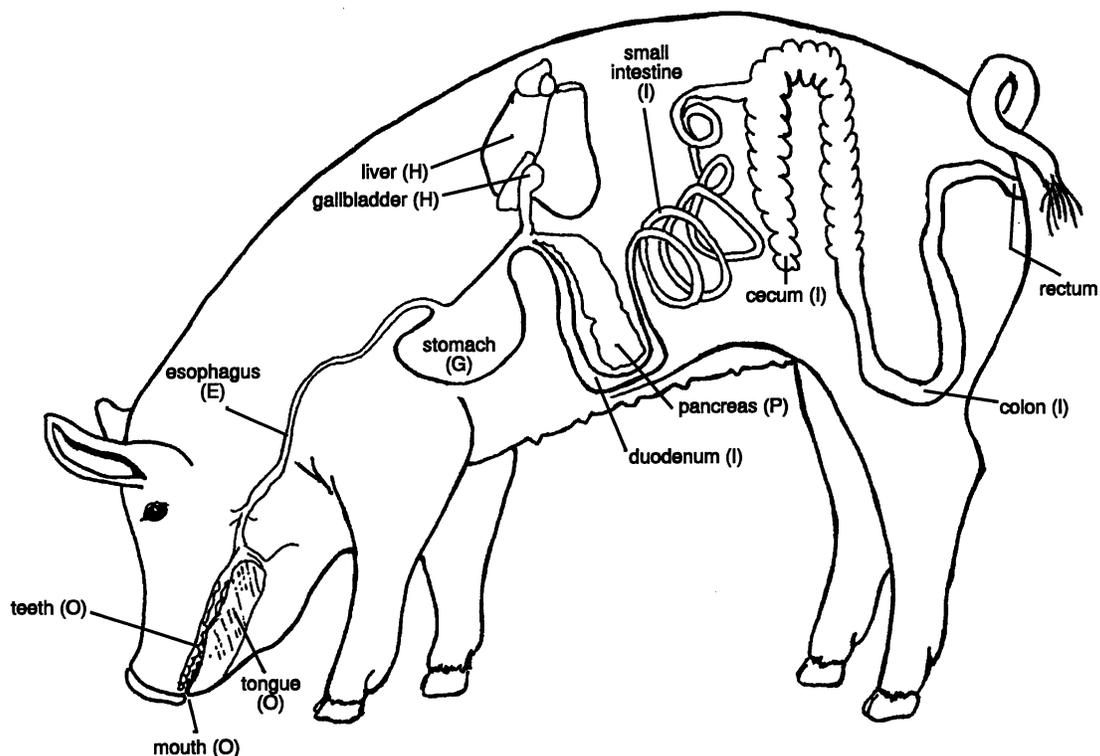
animals. Protein is digested here and in the small intestine.

The gastric region for nonruminant and modified nonruminant animals is based on a simple stomach system. With the enzymes and acids present in the stomach, digestion begins on proteins. Fats are partially broken down in the stomach. Carbohydrates move the fastest through the stomach, because digestion occurs in the small intestine.

Pancreatic region - The pancreatic region consists of one organ: the pancreas. It is made up of two glands, the endocrine and exocrine glands. The endocrine gland secretes the hormones insulin and glucagon. These hormones are necessary for digestion in the small intestine. The exocrine gland secretes trypsinogen, which is an enzyme necessary for digestion. Trypsinogen is produced in an inactive form, and then activated in the small intestine. The pancreas serves the same function in all four classes of livestock.

Hepatic region - In this region are two organs: the liver and the gallbladder. The liver is the largest gland in an animal's body. It serves the same purpose in ruminants, nonruminants, and modified nonruminants. The liver is one of the most important digestive organs for all animals, including humans.

The liver provides many physiological functions. It produces bile, which is an essential fluid for lipid (fat) absorption. The liver is used in detoxification of harmful compounds. It also acts as a storage facility for vitamins and carbohydrates. The liver aids in metabolism of proteins, carbohydrates, and lipids. The liver destroys red blood cells so more blood cells can be made. It is used in the plasma proteins and urea formation in all livestock except avians. Polypeptide hormones are deactivated in the liver, as well.

The only function of the gallbladder is to store bile produced by the liver. Gallbladders serve the same purpose in ruminants, nonruminants, and poultry. Some animals do not have a gallbladder (horses, rats, gophers, doves, pigeons, elephants, moose, elk, deer, camels, and giraffes).

Intestinal region - The intestinal region consists of four organs: the duodenum, colon, cecum, and the small intestine. Fats are emulsified in the duodenum. When fats are mixed with bile in the duodenum, they become soluble in water. This process is called emulsification. Once fats are emulsified, they are absorbed into the bloodstream in the small intestine.

Proteins and carbohydrates are broken down further in the duodenum, where the food mixture becomes neutral when alkaline enzymes are added. Bile and pancreatic fluids are added to the partially digested food mixture in the duodenum. The duodenum functions similarly in ruminants, nonruminants, and modified non-ruminants. Avians do not have a duodenum.

Except for water and fiber, all nutrients are absorbed into the bloodstream in the small intestine. At this point in digestion, food is broken down enough to be absorbed into the bloodstream and used by the animal. Absorption takes place in the small intestine by hairlike projections called villi. Villi are used to increase the surface area in the small intestine so more nutrients can be absorbed.

Peristalsis occurs in the small intestine so undigested food can be pushed through the colon, cecum and finally through the rectum. The small intestine functions similarly in all classes of livestock, except the avian class.

The cecum functions similarly in all classes of livestock, except poultry. It has a very limited function in nonruminant animals--the storage of microorganisms. In ruminant animals, the cecum absorbs 5-15 percent of the fiber the animal eats. It also stores microorganisms needed for ruminant fiber digestion. The modified non-ruminant cecum is much larger than other classes of livestock. It is also very functional. Roughage is totally digested in the cecum in modified nonruminant animals.

The colon functions similarly in ruminant, non-ruminant, and modified nonruminant systems. Water is absorbed and fecal formation occurs in the colon. Mucus is added to the fecal matter to provide lubrication. The fecal mixture remains neutral during this process.

Parts and Functions of the Avian Digestive System

Oral region - Only two physical processes occur in this region. In prehension, the beak and tongue of the bird bring food into the mouth. Deglutition is the process of swallowing. In avians, food goes directly into the mouth and down the esophagus; mastication does not occur.

Esophageal region - This region includes the esophagus, pharynx, and larynx. At the top of the esophagus, the pharynx controls the passage of food, water, and air. When deglutition occurs, the larynx closes. This allows the feed to go into the esophagus--not into the respiratory tract.

The muscular tube that extends from the mouth to the crop is the esophagus. In peristalsis, the coordinated contraction and relaxation of smooth muscles creates a unidirectional movement. This movement pushes food through the digestive system. Reverse peristalsis is considered an abnormal function.

Gastric region - In avians, the gastric region uses both chemical and mechanical processes to aid digestion. Three organs make up the gastric region: the crop, proventriculus, and gizzard. The crop stores food after it enters the body. Mucus is secreted in the crop and added to the food to softens and lubricates it. The food then moves from the crop to the proventriculus, where it secretes gastric fluids and adds these fluids to the slightly digested food. The food then continues on to the gizzard, a muscular organ that mechanically mixes and grinds food. The gizzard acts as mixing machine for gastric fluids and food. Grit, which accumulates in the gizzard, is sometimes added to the diet to aid in digestion. Grit, plus the mixing motion, replace teeth for the grinding and tearing of food.

Pancreatic region - This region consists of one organ: the pancreas. The pancreas is made up of two glands: the endocrine and exocrine glands. The endocrine gland secretes the hormones insulin and glucagon, which are necessary for digestion in the small intestine. The exocrine gland secretes trypsinogen, an enzyme necessary for digestion. Trypsinogen is is produced in an inactive form and then activated in the small intestine by pH changes.

Hepatic region - The hepatic region consists of two organs: the liver and the gallbladder. The liver is a very important digestive organ and is the largest gland in an animal's body. It serves the same purpose in all classes of livestock. The liver aids in digestion for all animals--including humans.

The liver provides many physiological functions; it produces bile, an essential fluid for lipid absorption. It detoxifies harmful compounds and stores vitamins and carbohydrates. Metabolism of carbohydrates, proteins, and lipids is aided by the liver. It also destroys red blood cells so more blood cells can be made. The liver is needed to form plasma proteins and to deactivate polypeptide hormones.

The only function of the gallbladder is storage of the bile produced by the liver.

FIGURE 2.3 - Digestive System Parts of an Avian
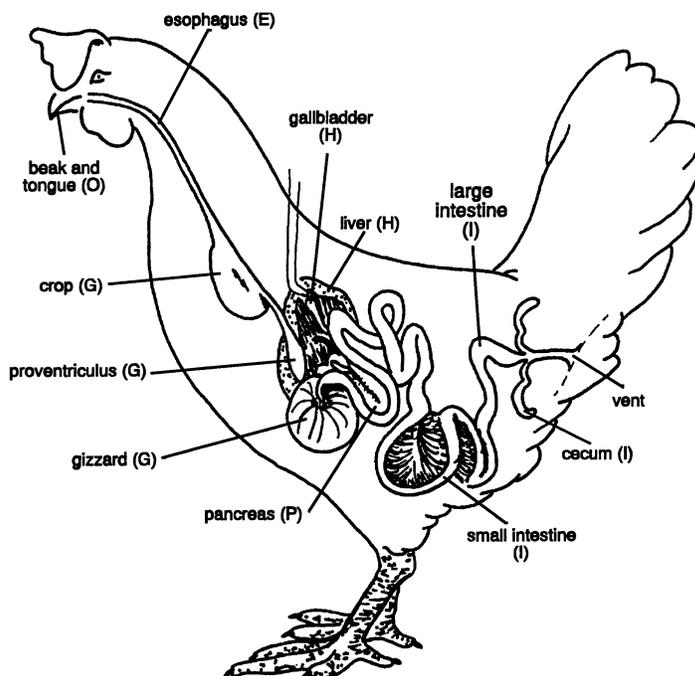
Intestinal region - Three physical movements occur in the small intestine which aid in the movement of digested food through the intestinal region: pendular motion, segmentation contractions, and peristalsis. Pendular motion mixes food by shortening and lengthening the intestine. Segmentation contractions are ringlike contractions that mix food at regular intervals. The last movement is peristalsis, the coordinated contraction and relaxation of smooth muscles. The small intestine is the primary organ in digestion and absorption in the avian class. Special enzymes in the small intestine provide an effective and efficient manner of breaking down proteins, lipids, and carbohydrates into particles that can be absorbed.

The ceca is a blind-ended tube found at the junction of the small intestine and the large intestine. Ceca (two or more) is the plural form of cecum. Poultry have two nonfunctioning cecum in their digestive systems.

The function of the large intestine, or colon, is to remove water from digested food for fecal formation. Urinary and fecal materials are mixed in the cloaca before they leave the body through the vent.

Summary

All of these digestive systems use chemical and mechanical processes to help in digestion and absorption.

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Livestock Nutrition and Feeding (Student Manual). 2nd ed. Columbus, OH: Ohio Agricultural Education Curriculum Materials Service, 1991.

Ensminger, M. E. *Poultry Science*. 3rd ed. Danville, IA: Interstate Publishers, Inc., 1992.

Ensminger, M. E., and C. G. Olentine, Jr. *Feeds and Nutrition*. 2nd ed. CA: The Ensminger Publishing Company, 1990.

Largen, Velda L. *Guide to Good Food*. South Holland, IL: Goodheart-Willcox Company, Inc., 1988.

Lesson 3:
Energy's Role in Livestock Nutrition

Two sources of energy are carbohydrates and fats. As in humans, excess energy consumption in livestock results in fat storage in the body (excess body weight). For the producer, the right balance of carbohydrates and fats in a ration can also mean lower production costs.

Basic Functions of Energy

Maintenance of life - Nutrients providing energy are needed for maintenance. Work done by the animal's vital functions is called its basal metabolism. The basal metabolism of an animal is the animal's heat production while it is at rest and not digesting food. Vital life processes, such as the beating of the heart, maintenance of blood pressure, nerve impulse transmission, breathing, and the work of other internal organs depends upon a supply of nutrients.

Energy nutrients are oxidized in the muscles to keep them in a state of tension. An animal requires more energy standing than lying down, and even more energy to move about or do work.

Energy supplies the fuel that maintains the body temperature of the animal. There are several sources of heat to maintain body temperature. These include the work of the vital organs, normal activity of the animal, work done by the animal, and shivering.

Growth and production - It is only after all the maintenance needs of the animal are met that energy nutrients can be used for growth and production. Some energy is also lost through the feces, urine, and gases produced by the body.

Fattening livestock requires a large amount of energy nutrients. Energy is used in the secretion of milk and the production of eggs and wool. The energy not used for other needs becomes fat within the body tissues. Fat deposits in the tissues makes the meat tender, juicy, and gives it a better flavor.

The energy requirements of lactating animals are almost twice as high as for those not producing milk. This energy must also be in the form of net energy. A shortage of energy in the ration will limit milk production, although the animal will use some body fat for milk production if the ration is energy deficient.

Energy is used for the development of the fetus in pregnant animals. It is important that rations during the gestation period have sufficient energy to maintain the animal in a healthy condition without its getting too fat.

When feeding working horses, energy above the needs for maintenance must be provided for work. Several factors affect the amount of energy needed, including the intensity and duration of the work, the condition and training of the horse, the ability and weight of the rider or driver, the horse's degree of fatigue, and environmental conditions under which the horse is performing work.

Carbohydrates and Fats (Lipids)

Carbohydrates and lipids are the major sources of energy in livestock rations. Some energy also comes from protein in the ration. Of these sources, carbohydrates are the most readily available, are easily digested in greatest quantities in most feeds, and are generally lower in cost. Lipids (fats and oils) are the second most important source of energy for livestock. However, during warm weather, it is difficult to store feeds that are high in fat content because they tend to become rancid (bad odor and flavor). This makes the feed unpalatable, and animals are reluctant to eat it. Sometimes, rancid feed may cause digestive disturbances, making the animal sick. Proteins are seldom fed for their energy content because of the higher cost.

Carbohydrates - Carbohydrates make up almost 75 percent of a ration. Carbohydrates are organic compounds that contain three major elements: carbon, hydrogen and oxygen. Growing plants produce carbohydrates by photosynthesis (6 CO_2 + 6 H_2O + energy from the sun = $C_6H_{12}O_6$ [glucose] + 6 O_2). Carbohydrate compounds found in plants include starch, sugars, hemicellulose, cellulose, pectins, gums, and lignins. Most carbohydrates are combinations of sugars. One way carbohydrates are classified is by the number of sugar

molecules they contain. For example, monosaccharides contain one sugar molecule.

The simplest carbohydrates are sugars. Sugars are the most easily digested, while cellulose and lignin are more difficult to digest. Sugars provide the energy requirements necessary for various body functions.

Carbohydrates make up about 75 percent of all dry matter in plants. The more easily digested forms of carbohydrates are generally found in the seeds, roots, and tubers of the plants. Most carbohydrates are combinations of saccharides or sugars. One way carbohydrates are classified is by the number of molecules of sugars they contain. For example, monosaccharides contain only one sugar molecule.

The plant's fiber cells contain hemicellulose and cellulose, which are harder to digest. As a result of digestion, some of the hemicellulose and cellulose are converted to glucose. Because digestion of these forms is more difficult, they are less efficient sources of energy for the animal.

Carbohydrates fall into two groups--fiber and nitrogen-free extract (NFE). Fiber contains hemicellulose, cellulose, and lignin. The NFE group includes sugar, starch, some hemicellulose, and the more soluble parts of cellulose.

Starch is made up of many molecules of glucose. Plants store energy as starch in grain. Grains have a high feeding value because the starch digests easily.

An animal's ability to use fibrous sources of carbohydrates is related to the bacteria in the digestive system. Ruminants, which have a high bacteria population in the rumen, also make use of energy from the ration's fiber portion. Bacterial action breaks down the fiber into volatile fatty acids, which are absorbed through the rumen wall. Roughage in a ruminant's ration can provide much of the maintenance energy needed by the animal. On the other hand, avians and animals with one stomach are less able to use energy from fiber.

To prevent excessive weight gains, increase the level of fiber in the ration for mature breeding animals. Fiber helps keep an animal's waste elimination "regular." Fiber is also an important part of the ration, keeping the monogastric (single-stomached) animal's digestive system regular, and giving the feed bulk.

Lipids (fats and oils) - Chemically, lipids are made up of carbon, hydrogen, and oxygen. There is more carbon and hydrogen and less oxygen in a fat molecule than in a carbohydrate molecule. Therefore, lipids supply approximately 2.25 times as much as energy as an equal weight of carbohydrates.

At body temperature, fats are solids and oils are liquids. In animal nutrition, both are generally called fats.

FIGURE 3.1 - Carboxyl Group

Fat composition - Fats are composed of two units--fatty acids and glycerol. Fatty acids consist of a carbon chain, 2-20 carbons in length, which contains a carboxyl group (COOH). Saturated fatty acids contain carbons attached with all single bonds. Unsaturated fatty acids contain carbons attached by double bonds. These double bond sites are chemically reactive; as a result, they are less stable than saturated. As the number of double bonds increases, the melting point of fat is lowered and the fats become softer (oils).
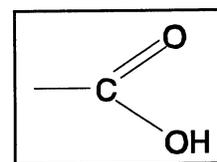
Glycerol is the second constituent of fat. Fats are formed when one glycerol combines with three fatty acids to form a triglyceride.

Rancidity - Bad odors and flavors may be a problem with both saturated and unsaturated fats. Oxidative rancidity occurs only in unsaturated fats. The presence of oxygen is needed, and rancidity is favored by moist conditions. Rancid foods have a changed flavor, odor, and nutritional value because essential fatty acids are destroyed. Rancidity is part of hyperoxide formation, which promotes aging and destroys the immune system. It can be prevented with antioxidants (Vitamin E) and by storing fats in a cool environment.

Three fatty acids (linoleic, linolenic, and arachidonic acids) are considered dietary

essential nutrients since they are not synthesized by nonruminants. However, these fatty acids *are* synthesized by microorganisms in the rumen.

Fat storage - The animal body stores fat as marbling in the muscle tissue or in adipose (fatty) tissue. Adipose tissue contains reserve energy, which an animal could use to help sustain life if feed supplies were cut off.

Fats can raise the energy level of the diet and/or the flavor, texture, and palatability of the feed. Added fat will reduce the dustiness of the feed. Show animals are sometimes fed rations high in fat to improve the glossiness of the hair coat.

Rations for adult animals should contain no more than 3-5 percent fat for ruminants and 15-20 percent fat for non-ruminants. Because fats carry fat-soluble vitamins, some fat in the ration is desirable. Too much fat in the diet will reduce feed intake and increase the chances of scouring (diarrhea).

Absorption of Carbohydrates and Lipids

Carbohydrates - Most carbohydrate absorption occurs in the small intestine; a small amount is absorbed in the large intestine. Starches and sugars are converted to glucose, fructose, and galactose. Crude fiber converted to short, chained fatty acids or glucose by digestion. By osmosis, nutrients pass into the blood capillaries through semipermeable membranes of the digestive tract, then through the liver and into the bloodstream for circulation throughout the body.

Lipids - The digestion process separates fatty acid from the glycerol molecule. Fatty acid is absorbed into lacteals (lymphatic vessels) and then into the bloodstream, where it moves to various parts of the body and is recombined with glycerol to form fat.

Sources of Energy for Animals

Primary sources of energy nutrients are grain and grain by-products. Feeds are energy concentrates when their crude protein content is less than 18 percent.

Shelled corn - The highest energy feed available for livestock rations is shelled corn. It is the most widely grown and used feed grain crop. Corn produces more pounds of total digestible nutrients (TDN) per acre than any other feed grain. It is an economical and superior source of energy for livestock.

Oats - Oats have about 85 percent of the energy of shelled corn. They are higher in crude protein than shelled corn and add fiber and bulk to the ration. When fed to ruminants, oats help to maintain the rumen function. Oats are not a good fattening feed, but they are used extensively for horses, young growing stock, show stock, and breeding animals. Oats are generally rolled, crimped or ground for feeding.

Barley - Barley is almost equal to corn in energy value, but it lies between corn and oats in fiber content. It is used in the ration similarly to oats. Barley can replace up to 50 percent of corn in fattening animal rations. To improve taste, barley is usually steam rolled, crimped or coarsely ground. Barley is sometimes cooked to improve its taste when used for beef show animals.

Grain sorghum - There are many varieties of grain sorghum, including milo, kafir, and various hybrids. Most grain sorghum is grown in the western part of the U.S. in semi-arid regions where corn does not grow well. Grain sorghum is similar to shelled corn in composition and can replace up to 100 percent of the corn in a feedlot ration. It is usually rolled or crimped when included in livestock rations.

Forages (roughages) can supply some energy needs in the livestock ration, although they are not as concentrated an energy source as grains. The value of forages for livestock feed is highly dependent on the time of harvesting. As forage plants mature, the crude fiber content increases, which lowers the digestibility of the feed.

Corn silage - Corn silage, which contains almost 50 percent grain, is an excellent energy source for certain classes of livestock, such as cattle.

Hay - Good quality hay, especially legumes, can provide almost all of the energy needs of a ruminant animal. The quality is greatly dependent upon the time of harvesting.

Pastures - Properly managed pastures can be a good source of nutrients for livestock. Rotate and fertilize pastures to get the best yield and nutritional value.

Fat - Feed-grade animal fat is a byproduct of packing, poultry processing, and animal rendering plants. Animal fat is an economical source of energy used in the manufacturing of commercial mixed feeds. Commercial feed mixes contain 1-7 percent animal fat, depending on the type of feed. Animal fat in the feed reduces the dustiness of the feed, improves its color, texture and palatability, reduces wear on feed mixing equipment, and improves pelleting characteristics.

Deficiency and Toxicity Symptoms

Deficiency - Too little energy in the ration causes several problems for all classes of livestock. Typical of these are:

1. Slower growth in the young
2. Delay in the onset of puberty
3. Decrease in milk yield in lactating females
4. Shortened lactation period
5. Loss in body weight
6. Several kinds of reproductive problems, including reduced fertility and delayed estrus
7. In sheep, a reduction in wool quantity and quality
8. Higher mortality rate
9. Lowered resistance to disease and parasites
10. Weakness, generally poor condition, and an unthrifty appearance
11. Loss of subcutaneous fat
12. Reduction in levels of blood glucose, calcium, and sodium.

Toxic effects - Feeding too much energy results in ketosis or obesity. Animals that are too fat can be less fertile, conceive less, and have delayed estrus.

Ketosis occurs when an animal has a higher energy demand (such as lactating dairy cattle) and a low supply of carbohydrates. To meet the energy demand, the animal increases the metabolism of fats. The increased fat metabolism rate overloads the liver with ketone acids. Ketone acids can provide energy for muscles but **cannot** provide energy for the brain.

If the situation is not corrected, glucose blood levels drop so low that the animal collapses, goes into a coma, and dies. This often happens to the best milk cows because of high energy requirements.

Summary

Fuel is supplied to the body by energy nutrients. The major sources of energy in livestock rations are carbohydrates and fats. Energy is used for digestion; absorption of nutrients; breathing; heart action; movement of muscles; production of milk, eggs, wool, and mohair; waste formation and excretion; and to supply heat to maintain body temperature. Some feed energy is lost through the feces, urine, and gases produced in the body. Excess energy not used to sustain life is stored as body fat.

Credits

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Lesson 4:
Protein's Role in Animal Nutrition

Every nutrient plays an important role in animal nutrition. Protein plays an integral part in several body functions in animals and humans. Protein deficiencies in humans appear as stunted growth, discolored skin, and body sores. Protein deficiencies are rare in humans because there is a great emphasis on proper diets. But there is an increasing problem with excess amounts of proteins in human diets. Unused, excess protein in a diet turns into body fat. Research has shown excess body fat leads to many health problems in humans. Good sources of protein for humans are poultry, fish, dairy products, and dried peas and beans.

Functions of Protein

Protein plays similar roles in livestock nutrition as it does in human nutrition. The word "protein" originates from the Greeks. It means "of primary importance." Proteins are the lumberyards that supply the materials necessary for building and maintaining the body. Proteins consist of carbon, hydrogen, nitrogen, and oxygen compounds.

Uses of protein include building, repairing, and maintaining body parts such as muscles, skin, body tissues, hair or feathers, and hooves. Protein also produces body regulators, such as enzymes and hormones. These body regulators aid in the reproduction, digestion, and health maintenance of an animal.

Protein is a good source in the production of blood glucose, which is an important function of proteins. Proteins can be modified for use in genetic compounds, such as DNA, RNA, and ATP. Proteins can also be used as energy when excess amounts are fed, but they are *only* used as energy after the body's needs are met. Proteins also function as precursors to some B-complex vitamins.

Loss of weight, rough hair coats, poor appetites, low digestive efficiencies, and lower reproduction rates are symptoms of animal protein deficiencies. If these deficiencies are not corrected, an animal may die and the investment will be lost.

Death usually occurs because of a lack of amino acids, which are produced by proteins. Functions of protein and deficiency symptoms apply to each class of livestock.

The Role of Amino Acids in Protein Synthesis

During digestion, amino acids synthesize food proteins to be used for a specific physiological function. Genetic compounds, such as DNA and RNA, determine which proteins are needed by the body. This information is sent to the amino acids, which synthesize the proper protein for the situation. These proteins can be used for skin, hair, hoof, or muscle development. Amino acids are nitrogen compounds that originate from proteins fed to the animal. A good description of amino acids is "the bricks and mortar of which muscles, body tissues, skin, and hair are built."

Amino acids are separated into two groups: essential and nonessential. Essential amino acids must be provided in non-ruminant diets. Nonessential amino acids can usually be synthesized by the animal. There are 23 amino acids--10 essential ones and 13 nonessential ones. All classes of livestock require both essential and nonessential amino acids.

Classes of livestock synthesize amino acids differently. Ruminants can synthesize their own amino acids as long as enough nitrogen and protein are fed in the diet. Non-ruminants can produce some nonessential amino acids, but they cannot produce any essential amino acids. These must be provided in their diet. DNA serves as the information center that links amino acids together to form a specific protein. The role of amino acids is to link together to form a specific protein for a particular physiological function.

Essential Amino Acids

The 10 essential amino acids are:

Phenylalanine	Histidine
Valine	Arginine
Threonine	Lysine
Tryptophan	Leucine
Isoleucine	
Methionine	

There are 13 nonessential amino acids, as well.

FIGURE 4.1 - Protein Utilization in the Ruminant
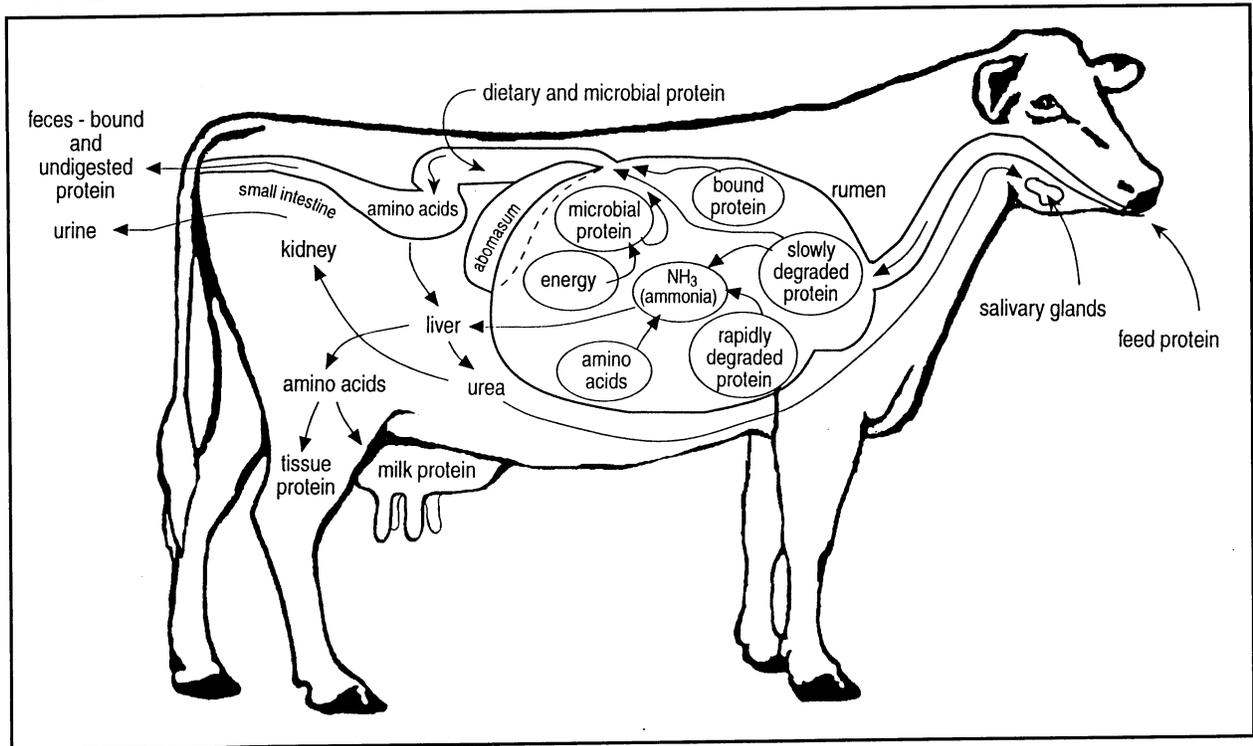
Symptoms of Protein Deficiency

Symptoms of amino acid/protein deficiency are lack of growth, poor hair coat, lack of muscling, and lack of energy. Dietary proteins are necessary for amino acids, and amino acids are needed for making specific proteins for usage by the body. If a food is lacking in an essential amino acid and the animal cannot synthesize it, the amino acid must be supplied in the diet. For example, corn is deficient in lysine, which is an essential amino acid. Therefore, for certain proteins to be synthesized, lysine must be supplied from another feedstuff.

Sources of Protein

Strong sources of protein are very important as livestock feed. Protein sources are divided into three groups: animal, plant, and synthetic. Rations are figured by the percentage of crude protein (CP) supplied by a source. Therefore, all sources of protein are listed by percentage of crude protein. Following are some good sources of plant and animal protein sources. (Note: These are book value ranges. Home-raised protein sources should be tested for CP values.)

Animal protein sources
Feather meal, 87 percent CP
Blood meal, 80 percent CP
Fish meal, 60 percent CP
Poultry by-product meal, 55 percent CP
Meat scrap, 55 percent CP
Meat and bone meal, 50 percent CP
Dried skim milk, 34 percent CP
Dried whole milk, 25 percent CP

Plant protein sources
Sunflower meal, 47 percent CP
Soybean meal, 44 percent CP
Cottonseed meal, 41 percent CP
Rapeseed meal, 37 percent CP
Dehydrated alfalfa meal, 18 percent CP
Alfalfa hay, 15 percent CP
Red clover hay, 13 percent CP
Wheat grain, 12 percent CP
Oat grain, 12 percent CP
Corn grain, 9 percent CP

Synthetic protein sources - The most commonly used synthetic protein is urea. Urea can only be fed to ruminants because microbes present in these animals feed on the urea. It should be fed only to ruminants on high energy diets, such as

fat cattle on the dry lot. Urea consists of 45 percent nitrogen and is a good source for amino acids. Toxicity (poisoning) can occur if excess amounts are fed to ruminants. If the microbes cannot digest all of the urea, an ammonia byproduct is produced, which is damaging to the urinary tract.

Determining Which Proteins Should be Used

Ruminants - The first step in deciding which proteins to feed ruminants is to determine which proteins will feed the microorganisms or "bugs" in the rumen. These **microbes** can synthesize amino acids from nonprotein nitrogen that non-ruminants cannot.

A producer can choose true proteins, such as soybean meal or cottonseed meal. The other option is to feed a nonprotein nitrogen (NPN) feedstuff, such as urea or anhydrous ammonia. These two types of proteins supply nitrogen used by the microbes for protein synthesis.

When using true proteins such as plant protein or animal protein, crude protein does not determine digestibility (amount of protein available to the animal). Crude protein is the total amount of protein available in the feedstuff, but an animal cannot digest all the protein available. Digestible

protein best describes the amount of protein used by the animal. Price, of course, is another influencing factor.

The next consideration is the **amount** of protein digested by the rumen. Most nonprotein nitrogen feedstuffs are digested and utilized by microbes in the rumen.

In Figure 4.1, nonprotein feedstuffs are considered rapidly degraded proteins. Excess amounts of nonprotein nitrogen can result in higher levels of ammonia in the rumen. Excess rumen ammonia is absorbed into the bloodstream and converted to urea in the liver. The nonprotein nitrogen (rapidly degraded protein) is converted into NH_3 (ammonia), and the excess enters the bloodstream, is transformed into urea in the liver, and leaves the body through the urine. Excess nonprotein nitrogen can result in ammonia toxicity due to high levels of blood ammonia. Only limited amounts of NPN can be used. (Four pounds of urea per cow per day is a safe maximum.)

In Figure 4.1, bound proteins are the undigestible portions of true proteins. These proteins cannot be digested by the rumen or the small intestine. These proteins are the difference between crude protein and digestible protein. Bound proteins

TABLE 4.1 - Digestibility in Swine Feedstuffs

Source	Crude Protein		Isoleucine		Leucine		Lysine		Meth. & Cystine		Threonine		Tryptophan	
	Tot.%	Total Dig.%	Tot.%	Total Dig.%	Tot.%	Total Dig.%	Tot.%	Total Dig.%	Tot.%	Total Dig.%	Tot.%	Total Dig.%	Tot.%	Total Dig.%
Blood meal	86	78	1.13	.75	11	9.24	7.85	6.51	1.91	1.45	3.57	2.9	1.08	.85
Meat and bone	61	44	1.66	1.11	3.7	2.63	3.1	2.29	1.9	1.33	1.86	1.2	.37	.23
Soybean meal	47.6	38.5	2.2	1.83	3.66	3.07	3.01	2.55	1.3	1.05	1.88	1.48	.57	.46
Raw soybeans	38	21	1.7	.88	3	1.56	2.5	1.52	1.2	1.0	1.6	.9	.46	.26
Heated soybeans	39	28	1.8	1.3	3.2	2.37	2.5	1.97	1.1	.83	1.6	1.15	.54	.38
Feather meal	83	59	3.69	2.9	6.63	5.1	1.59	.81	4.24	3.0	3.49	2.58	.42	.25
Corn	8	6	.32	.25	1.11	.95	.27	.18	.37	.11	.32	.07	.08	.004
100 lb. pig needs per day (4.1 lbs. feed total)	16			.019		.025		.031		.017		.02		.005

Source: "Apparent Ileal Digestibility of Crude Protein and Essential Amino Acids in Feedstuffs for Swine - 1992." Chicago, IL: Heartland Lysine, Inc., 1992.

FIGURE 4.2 - Effects of Amino Acids on Milk Production
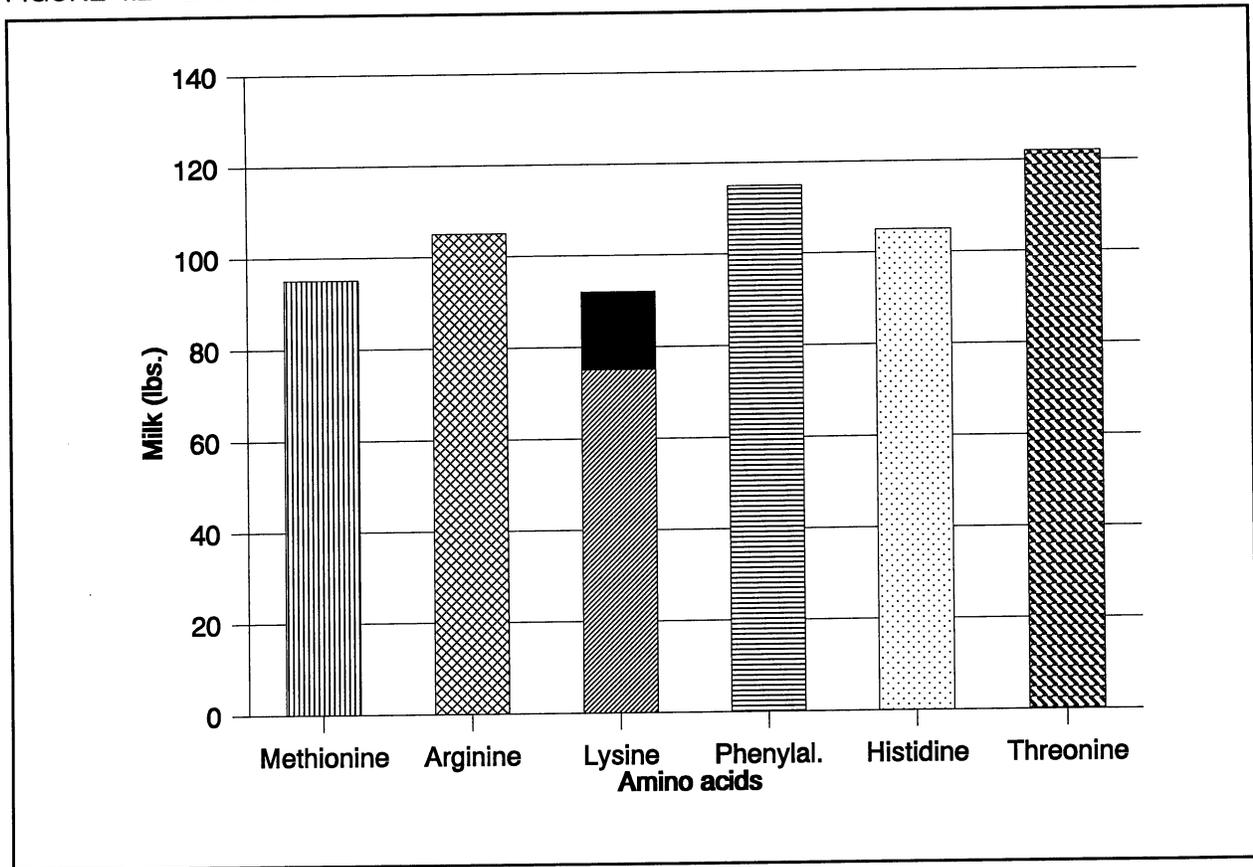
enter and leave the body virtually undigested. There are also true proteins that are considered rapidly degraded proteins. A large part of these proteins are used by microbes in the rumen.

The last form of protein is slowly degraded protein. Part of these true proteins are digested in the rumen. Microbes in the rumen use some of them, and the remaining portions escape into the small intestine, where it is digested along with microbial protein and then used for muscle formation and milk production.

The last step in classifying feedstuffs is based on **rumen digestion.**

1. Soluble proteins disappear or are digested in two hours or less after entering the rumen. These proteins are classified as "rapidly degraded protein" in Figure 4.1. Example sources are urea, alfalfa silage, and anhydrous ammonia. Most of these proteins are used by microbial cells ("bugs").

2. Degradable proteins are broken down at a measurable rate over time. The amount of protein digested in the rumen depends on the rate and amount of time spent there. These proteins are classified as "rapidly and slowly degraded proteins" in Figure 4.1. These proteins are used by microbial cells and the small intestine. Examples are soybean meal and cottonseed meal.

3. Escape or bypass proteins bypass rumen digestion. Most of them are digested and absorbed in the small intestine. These proteins are classified as "slowly degraded proteins" in Figure 4.1. Examples are fish meal, blood meal, meat and bone meal, and corn gluten meal.

4. Nonprotein feedstuffs cannot supply all the protein necessary in the diet, but true proteins can. Nonprotein feedstuffs must be supplemented with true proteins.

FIGURE 4.3 - Balancing a Ration

Corn **8**		**32**	80% x 4.1 = 3.28 lbs. of corn
	16	**8**	20% x 4.1 = .82 lb. of soybean meal
Soybean meal **48**		**40**	

5. Figure 4.2 shows the effects of amino acids on milk production. Milk production in dairy cattle is limited by the lowest limiting amino acid (here, lysine). In Figure 4.2, this animal would only produce 75 lbs. of milk daily because the lysine becomes limiting at this level of milk production.

Figure 4.2 also shows what would happen if the diet was supplemented with a bypass protein high in lysine. When this occurs, lysine is no longer the limiting amino acid; methionine now becomes the limiting amino acid. This change results in increased milk production (75 lbs. to 92 lbs. daily). Paying close attention to ration balancing can mean a much more profitable operation. This concept of limiting amino acids also applies to nonruminants.

Nonruminants - Protein digestibility is easier to understand in nonruminants because there are no microbial cells to feed and no predigestion before entering the stomach. Table 4.1 shows the requirements for a growing 100 lb. market hog, as well as the crude protein, digestible protein, and amount of amino acids present in different feedstuffs. A 100 lb. market hog requires a 16 percent crude protein diet. The average 100 lb. hog consumes 4.1 lbs. of feed daily. Of that, 16 percent needs to be crude

FIGURE 4.4 - Swine Percentage Lean Over Time

Based on carcass data from southeast Missouri, 1993

Source: Mark Newcomb, Animal Sciences Ext., University of Missouri-Columbia
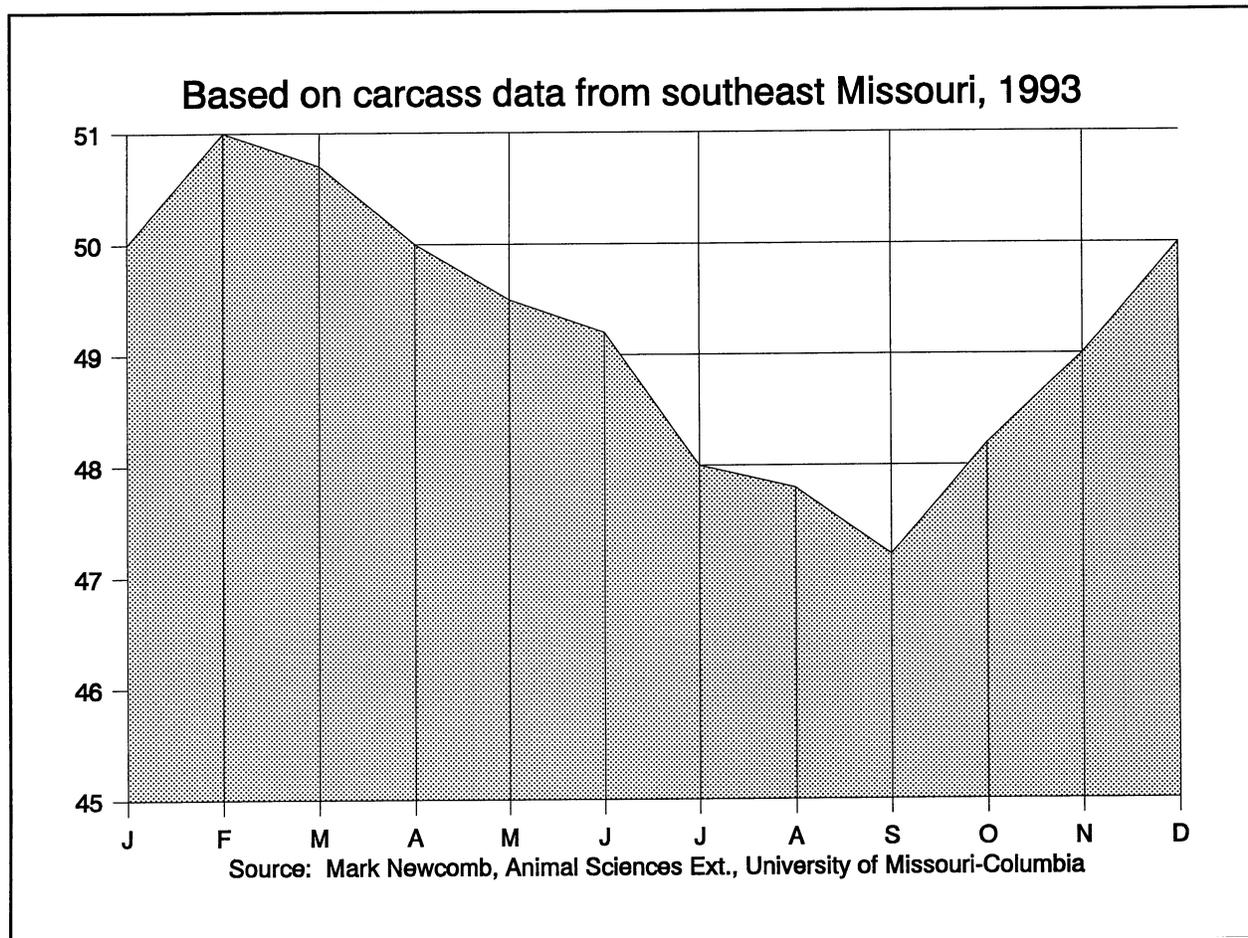
protein, which is .66 lb. of crude protein. (Remember, this is an estimate.)

To further understand the hog's requirement, look at the bottom line of Table 4.1. It shows that the amino acid requirement for the 100 lb. hog is .019 lb. of isoleucine, .025 lb. of leucine, .031 lb. of lysine, .017 lb. of methionine and cystine, .02 lb. of threonine, and .005 lb. of tryptophan.

Blood meal, for example, has a crude protein percentage of 86 percent, of which 70 percent can be digested. Of 100 lbs. of blood meal, 86 lbs. are crude protein, while 70 lbs. are usable (digestible) protein. Of the 100 lbs. of blood meal, the total amount of isoleucine is 1.13 lbs. There is .75 lb. of usable (digestible) isoleucine available in 100 lbs. of blood meal. To find out the digestible amount of isoleucine available in 50 lbs. of blood meal, multiply 50 lbs. of blood meal by .0075 digestible isoleucine. (50 x .0075 = .375 lb. of digestible isoleucine)

To find the available digestible leucine in 50 lbs. of blood meal, multiply 50 lbs. of blood meal by .0924. (50 x .0924 = 4.62 lbs.) Let's use this information in a real-life ration. On the average, a 100 lb. hog eats 4.1 lbs. a day. To find out if the ration below meets the amino acid requirements of this hog, find out the total amount of each feedstuff.

In the following ration, 3.28 lbs. of the 4.1 lbs. eaten is corn, and .82 lb. is soybean meal. Usually, lysine is the limiting amino acid in most hog rations. Soybean meal will supply .021 lb. of lysine (.82 lb. x .0255 = .021). The corn supplies .006 lb. of lysine (3.28 x .0018 = .006). The hog requires .031 lb. of lysine; these feedstuffs supply .027 lb. of lysine (.021 + .006). This ration, therefore, is lacking lysine. Remember that all hog rations need vitamins and minerals, which have not been figured in yet. In real life, this ration would be balanced for lysine (not protein) to prevent this deficiency from occurring. (See Figure 4.3.)

Remember that the 4.1 lbs. eaten daily is an average. In the winter, hogs will eat more than in the summer. To the average producer, using the above ration in the winter wastes money because it includes more amino acids than the hog needs. In the summer, the hog's appetite decreases and its needs are not met because it eats less than 4.1 lbs. a day. Figure 4.4 shows this difference in eating habits.

If using the above ration, packers receive leaner hogs in the winter because hogs are eating more, so their amino acid needs are met, resulting in more muscle. In the summer, when hogs eat less, their amino acid needs are not met and fat is produced instead of muscle.

The processing of feedstuffs improves protein digestibility. Compare raw soybeans to heated soybeans on Table 4.1. Crude protein remains about the same, but the digestibility of heated soybeans jumps up 7 percent. This concept also applies to digestibility of amino acids. (See Table 4.1.)

Summary

Understanding protein's role in nutrition is economically important because protein is one of the more expensive components in ration development.

Credits

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Lesson 5:
Minerals' Role in Animal Nutrition

General Functions of Required Minerals

When an organic material such as feed is burned, the leftover ash is the material's mineral content. Minerals are inorganic substances needed by animals for production and maintenance; they are needed in very small amounts in the ration. If a particular mineral is needed, it must be provided in the diet in a form that can be digested, absorbed, and used in metabolism. Rations must be formulated so that a mineral imbalance does not occur.

At least 19 mineral elements are needed by various animal species. These minerals are divided into two groups based on the quantities needed. Those needed in larger amounts are called macro-minerals, and those needed in small amounts are called trace or micro-minerals.

Macro-minerals include calcium (Ca), sodium (Na), phosphorus (P), magnesium (Mg), potassium (K), and chlorine (Cl). Trace or micro-minerals needed include sulfur (S), chromium (Cr), cobalt (Co), copper (Cu), fluorine (F), iodine (I), iron (Fe), manganese (Mn), molybdenum (Mo), selenium (Se), silicon (Si), and zinc (Zn).

Although the mineral content of an animal's body is small (2-5 percent, depending on the species), minerals perform many essential functions. Minerals provide material for the growth of bones, teeth, and soft tissues. Minerals fill in soft bone and teeth cells to make the cells hard and rigid. Minerals regulate many vital chemical processes. They also aid in muscular stimulation and activity, reproduction, digestion of feed, repair of body tissue, formation of new tissue, and release of body heat for energy.

Minerals are an essential part of the blood, body fluids, and some secretions in the body. They help regulate the acid-base balance to maintain body fluids at a pH of about 7.0. Other functions of minerals include cell structure and integrity; part of organic compounds such as proteins, amino acids, carbohydrates, and fats; control the location of body water through osmotic pressure;

coenzymes that activate enzymes; necessary components of hormones; and egg production.

Toxic minerals - Some minerals, such as arsenic, cadmium, mercury, and lead, are toxic to animals. Selenium helps protect against arsenic, cadmium, and mercury poisoning.

Arsenic is found in some herbicides, insecticides, and defoliants. Crops do not grow well on soils contaminated with arsenic. Crops recently sprayed with a material containing arsenic can cause arsenic poisoning if livestock graze on the foliage.

Cadmium is normally not found in soils in excessive amounts; however, contamination from industrial plants or sewage from cities causes a buildup of cadmium in the soil.

Mercury can be discharged into air and water by industrial plants, and is used in herbicides and fungicides for seed treatment.

The major danger from lead is contamination of plants from lead in the air. The most common source of lead toxicity is lead-based paint from discarded paint cans or peeling buildings.

Macro-Minerals: Functions, Deficiencies, Interactions, Sources

Calcium (Ca)
Major functions - An animal's bones and teeth contain 99 percent of the calcium found in its body. Calcium is also an important part of milk and eggs, so it is essential in the diets of lactating animals and laying hens. Calcium is also important for proper nerve and muscle functioning, for maintaining the acid-base balance of the body fluids, and for blood coagulation.

Deficiencies - A deficiency of calcium will result in abnormal bone growth and weak bones in all classes of livestock. Young animals that are deficient in calcium can develop rickets, where the normal amount of calcium is not deposited in the growing bones. The joints then become enlarged and bones become weak, soft, deformed, and fragile. The calcium in the spongy part of the bones is withdrawn first to meet the needs of the animal. If the deficiency continues, the calcium is withdrawn from the shafts and

other structural parts of the bone. Bones then become porous, weak, and fragile. Older animals with a calcium deficiency can develop osteoporosis.

Calcium-deficient poultry have thin-shelled eggs, reduced egg production, and lowered hatchability. Milk fever can occur when cattle are deficient in calcium shortly before or after calving.

Interrelationships - The ratio of calcium to phosphorus, magnesium, and zinc must be correct for the proper utilization of these minerals. The calcium-to-phosphorus (Ca:P) ratio should be 1:1 to 2:1. Excessive calcium in the ratio will result in poor utilization of these other minerals. An excess of magnesium decreases the absorption of calcium, replaces calcium in the bone with magnesium, and causes an increase in the excretion of calcium from the body. The vitamin D level is critical because a deficiency of vitamin D in the ration prevents the proper utilization of calcium. Also, an excess amount of calcium reduces the absorption and utilization of zinc.

Sources - Legume forages and animal-origin protein supplements are the highest in calcium content, ranging from one to two percent on a dry weight basis. Plants grown on well-fertilized soils are higher in calcium content than those grown on poorer soils. Other good feed sources of calcium include milk, bonemeal, and citrus pulp. Rations that are high in grain need more calcium supplements, while legume forage rations need little or no added calcium.

Calcium supplements come from various materials. Typical sources are ground limestone, oyster shell flour, and marble dust. Supplements can be fed free choice in a mineral mix or added to the ration at the proper level.

Grains, straw, dried mature grasses, and protein supplements from plant sources contain the least amount of calcium, ranging from 0.01 to 0.15 percent. Grass forages generally contain 0.35-0.75 percent calcium. In the end, only about 20-30 percent of calcium in the average ration is absorbed from the intestinal tract and taken into the bloodstream.

Salt (NaCl)

Major functions - Salt contains the mineral elements sodium (Na) and chlorine (Cl), which are needed by all classes of livestock. Cattle, sheep, and horses usually require more salt supplements than swine or poultry because of the higher levels of forages in their diets. Most grains and forages produced on nonirrigated soils are low in sodium and chlorine content. Sodium and chlorine are important for maintaining osmotic pressure in the body cells. The assimilation of nutrients and removal of waste from cells depend on maintenance of the proper osmotic pressure. Sodium is the major mineral responsible for maintaining a neutral pH level in the body tissues. Chlorine is essential for the formation of bile and hydrochloric acid in the digestive juices. Both sodium and chlorine affect muscle and nerve activity.

The requirements for salt in the diet vary with the specie, type of feed fed, activity of the animal, air temperature, water salinity, and production. Milk is especially rich in salt; therefore, lactating animals have a higher salt requirement. Heavy sweating causes a rapid loss of salt from the body, increasing the animal's salt requirement.

Deficiencies - Animals that are temporarily deprived of salt can develop an abnormal appetite for dirt, manure or urine. Symptoms of salt deficiency are slow to develop because the salt in the body is recycled when the intake is low. However, some symptoms which may occur include reduced growth and efficiency of feed utilization in growing animals, and lowered reproduction, reduced milk production, and weight loss in adult animals. In laying hens, lowered production, loss of weight, and cannibalism may result from a salt deficiency.

Ration requirements - Salt can be mixed in the ration at 0.25-0.50 percent of the ration and/or fed free choice. During the lactation period of cattle, sheep, and horses, include salt at about one percent of the ration. Generally, include about 0.50 percent salt in a ration for swine. Including salt in the ration helps to ensure that all animals get an adequate amount; it also improves palatability.

Sources - Supplemental salt can be added in block form, as loose salt or in the mineral mix.

The price and availability of the various sources are the main considerations when deciding which to use. In a ration, it is a common practice to add salt (0.25-0.50 percent) as the carrier for trace minerals because of the improved palatability of the mix. Salt fed to cattle on pasture often has organic iodine added to prevent foot rot and magnesium oxide added to help prevent grass tetany. Block salt is easy to use, does not need protection from wet weather and stimulates salivation. There is little danger of the animal overeating salt. However, some animals might not get enough salt or might develop sore tongues if available only in the block form.

Loose salt can be plain or have trace minerals added. It is easy for the animal to consume but needs protection from rain or snow. Another disadvantage is that animals starved for salt might eat too much of the loose form. When salt is fed loose, make sure there is an adequate water supply to prevent toxic reactions from overeating. Salt fed loose should be protected by a mineral feeder.

Toxicity - Toxicity rarely develops from the consumption of salt, unless ruminants that overeat salt are restricted in their access to water. As much as 15 percent of the ration can be given to cattle on pasture to limit grain intake, with no toxicity resulting. However, salt toxicity can readily occur in nonruminants. It is characterized by a staggering gait, blindness, and other nervous disorders. Also, ruminant animals that have been salt starved can overeat if given unlimited access to salt, and overeating can cause digestive upset or death.

Phosphorus (P)
Major functions - Phosphorus is a vital element in many body functions, and is helps interrelationships with several other macro- and trace minerals. Approximately 80 percent of phosphorus in the body is found in the bones and teeth; therefore, it is a key element in their proper growth and development. Phosphorus is a component of phospholipids, which are important in lipid transport and metabolism, as well as cell-membrane structure. Phosphorus affects appetite, milk and egg production, energy metabolism, conversion of carotene into vitamin A, and utilization of vitamin D. Phosphorus is a

component of RNA and DNA and is involved in other metabolic processes as a constituent of several enzyme systems.

Deficiencies - A deficiency can result in rickets or osteoporosis, as well as in poor appetite, slow gains, lower milk and egg production, reproductive problems, poor utilization of vitamin D, deficiency of vitamin A, and generally unthrifty appearance. While it is not a specific symptom of phosphorus deficiency, the deliberate eating of soil and chewing on other nonfeed objects can suggest a phosphorus deficiency in the diet.

Interrelationships - Excessive amounts of calcium and magnesium in the diet reduce phosphorus absorption. In ruminants, an excess of phosphorus can cause urinary calculi, lameness, spontaneous fracture of long bones, and a laxative effect. Phosphorus is more efficiently absorbed than calcium; about 70 percent of ingested phosphorus is absorbed. The Ca:P ratio in the diet should be 1:1 to 2:1.

Sources - Feeds that are good sources of phosphorus include wheat bran, cottonseed meal, and dried skim milk. Legume and grass pastures grown on fertile soils are fairly good sources, while mature, weathered grass forage is generally low in phosphorus. Cereal grains and grain products are fairly high in phosphorus, but much of it is not readily available to nonruminants. An adequate vitamin D level in the diet improves the assimilation of phosphorus. Ruminants are better served by plant sources of phosphorus, while poultry and swine need phosphorus from inorganic sources. Phosphorus supplements can be included in a mineral mix fed free choice and/or added to the ration at the proper level.

Magnesium (Mg)
Major functions - Magnesium helps activate several enzyme systems, relaxes nerve impulses, and is involved in protein digestion. It also serves as a ruminant alkalizer and buffer. Magnesium is a constituent of bones and teeth and is necessary for normal skeletal devel-opment. While magnesium is essential for life, it is present in only small amounts in the body.

Deficiencies - A low level of magnesium in the ration can cause decreased utilization of phos-

phorus and may cause hyperirritability in animals. Magnesium deficiency can cause vasodilation (dilation and relaxation of the blood vessels) which is evidenced by the flushing of the skin.

An acute magnesium deficiency can result in grass tetany. Older, lactating animals are generally affected, but younger animals can develop grass tetany, as well. Grass tetany is likely to develop when levels of magnesium drop below 0.001 percent in the blood serum. Tetany is more likely to develop in cattle and sheep grazing on grass pastures, small grains, highly fertilized fescue in late winter or early spring or grass hay diets. The affected animals become nervous, stagger, and then fall down. Other characteristics of grass tetany include loss of appetite and convulsions. Unless they are quickly treated by an injection of magnesium, they often die.

Interrelationships - Adding magnesium to the ration can cause a zinc deficiency if the ration is not properly supplemented with zinc. Too much magnesium in the ration can interfere with the metabolism of phosphorus and calcium.

Sources - If the diet is low in magnesium, the animal will draw upon the magnesium reserve in its bones. While most rations contain enough magnesium, it might be necessary to supplement the ration, especially under conditions described above that can result in grass tetany. A little more than one ounce of magnesium per head per day for cattle is enough, with a proportionately smaller amount for sheep. Magnesium sulphate or magnesium oxide can be mixed with salt, supplement or fed free choice in areas where grass tetany is a risk.

Potassium (K)
Major functions - Potassium is a major cation (positively charged ion) which affects the osmotic pressure and acid-base balance of the body fluids. It is also involved in controlling muscle activity and the metabolism of carbohydrates and protein synthesis. Potassium is also related to the relaxation of the heart muscle and the secretion of insulin.

Deficiencies - Potassium deficiency may result in reduced growth, general muscle weakness, diarrhea, and an unsteady gait. It may also cause the enlargement of the heart and kidneys, followed by death. Potassium deficiency most often occurs in dry lot finishing cattle or sheep on a high-concentrate ration.

Interrelationships/toxicities - Too much potassium in the diet can result in poor assimilation of calcium and magnesium. The resulting magnesium deficiency leads to poor retention of potassium, and a potassium deficiency results. A high potassium intake causes increased urine output as the animal tries to excrete the excess amount. A toxic level of potassium results in diarrhea, tremors, and heart failure. Excessive salt intake depletes the body's potassium.

Sources - While potassium is essential for life, it is usually adequate most animal rations. Forages are especially high in potassium, containing 3-4 percent on a dry weight basis in the early growth stage. Grains and concentrates contain 0.3-0.7 percent potassium. Animals generally need less than one percent potassium in the ration on a dry weight basis.

Micro-Minerals: Functions, Deficiencies, Interactions, Sources

Sulphur (S)
Major functions - Sulphur is an essential part of the amino acids cystine and methionine and is important in the metabolism of lipids, carbohydrates, and energy. It is also a component of hair, wool, and feathers.

Deficiencies - A deficiency of sulphur in the ration will appear as a protein deficiency. Slow growth and a general unthrifty condition are symptoms of a possible sulphur deficiency. Sheep that are fed nonprotein nitrogen without sulfur supplements show reduced wool growth. (Wool contains about four percent sulfur.)

Ration requirements - Ruminant rations that are high in nonprotein nitrogen (NPN) can be sulphur deficient. A nitrogen-to-sulphur ratio of 15:1 is more desirable as this improves the utilization of NPN in the ration. Nonruminants should be provided sulfur-containing proteins, as well.

Sources - Forages, especially legumes which are harvested in the earlier growth stages, should contain enough sulphur for ruminants. For

forages harvested in more mature stages, sulphur supplements might be needed to improve nitrogen utilization. Water supplies in some areas have a high sulphur content. This should be checked to learn the amount of sulphur being included in the diet through the drinking water.

Chromium (Cr)
Major functions - Chromium is believed to be related to glucose metabolism. It is also an activator of certain enzymes and a stabilizer of nucleic acids. Chromium is necessary for the stimulation of the synthesis of fatty acids and cholesterol in the liver.

Deficiencies - A deficiency of chromium is shown by impaired glucose tolerance and a disturbance of lipid and protein metabolism. Supplementation is not generally needed for chromium because such small amounts are required.

Cobalt (Co)
Major functions - Cobalt is used by rumen and cecal bacteria in the growth of rumen bacteria and is essential in the synthesis of vitamin B_{12}.

Deficiencies/toxicities - Cobalt deficiency symptoms are similar to vitamin B_{12} deficiency symptoms. These include poor appetite and general malnutrition, weakness, slow growth, decreased fertility, lower milk and wool production, emaciation, anemia, and eventually death. Toxicity is not likely.

Sources - Good sources of cobalt are usually commercial minerals, poultry by-products, soybean meal and molasses.

Copper (Cu)
Major functions - Along with iron and B_{12}, copper helps in hemoglobin formation. It is essential in some enzyme system activation, hair development and pigmentation, wool growth, bone development, reproduction, and lactation.

Deficiencies - Symptoms of copper deficiency include severe diarrhea, slow growth caused by anemia, swelling of joints, swayback in newborn lambs, difficulty in breathing, loss of hair color in cattle, and abnormal wool growth in sheep. Milk is low in copper; therefore, young animals raised solely on milk may develop anemia.

Interrelationships - Only small amounts of copper are needed by the animal; however, the level required is influenced by the amounts of iron, manganese, zinc, lead, nitrate, and molybdenum in the ration.

Toxicity - Copper levels above 250 ppm are toxic with death resulting. Levels above 50 ppm are considered potentially dangerous to animal health. Excessive amounts of copper accumulate in the liver and may result in death. Other toxicity symptoms include anemia and jaundice.

Sources - Most livestock feeds have 3-4 times the amount of copper needed by animals. Also, a variable store of copper is located in the liver and spleen. If needed, use commercial minerals or trace-mineralized salt containing copper sulfate. Commercial minerals fed to sheep should not contain copper because it may be lethal. Copper accumulates in bodies and does not metabolize.

Fluorine (F)
Major functions - Fluorine helps prevent cavities in teeth and possibly slows osteoporosis in older animals.

Deficiencies - Fluorine deficiency in the diet is rare, and supplements are not recommended. However, large amounts of calcium, aluminum or fat will lower the absorption of fluorine. Drinking water and forages usually contain enough fluorine to meet livestock needs.

Interrelationship - High dietary calcium depresses fluorine uptake in bone.

Toxicity - In excessive amounts, fluorine is toxic. The symptoms of too much fluorine in the diet develop slowly over time because fluorine is a cumulative poison. High levels will result in enlarged bones; softening, mottling and irregular wear of the teeth; a roughened hair coat; delayed maturity; and less efficient utilization of feed.

Iodine (I)
Major functions - Iodine is necessary for the production of the hormone thyroxine in the thyroid gland. This hormone controls the rate of oxidation of nutrients in the cells, and thus controls heat production in the animal's body.

Deficiencies - A deficiency in iodine reduces the production of thyroxine and leads to goiter (the enlargement of the thyroid gland). Enlargement of the thyroid gland is nature's way of trying to make enough thyroxin when there is insufficient iodine in the diet. There is no satisfactory treatment for animals that have developed pronounced iodine deficiency symptoms. Other deficiency symptoms include stillbirths and weak young; hairless pigs and wool-less lambs at birth.

Toxicity - Long-term chronic intake of large amounts of iodine reduces the thyroid uptake of iodine.

Sources - Good sources of iodine include iodized salt, calcium iodate, whey, and molasses.

Iron (Fe)
Major functions - Iron is necessary for hemoglobin formation and is also involved in oxidation of nutrients in the cells. (Hemoglobin is the part of the blood that transports oxygen to the cells in the body.) Other minerals needed for hemoglobin formation are copper and cobalt.

Ration requirements and deficiencies - The amount of iron required in the diet is believed to be as little as 80 mg per kg of diet for most animals. Livestock feeds generally contain enough iron to meet the needs of older animals.

Milk is low in iron; therefore, iron deficiency occurs with young, nursing animals. Iron deficiency occurs more frequently with nursing pigs raised in confinement than with other species. Other young appear to have sufficient reserves of iron in the liver and spleen to carry them through the nursing period. Oral doses or injections of iron for young pigs are necessary to prevent anemia, which is the most common symptom of iron deficiency.

Symptoms of anemia in young pigs include labored breathing; listlessness; pale eyelids, ears, and nose; and flabby, wrinkled skin. A concentrated ferrous sulphate or other iron solution can be given to young pigs orally. An iron dextran injection of 150-200 mg at three days of age can be used instead of oral administration.

Interrelationships - Too much iron in the diet will interfere with the assimilation of phosphorus because of the formation of insoluble iron phosphates. Copper is required for proper iron metabolism to occur.

Sources - Legumes and leafy plants contain enough iron to meet the needs of older animals. Trace-mineralized salt containing iron should be fed to all livestock to prevent iron deficiency.

Manganese (Mn)
Major functions - Manganese is essential for normal bone formation and growth of other connective tissue. It is also involved in enzyme systems that influence estrus, ovulation, fetal development, milk production, and growth. Manganese also functions in the synthesis of fatty acids, amino acid and cholesterol metabolism, and in blood clotting.

Deficiencies - A ration is manganese deficient when the level of manganese drops below 20 ppm. Indications of low manganese levels in the diet are: poor growth, abnormal bone development, sterility, delayed estrus, reduced ovulation, abortions, pinkeye, and slipped tendon in poultry. Swollen and stiff joints are evidenced by knuckling over (in calves) and crooked legs and enlarged hocks (in pigs).

Interrelationships - The normal range of manganese is 50-150 ppm. Levels in excess of 500 ppm will cause problems with phosphorus and iron utilization. Excess calcium and phosphorus decrease manganese absorption.

Sources - While the availability of manganese is not as good from manganese sulphate or manganese oxide, these inorganic sources can be used to add manganese to the ration. Most livestock rations have enough manganese, with roughages having higher levels than grain and corn being low. Beef cattle on all-concentrate diets based on corn and NPN supplements might need manganese supplements in the diet. Corn and soybean meal rations for swine can be improved with manganese supplements.

Molybdenum (Mo)
Major functions - Molybdenum is a component of an enzyme found in milk and in body tissues. It is also involved in stimulating rumen organisms.

Molybdenum is also part of three different enzyme systems involved in the metabolism of carbohydrates, fats, proteins, and iron.

Interrelationships/toxicities - Utilization of molybdenum is reduced by excess copper sulfate and tungsten. Molybdenum is related to uric formation in poultry and microbial action in ruminants. Toxic levels of molybdenum interfere with copper metabolism. Toxicity symptoms include severe scours and loss of condition.

Selenium (Se)

Major functions - Selenium is needed in small amounts because of its relationship with vitamin E absorption and utilization. Selenium prevents degeneration and fibrosis of the pancreas in chicks. Most importantly, it protects tissue against certain poisonous substances, such as arsenic, cadmium, and mercury.

Deficiencies - A deficiency of selenium causes nutritional muscular dystrophy (white muscle disease) in cattle, sheep, chickens, swine, and horses. It may also cause liver damage in swine.

Toxicity - Three types of selenium toxicity occur in livestock: acute, chronic blind staggers, and chronic alkali-disease. Symptoms include blind staggers, lameness, anemia, excess salivation, grinding of the teeth, and blindness. Excess selenium in poultry results in reduced egg production and deformities such as lack of eyes and deformed wings and feet.

Sources - Good sources of selenium include marine by-products, such as seaweed and kelp, cereal grains and wheat by-products.

Silicon (Si)

Major functions - Silicon is necessary for normal growth and skeletal development of chicks.

Deficiencies - A deficiency of silicon in a chick's diet results in slow growth and skeletal deformities, especially in the skull.

Sources - Silicon is present in large amounts in soil and plants. Also, on purified diets, the addition of silicon to the diet has increased the growth rate of chicks.

Zinc (Zn)

Major functions - Zinc is important for the normal development of skin, hair, wool, feathers, bones, and eyes; preventing parakeratosis; and healing wounds. Zinc is necessary in several enzyme systems, for protein synthesis and metabolism, and as an insulin component. Zinc also gives bloom to the hair coat.

Deficiencies - Symptoms of zinc deficiency in livestock include rough, thick skin in swine (commonly called parakeratosis); thickening of skin on the neck; loss of hair; wool slipping; poor feather development; slow wound healing; and poor appetite and growth.

Interrelationships - Excess calcium reduces the absorption and utilization of zinc. Animals are generally tolerant of excessive levels of zinc in the ration, although high levels will interfere with the utilization of copper and iron and might cause anemia. If the ration is high in zinc, additional copper and iron may be needed. Grains and forages seldom contain excessive levels of zinc, even if grown on soils with high levels of available zinc.

Sources - Zinc is often added in trace-mineralized salt for all livestock to ensure against a possible deficiency. Swine rations usually have zinc added to the ration. Other sources include fish meal, corn gluten feed, and meal and poultry by-products.

Absorption of Minerals in the Body

Dissolved minerals are absorbed into the bloodstream through villi in the small intestine. In the large intestine, nutrients are absorbed directly into the bloodstream through capillaries in the wall of the intestines.

Summary

At least 18 mineral elements are needed by animals. Those needed in large amounts are referred to as major or macro-minerals, while those needed in small amounts are called trace or micro-minerals. Minerals are required for the development of bones and teeth, as well as for many other functions in the body. Deficiencies cause lower production and poor gains, but rarely cause diseases or death. Commercial feeds and

mineral mixes are the most common sources of minerals in livestock rations. Minerals can be mixed in complete feeds or fed free choice.

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Lesson 6:
Vitamins' Role in Animal Nutrition

Vitamins are organic compounds that are essential for normal growth and maintenance of animal life. Only small amounts of vitamins are needed because they function as catalysts (parts of enzymes or coenzymes) in metabolic processes. Vitamins are distinct from carbohydrates, fat, protein, minerals, and water.

Classification of Required Vitamins

In animal nutrition, 16 vitamins are essential. These vitamins are classified by their solubility (whether they dissolve in water or in fat).

Fat-soluble - These vitamins can be stored in the animal's fat tissue, reducing the need for a daily supply in the diet. This enables livestock to survive on vitamin-deficient diets for longer without deficiency symptoms. Included in this group are Vitamins A, D, E, and K.

Water-soluble - Water-soluble vitamins are generally stored in the animal's body for only 2-4 days. Therefore, these vitamins need to be supplied regularly in the diet. Water-soluble vitamins include inositol, niacin, vitamins C, B_1 (thiamin), B_2 (riboflavin), B_3 (pantothenic acid), B_6 (pyridoxine), B_{12}, biotin, choline, folic acid, and para-aminobenzoic acid (PABA).

Vitamins are available to animals in protein supplements, mineral and vitamin supplements, and commercially prepared complete feeds. Feed tags show guaranteed minimum and maximum percentages of calcium, minimum percentage of phosphorus, and minimum and maximum percentages of salt in the feed. Vitamins are usually added to mixed rations or provided free choice.

Fat-Soluble Vitamin Functions, Deficiencies and Sources

Vitamin A
Major functions - Functions include normal maintenance of the eyes and epithelium (membrane) tissue of the respiratory, digestive, urogenital systems, and the skin. Vitamin A is also needed for normal bone growth, body growth and normal tooth development.

Deficiencies - Night blindness (inability to see in dim light) is a symptom of severe vitamin A deficiency. Vitamin A is a part of the visual purple of the eye, which is depleted through the action of light. Visual purple is required for vision in dim light. Animals suffering from night blindness will recover when sufficient amounts of vitamin A are added to the diet. Animals can become permanently blind when vitamin A deficient.

Excessive watering of the eyes and development of cornea ulcerations are also indications of possible vitamin A deficiency. Other indications include nervous incoordination shown by a staggering gait, diarrhea, reduced appetite, poor growth and weight loss. Also, unsound teeth and rough, dry skin may be a sign of vitamin A deficiency. Paralysis of some parts can occur in some species. Young animals suffer from deficiency sooner because of their greater requirements and reduced storage ability.

Reproductive problems include poor conception rates, reduced fertility in males, shortened gestation periods, and increased retained placenta. In poultry, discharges from the eyes and nostrils can occur, as well as wobbly gait in chicks, reduced egg production and hatchability of eggs.

Sources - Vitamin A can be provided as a synthetic vitamin or as carotene. Vitamin A itself is only present in animals, but plants contain the precursor, carotene. Carotene is found in good quality, fresh, green forages in generally sufficient amounts. Excellent sources of carotene are green, leafy hays that have been in storage less than one year; dehydrated, pelleted legume hays; and good quality grass or legume silages. Other carotene sources include yellow corn, fish liver oil, dehydrated alfalfa meal and whole milk.

Storage in the body - Vitamin A is stored in the liver and fatty tissues of the body. The animal can use stored vitamin A when the diet is deficient in carotene.

Ration considerations - Conditions that might indicate a need for vitamin A supplements include (1) poor quality or low levels of forages,

(2) limited amounts of colostrum or whole milk in the diet, (3) diets of corn silage and low-carotene concentrates, (4) grazing during drought periods, and (5) rations made up mainly of cereal grains, except corn.

Additional comments - Vitamin A and carotene are readily destroyed by oxidation, thus resulting in considerable losses in processing and storing (such as in making and storing hay).

Vitamin D
Major functions - Vitamin D is important for calcium absorption and phosphorus metabolism in the body. Rickets is prevented by vitamin D, along with calcium and phosphorus. Vitamin D also promotes sound teeth.

Deficiencies - A shortage of vitamin D will result in rickets in young or osteoporosis in adults with insufficient calcification of the bones. However, less vitamin D is required when a good balance of phosphorus and calcium is present. Symptoms of vitamin D deficiency are decreased appetite, slower growth, digestive disturbances, stiffness in gait, and sometimes the development of tetany and convulsions. As the disease progresses, joints enlarge and become swollen and stiff. Pregnant animals might give birth to dead, weak or deformed young because of vitamin D deficiency. Chickens will show rickets, poor feathering and growth with a reduction of egg production, hatchability and poor eggshells in laying hens.

Sources - Diets that include sun-cured forages generally provide sufficient vitamin D. Animals regularly exposed to sunlight or ultraviolet light will not develop deficiency symptoms. Green forages, barn-cured hay, and silages have some vitamin D. Grain, grain by-products, and protein feeds have almost no vitamin D.

Additional comments - When animals are exposed to direct sunlight, the ultraviolet light in the sunlight penetrates the skin and produces vitamin D from traces of certain cholesterol in the tissues. However, tissue storage of vitamin D is very limited.

Vitamin E
Major functions - Vitamin E functions as an anti-oxidant, which helps in absorption and storage of vitamin A. As an antioxidant, it also acts in other metabolic functions in the cell. Vitamin E is essential for the integrity of red blood cells and in cellular respiration, primarily in heart and skeletal muscle tissues. It is also a regulator in the synthesis of DNA and vitamin C.

Deficiency symptoms - Vitamin E deficiency looks similar to selenium deficiency--white muscle disease or nutritional muscular dystrophy. Hatchability of eggs is reduced, although production does not appear to be affected. Extended vitamin E deficiency in poultry will cause permanent sterility in the male and reproductive failure in the female. The addition of selenium to the diet can prevent some symptoms of vitamin E deficiency.

Sources - Good dietary sources of vitamin E include whole cereal grains, the germ or germ oils of cereal grains, green forages, alfalfa meal, rice polishings, wheat germ meal, and good quality hay. After a long storage period, the vitamin E level in feeds declines. It is rapidly destroyed when near rancid fat. Vitamin E is seldom deficient in the diet unless feeds were produced on selenium-deficient soils. Vitamin E is produced commercially and can be added to the diet when needed by using a vitamin premix or injecting into the muscle.

Additional comments - Vitamin E is widely distributed in all natural feeds. Utilization of vitamin E depends on adequate selenium. There is some storage of vitamin E in the liver and other fatty tissues.

Vitamin K
Major function - Vitamin K is necessary for the formation of prothrombin in the blood, which helps blood clot.

Deficiencies - Vitamin deficiencies K rarely occur because it is synthesized in the rumen and in the intestinal tract of monogastric animals. Feeding moldy feeds with a high dicoumarol content, such as moldy sweet clover, might cause a vitamin K deficiency. This can lead to a bleeding syndrome called sweet clover poisoning or bleeding disease. Moldy feeds with a high dicoumarol

content fed to swine or poultry will also cause internal bleeding and death. Feeding vitamin K or water-soluble synthetic forms of the vitamin will counteract deficiency effects.

Sources - Dietary sources of vitamin K include green, leafy feeds (either fresh or dry); fish meal; liver; and soybeans. Vitamin K is usually widely available in normal farm rations, and is synthesized by all classes of farm animals. However, it is common to add vitamin K to swine diets and chick starter rations.

B Complex Vitamins: Functions, Deficiencies and Sources

Ruminants (cattle, sheep, goats) generally do not need vitamin B complex supplements. Microorganisms in the functioning rumen synthesize many of these vitamins, and feeds used in ruminant nutrition also supply many B complex vitamins.

However, the rumen does not function in young animals, so supplements are recommended if the young animal is not nursing. Mother's milk contains many B vitamins needed by the young.

Biotin
Major functions - Biotin is required in many reactions in the metabolism of carbohydrates, fats and proteins. Biotin serves as a coenzyme for transferring carbon dioxide from one compound to another. It is also a coenzyme for the production of energy.

Deficiencies - Deficiency symptoms include dermatitis, loss of hair, cracks in the feet, slow growth, hind leg spasticity in swine, and reduced hatchability of eggs.

Sources - Feed sources of biotin include most grains (except wheat and barley), soybean meal, green forages, alfalfa meal, synthetic biotin, and black strap molasses. Animals can readily synthesize biotin, and it is generally not deficient in normal rations. Biotin is available in commercial vitamin premixes.

Choline
Major functions - Choline is a structural component of fat and nerve tissue and is required in the diet at levels higher than other vitamins. It

functions as a part of the cell structure, lipid transport, nerve impulse transmission, and fat metabolism in the liver.

Deficiencies - Choline deficiency symptoms include slow growth rate, unthriftiness, fatty livers, poor coordination, reproductive problems, lower milk production, and higher death rate in the young. It can also result in slipped tendons in chickens and turkeys. In swine, an abnormal gait and reproductive failure in adult females may develop. Deficiency symptoms are more visible as the protein content is lowered.

Sources - Good dietary sources of choline include meat scraps, canola meal, fish meal, soybean lecithin, and yeast. Some grains, forages, and dairy byproducts contain lesser amounts of choline. Most farm rations contain enough choline. It is synthesized in the body when there is sufficient protein and other vitamins, especially vitamin B_{12}.

Folic acid
Major functions - Folic acid is a part of the folate coenzymes; it is key to the normal function of body cells and essential amino acid formation. Folic acid is involved in the combining of single carbon units into larger molecules. It is closely related to vitamin B_{12} metabolism, and deficiencies of either one affect the function of the other.

Deficiencies - Shortages of folic acid result in weakness, slow growth, and anemia. Additional signs in young chicks include reduced growth, depigmentation of colored feathers, and poor feathering. In breeding hens, the result is lower egg production and hatchability.

Sources - Green pasture; green, leafy alfalfa hay; soybean meal; wheat germ; and cottonseed meal are good dietary sources of folic acid. Synthetic folacin is readily available when dietary supplements are needed, although for most animals, there is generally enough available through the diet and synthesis in the body.

Thiamine (B₁)
Major functions - Thiamine functions as a coenzyme in energy metabolism and is involved in peripheral nerve functioning. Thiamine helps

maintain a normal appetite, muscle tone and a healthy mental attitude.

Deficiencies - Utilization of thiamin is hindered by high fat diets. Indications of thiamine deficiency are anorexia, slow growth, weakness, increased irritability, lowered body temperatures, slower heartbeat, and enlargement of the heart. In laying hens, egg production is lowered.

Sources - Dietary sources of thiamine include cereal grains; grain byproducts; brans; green, leafy hay; green pastures; and milk. Infection of grains with certain kinds of mold can destroy the thiamine content. Thiamine is unstable when heated; therefore, drying grain or cooking soybeans reduces the amount of available thiamine in these feeds. Except for ruminants like cattle, sheep, and goats, all animals must have a dietary source of thiamine. It is also available in commercial vitamin premixes.

Riboflavin (B$_2$)
Major functions - Riboflavin promotes growth and functions as a constituent of several enzyme systems. It is also important in carbohydrate, fatty acid, and amino acid metabolism.

Deficiencies - Indications of riboflavin deficiency include slow growth in most species; poor reproduction and lower milk production in sows; anemia, diarrhea, vomiting, eye cataracts, stiffness of gait in young pigs; lesions around the mouth and loss of hair in calves; curled-toe paralysis in young chicks; and periodic moon blindness in horses.

Sources - Dietary sources of riboflavin include synthetic riboflavin; milk; green, leafy hay (especially alfalfa); green pastures; and grass silage. Riboflavin is commercially available in vitamin premixes. Ruminant rations may need riboflavin supplements, and swine and poultry rations generally have riboflavin added.

Additional comments - Grains are considered poor sources of riboflavin. Riboflavin is destroyed by light or heat.

Pantothenic acid (B$_3$)
Major functions - Pantothenic acid is a component of coenzyme A, which is important in

energy metabolism and is required by the cells in the biosynthesis of fatty acids.

Deficiencies - In all species, deficiency symptoms include slow growth, loss of hair, and enteritis (inflammation of the intestine). In young pigs, it results in stiff legs, lack of coordination, and poor condition of the hair and skin. Young chicks will have extremely ragged feather development and lesions on the mouth. B$_3$ deficient calves show a rough coat, dermatitis, anorexia, and loss of hair around the eyes. (Mature ruminants synthesize vitamin B$_3$ in the rumen.)

Sources - Good feed sources of pantothenic acid include brewer's yeast, cane molasses, dried milk, alfalfa meal, and whey. Grains are deficient in this vitamin, and deficiencies are most likely to appear when confinement animals eat high grain diets. Mature ruminants synthesize pantothenic acid. However, pantothenic acid is commonly added to commercial swine and poultry rations.

Pyridoxine (B$_6$)
Major functions - Pyridoxine is a component of amino acid coenzymes and essential fatty acid metabolism. It assists in the production of red blood cells and in the endocrine system. Pyridoxine is a coenzyme in protein and nitrogen metabolism.

Deficiencies - Indications of pyridoxine deficiency are anorexia, slow growth, and convulsions in all species; anorexia and poor growth in pigs; abnormal feathering and stunted growth in chicks; and lower egg production, poor hatchability, rapid weight loss, and eventually death in hens.

Sources - Dietary sources of pyridoxine include cereal grains (especially wheat) and grain byproducts; green pastures; and green, leafy hay (especially alfalfa). Livestock rations generally do not need pyridoxine supplements. Pyridoxine is synthesized in the rumen of cattle, sheep, and goats and perhaps in the cecum of the horse.

Vitamin B$_{12}$
Major functions - Vitamin B$_{12}$ is needed for red blood cell maturation and functions as a coenzyme in a variety of metabolic reactions. Cobalt is found in vitamin B$_{12}$ and must be present for

synthesis of the vitamin to occur. This is the only function of cobalt in the animal's body.

Deficiencies - A B_{12} deficiency is shown by slow growth in all species; lack of hind leg coordination in young pigs; reduced litter size and higher pig death rate in breeding swine; and lower egg hatchability in breeding chickens.

Sources - Good dietary sources of vitamin B_{12} include synthetic B_{12}, animal proteins, and fermentation products. Vitamin B_{12} is also available in commercial vitamin premixes. It is apt to be lacking in swine and breeder poultry rations.

Para-aminobenzoic acid
Functions and deficiencies - Para-aminobenzoic acid is essential for the growth of some microorganisms and is an essential part of the folacin molecule. Deficiency symptoms have not been observed in animals.

Sources - Para-aminobenzoic acid is synthesized readily in the intestine tract and is usually not deficient in livestock rations. Dietary sources include lecithin, soybean meal, peanut meal, and synthetic PABA.

Functions, Deficiencies and Sources of Other Water-Soluble Vitamins

Inositol
Functions and deficiencies - In combination with choline, inositol prevents hardening of the arteries and protects the heart. It also helps reduce blood cholesterol. Deficiency symptoms are not demonstrated in animals.

Sources - Inositol is synthesized in the intestinal tract and is generally not deficient in the diet. Dietary sources include synthetic inositol, yeast, and liver meal. Inositol is widely distributed in animal feeds.

Niacin
Major functions - Niacin is an essential part of two coenzymes necessary in cell respiration. It is also necessary for the release of energy from carbohydrates, fats, and proteins.

Deficiencies - General indications of deficiency include poor appetite, slow growth, and unthriftiness. In addition, swine show signs of diarrhea,

vomiting, ulcerated intestines, dermatitis, and loss of hair. Niacin-deficient chicks develop an inflammation of the tongue, mouth cavity, and upper esophagus; reduced feed consumption; and poor feather development.

Sources - Some niacin is available in feeds, with meat and bone meal being good sources and green alfalfa being a fair source. However, niacin in cereal grains is largely unavailable, so swine and poultry need dietary supplements of this vitamin.

Additional comments - Niacin is a dietary essential for pigs, chickens, and humans. It is synthesized in the digestive tract of ruminants; therefore, they do not need dietary niacin under most conditions.

Vitamin C
Major functions - Vitamin C is necessary for the formation of collagen, a gelatin-like protein that is the main constituent of the fibrils of connective tissue and bones. Vitamin C is required for the absorption and movement of iron, and in the metabolism of fats and lipids. It is also related to cholesterol control, sound teeth and bones, strong capillary walls, and healthy blood vessels.

Deficiencies - Vitamin C deficiency symptoms have not been observed in farm animals. Normally, they synthesize sufficient amounts in body tissues to meet their needs; therefore, it is not required as a supplement to their diet. However, if a deficiency does occur, its symptoms include scurvy (swollen, bleeding, and ulcerated gums), loosening of teeth, and weak bones. It has been shown that more vitamin C may be needed in times of stress.

Sources - Good sources of vitamin C include synthetic vitamin C, citrus pulp, well-cured hay, and green pasture. Usually, ordinary rations provide adequate vitamin C.

Summary

Vitamins are organic compounds essential for life but needed only in trace amounts. Sixteen vitamins have been identified as essential in animal nutrition. They are classified by their solubility--either fat-soluble or water-soluble. Fat-soluble vitamins can be stored in the body,

reducing the need for dietary sources. Water-soluble vitamins are not generally stored in the body and must be supplied in the animal's diet. Vitamins play a vital role in various body system functions and are an important part of the animal's overall nutrition.

Credits

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Lesson 7:
Water's Role in Animal Nutrition

Water is a very important component in animal nutrition. An animal cannot use proteins, energy, vitamins, and minerals without water. This also applies to humans. Water makes up 50-75 percent of the weight of the human body. It also helps human digestion, cell growth, chemical reactions, body temperature regulation, and joint lubrication. Lack of water creates kidney failure, fever, increased pulse rate, and flushed skin in the human body. Similar functions apply to livestock, as well.

Functions of Water

In livestock, water has many functions. It serves as a body fluid throughout the animal's body. Body fluids are present at every joint in the skeletal system to aid in joint lubrication. Body fluids also lubricate the eyes so they can rotate within sockets, and body fluids accumulate around nerves to provide a cushion. In the ear, body fluids help conduct sound for hearing.

Water also dilutes toxic substances within the body. Undiluted urea can be very harmful, but watered-down urea is carried it safely through the urinary tract.

Water plays an important role in the circulatory system. It acts like a car radiator by transferring heat from one part of the body to another. Animals do not have sweat glands, so they do not perspire. Water cools bodies through evaporation through the animal's skin.

Animals produce gases as byproducts during respiration and digestion. Carbon dioxide and methane are two forms of gas byproducts. These gases are released when they are mixed with water vapor in the lungs and then exit through respiration. Therefore, water plays a major function during gas exchange in the animal's body.

If an animal has an inadequate water supply, it will soon develop a fever because of dehydration. Water plays an important role in regulating animal body temperature. A lack of water also decreases heat transfer, which aids in body temperature regulation.

How do animals recognize their food? How do humans recognize their food? Humans use sight most of the time, but sight can fool the other senses. Animals distinguish food through their sense of taste. Taste buds are used to evaluate food. Water carries chemicals in food to the taste buds so they can decide if it should be eaten. Palatability is extremely important in feeds, because if the animal's taste buds don't recognize the feed, it will not eat the feed.

Since water makes up 60-75 percent of an animal's body weight, it is obvious that the animal would lack form without water. Water maintains the animal's shape in several different ways. Blood consists mainly of water, and without water, blood would not flow. Living cells consist mainly of water, which are the building blocks in which life exists.

As previously mentioned, water plays an important role in blood by acting as a carrier of nutrients in the bloodstream. Without water, nutrients could not be carried to different parts of the body to be utilized.

The last function of water is the elimination of waste products. Byproducts of digestion are carried in urine, which consists of water. In the previous lesson, it was mentioned that water is absorbed to form fecal material. Some water also remains in fecal material to ease its move through the digestive tract.

Daily Requirements for Water

Factors - There are several factors that determine the daily requirements for water needs in animals. The type of species is an important consideration, since larger species like cattle require more water than sheep. Lactating species require more water than a dry species. Age also influences the daily requirements of water. A younger animal requires more water per pound of body weight because it has higher needs for body water. Younger animals have less bone and muscle mass than older animals.

Environment affects the daily requirements of an animal. When environmental temperatures

increase, the need for water increases to maintain a constant body temperature. The amount of exercise an animal gets affects its daily water requirement. An active animal needs more water than a sluggish animal.

Moisture content of a feed also influences daily water requirements. An animal on a high grain diet will need more water than an animal grazing on a fresh green pasture.

Environmental temperature affects requirements, but so does humidity. The higher the environmental humidity, the greater the water intake. The level and kind of production of the animal (whether they are gestating or producing milk, meat, etc.) also affects daily water requirements.

If the mineral content is increased in the diet, the animal will increase the water intake.

Average daily requirements - Listed below are several average daily requirements needed by different species of livestock.

Beef cattle
    Growing cattle
        100 lbs. = 1.5 gallons
        400 lbs. = 5 gallons
        800 lbs. = 7 gallons
    Mature cattle
        Fattening = 9 gallons
        Lactating = 10-15 gallons
Lactating dairy cattle
    Average production = 12-25 gallons
    Heavy production = 35+ gallons
Growing sheep
    20 lbs. = .5 gallons
    50 lbs. = .4 gallons
    150-200 lbs. = 1+ gallons
Swine
    Growing swine
        50 lbs. = 1+ gallons
        100 lbs. = 1.5+ gallons
    Mature swine
        Pregnant = 5+ gallons
        Lactating = 6+ gallons

Sources of water - There are several sources of water that an animal can use. Drinking water is the first source. It must be fresh, clean, and provided at all times for the animal's use. Water provided by feeds is the second source. Each feed provides a different moisture content. Fresh green pastures have an 80 percent moisture content. Green cut forages, such as silage, have a 65-75 percent moisture content. Dry harvested forages, such as hay, have a 15 percent moisture content. Harvested grains, such as corn, have only 10-15 percent moisture content.

The last source is water produced by body metabolism. This source should not be figured in a ration, because it supplies an insignificant percentage of water. Water can be produced when fats, proteins, and carbohydrates are digested and metabolized.

Water Toxicity

What is water toxicity and how does it occur? Water toxicity is water dehydration accompanied by concentration of sodium and other ions in the brain cells that cause cerebral edema. Water toxicity occurs in animals that have been without water for a long time and suddenly have access to fresh water. The animal basically overdoses itself on water by drinking too much. Dehydrated body tissues can't handle the sudden overdose of water.

Water toxicity occurs more commonly in younger animals. As mentioned earlier, younger animals have a higher water content in their bodies because they lack muscle and bone mass. Younger animals will try to drink 35-50 percent of their body weight within a half hour period.

There are several symptoms that define water toxicity. They are hemoglobinuria (red urine), diarrhea, irregular heartbeat, body hair standing on end, excessive salivation, extended head and neck, nervous signs, and finally coma and death. Fluids usually collect in soft tissues under the skin and is most apparent as swollen and puffy eyelids.

The most noticeable symptom of water toxicity is the extension of the head and neck. This symptom is similar to a young calf sucking on its mother, with the neck extended and head laid back.

The animal also shows some nervous signs. It might have an unstable walk and appear

disoriented. The animal might also excessively rub and lick its body.

If water toxicity is detected soon enough, treatment can be effective. Saline or hypertonic glucose can be given intravenously to remove excess water from body tissues. The animals can drink salt water to pull excess water from body tissues, but this must occur before animal drinks the initial overdose of water.

Water toxicity is a slow process, so there is time to correct its effects. It takes 4-6 hours for water toxicity to kill an animal. It is always smart to observe animals that haven't had fresh water for a long time for water toxicity symptoms. Observation is a good management practice when an animal breaks from its normal routine.

Effects of Inadequate Water Supply

An inadequate water supply means a lack of water, not an absence of water. Several things occur when animals have a low water intake or the water is not fresh. A lack of appetite signals an inadequate water supply. The less water an animal drinks, the less feed it eats. Remember, water plays an important role in digestion. Since a lack of appetite occurs, weight loss is also a sign of inadequate water supply. When an animal is losing weight, its performance and production are reduced considerably.

A lack of water causes the blood to thicken in the animal because water composes the highest percentage of blood. Inadequate water supply can be fatal because it leads to dehydration and water toxicity.

Good management practices also include knowing normal body functions that can influence water intake. If the animal develops scours or diarrhea, the water requirement increases because of the digestive disturbance. Respiration is a normal body function that affects an animal's water intake. During respiration, moist air is exhaled. Respiratory problems could occur if inadequate water supply is not provided. Regulating body temperature is another normal body function. In the animal's body, heat is transferred by the release of moist air through the skin. When the environmental temperature and humidity increase, so will the water intake of the animal.

Summary

Understanding the roles of nutrients is vital for the management of livestock. A deficiency in one or more nutrients can cause severe losses in the production of livestock. Water is critical in maintaining all animal body functions; understanding this concept will lead to success as a livestock producer.

Credits

Livestock Nutrition and Feeding (Student Manual). 2nd ed. Columbus, OH: Ohio Agricultural Education Curriculum Materials Service, 1991.

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Lesson 8:
Environmental Effects on Nutrition

Environment simply means everything surrounding an animal--weather, shelter, other animals, nutrition, etc. These surroundings can and do affect growth, development, and production in all animals.

An Animal's Environment

Environmental control includes nutrition, space requirements, light, air temperature and velocity (wind), relative humidity, wet bedding, dust, ammonia buildup, odors, and manure disposal. Enhancing these factors can enhance animal performance.

Factors with the most impact on an animal's nutritional needs are nutrition, weather and facilities/shelter, health, and stress.

Weather's Effects on Nutrition Requirements

Webster's dictionary defines weather as a "state of the atmosphere with respect to heat or cold, wetness or dryness, calm or storm, clearness and cloudiness."

Animals have a thermo-neutral (comfort) zone (C to F in Figure 8.1). This is the range within which the animal can perform with little discomfort by using physical regulation (such as shivering or seeking shade). Extreme weather can cause wide fluctuations in animal performance.

An animal's requirements increase as temperature, humidity, and air movement (wind) exceed or fall short of the animal's comfort zone. These three factors also influence an animal's heat loss. Animals adapt to weather in the following ways.

Cold weather - In cold weather, heating mechanisms used include (1) increased insulation from growth of hair and more fat, (2) increase in thyroid activity, (3) seeking protective shelter and warming sunshine, (4) huddling together, (5) consumption of more feed, which increases the heat increment and warms the

TABLE 8.1 - Comfort Zones of Animals

Class of animal	Temperature		Acceptable humidity (%)
	Comfort zone (°F)	Optim. (°F)	
Cattle Beef cow	40-70	50-60	50-75
Steer, enclosed building	40-70	50-60	50-75
Dairy cow	40-70	50-60	50-75
Dairy calves	50-75	65	---
Sheep Ewe	45-75	55	50-75
Feeder lamb	40-70	50-60	50-75
Newborn lamb	75-90	---	---
Swine Sow, farrowing house	60-70	65	60-85
Newborn pigs	80-90	85	60-85
Feeder/finishing	60-65	60	60-85
Horses Horse	45-75	55	50-75
Newborn foal	75-80	---	---
Poultry Layers	50-75	55-70	50-75
Broilers	85-95	70	50-75
Turkeys	95-100	---	---

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

animal, and (6) increasing activity. The most important heating mechanisms are body activity and amount of feed consumed.

Hot weather - In hot weather, cooling mechanisms include (1) moisture vaporization (from the skin and lungs), (2) avoidance of the sunshine (seeking shade), (3) depression of thyroid activity, and (4) loafing (including lessening the production of meat, milk, and eggs, since they increase heat production).

The diagram in Figure 8.1 shows (1) influence of thermal zones and temperature on warm-blooded animals, and (2) the peak of milk yields in the spring, followed by the summer slump due to the high temperatures and lower-quality forages.

Heat production (metabolism) is plotted against ambient temperature to depict the relationship between chemical and physical heat regulation. Terms pertaining to Figure 8.1 follow.

Optimum temperature - This is the most comfortable temperature for the animal, and the greatest amount of energy can be used for production and feed efficiency (D to E in Figure 8.1).

Lower critical temperature - The low point of the cold temperature beyond which the animal cannot maintain normal body temperature. In the zone below C, chemical temperature regulation is utilized (such as using fat deposits or increased respiration). When the environmental temperature reaches below point B, the chemical-regula-

tion mechanism is no longer able to cope with cold. The body temperature then drops, followed by death.

Upper critical temperature - This temperature is the high point on the range of the comfort zone, beyond which animals are heat stressed and physical regulation cools them (F).

The cow produces the maximum yield of milk during the spring when the temperature is optimum (D to E) and the minimum yield in the summer when it is hot (F to G).

Comfort zone, optimum temperature, and both upper and lower critical temperatures vary. Factors include different species, breeds, ages, body sizes, physiological and production status,

FIGURE 8.1 - Thermo-Neutral Zone (Comfort Zone)
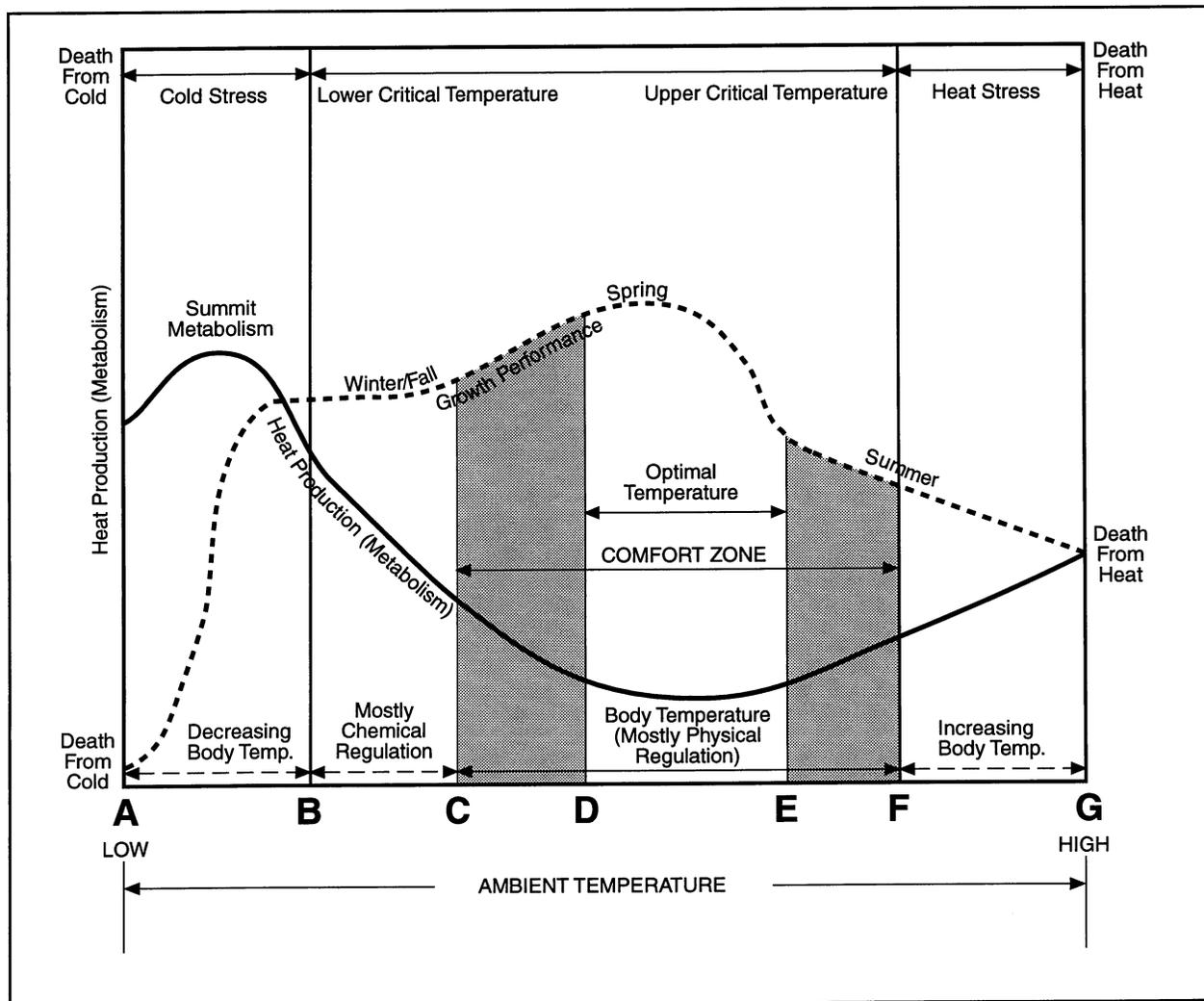
adaptations, climate, feed consumed (kind and amount), the activity of the animal, and the opportunity for evaporative cooling.

Animals that consume large quantities of roughage or high-protein feeds produce more heat during digestion; hence, they have a different critical temperature than the same animals fed a high-concentrate, moderate-protein ration. During hot summer months, experienced cattle feeders decrease the roughage and increase the concentrate of finishing cattle.

High humidity increases both high and low temperature stresses. There is less of a cooling effect from evaporating moisture and respired air. As humidity increases, discomfort and nutrient utilization decrease proportionately.

Air movement (wind) results in body heat being removed at a more rapid rate than when there is no wind. In warm weather, air movement can make the animal more comfortable, but in cold weather it adds to the stress temperature. (See Table 8.2.) At low temperatures, the nutrients required to maintain the body temperature are increased as the wind velocity (wind chill) increases.

Rain reduces feed intake by 10-30 percent. Mud reduces feed intake by 5-30 percent, depending upon its depth and the amount of bedded area.

There are several ways in which animals cope with inclement weather. These include adaptation, environmentally controlled buildings, and increased/decreased nutrient needs. Adaptation is shown by Brahman cattle being more heat tolerant and British breeds, such as Herefords, being more cold tolerant.

Other Factors Affecting Nutritional Needs

Gestation - Nutrient requirements for pregnant females are most critical during the last third of the gestation period (trimester), when the developing fetus grows most. Especially critical are nutrient requirements for young females during the first pregnancy. Poor nutrition at this stage will result in a poorly developed fetus and poor growth of the mother.

Lactation - Producing milk requires a liberal supply of energy, protein, minerals, and vitamins in the ration. After giving birth, feed requirements increase tremendously because of milk production. A female suckling young needs approximately 50 percent greater feed allowance than during the pregnancy period.

Stress - Stress is any environmental factor that is counter-productive to an animal's well-being, either external or internal. Animals under stress demand the very best nutrition.

Many kinds of management-related stress affect animal production: excitement, the presence of strangers, changing animals that are together, crowding, disease, hauling, how animals are handled, and weaning.

The right kind of animal handling can reduce stress. Preconditioning reduces the amount of stress present at weaning. It involves starting

TABLE 8.2 - Wind-Chill Factors for Cattle with a Winter Coat

Wind speed (mph)	Temperature (°F)										
	-10	-5	0	5	10	15	20	25	30	35	40
5	-16	-11	-6	-1	3	8	13	18	23	28	33
10	-21	-16	-11	-6	-1	3	8	13	18	23	28
15	-25	-20	-15	-10	-5	0	4	9	14	19	24
20	-30	-25	-20	-15	-10	-5	0	4	9	14	19
25	-37	-32	-27	-22	-17	-12	-7	-2	2	7	12
30	-46	-41	-36	-31	-26	-21	-16	-11	-6	-1	3
35	-60	-55	-50	-45	-40	-35	-30	-25	-20	-15	-10
40	-78	-73	-68	-63	-58	-53	-48	-43	-38	-33	-28

Credit: Taylor, Robert E. *Beef Production and Management Decisions.* 2nd ed. New York: MacMillan Publishing Co., 1994, p. 333. Reprinted by permission of Prentice Hall, Upper Saddle River, N.J.

young animals on feed and vaccinating them before weaning. Proper handling during vaccinations, movement, and hauling can greatly reduce stress and its results.

Health - Health is the state of complete well-being--not merely the absence of disease. It is estimated that animal diseases and parasites in the U.S. decrease animal productivity by 15-20 percent. Nutrition could be involved in 85 percent of veterinary-treated cases.

Muddy lots - Muddy lots often plague livestock producers, especially during the winter months. Mud increases scours and other diseases in newborn animals and reduces production and feed efficiency in older animals. California Agricultural Experiment Station studies show that mud can reduce finishing cattle gains and increase the feed required per pound of gain by 10-35 percent.

It is important to minimize this problem by picking a location for the feedlot that allows for proper drainage. Mounds that are 6-12 feet high provide finishing cattle a dry place on which to lie. Also, lessening the number of cattle in the feedlot during the muddy periods is an effective method of controlling the mud problem.

Temperature's Effect on Feed Requirements and Production Yields

Dairy cattle - The optimum temperature for the production of milk is 55-64°F. Temperatures below optimum result in a reduced water intake and approximately 35 percent increase in feed intake (down to -4°F). There is a corresponding reduction in milk production. This decrease can be corrected by increasing the proportion of concentrate in the diet (20 percent roughage/80 percent concentrate) and providing shelter. Higher concentrate levels help maintain milk yield without excessive loss of body weight.

Temperatures above the optimum result in an increase in water intake, a decrease in feed intake at 77-81°F, with greater decrease above 85°F. There is a decrease in dry-matter intake and a corresponding decrease in milk yield. At 95°F, milk yield might drop as much as 33 percent. Using confined housing for lactating

dairy cows will help reduce the impact of weather extremes.

Beef cattle - The temperature range of 59-77°F is best for beef production. Variations from this range change feed intake as follows:

1. 77-95°F: depressed feed intake 3-10 percent
2. 41-59°F: increased feed intake 2-5 percent
3. 23-41°F: increased feed intake 3-8 percent
4. 5-25°F: increased feed intake 5-10 percent
5. Below 5°F: increased feed intake 8-25 percent

During cold weather, increase the amount of roughage for cattle on a restricted feed intake. However, with cattle on full feed, increasing the amount of roughage during cold weather can *decrease* the amount of energy available, thus reducing productivity.

Sheep - There is little experimental data available for sheep that describes the interaction of temperature and feed intake. Sheep can tolerate colder climatic extremes than other animals. Fleece length and the feeding level affect feed intake as temperatures change. Sheep need higher energy intake during cold stress. This can be economically met by increasing the roughage in the ration. During hot weather, decrease the roughage to lower the amount of heat produced by digesting the feed.

Swine - A temperature range of 64-70°F is considered optimum for growing/finishing swine. For each 1.8°F of temperature drop, the feed requirement increases 1-1.4 oz. daily. Heavier hogs are more sensitive to hot weather than lightweight hogs.

Poultry - Laying hens can adjust to a fairly wide range of temperatures. When temperature change occurs, feed intake will change temporarily and then return to approximately the level before the temperature change. Adequate drinking water is more critical for poultry growth or productivity. Compared to water intake at 70°F, water intake is doubled at 90°F and is 2.5 times greater at 98°F.

Summary

Livestock nutrient requirement tables are generally based on the assumption that no environmental stress is present. Feed and nutritional requirements need adjusting for changes in the animal's environment. Efficiency of nutrient use is affected by the weather and facilities, stress, and health.

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Lesson 9:
Formulating and Balancing Rations

An animal must receive the proper amounts of nutrients in the right proportion to efficiently produce meat, milk, eggs, wool, work, etc.

General Principles in Formulating Rations

A ration is balanced when it provides the nutrient needs of the animal in the proper proportions. Balanced rations have nutrient allowances that are only 1-3 percent below the animal's requirement. Nutrient requirements are listed in tables usually available from the National Research Council. Diets must include a minimum level of dry matter for proper digestive tract functioning. Diets are commonly balanced to meet the protein, energy, calcium, phosphorus, and vitamin A requirements for the animal. Also, the cost of the nutrients should be considered when formulating a ration.

Protein - The amount of protein in the diet can be measured by crude protein (CP) or digestible protein (DP) content. For nonruminants, include essential amino acids in the ration. It is acceptable to have the protein content of the formulated diet as much as 5-10 percent above the nutrient requirements listed in the tables. However, remember that protein is an expensive part of the diet; using excessive amounts will substantially raise the cost of the ration.

Crude protein refers to all of the nitrogenous compounds in a feed. It is determined by finding the nitrogen content and multiplying the result by 6.25. The nitrogen content of protein averages about 16 percent. Not all crude protein is digestible.

Digestible protein refers to a ration's approximate amount of protein available for use by the animal. Digestible protein is the difference between the feed's protein content and what is found in feces. About 60 percent of a roughage ration and 75-85 percent of a high-concentrate ration is digestible.

Energy - Four measures of energy commonly used when formulating diets are digestible energy

(DE), total digestible nutrients (TDN), metabolizing energy (ME), and net energy (NE). The energy provided in the diet should not be more than about five percent above requirements because animals are limited in the total amount of energy they can use.

Digestible energy is equal to the gross energy of the feed consumed minus the gross energy excreted in the feces.

Total digestible nutrients include the totals of the digestible protein, digestible nitrogen-free extract, digestible crude fiber, and 2.25 times the digestible fat.

Metabolizing energy is the gross energy of the feed consumed minus the energy in the feces, urine, and gaseous products of digestion.

Net energy includes the metabolizable energy minus the heat increment (heat used for digestion or metabolism). It is the energy used for growth, maintenance, production, work, fetal development, and heat production.

Minerals - Calcium and phosphorus are the two minerals generally needed in larger amounts. The ratio of calcium to phosphorus (between 1:1 and 2:1) is just as important as the total amount being fed. Other mineral needs of the animal are generally not considered when balancing rations. There are usually enough minerals provided in the ingredients used or by the addition of trace-mineralized salt.

Vitamins - A vitamin supplement is usually added to the ration to meet the animal's vitamin needs. However, vitamin A requirements might be considered in balancing rations. When low-quality legume hay is included in the diets of pregnant cattle or sheep, a vitamin deficiency can occur. Always add a vitamin supplement to a gestation ration.

Cost of nutrients - The cost per pound of each nutrient must be considered when developing least-cost rations for maximum efficiency. Energy and protein nutrients are the major ones considered when making nutrient cost comparisons.

Steps in Balancing a Ration

Step 1 - Identify the kind, age, weight, and function of the animal(s).

Step 2 - Consult a table of nutrient requirements to determine the nutrient needs of the animal(s). These requirements are called feeding standards. Feeding standards are based on average requirements and might not meet the needs under specific feeding conditions.

Step 3 - Choose the feeds to be used in the ration and consult a feed composition table to determine the nutrient content of the selected feeds.

Step 4 - Calculate the amounts of each feed to use in the ration. Several methods are available. The Pearson Square or algebraic equation methods can be used to balance a ration using two or more feeds. (See Figure 9.1.) Computer programs can also help balance rations.

Step 5 - Check the ration formulated against the needs of the animal(s). Be sure it meets the requirements for minerals and vitamins. Check the cost of the nutrients in the ration to determine if this is the most economical ration that is practical to feed.

Eight Essentials of a Balanced Ration

A good ration includes certain basics:

1. Nutrients in the ration should be balanced. Faster gains, less expense, and more profits are the benefits of feeding balanced rations.

2. The ration should contain a variety of feeds. This variety generally increases the palatability of the ration and make it easier to balance the nutrients.
3. The ration should be fresh and appealing. Livestock consume more of a fresh ration, thus increasing productivity.
4. A palatable (good tasting) ration is more readily consumed, adding to the producer's gains.
5. Bulk in the ration is usually more desirable. Feeds such as ground oats, beet pulp, etc., add bulk.
6. A ration should be slightly laxative because a laxative ration usually improves efficiency.
7. The ration should be economical.
8. Since digestive systems of animals are different among species, the ration should be suited to the animal. Cattle and sheep can consume large quantities of roughage, while poultry and swine rations must consist largely of concentrates.

Summary

There are basic nutritional needs for different classes of livestock. For growth to occur, every one of the five nutrients (protein, energy, minerals, vitamins, and water) must be present in sufficient quantity.

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FIGURE 9.1 - Pearson Square Computation

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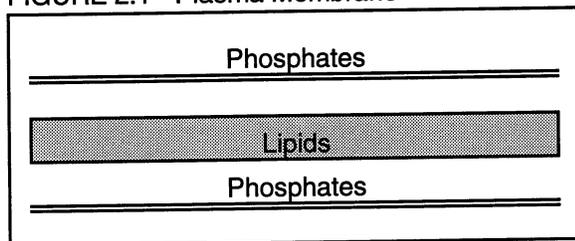
The spherical organelle that is located near the center of the cell is the cell nucleus. It controls the production of proteins in the cell. The nucleus also holds important information about the cell in DNA. The parts of the cell nucleus include the nuclear membrane, chromatin, chromosomes, and nucleolus.

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

Golgi Bodies
Vacuoles
Lysosomes
Centrioles*
Ribosomes
Rough Endoplasmic Reticulum
Mitochondria
Nucleolus
Cell Nucleus
Ribosomes
Plasma Membrane

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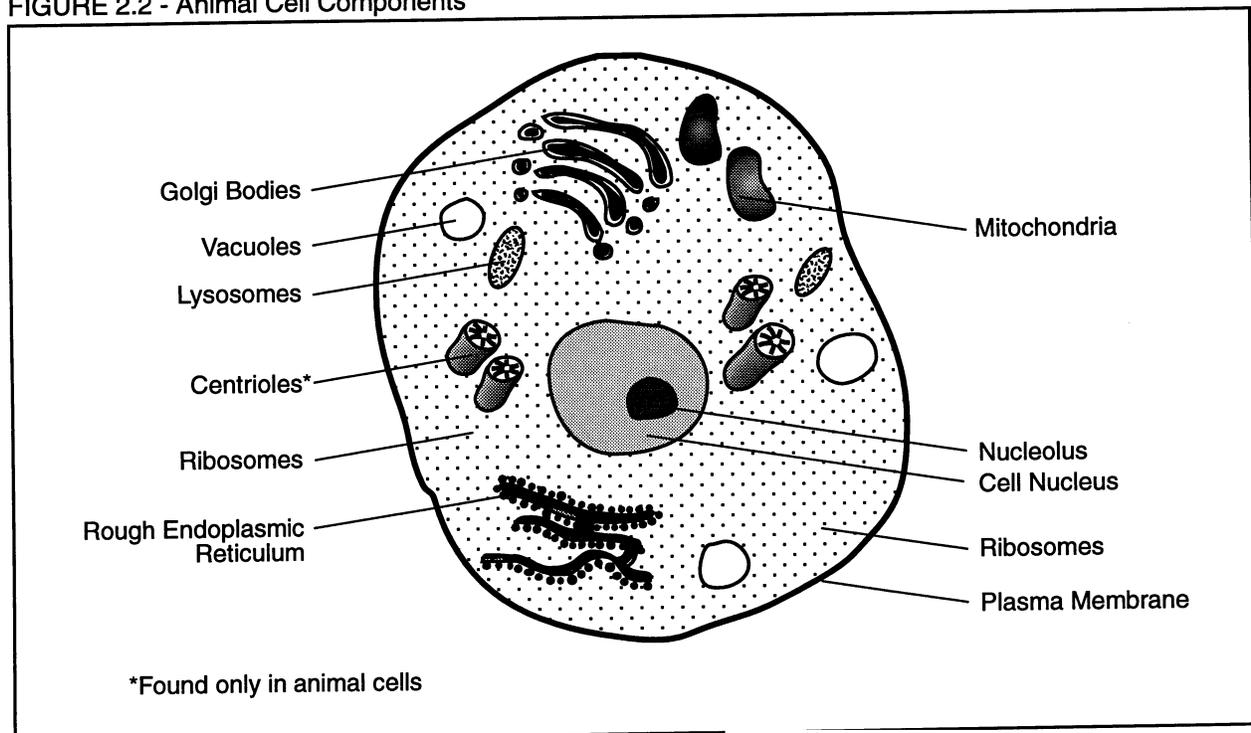
wall does not determine what enters or exits the cell, but adds strength to the cell. Even when the plant cell dies, the cell wall remains (for example, as bark on trees).

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 (deoxyribo-nucleic acid) 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.

* Adenine
* Guanine
* Thymine
* Cytosine
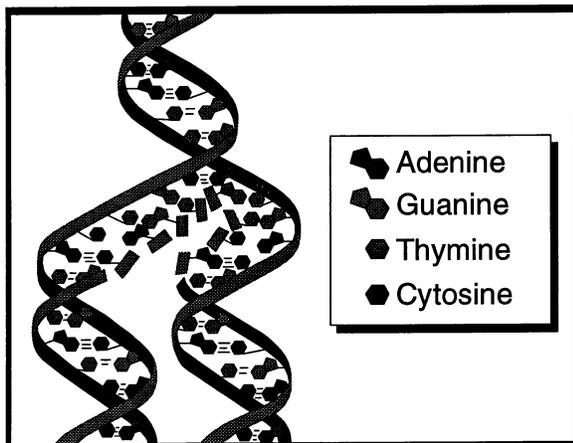
TABLE 2.1 - DNA strand	TABLE 2.2 - RNA strand
S ------ GC ------ S P P S ------ CG ------ S P P S ------ AT ------ S P P S ------ TA ------ S P P S ------ GC ------ S P P S ------ CG ------ S P P S ------ AT ------ S P P S ------ TA ------ S	R--G P R--A P R--U P R--C P R--G P R--A P R--U P R--C
P-Phosphate S-Deoxyribose sugar Nitrogen bases: A-Adenine T-Thymine G-Guanine C-Cytosine	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) Histidine (GTA, GTG) Isoleucine (TAA, TAG, TAT) Leucine (AAT, AAC, GAA, GAG, GAT, GAC) Lysine (TTT, TTC) Methionine (TAC) Phenylalanine (AAA, AAG) Threonine (TGA, TGG, TGT, TGC) Tryptophan (ACC) Valine (CAA, CAG, CAT)	Alanine (CGA, CGG, CGT, CGC) Asparagine (TTA, TTG) Aspartic acid (CTA, CTG) Cysteine (ACA, ACG) Glutamic acid (CTT, CTC) Glutamine (GTT, GTC) Glycine (CCA, CCG, CCT, CCC) Proline (GGA, GGG, GGT, GGC) Serine (AGA, AGG, AGT, AGC, TCA, TCG) 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.

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.

Prophase - 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.

Metaphase - 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*

INTERPHASE

EARLY PROPHASE

TELOPHASE

LATE PROPHASE

ANAPHASE

METAPHASE

Cell Division by Meiosis
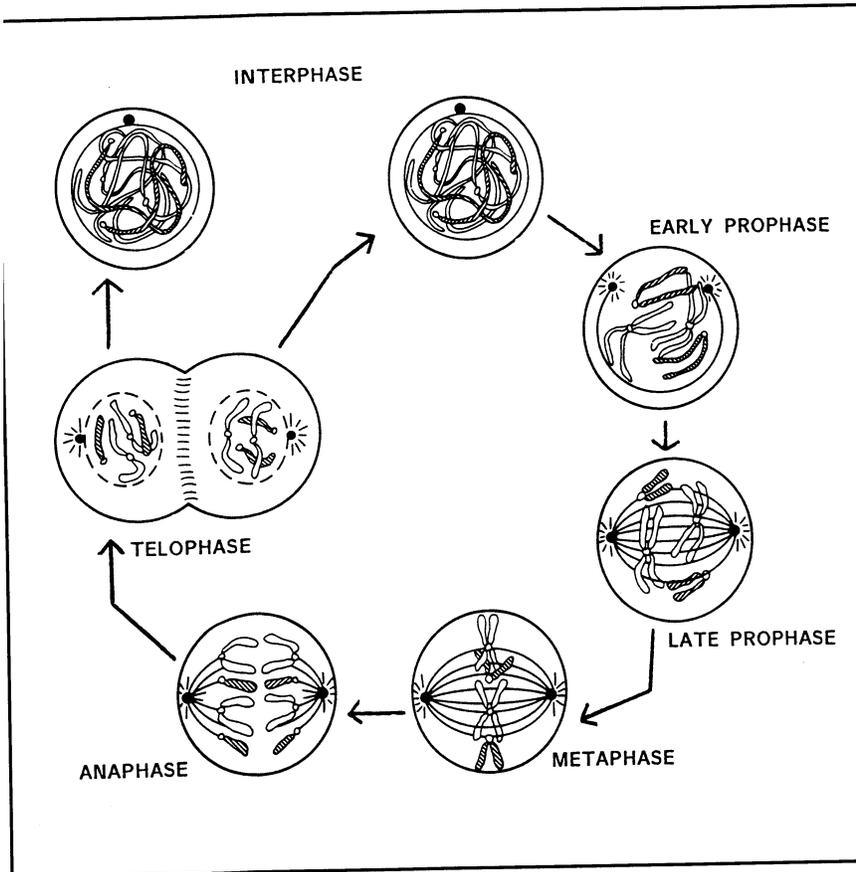
Inheritance is determined by meiosis and in fertilization. In meiosis, the chromosome number of gametes or sex cells is reduced by one-half from the diploid (2n) number to the haploid (1n) number. When the egg and sperm unite in fertilization, the diploid number of chromosomes are restored to normal. 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).

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.

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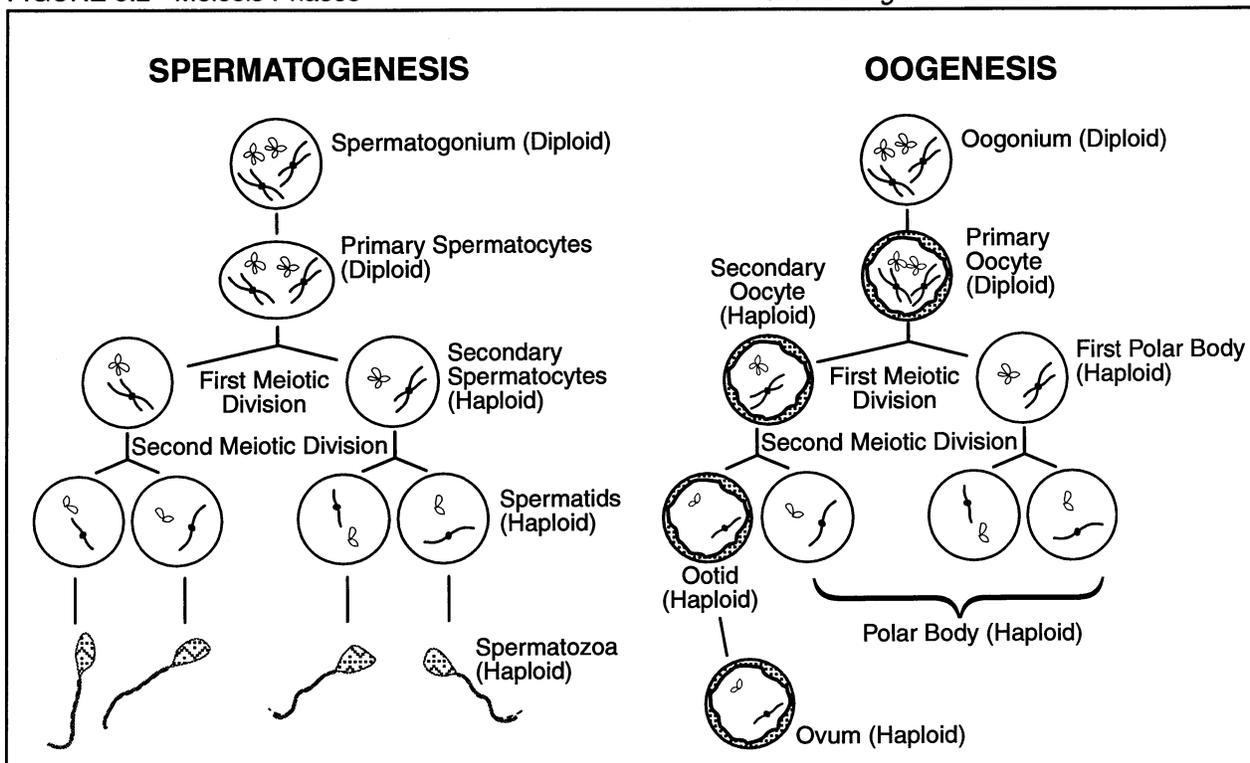
cytoplasm divides again. The end product results in four individual sex cells that contain a haploid number of genetic material in each. The process is more simply described in consecutive steps:

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

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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.
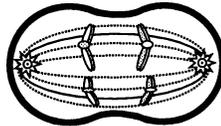
5. Two cells result. Each contains half the number chromosomes that were in the original cell. The chromosomes are still in the form of chromatids.
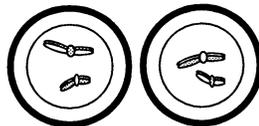
MITOSIS

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.
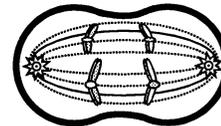
5. Two cells result. Each contains the same number of chromosomes as in the original cell. Each chromosome is now a single unit.
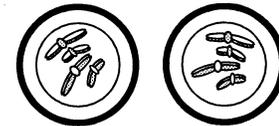
MEIOSIS (Second Division)

6. Chromosomes line up on a spindle again. Each contains two chromatids.
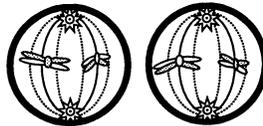
7. This time the chromatids separate from each other and pull apart. The cells divide.
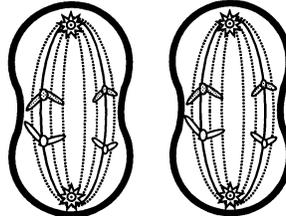
8. Four cells result. Each contains half the number of the chromosomes in the original cell. Each chromosome now consists of a single unit.
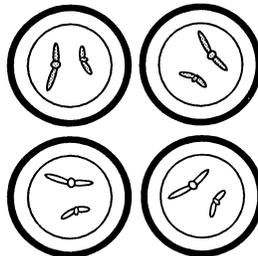
Lesson 4:
Basic Principles of Genetics

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

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.
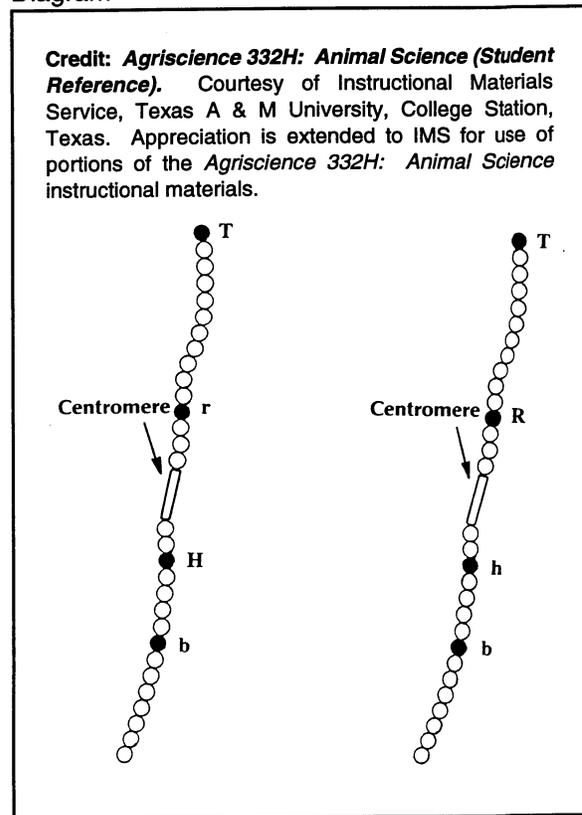
traits might be affected by many pairs of genes.

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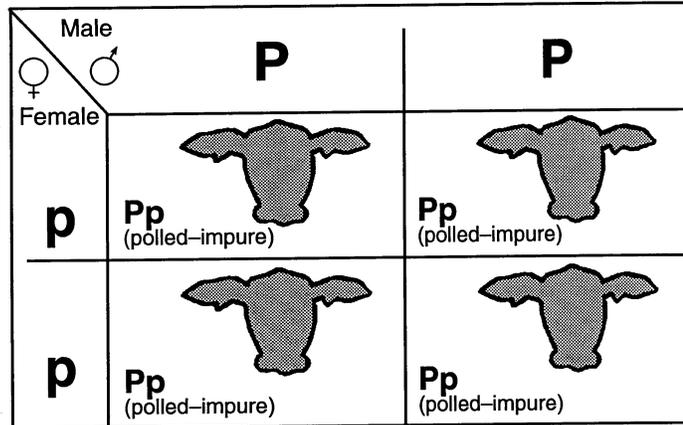
individual produced from the cross will not carry a gene for the polled trait, although both parents were polled. This cross is shown in Figure 4.3.

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*
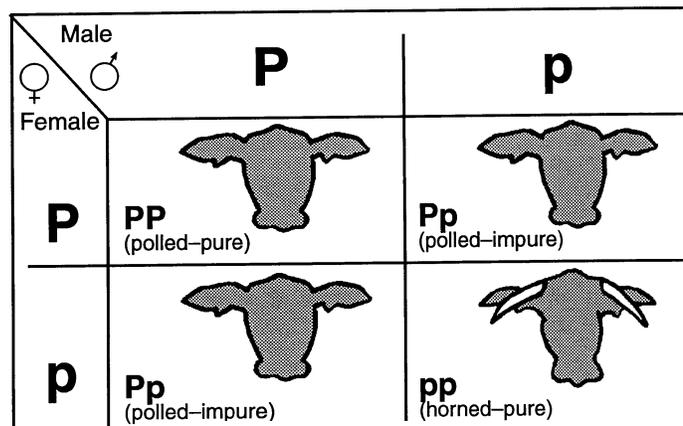
FIGURE 4.4 - Two Pairs of Heterozygous Genes, Each Affecting a Different Trait

Credit: *Agriscience 332H: Animal Science*

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*

Male ♂ / Female ♀	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

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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.

Four bases of selection in beef cattle - 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.
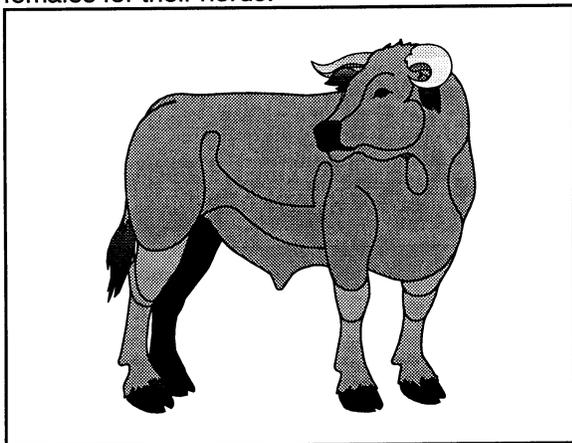
Crossbreeding and Hybrid Vigor

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
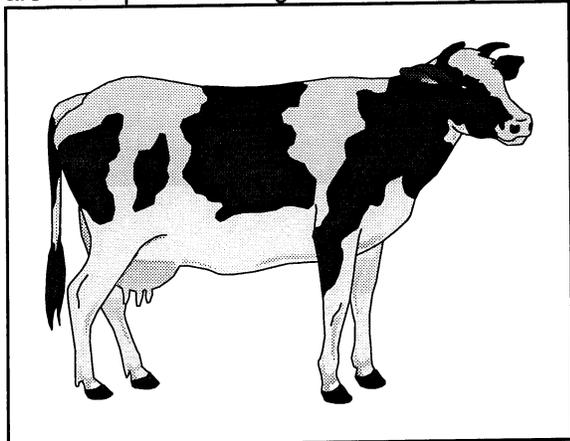
also be straight and square under the cow when viewed from the side. A front view should show legs that are wide apart, allowing for good width to the chest.

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.

Production records - 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

FIGURE 6.1 - Sample Dairy Cow Pedigree

example pedigree in Figure 6.1)

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

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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.
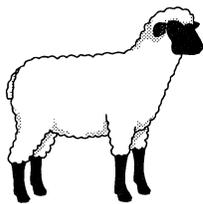
With the presence of fleece, the selection based on type and individuality becomes difficult. Selection should not be based on observation only. Production records are very important when selecting stock for the flock. The "touch method" helps eliminate fleece-covering problems. The touch method helps 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.
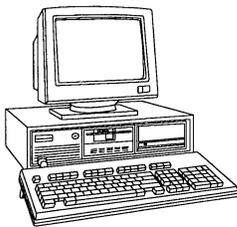
Input needed for NSIP - First, there must be data collected on the ewes in the flock for each year, such as: the number of lambs born, the number of lambs reared, weights at birth, and weights at various days (30, 60, 90, 120, 240, or 365), gains between designated ages, ram days to lambing, fleece weight (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.

Performance testing - 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 perfor-

mance, 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.
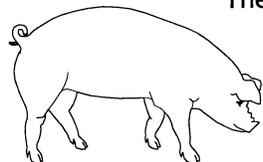
Independent culling levels and selection indexes - In most selection programs, two or more traits must be considered simultaneously when making selection decisions. Two successful methods of simultaneously selecting for more than one trait are *independent culling levels* and *selection indexes.* Independent 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.
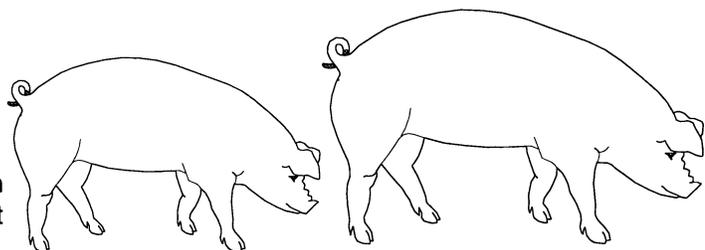
Susceptibility to these conditions can result from the combination of several genes, particularly when aggravated by infection or excessive pressure. None of these conditions, however, result from a single gene, as does PSS.

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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Lesson 1:
Importance of Reproduction in Livestock

How does livestock reproduction affect the average consumer? For producers to receive the optimum price for their products, they must improve the herd's quality through reproduction and genetics. This improvement influences the quality of products available in the store. In turn, consumers influence livestock quality through their buying power.

Careers Associated With Livestock Reproduction

There are many careers associated with livestock reproduction. Most of these occupations require an intense educational background with a strong science emphasis. This usually requires a baccalaureate college degree from a four-year institution, and some require additional educational experience.

Some of the careers associated with livestock reproduction are: veterinarian, breed association representative, breeding services technician, livestock scientist, Extension livestock specialist, sales representative, and livestock producer.

A veterinarian deals with a wide spectrum of livestock reproduction activities. Some of these activities are: AI programs, semen collecting, pregnancy testing, embryo transfer, cloning, and assisting with the birth process. Becoming a vet usually requires eight years of postsecondary education, in which the last four years are completed at specific institutions.

An occupation in a breed association is concerned with improving that particular breed through genetics. Breed associations compete with other associations to promote the superiority of their breed. This occupation usually requires four years of postsecondary education.

Breeding service companies, such as ABS, provide semen access and drugs associated with livestock reproduction. The educational requirement of breeding services is four years of postsecondary education.

Livestock scientists provide the latest research on livestock reproduction, such as genetic engineering, cloning, and embryo transfer. The educational requirement for this occupation is 7-8 years of postsecondary education.

An Extension livestock specialist provides information to the livestock producer on new and old methods and techniques in livestock reproduction. Extension specialists are available resources to any livestock producer in the U.S. The educational requirement for an Extension livestock specialist is usually at least four years of postsecondary education.

The main emphasis of a livestock producer is to produce quality livestock for his/her living. A livestock producer must have a strong experience background with livestock reproduction. Experience is more valuable than an educational background; however, gaining an educational background is becoming more and more valuable with all the new information bombarding the livestock industry.

A sales representative for livestock breeding products provides products used in purebred and commercial breeding programs. The educational requirement is usually four years of postsecondary education.

Economic Factors Associated With Reproduction

There many economically important reproductive traits that are influenced by inheritance. These traits determine profit or loss in a livestock operation.

Beef cattle - With beef, the first trait is calving interval. Cows which do not produce yearly calves are too costly to keep. Birth weight is an economic trait that is associated with calf survival rate. Low birth weight decreases the survival rate in calves.

Weaning weights are a good indication of milking ability and mothering ability. Gains before weaning are cheaper than after weaning, which result in increased profits for the producer. Maternal ability is important for calf survival and weaning weights.

Daily rate of gain becomes increasingly important in getting animals to market weight in a shorter period of time. Daily rate of gain is also highly correlated to efficiency gain. Pasture gain becomes extremely important when animals are raised on pastures, in backgrounding, and with cows on pasture.

Another economic trait influenced by livestock reproduction is efficiency of gain, which is the conversion of feed into muscling and rate of gain. More money can be made on animals that reach final feedlot weight at a faster rate. This weight is also influenced by birth weight, weaning weight, and rate of gain.

Conformation score is significant in relation to animal longevity (life span) and appearance. Finally, carcass traits measure the final product of the producer's efforts. Carcass traits are measured by the quality and quantity of the edible final product. More profit comes from a larger, quality carcass. Beef producers instill a breeding system that builds on these economic traits to improve their entire herd genetically.
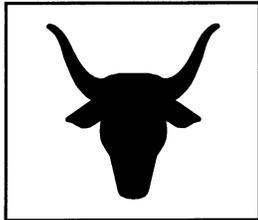
Dairy cattle - In dairy, milk production is the essence of a dairy operation. The more milk that is produced, the more income received by the producer. Percent fat is considered icing on the cake; the higher the percentage of butterfat, the higher the price paid for a pound of milk. Percentage of protein in milk also increases the price paid for milk.

Soluble nitrogen-free extracts help animals take advantage of more nutrients in feed and convert nutrients into usable products. Feedlot gain is not as important in dairy cattle as it is in beef cattle, but it is vital for dairy steers on a feedlot.

Like beef cattle, stature becomes important to the longevity of animals. Stature is important in dairy cattle because of the length of time spent on hard surfaces such as concrete.

Legs and feet are strongly related to the animal's stature and are also influenced by reproduction.

Correct legs and feet will influence the animal's production span.

To continue to produce milk, a dairy animal must have strong udder support. A strong udder will increase the longevity of the animal to continue to produce milk.

When considering economic traits, milking speed becomes important in a dairy operation. The quicker a cow milks, the quicker the milking procedure is completed, and the producer can move on to other projects.

Like other classes of livestock, birth weight is associated with survival rate and calving ease. Temperament becomes very important, especially in dairy cattle. An animal that becomes excited every time it enters the milking parlor will become extremely hard to milk and will be replaced soon.

As in any class of livestock, fertility is important. The longer it takes a female to become fertile, the longer it takes for that animal to come into her milking cycle; this is very costly for the producer. All dairy producers instill a breeding system that builds on these economic traits to improve their entire herd genetically.

Sheep - In sheep, multiple births are the first economic trait influenced by reproduction. Additional lambs produced by a single ewe will increase the amount of money that can be made by the producer. Like other classes of livestock, larger birth weights generally mean more vigorous lambs that have higher rates of gain.

Again, weaning weights reflect maternal ability and a cheaper rate of gain at weaning time. Rate of gain generally reflects milking ability of the mother and faster growth rate, which means more money in the pocket.

Type score in sheep determines market value and the ability to thrive under certain environmental conditions. Finish or condition at weaning is very important to the feeder lamb producer. The better the condition and finish at weaning weight, the better the price paid at market.

Wrinkles and skin folds become an economic factor because they determine shearing ease and

wool fiber uniformity. Face covering determines the ease of grazing for animals. Because of the wool hanging in their eyes, wool-blinded animals have decreased grazing ability and require extra labor for trimming. Fleece weight largely decides the price received for wool. Like fleece weight, staple length influences the price received for wool because it measures the length of fibers.

Finally, carcass quality largely influences profit or loss for the mutton producer. All sheep producers instill a breeding system that builds on these economic traits to improve their entire flock genetically.

Swine - For swine, a litter size at birth is an important economic trait related to reproduction. A high pig average is a desirable economic trait. Litter size at weaning is just as important as litter size at birth. Litter size at weaning reflects maternal ability. Heavier pigs at birth have more vigor and an increased survival rate. Like other classes of livestock, litter weight at weaning is an important economic trait for a swine producer. Remember, it is cheaper to put on pounds from birth to weaning than on post-weaning pounds.

An economic trait that is important for any swine producer is daily rate of gain from weaning to market weight. The more efficient the hogs, the quicker they go to market, which lowers feed costs for the producer. Like daily rate of gain, efficiency of feed reflects the conversion rate of pounds of feed to pounds gained. Every swine producer understands that efficiency of feed is an important economic trait influenced by inheritance.

Hard surfaces found in confinement facilities are very hard on hogs' legs and feet. Conformation score becomes important to swine producers who raise hogs in confinement facilities.

Finally, carcass quality is important to every swine producer. Buyers pay more for a quality swine carcass.

Parts and Functions of the Male Reproductive System

The scrotum is a heat-regulating structure that provides the proper temperature for sperm production. Sperm cannot be produced at normal body temperatures. The scrotum's function is to lower the testes when cooling is needed and contract them when warmth is needed. For sperm production to occur, the testes must be 4-7 degrees Celsius lower than normal body temperature.

All classes of male livestock are born with two testes, unless an abnormality occurs. The testes produce sperm and secrete male sex hormones. The testes are made up of several thousand feet of very small, tangled tubules called seminiferous tubules. These tubules are the actual structures that produce sperm within the testes.

The epididymis is an elongated body close to the testes. It consists of three parts: the head, the body, and the tail. The epididymis has four functions: to store, mature, transport, and concentrate sperm. Sperm storage occurs in the tail of the epididymis. Sperm maturation is achieved through secretions from the epithelial cells. The epididymis transports sperm produced by the seminiferous tubules to the tail of the epididymis. Water absorption aids in this transportation.

The vas deferens transports sperm from the tail of the epididymis to the penis. The sperm passes by accessory glands like the seminal vesicles, prostate gland, and the Cowper's gland to produce the fluid called semen. Seminal vesicles are located posteriorly under the prostate gland and empty into the urethra. Secretions produced by the seminal vesicles make up 50 percent of the fluid in semen. This yellow fluid consists of high concentrations of proteins, potassium, citric acid, fructose, and several enzymes. It usually has a pH of 5.7-6.2.

Surrounding the urethra, the prostate gland's secretions pass into the urethra through small ducts along the urethra. Prostate secretions are similar to secretions produced by the Cowper's gland. Prostate secretions usually have a pH of 7.5-8.2.

The Cowper's gland is located above the urethra and near the rectum. The Cowper's gland is about the size of a walnut; like the prostate gland, it produces secretions to flush the urethra before mounting. The secretions are clear, watery, and

FIGURE 1.1 - Comparison of Male Livestock

Bull

Stallion

Boar

Ram
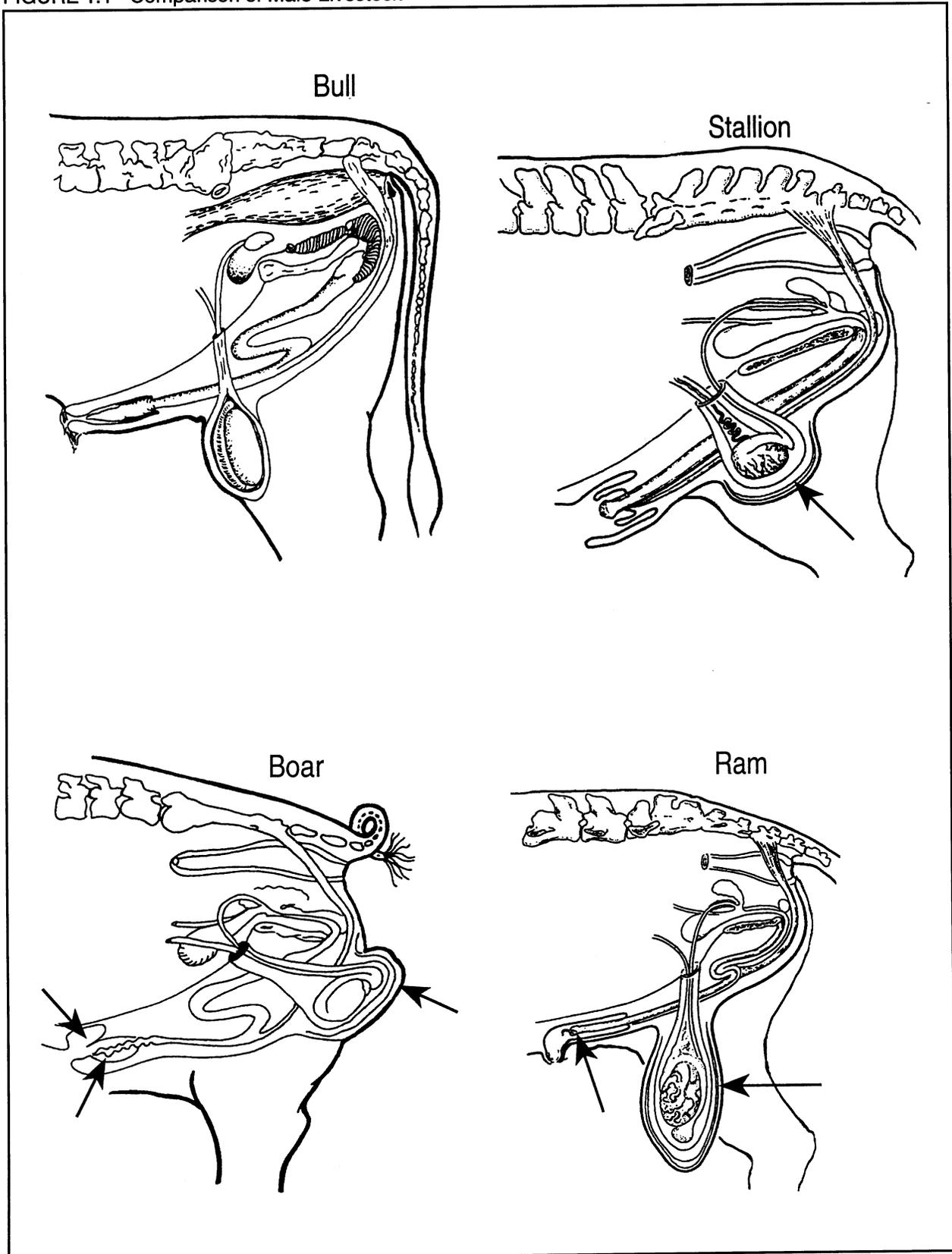
sperm-free in nature. These secretions have the same pH as those found in the prostate gland.

The urethra is a jointed canal used for both semen and urine transportation. The urethra uses the length of the penis to carry urine from the bladder, or semen from the accessory sex glands, to the head of the penis.

In a dual role, the penis excretes urine from the body or deposits semen into the reproductive tract of the female. The length of the penis begins at the bladder and accessory glands and ends at the free part located in the sheath. Blood is pumped into the chambers of the penis during sexual excitement, which causes the straightening of the sigmoid flexure. When the sigmoid flexure straightens, it causes an erection and aids copulation. After copulation, the sigmoid flexure contracts and the retractor muscle pulls the penis back into the sheath. The sheath is the protective opening where the retracted penis is kept in a fixed position when relaxed.

and gives it a bad taste. This is why boar carcasses are seldom used for human consumption.

On a stallion, the scrotum is less pendulous than a bull's. In a relaxed state, the stallion's testes lie horizontally, but in an excited state, the testes become almost vertical in nature. A stallion is without a sigmoid flexure.

Parts and Functions of the Female Reproductive System

The bladder's sole function is to store urine in the female. The urethral opening is the bladder's opening into the reproductive tract. The vulva is the external opening of the urinary tract and the female reproductive tract. (See Figure 1.2.)

The ovary is the structure that produces the egg or ovum. The ovary is connected to the Fallopian

Differences in male repro- ductive systems - The ram's scrotum is shorter than the scrotum found on a bull. The ram's scrotum is also covered with wool. In a ram, the urethra opening extends out further than the head of the penis, which rotates and sprays semen during ejacu- lation. (See Figure 1.1.)

The boar's scrotum is located just below the rectum, not hanging from the bottom of the animal as in other species. In the boar, the free part of the penis is shaped like a corkscrew. The boar has a preputial pouch above the opening to the sheath, which is responsible for the strong sex odor in boars. This pouch contains a mixture of decomposing urine and macerated epithelial cells, which permeates their meat

FIGURE 1.2 - Parts of a Cow's Reproductive Tract
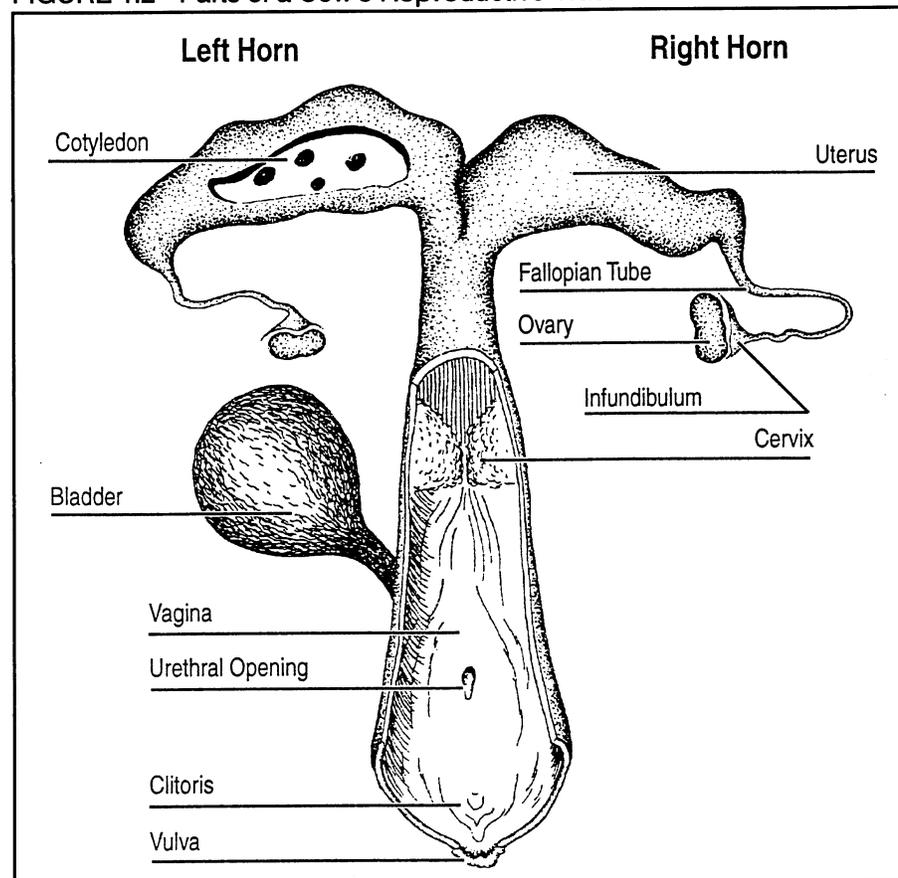
tube by the infundibulum. Then, the Fallopian tube carries the egg or ovum from the ovary to the horn of the uterus.

Twelve hours after the estrous cycle is completed, the ovary releases the ovum or egg into the upper third of the Fallopian tube, where fertilization occurs if the egg unites with sperm. The fertilized egg empties from the Fallopian tube into the uterus, where the fetus begins to develop. The cotyledon is used as an attachment point for connecting the placenta to the uterus.

When fertilization occurs, the cervix acts as a plug for the uterus. Once the fertilized egg empties into the uterus, the cervix closes, completely sealing the uterine cavity from the vagina. This closure protects the fetus from bacterial and foreign invasions. The cervix liquifies shortly before the birth, allowing the fetus to be expelled from the uterus.

The vagina is the female organ where semen is deposited at copulation. Semen is deposited at different places, depending on the class of livestock and the copulation process. Semen can be deposited as far in as the uterus. Like the cervix, the vagina dilates during the birth process to allow the fetus to be born.

Located in the vulva, the clitoris is the sensory organ allowing the penetration of the male penis. This sensory organ allows copulation to occur and is stimulated during the estrous cycle.

Summary

A good knowledge of animal reproduction helps people in livestock production and related occupations understand the complexity of this process. Knowing economically important reproductive traits is a necessity for a person in this field.

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Lesson 2:
Reproductive Hormones

The reproductive system of livestock is highly influenced by certain hormones. Therefore, to better understand the reproductive system, it is important to know the reproductive hormones and their functions.

Female Reproductive Hormones

Estrogen - The ovaries produce estrogen, which signals the rest of the reproductive system to prepare for ovulation. Estrogen is responsible for female sex characteristics. It causes uterine growth and contractions, as well as mammary duct system growth.

Estrogen's main role is to control the estrous cycle. When heat signs are especially obvious, the blood has a high level of estrogen. As the hormone's level decreases in the bloodstream, heat signs also decrease.

Progesterone - Progesterone is produced by the corpus luteum. The corpus luteum is a scar-like structure produced immediately after ovulation by an increase in follicular cells from the cavity left by the vacated egg. Progesterone prepares the uterus for pregnancy by reducing uterine movement and promoting nurturing secretions. Progesterone also blocks the release of the follicle-stimulating hormone from the pituitary gland. If pregnancy does not occur, the corpus

luteum regresses (returns to its original form) and stops progesterone production. Progesterone is responsible for blocking the estrous cycle. It also stimulates alveolar growth in the mammary glands.

Follicle-Stimulating Hormone (FSH) - FSH is produced by the anterior pituitary gland. FSH causes growth of the follicle (part of the ovary that contains a mature egg). FSH is produced midway between the heat periods.

Luteinizing Hormone (LH) - When FSH production ceases, the anterior pituitary gland produces LH. LH travels to the ovary and causes the follicle to rupture, which causes the egg ovulation (release). After releasing the egg, the follicle collapses. LH continues to affect the ovary, and cells begin to grow in the void left by the ruptured follicle. The corpus luteum then takes the follicle's place, thus stimulating the production of progesterone.

Oxytocin - Oxytocin is produced by nerves in the brain and stored in the posterior pituitary gland. This hormone causes milk ejection and egg expulsion. It also causes uterine contractions. Oxytocin is often given to induce birth or to increase milk let-down in lactating mothers.

Relaxin - Relaxin is produced in the corpus luteum in most livestock, except for the mare, where it is produced by the placenta. This hormone causes the relaxation of ligaments and cartilage in the pelvis and dilation of the cervix, which assists in birth.

FIGURE 2.1 - Normal Estrous Cycle Development and Hormone Levels (Cattle)

Credit: *Livestock and Poultry Breeding (Student Manual)*
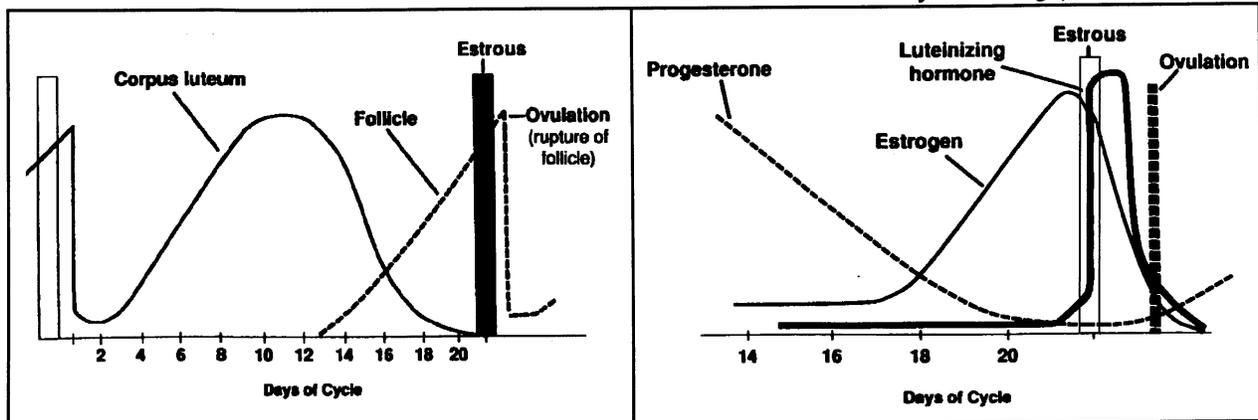
Prolactin - Prolactin is produced by the anterior pituitary gland. It initiates lactation and induces maternal behaviors.

Prostaglandin f-2-alpha - If fertilization does not occur, the uterine lining starts secreting the hormone prostaglandin. This hormone causes destruction of the corpus luteum, a reduction of progesterone secretion, and therefore an increase in FSH secretion. At this point, the estrous cycle begins again.

Male Reproductive Hormones

Testosterone - Testosterone is produced in the tissue of the testes. As the male matures, increased testosterone levels in the bloodstream trigger the development of the sex glands and secondary sex characteristics, including an aggressive nature and heavy muscling (especially around the neck and shoulders). Testosterone also controls the male's sex drive or libido. This hormone causes the maturation of sperm cells and the production of seminal plasma.

Follicle-Stimulating Hormone (FSH) - FSH is produced in the anterior pituitary gland. This hormone stimulates sperm production in the male (spermatogenesis).

Luteinizing Hormone (LH) - LH is also produced in the anterior pituitary gland. LH causes testosterone production in the tissues of the testes.

Summary

Hormones are chemical compounds that help regulate body functions. Hormones have a tremendous effect on the reproductive cycles of livestock. They control the development of sex characteristics, mating, and eventually fertilization. Therefore, hormones control the entire life cycle of livestock.

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Lesson 3:
Reproductive Cycles of Common Livestock

In humans, puberty occurs when male and female characteristics become more prominent than in the adolescent stage. Puberty begins with the release of hormones into the bloodstream. These hormones stimulate growth of the reproductive organs. Like humans, animals reach puberty in the same manner. Animals mature at a much faster rate than humans, however. Most production livestock species have reached puberty by the first year of life.

The Age of Puberty

In most classes of livestock, the initial sign of puberty in the female is the first estrous cycle. Puberty can be delayed by a poor nutritional diet or poor environmental conditions.

Cattle - A heifer's first estrous cycle can begin at 8-12 months old. The age difference depends on the breed, nutritional factors, and environmental factors. Smaller breeds usually mature faster than larger breeds.

The bull shows signs of puberty with the production of viable sperm and the desire to mount (about 8-12 months old). Both these indications are influenced by the hormone testosterone. The desire to mount can appear earlier in age, but usually viable sperm are not present.

Heifers are usually mated at 13-14 months or when they weigh 600-650 pounds. The age at which to breed is usually based on the producer's preference. The heifer's condition influences the time to breed. An older bull can service more females than a yearling bull.

Sheep - The first sign of puberty in the female is the estrous cycle, which can begin at 8-10 months. The beginning of the estrous cycle depends on the type of breed, nutritional requirements, and environmental conditions. In general, mutton breed ewes usually have their initial estrous cycle in the fall of their first year. Ewe lambs are somewhat slower reaching their sexual maturity than ram lambs.

The first signs of puberty in the ram are the production of viable sperm and the desire to mount. Testosterone released into the bloodstream influences sexual maturity in the male. These signs of puberty generally occur at 5-7 months.

Generally, young ewes are bred after they are 12 months old so that they lamb before 24 months of age. As in cattle, producer preference and the condition of ewe lambs determine the breeding schedule. Rams used for service before they are yearlings usually service a small number of females. After the rams have reached yearling age, they can service larger numbers of ewes.

Swine - A similarity between swine and other classes of livestock is that the first sign of puberty in the female is the first estrous cycle at 4-8 months of age. The wide age range depends on the type of breed, environmental conditions, and especially nutrition. All these differences can lead to a delay in puberty in swine. Nutrition is important in swine sexual maturity. If gilts receive a poor nutritional diet, puberty can be delayed dramatically. Gilts should reach 180 lbs. before 8 months of age. Most gilts do not begin their first estrous cycle until they weigh 180 pounds or more.

The first signs of puberty in the boar are the production of viable sperm and the desire to mount. Again, the desire to mount usually comes before the production of viable sperm. The first signs of puberty generally begin at 4-8 months. In general, boars reach their sexual maturity later than gilts. Gilts are usually bred to farrow at 11-12 months. In swine, breeding gilts largely depends on development, not age. A general rule is to breed gilts when they reach a weight of 225 lbs., instead of when they reach a certain age. Boars can begin service at 8-12 months. Younger boars service a smaller number of females in the earlier stages of their sexual maturity.

Horses - The ages of sexual maturity are very similar in horses. Both the male and female reach puberty at 12-15 months. As in other classes of livestock, the first signs of puberty in horses are the first estrous cycle and the production of viable sperm with the desire to mount.

Mares are bred based on their maturity level. Well-developed mares have been bred as early as 2 years old to foal when they are 3 years old. The best time to breed mares is when they are 3 years old so they foal when they are 4 years old. Stallions are ready for service when they have reached sexual maturity.

Estrous Cycle

Before puberty occurs, the female reproductive tract and ovaries grow slowly and show no functional activity. The growth of the reproductive tract seems to parallel the increase in body weight as the animal gets older. As puberty nears, the anterior pituitary gland releases FSH (follicle-stimulating hormones) into the bloodstream. FSH stimulates follicle growth in the ovary. As follicle growth occurs, ovarian weight increases and estrogen (a female sex hormone) is released. This release is triggered by a hormone called LH (luteinizing hormone), which is also produced by the anterior pituitary gland. The LH ruptures the follicle and releases the egg, which is called ovulation. Once this has occurred, the animal has reached puberty.

Puberty is reached at different ages, depending on the species. The estrous cycle or heat period begins when the female is willing to accept the male for mating. The cycle begins with release of estrogen from the ovaries, and the egg is ovulated. The length of the heat period, distance between heat periods, and release of the egg are different in each class of livestock. Table 3.1 shows the differences for each class of livestock.

Outward signs of heat - Successful, practical

artificial insemination requires that a person's judgment be substituted for a sire's instinct. This is difficult, but not impossible if one is diligent. Similar conditions to some of those described below for finding cows in heat are often observed in other classes of livestock.

Cows in heat are affected by a sudden, high-level presence of the female or "heat" hormone (estrogen). The egg-containing follicle which produces the hormone is at the height of its growth.

The cow's nervous system is greatly affected; she is excitable and may bawl excessively. She is restless and often walks the fences. The producer who knows the cows well can often recognize heat by the alert, bright-eyed, nervous appearance shown by cows during this period.

Cows in heat attempt to ride other cows and stand to be mounted by other cows. Under natural conditions, they would stand and accept service by a bull. Standing is the only reliable, practical test for heat. When a cow stands, she is in heat and is ready for service.

Ruffled hair over the tail head suggests that a cow has recently been ridden; she may or may not have been in heat. Many heifers and cows in heat flatten themselves down in the loin region. This presents a "sway back" and "high tail head" appearance.

The sex hormone from the ovary also has an effect upon the genital organs. Genital mucous may flow from the vulva in long strings. Wet mucous smears are often seen on the buttocks, over the pin bones and under the tail. Also, the

TABLE 3.1 - Differences in Estrous Cycles

Type of stock	Length of heat period		Interval of heat period		When egg is released
	Range	Average	Range	Average	Time
Cattle	6-30 hrs.	16-20 hrs.	19-23 days	21 days	12 hrs. after estrous is completed
Sheep	20-42 hrs.	30 hrs.	14-20 days	16-17 days	24-30 hrs. after estrous cycle is completed
Swine	1-5 days	2-3 days	18-24 days	21 days	36-40 hrs. after onset of heat
Horses	2-10 days	4-6 days	10-37 days	21 days	In latter part of the estrous cycle

vulva of a cow in heat appears somewhat swollen.

On the second or third day after heat (or earlier), bloody mucous passes from the cow's vulva. This may be smeared on the buttocks, on the tail, or in a pool behind the cow after lying down. Bleeding from the cow means that she has been in heat (ovulated) 2-3 days before.

To ensure accurate results for an artificial breeding program, check for heat at least twice each day.

Spermatogenesis in Livestock

Spermatogenesis is the production of sperm within the seminiferous tubules in the male testes. This process occurs through meiosis, mitosis, and metamorphosis. Spermatogenesis starts with spermatogonia, which carry both sets of chromosomes (XY). Spermatogonia are sex cells in the form of immature sperm. Spermatogonia become mature sperm through spermatogenesis.

Mitosis is a form of cell division in which one cell divides into two separate cells, both containing two complete sets of chromosomes. In meiosis, sex cells divide and split the chromosome number in half. The spermatogonia have two X chromosomes and two Y chromosomes. Spermatogonia first divide during mitosis and make an identical cell with two X chromosomes and two Y chromosomes. A cell having two X chromosomes and two Y chromosomes is called a diploid. In the first meiotic division, the diploid is split in half, creating a haploid. A haploid has only one X chromosome and one Y chromosome.

The spermatogonium goes through a second meiotic division where the first haploid divides into a second haploid. Once this division occurs, the new haploid is left with either an X chromosome or a Y chromosome. The new haploid has either an X chromosome or a Y chromosome, not both. This is important because it determines the sex of the offspring.

Before the second haploid becomes a mature sperm, it must go through a metamorphosis (change). Then, the haploid receives a head and a tail to move through the female reproductive tract. Once this metamorphosis occurs, the haploid is a mature sperm. An X chromosome

sperm that reaches the egg first determines a female offspring, while a Y chromosome sperm determines a male offspring. The whole process of spermatogenesis takes about 46-49 days to occur.

Gestation Lengths

Gestation or pregnancy period is the length of time between fertilization and the birth of the offspring (parturition). To understand gestation, begin with the ruptured follicle that released the egg. This ruptured follicle develops into an endocrine gland called the corpus luteum. The endocrine gland produces hormones for the reproductive system, while the corpus luteum produces a hormone called progesterone, which maintains pregnancy in livestock.

Once the egg is fertilized, it floats freely in the uterus for a short time. Then, the fertilized egg begins development of the placenta. The placenta is attached to the uterus by the cotyledons, which hold the placenta in place for the remainder of the gestation period. Gestation lengths vary from one class of livestock to another. Table 3.2 shows the differences of gestation lengths in each class of livestock.

TABLE 3.2 - Gestation Length

Livestock class	Range (days)	Average (days)
Cattle	240-330	283
Swine	111-115	114
Sheep	144-152	148
Horses	315-350	336

Summary

It is especially vital for a livestock producer to understand the reproductive cycles of livestock. This understanding helps in AI programs, hand or pasture mating, determining the number of females per male, the age at which to breed young stock, and record keeping.

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Lesson 4:
Fetal Developmental Stages

The livestock industry relies on the production of quality animals to ensure a quality product for the consumer. The production of such animals begins with proper care of the developing fetus and its mother. Understanding developmental stages of livestock enables the producer to ensure the delivery of healthy young.

TABLE 4.1 - Timetable of Calf Development

Time (days)	Development
0	**First trimester** Fertilization in oviduct
4	Embryo (in eight- to 16-cell stage) reaches uterus.
8-11	Embryo transfer possible
12	Embryo forms weak attachment to uterine wall.
18	Amnion encloses embryo.
21	Heart begins to beat; reproductive tract begins to develop.
23	Head region is recognizable.
25	Forelimb buds appear.
30	First placental plates appear.
33	Fragile cotyledonary attachment forms.
37	Facial features appear.
46	Developing animal is now a fetus.
60	Eyelids can close.
100	**Second trimester** Horn pits appear.
110	Tooth development begins.
230	**Third trimester** Hair covers the body.
283	Birth

Developmental Stages of the Livestock Fetus

Animal life begins as a single cell (the fertilized egg). Through the processes of cell division, the cell multiplies and develops into a mature animal. Growth includes all of the physiological processes that allow the fertilized egg to develop into a many-celled animal.

Growth - Animal growth occurs because of an increase in both the size and number of body cells. The increase in the number of cells is called hyperplasia, while the increase in size of cells is hypertrophy.

During embryonic growth, all cells increase in size and number. However, in the adult animal, there are three different types of cells. Permanent cells, which include muscle and nerve cells, stop dividing or increasing in number early in prenatal life. Stable cells continue to increase in number and size throughout most of the postnatal growth stage and until the animal reaches maturity.

Prenatal growth - Growth/development before birth or hatching is one of two types of growth in livestock. This period involves the time between the fertilization of the ovum by the sperm (the formation of a zygote) and birth. The embryonic growth period includes early stages of prenatal growth and development. After fertilization, the zygote begins as one cell that contains chromosome pairs, one each from the mother and father. The zygote's single cell then begins a series of divisions into two cells, then four, then eight, etc. The cell division rate varies with different species of animals.

In the first stages of its life, the newly fertilized egg free-floats in its mother's reproductive tract. This embryo spends the first few days traveling in the oviduct toward the uterus. By the time it reaches the uterus, 16 or more cell divisions have taken place within the cell wall of the egg. Also, the hormone progesterone has prepared the uterus to care for the new animal. The egg's cytoplasm provides the necessary energy for cell division until the egg reaches the uterus.

After reaching the uterus, the egg continues to free-float and absorb nourishment from fluids in the uterus. This free-floating period lasts as long

as 30 days in the dairy cow and the mare, but is somewhat shorter in other mammalian livestock.

During this time, the embryo surrounds itself with a set of membranes. These membranes form a sac of fluid to keep the embryo moist and act as a shock absorber. These extra membranes and fluid (known as the placenta or afterbirth) attach to the rich uterine lining.

In hogs, the entire placenta attaches to the entire surface of the uterus. In sheep, horses, and cattle, there are cotyledons (button-like spots on the placenta) that attach to caruncles (spots) on the uterus. These points of attachment, along with arteries and veins in the umbilical cord, provide the calf with nourishment from the mother and waste disposal. Until birth, the embryo has its own blood circulation system plus the external (mother's) system, which passes through the umbilical cord.

Swine also have another reproductive characteristic that is unique compared to cattle, sheep, and horses. Swine are polytocous (litter bearing) animals producing multiple ova, which can all be fertilized to produce multiple births. It is not unusual for sows to ovulate 15-20 ova during an estrous period. This is the main reason why the entire placenta is attached to the entire surface of the uterus in swine.

Morphogenesis - The cells in the developing embryo go through a process of differentiation in which the cells organize into specific structures.

TABLE 4.2 - Timetable of Chick Development

Time (days)	Development
3	Blood circulation between embryo and yolk is established.
5	Sex can be determined.
8	General outline is recognizable.
8-9	Lungs, nervous, muscular, and sensory systems are in place.
10-11	Embryo is covered with down and first feathers.
21	Hatching occurs.

This differentiation of cells into organs and tissues with a specific purpose is called morphogenesis. It begins with the cells dividing into three basic layers: the ectoderm (outer) layer, the mesoderm or middle layer, and the endoderm (inner) layer.

The ectoderm develops into the brain and other parts of the central nervous system, skin, hair, wool, hooves, and certain endocrine glands. The mesoderm develops into both voluntary and involuntary muscle tissue; the heart and other parts of the circulatory system; and connective tissue, such as bone, cartilage, ligaments, and tendons. The endoderm develops into the liver, digestive system, and other endocrine glands.

Body organs and tissues are formed in a specific sequence. For example, the head forms before the tail, and the beginning of the spinal chord forms before other organs. This process continues until all body organs and tissues are formed.

Highly differentiated cells, such as the brain, cannot be replaced if destroyed after the original number is fixed during the fetal stage (second stage of prenatal growth and development). Therefore, seriously damaged nerve cells are not replaced and usually remain damaged. Muscle cell numbers are also fixed during the fetal stage and increase only in size after birth. Bone tissue grows both before and after birth.

The rate of prenatal growth in livestock varies among species. For example, the length of gestation in pigs is 111-115 days, while in horses it is 315-350 days. Although the rate of prenatal growth varies, most livestock are born with a fairly equal degree of maturity.

Development of Embryo During Incubation

In birds, the process of incubation (causing something to develop or take form) corresponds to gestation in mammals.

Terminology - The amnion is the sac that surrounds the embryo. The chorion is the lining between the egg shell and the internal portion of the egg. Allantois refers to the part of an egg that stores excretory wastes; it fills the space between the amnion and the chorion.

Incubation - When fertilization occurs in poultry, the embryo begins development around a well-defined germinal disk. This area is clearly visible to the naked eye when a freshly laid, fertilized egg is broken. Within 48 hours after fertilization, a chick embryo establishes an intricate blood circulation system between itself and the life-sustaining yolk. (See Table 4.2.) Since there is no placenta, as in mammals, the poultry embryo has to develop on this circulation network to provide nutrients and remove waste products.

By the end of the third day, the embryo has a full set of membranes. The allantois, which stores excretory wastes, fills the space between the amnion and the chorion. Later, the allantois merges with the chorion to form the chorio-allantois, which expands and contacts the shell membrane. The chorio-allantois serves as the respiratory organ for the developing embryo until the pulmonary organ takes over about 24 hours after hatching. The shell and the membranes also protect the developing embryo from harmful microorganisms or molds.

As in mammals, the embryo floats within fluid in the amniotic cavity. The developing embryo is protected by this floating movement, and it must continue until the last 3-4 days before hatching. Without this movement, malformations can occur that endanger the life of the newly hatched chick. In an incubator, the egg must be turned several times a day to prevent adhering of the embryo to the chorio-allantois membrane. Under natural conditions, the hen instinctively shifts the egg several times a day.

Physical factors - Several physical factors are critical for adequate levels of egg incubation and hatching.

1. Temperature - To have most of the chick embryos survive, store the eggs for a maximum of seven days at 60°F outside the incubator. This allows for development processes to continue without adverse effects after the eggs are placed in the incubator. With some minor differences between breeds, a temperature range of 98-104°F within the incubator is best.
2. Humidity - Since the egg is approximately 70 percent water, it is important to maintain a certain humidity level to prevent water loss. Pre-incubation storage of hatching eggs should be at 85 percent relative humidity; during incubation, store eggs at 60-65 percent humidity. This water allows for excretion of the embryo's metabolic wastes and serves as a heat regulator, much like a car radiator transfers heat through water.
3. Air velocity - Although the rate of moving air in an incubator does not appear to have much influence on hatchability, a constant supply of fresh air is necessary for the developing embryo.
4. Energy supply - The egg represents a highly concentrated form of energy provided by the hen. This stored energy is extremely important for the developing embryo during incubation *and* in later stages. Embryo development uses 25 percent of the egg's energy; the rest is incorporated into the developing chick.

Nutritional Requirements During Pregnancy and Lactation

Cattle - The period during which the calf crop is affected most by nutrition extends from 30 days before calving until 70 days after calving. The nutritional needs of nursing cows are higher and more critical than those of pregnant cows. After a cow has calved, her energy needs jump about 50 percent; her protein needs double; her calcium and phosphorus needs triple. Compared to during pregnancy, she needs approximately 50 percent more feed for milk production.

During the last trimester, the nutritional requirements are higher than in an open female because of the requirements of the growing fetus.

Sheep and goats - In general, feeding a suitable, well-balanced ration with necessary minerals and vitamins will ensure a strong, healthy lamb crop. During the last 4-5 weeks before lambing, the fetus develops rapidly and demands on the ewe are heavy. Ewes should be fed 0.5-1.0 pounds of grain per head daily during this time.

Following lambing, the feed allowance of the ewe should be increased according to her capacity and needs. Though varying somewhat with size and condition of the ewe (and whether she is raising

twins or a single lamb), an adequate ration can consist of 4 pounds of high-quality alfalfa hay plus 1-2 pounds of grain daily.

Swine - About two-thirds of the fetal growth occurs in the last month. During gestation, it is important that body reserves be stored for lactation. Feed should be increased to 4-5 pounds daily. However, sows should not be overfed because fat sows have farrowing difficulties. Four to five days before farrowing, it is a good practice to decrease feed intake and feed a bulky, laxative feed.

Nutrient requirements of a lactating sow are more rigorous than requirements during gestation. The lactating sow should be fed 2.5-4.5 pounds daily for each 100 pounds of body weight.

Summary

Although gestation periods of various species of livestock differ, the stages of fetal growth and the effects of gestation on the mother are very similar. The growth of the fetus is just more rapid when the length of gestation is shorter. To ensure a safe pregnancy and healthy offspring, it is important to make management changes that relieve stresses placed on the mother during gestation.

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Lesson 5:
Effects of the Environment
on Reproduction

Plant *and* animal growth are affected by the photo period, environmental conditions, and fertilization requirements. Both plants and animals are affected by the length of daylight hours. Like plants, animals that do not receive the correct amount of nutrients have reproductive (growth) problems. Like plants, livestock reproductive difficulties become more apparent during extreme environmental conditions. If animals cycle naturally and receive adequate nutrition and temperature, they will also reproduce abundantly.

Effects of Nutrition and Body Condition

Nutritional diet - Nutrition is related to several reproductive difficulties in female livestock. These difficulties seem more prominent in younger females than mature females. Older females have built up reserves within their bodies to pull from, but younger females do not.

Longer breeding and calving seasons can occur from poor nutritional diets. Because of deficiencies in their diet, a smaller percentage of females come into their heat period in the first 21 days after calving. Frequently, nutrient-deficient females will be less synchronized in their heats. This disturbance could result in a longer breeding and calving season. A low percentage of females conceive on the first service by the sire. Nutrient-deficient females have lower conception rates on the first estrous cycle.

Worse yet, poor nutrition can cause more calving deaths at birth (parturition) and in the first two weeks after birth, which results in extreme losses for that year. Since all these difficulties can be prevented through a proper nutritional diet, producers can control their own destiny.

Livestock producers must be aware of nutritional requirements for females during lactation, gestation, and the pre-breeding period. Most reproductive failures are caused by deficiencies in one or more nutrients during the 100-day period before birth and the days immediately following birth. Critical nutritional deficiencies during this 100-day period will determine the conception rate and calving difficulties during the next breeding season.

Flushing is a nutritional technique used by swine and sheep producers to prepare breeding stock for the breeding season. Flushing keeps sows and ewes on a full feed ration to allow the body and reproductive tract to build back up before the next breeding. If this method is used, reproductive problems associated with nutrition will be reduced.

Energy is more important than protein when it comes to reducing reproductive problems. Livestock receiving inadequate levels of energy have more reproductive difficulties. Diets containing low levels of phosphorus have a reduction in the calf crop. Low phosphorus diets usually occur in the range land in the western states, where forages have lower levels of phosphorus. Heifers on a dry forage diet benefit from supplements of vitamin A.

The amount and type of feedstuffs fed before and after calving determine conception rate and proper timing of heat periods for the next breeding season. Feed requirements increase after calving, so feeding allowances must parallel this need. If not met, the female will have severe weight loss, which will delay the heat cycle and decrease conception rates.

Body condition - The female's condition also affects reproductive difficulties. During gestation, the female's condition determines reproductive difficulties for the next breeding season. An average conditioned cow should have a minimum gain of 100 lbs. during gestation. After calving, an average conditioned cow should gain $1/_2$ to $3/_4$ lb. daily to build up reserves for the next breeding season. A cow in thin condition should also have a 100 lb. minimum gain during gestation, but it should gain $1^1/_2$ to 2 lbs. daily after calving to build up reserves for next breeding season.

In reality, the condition of the female body during gestation and after birth applies to all classes of livestock. Adequate gains can be achieved through a proper diet and quality feedstuffs. A proper diet during these periods will produce healthier offspring, lower mortality rates, quicker breed back, and longer female productive life. The

principles of nutrition apply to all classes of livestock; only the numbers will be different.

In females that have not reached puberty yet (prepubertal), a restricted or nutrient-lacking diet can delay puberty or cause hypoplasia. Hypoplasia is the defective or incomplete development of reproductive organs; it is usually the reason reproductive organs remain below normal size. Nutritional disorders can be detected in females by the lack of an estrous cycle. A proper diet can solve prepubertal disorders if the problem is caught in time.

Effects on sires - Nutritional deficiencies also affect the reproductive efficiency of the male. Younger sires are affected more than more mature sires. Older sires can go many months on a poor or deficient diet without reducing sperm numbers. These mature sires use body reserves to maintain proper sperm production.

A poor nutritional diet can delay puberty and can be fatal if the nutrient deficiency is extreme enough. A nutritional deficiency in younger sires can cause irreparable damage over prolonged periods of time. This damage results in reduced testes size, low sperm production, and sperm re-plenishment.
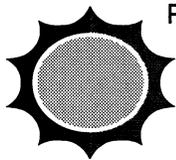
Effects of the Photo Period

Photo period refers to the length of daylight. Corn, for example, needs a certain number of day-light hours to grow normally. Like plants, animals' reproductive cycles are influenced by daylight. Imported livestock breeds had to adjust to new environments, as did their reproductive cycles. Sometimes, these new breeds never adjusted to the new environment and they could not reproduce in this country. All classes of livestock are influenced by the photo period, although some are affected more than others.

Beef - Cattle are considered continuous breeders. Most beef producers aim for calving during September, October, and November, so the breeding season is during the months of January, February, and March.

Hogs - Swine are also continuous breeders. For this reason, most confinement pork producers plan breeding systems to keep their farrowing houses full year-round. For producers farrowing twice a year, breeding systems are more influenced by heat, funds available, and available feeds, not by photo period. Feed costs aren't significant in breeding swine since they are continually fed.

Horses - Sometimes, horses are considered continuous breeders. The breed usually has a greater influence on the reproductive cycle than the photo period. Since most equine breeds originated overseas, environmental conditions influence the timing of the reproductive cycle. Horses tend to show more sexual activity during the spring months.

Sheep - Although not considered continuous breeders, some sheep breeds can produce more than one lamb crop per year. Generally, sheep have a set breeding season stimulated by the photo period. Estrous cycles in sheep usually begin in September and end in March. The Dorset breed has the longest breeding season (June through April). If managed correctly, Dorsets can have two lambing seasons. Sheep are heavily influenced by the shortening of day hours.

Poultry - The early ancestors of poultry only laid eggs in the spring months. Through selection and improved management techniques, poultry now lay eggs continuously. Photo period has the greatest influence on poultry than on any class of livestock because the bird's eye is sensitive to light intensity. The optic nerve is responsible for detecting light intensity. When light intensity increases, activity in the pituitary gland increases. This pituitary gland activity continues hormone production, which stimulates the reproductive cycle. Continuous light in hen houses is the sole reason for continual laying by hens.

Temperature's Effects

Females - Environmental temperatures affect the reproductive cycle in livestock in many ways. Heat stress causes several problems in the female reproductive cycle. Extreme heat can delay the estrous cycle in many classes of livestock, especially in sheep. Remember, most sheep have a limited breeding season. Sheep do not begin

showing signs of heat until late summer and early fall. Ewe lambs show the first signs of puberty in the fall of their first year.

Extreme heat influences offspring weights at birth by causing the female to expel more energy to cool her body than she provides to the offspring. Also, extreme heat causes a loss of appetite in animals, which decreases the amount of feed intake. This reduced feed intake lowers the amount of nutrients supplied to the offspring.

During the last trimester, extreme heat conditions can be detrimental. Extreme heat conditions contribute to abortions, fetal deaths, low birth weights and litter sizes, and abnormalities in offspring. The size of the placenta is reduced under extreme heat conditions, which can cause birthing difficulties.

Extremely cold temperatures usually do not have as much impact on reproduction as extreme heat. When extremely cold conditions do arise, the only factor that usually develops is a lower birth weight, since the female uses more energy to control body temperatures than it contributes to the offspring.

Males - The male's reproductive ability is affected by environmental conditions to a smaller degree. The production of testosterone is not influenced by extreme environmental conditions, but there can be some fluctuations in sperm production and abnormalities due to extreme heat periods.

There are seasonal variations in sperm production in males, but they have little effect on the reproductive efficiency of sires like extreme heat conditions do. The number of females serviced during extreme heat conditions is reduced because sires become exhausted more quickly. The testosterone levels are there, but the desire to mate is greatly reduced because of the extreme heat conditions.

Extremely cold temperatures do not have an affect on male reproduction because breeding seasons usually do not occur during these months.

Summary

For people associated with livestock production, it is vital to have a solid knowledge base of factors influencing the reproductive cycle. One must produce the greatest number of offspring to sustain a profit in the operation. Knowing that photo period, nutrition, and environmental conditions influence livestock reproduction will greatly improve monetary success for a producer.

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Lesson 6:
Management and Technology
in Reproduction

The advancement of the livestock industry is due largely to the great strides made in improving the management and technology available in reproduction. Understanding these techniques and their effects greatly increases the success of livestock producers.

Artificial Insemination

Artificial insemination (AI) is the introduction of male reproductive cells (sperm) into the reproductive tract of a female by artificial means. The origin of AI is unclear, but an Arabian legend dating to 1322 maintains that the method was first used by a chieftain who had stolen the "seed" of an enemy's stallion to deposit into his own mare.

The first scientific research about AI of domestic animals was conducted on dogs by the Italian physiologist, Lazarro Spallanzani, in 1780. By the late 1800s, American veterinarians used it to get mares in foal that consistently did not settle by natural methods. AI has been in practical use successfully in the U.S. since the 1950s. In 1988, more than 65 percent of the nation's dairy cattle were artificially inseminated. AI is becoming increasingly popular in other classes of livestock, as well.

Benefits from AI - There are several advantages of using artificial insemination.

1. Through the use of AI, many more animals are bred to superior males selected on the basis of similar traits. These traits are often economically important or considered to be aesthetically pleasing. This provides greater uniformity in a breeding program.
2. With reasonably priced semen, the value of progeny produced exceeds the costs of semen and service. The offspring of outstanding sires are usually higher and more efficient producers--more profitable than other offspring.
3. It helps control disease. AI is a valuable tool in preventing and controlling the spread of venereal diseases. Also, reproductive problems in females are more easily detected.
4. AI improves herd records. The sires and breeding dates of each offspring are known. Thus, improved culling and management result from closer herd records and observations.
5. AI allows the development of genetically superior animals in a more timely manner. For example, in the cattle industry, the semen from a superior bull can be used through AI to service as many as 20,000 cows per year. Using natural service, this same bull would only be able to service approximately 60 cows per year.

Limitations of AI - Although there are many advantages to using AI, there are also some limitations.

1. Successful AI requires a skilled and conscientious technician. Adequate training is a must for any person performing this technique.
2. Just as superior genetics are passed to the next generation in a more timely manner, inferior genetic traits are perpetuated, as well. Often, selection *for* one trait can lead to selection *against* another.
3. There is some potential for abuse (e.g., improperly labeled semen).
4. AI requires more time and management knowledge. Proper heat detection of the female takes a great deal of time and knowledge. Also, because of the extra handling for palpation and insemination of each individual, extra labor and facilities are needed.

Semen collection - The most popular means of semen collection is through the use of an artificial vagina (AV). An AV is constructed to mimic natural copulation. It consists of an outer tube with a thin rubber lining. Water that is warmed to body temperature is used to fill the space between the lining and the outer tube. The liner is often lubricated, and one end of the AV is left open for entry of the penis. The other end has a small collection vesicle, usually a test tube, for the ejaculated semen.

Most sires can be trained to use cows, steers, or dummy mounts. The artificial vagina is forced over the erect penis when it tries to penetrate the dummy (or other mount). When filled, the test tube is removed and taken to a processing lab, where the semen is processed.

Electrical stimulation in conjunction with the artificial vagina is the second most common way to collect semen. The electro-ejaculator produces an electrical impulse to stimulate the nervous system, causing erection and ejaculation. Electrodes are placed in the bull's rectum, and low-power stimulations are given until semen is produced. This method is generally used to obtain semen samples for fertility testing or when a mounting dummy is not available.

Semen testing - Semen density is tested to estimate the number of sperm in the semen. Next, the semen is examined under a microscope. A drop of fresh semen is placed on a glass slide. The observer notes what percentage of the sperm move. If 80 percent or more of the sperm move, the "percent motility" is excellent; 70 percent is good; 50-60 percent is fair. Rapid forward movement is desirable.

Extending semen - Millions of sperm are ejaculated by the male at the time of mating. In natural mating, all these sperm are used to breed one female, although only one sperm of the millions fertilizes the egg. With AI, a male's ejaculation can be extended or diluted so that many more females can be bred with it. This is accomplished by adding materials to the semen that help keep it alive and give the sample more volume.

See Table 6.1 for some common extenders and the classes of livestock for which they are used.

TABLE 6.1 - Semen Extenders

Type of diluent	Animals used for
Egg-yolk citrate	Bull, ram
Egg-yolk phosphate	Bull, ram, stallion
Homogenized milk	Bull, ram, boar
Glycine-containing diluents	Boar

Antibacterial agents are added to the extenders to help control bacterial growth. To keep sperm alive, it is important that the extenders be added a few minutes after the semen is collected from the male. It is also important that sperm never be cooled suddenly. Thus, the semen and extender should always be near the same temperature.

Undiluted semen will not live much longer than 24 hours at room temperature. By adding diluents and slowly cooling the semen to refrigerator temperature (41°F), the sperm can be kept fertile for nearly a week.

Storage of semen - After special treatment of semen with extenders, the sperm can withstand freezing to extremely low temperatures. Bull semen is often stored frozen, while boar semen does not withstand freezing well and is used fresh.

The basic unit for semen storage and shipment is an individual plastic straw containing enough semen for a single insemination. Each straw is identified with the sire's name and registration number. If the semen can withstand freezing using liquid nitrogen or dry ice in an alcohol bath, the diluted semen with the glycerol added is slowly frozen. When maintained at -320°F until needed for breeding, semen will stay fertile and can be stored for months or perhaps years. Most of the semen is stored in a liquid nitrogen container (semen tank).

General management practices - Some general management practices will increase AI conception rates if they are followed properly.

1. Avoid breeding diseased or infected females.
2. Have females that have been bred 2+ times without conception checked by a veterinarian.
3. Wait at least 60 days after calving to breed cows back.
4. Sows should be bred back 35-50 days after farrowing.
5. All semen collection equipment should be clean and sterile.

Timing of cattle insemination - The rule of thumb that generally provides good conception rates for cattle herds is: Inseminate approximately 12 hours after estrous is completed. Ovulation occurs 12-16 hours after standing heat.

Insemination techniques - To inseminate a cow properly, the inseminating gun must be inserted into the vagina and directed through the cervix before releasing the semen. Learning the proper technique of artificial insemination usually takes three days of concentrated practice on several cows. Following is a brief outline of the AI technique to give a better understanding of the procedure used.

1. Insert the gun with tip pointed upward at a 30° angle into the vagina. This angle keeps the gun from entering the urethra.
2. After the gun tip is inserted into the vagina, place a gloved hand into the anus of the cow to direct the inseminating gun. Next, direct the gun tip through the vagina and into the cervix. Inserting the gun into and through the cervix can be difficult. If the opening of the cervix is difficult to locate, straddle the cervix with the first two fingers of the gloved hand. Pin the cervix to the floor of the pelvis, and locate the opening of the cervix with the thumb.
3. Next, bring the gun tip up until it strikes the thumb. Insert the gun into and through the cervix by using light but steady forward pressure.
4. The cervical channel consists of three cartilage-type rings. Hold the cervix with the gloved hand until the insemination gun is worked through the three rings.
5. After passing through the three rings, the gun will slip forward with little resistance. When this happens, the tip of the gun will be in the uterine body. Since the uterine wall is thin, you should be able to feel the gun tip with the gloved hand. Next, slowly pull back the gun until it is even with the cervical opening. This ensures that the gun tip is inserted only 2" into the cervix. Otherwise, all the semen will be deposited into one uterine horn instead of both.
6. Take about five seconds to deposit the semen slowly.
7. After properly depositing the semen, slowly pull the gun from the reproductive tract. Clean the equipment.

Timing of insemination in horses - The mare's heat period lasts 2-10 days. The egg is ovulated 1-2 days before the end of the heat period.

Artificial insemination techniques in horses - AI has become popular for use in some breeds of horses. AI is not permitted by some horse breed registry associations. If AI is permitted, fresh semen is required by many breed associations. Normally, breed associations will not accept registration for foals conceived from frozen semen. When AI is used, a syringe is attached by a rubber adapter to a disposable insemination tube. Using a sterile sleeve glove, the inseminating tube is inserted directly into the vagina. Then the gloved fingers open the cervix and pass the rod into the uterus to place the semen directly into it.

Sheep - For many reasons, AI in sheep is not widely used in the U.S. outside of research. There are no reliable indicators of the onset of heat in ewes. The ewe has a small and highly folded cervix, making it difficult to deposit semen directly into the uterus. No suitable long-term storage method has been developed for ram semen. No method has been developed for identifying superior sires. The conception rates from a single insemination are not high enough to produce an adequate lamb crop. Most importantly, the additional labor requirements for AI economically outweigh the benefits.

Timing of swine insemination - In swine, the average length of the heat period is 2-3 days, but gilts' heat periods are usually slightly shorter than those of sows. Ovulation occurs about 40 hours after the onset of heat. However, even with daily observation, it is difficult to know precisely when first standing heat occurs. As a rule of thumb, breeding should take place about 12 hours after observing heat and at 24-hour intervals for as long as the female will stand. Allow at least 2-3 services to provide higher conception rates and larger litters.

Artificial insemination techniques in swine - To inseminate swine correctly, follow these steps.

1. Confine the female in a small pen.
2. Put about 100cc of extended semen in a 4 oz. squeeze bottle with a cone-shaped tip. A large syringe can be used, but it is more difficult.
3. Place a few drops of lubricant on the tip of the rubber spirette. Insert the tip into the vulva, pointing it toward the backbone at a 45° to

avoid the opening of the urethra. The cervix is usually 8-10" inside the vulva, but it can be deeper in larger females.

4. When the cervix is located, start rotating the rubber spirette counterclockwise until it becomes "locked" into the cervix.
5. When the spirette is in place, connect the semen container and begin squeezing the semen through the spirette. If the semen starts to run out of the vulva, release pressure, wait a few moments, and start again.
6. When finished, remove the catheter and clean the equipment.

Problems of using frozen semen - On the average, conception rates with frozen semen are 10-20 percent lower than those obtained with freshly collected semen. Also, litter sizes show a reduction of one pig per litter with frozen semen. When freshly collected semen is used, the results are very close to those of natural breeding.

Poultry - Natural mating in broad-breasted turkeys generally results in low fertility rates. For this reason, more than 90 percent of U.S. turkey breeders use artificial insemination in combination with natural mating. The insemination is done with a syringe.

Estrous Synchronization

For AI and embryo transfer, it is important to have a large number of females in estrous at the same time--hence the term estrous synchronization.

There are different advantages to the use of estrous synchronization, depending on the species. For example, horse breeders often strive to breed their mares so that they foal shortly after January 1. The reason for this is that the racing industry considers all foals a year old on January 1, regardless of when they were born during the preceding year. In the dairy industry, estrous synchronization is used frequently to facilitate the use of AI in heifers.

For all species, synchronizing estrous and (ultimately) breeding times shortens the period from birth to conception of the next offspring. For use with an AI program, it increases the number of females to breed at one time, cutting down on time and handling.

TABLE 6.2 - Optimum Breeding Times

Live-stock	Heat length (ave.)	Best time to breed after start of heat
Cattle	18 hours	12-19 hours
Horses	5 days	Third day
Sheep	30 hours	20 hours
Swine	3 days	End of first day

Products Used for Estrous Synchronization

Progestogens - These compounds mimic the hormone progesterone, which is produced by a structure on the ovary called the corpus luteum (CL). Progesterone from the CL controls the timing of estrous by preventing the release of other hormones needed for estrous to occur.

Administering progestogens in oral, injectable, or implant form mimics the action of the CL. Long-term administration (14-21 days) causes the CL on the ovary of the cow to disappear. When the progestogen is withdrawn, the female will typically come into estrous.

In mares, progesterone is effective in suppressing heat in mares that have long and erratic estrous cycles. It has also been used (with less consistent results) to maintain pregnancy in mares with history of abortions.

Prostaglandins - These hormone-like substances are administered to the female to induce the disappearance of the CL, also called CL regression. Regression of the CL causes blood levels of progesterone to fall. This induces estrous within 2-4 days. In all species, the CL is not responsive to prostaglandins early in an estrous cycle; therefore, not all animals would be expected to respond to a single injection.

In 1979, the Upjohn Company of Kalamazoo, Mich., received FDA approval on the use of Lutalyse®, a prostaglandin product, for synchronization of estrous in beef cows, beef heifers, and nonlactating dairy heifers.

Human Chorionic Gonadotropin (HCG) - This hormone, which has been used with some success in horse breeding, stimulates follicles to ovulate. It is most often given when the mare is bred. HCG will normally lead to ovulation of a mature follicle within 48 hours, aiding in appointment breeding (when a stud is being brought in from another farm at a specific date) and helping mares that fail to ovulate.

Syncro-Mate B® - This is the trade name for an estrous synchronization product approved by FDA in 1982. It contains Norgestomet®, a patented, potent, synthetic progestin, and estradiol valerate, a synthetic estrogen. SMB, which is used as an ear implant, is designed to cause cows or heifers to ovulate in a predictable period of time.

Melengestrol acetate (MGA) - This synthetic progesterone suppresses heat in feedlot heifers. A drawback of MGA is that FDA approval is pending. Research has shown that a combination of MGA and prostaglandins can make estrous synchronization practical for cattle producers. Feeding MGA to heifers for 14 days and then following up 16-18 days later with an injection of prostaglandin has resulted in a majority of the heifers coming into heat within five days.

Embryo Transfer

Embryo transfer (ET) is the placing of an embryo into the oviduct or uterus. ET in cattle was developed as a result of research done by Jim Rowson at Cambridge, England, in the early 1950s. The earliest work was done with sheep, then cattle and hogs. The first commercial embryo transfers in the U.S. were done in the early 1970s.

The steps of ET in cattle are:
1. Synchronize estrous in cows that will be used as *donors* of embryos and those that will be used as *recipients* of embryos.
2. Superovulation uses a drug that increases the number of embryos that can be collected from a single female by increasing the number of ova or eggs that she ovulates.
3. Breed the donor cow either through artificial insemination or natural service.
4. Recover the embryos from the donor cow (through a non-surgical method) 6-10 days after breeding.

5. Isolate and characterize each embryo to make sure it is normal.
6. Transfer healthy embryos to the recipient cows, which act as foster mothers.

Pregnancy can be confirmed in the recipient cows by rectal palpation of the uterus approximately 35 days after the transfer. Recipient cows with successful pregnancies from the embryo transfers will give birth to calves that are full siblings. Recipient cows have no genetic influence on the calves they carry. Producers often use recipient cows that are less desirable, grade animals because they make no genetic contribution to the calves that they carry.

The greatest advantage of ET is that it increases the reproductive potential of superior females in much the same way that AI increases the impact of superior males. Both of these reproductive techniques increase the number of offspring from a single valuable animal and the rate of genetic improvement in a herd.

Sexing Semen

Sexing semen determines if the semen contains the X or Y sex chromosome. If the semen contains the X chromosome, it will produce a female; if the semen contains the Y chromosome, it will produce a male.

Being able to obtain semen that has been sexed has great economic importance. Because the dairy producer has little use for bull calves, the use of sexed semen to produce only females would make milk production more efficient. Swine producers could market more pork if they could only produce females because females grow faster than males. The opposite is true in beef cattle and sheep, where males would be desired unless trying to produce replacement females.

Semen is sexed by the amount of DNA present on the X and Y chromosomes. The DNA content of the Y chromosome can be monitored because it contains less DNA than the X chromosome.

Cloning

Cloning of an animal is the production of an exact genetic copy. Cloning usually results from the

splitting of embryos, which produces genetically identical twins.

Summary

There are many management and technological techniques to control or synchronize an animal's reproductive cycle. All of the techniques need to be carefully analyzed before a producer decides whether to use any of them.

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Lesson 1:
Importance of Animal Health

Billions of dollars are lost every year due to general health problems, costing the average livestock producer 15 percent of annual cash receipts. Animal health is a large factor in the profit or loss of a livestock operation.

Careers Associated With Animal Health

There are many animal health occupations. Veterinarians are involved with many activities, including vaccinations, setting up health programs, deworming, curing sick or unhealthy animals, and detecting livestock diseases. They are also important information sources for livestock producers. Veterinarian services are an important part of any rural community that has a livestock base.

A livestock producer is also part of the animal health field. Most livestock producers do a majority of farm vaccinations and treatments, if they have the right facilities and equipment. Livestock producers are the first step in detecting diseases and administering the proper care before the disease affects the whole herd.

An extension livestock health specialist provides information about animal health problems and preventive measures. The Extension Service is a good resource for producers to use for questions about animal health problems. The service provides information about starting health programs, sanitation, and preventive programs.

An animal health products representative or salesperson offers equipment, medication, and necessary tools for administering on-farm treatments.

A livestock health scientist researches new cures and detects new diseases affecting livestock. Research by scientists reveals new drugs and cures every year. These scientists are usually employed by major universities, the U.S. Department of Agriculture, and in industry.

People in animal health enforcement make sure state or national regulations on transportation of animals, quarantining, and health certificates are obeyed. They also monitor livestock diseases so that they do not enter the country.

The animal health field is growing, especially in the service sector. The demand for specialized services grows every year. To meet this demand, anyone entering the animal health field needs a strong educational and experience background.

The Economic Importance of Animal Health

Literally billions of dollars are lost every year because of animal health problems associated with livestock. It costs the average producer 15 percent of cash receipts from livestock sales to cover losses due to poor animal health. This 15 percent means $11 billion lost every year in the U.S. These losses come from diseases of the respiratory, reproductive, and gastrointestinal tracts. External and internal parasites also cause income loss.

Producer losses - The following animal health facts influence the profit or loss of a livestock operation. Approximately 12 percent of the cows bred never calve due to general health problems. About 6 percent of all calves die between birth and weaning. Approximately 10 percent of all calves have scours, and about 18 percent of dairy calves with scours die. Cow-calf operators spend approximately $26.95 per cow on disease prevention and death losses. Approximately 1.5 million cattle are lost every year in the feedlot due to general health and/or nutrition problems, costing approximately $750 million.

About one in 10 dairy females have breeding difficulties due to general health problems. Approximately 40 percent of dairy cows are afflicted with a form of mastitis, which converts into $225 per year, per cow. Remember, mastitis-infected products cannot be used for human consumption.

About 5 percent of all ewes never lamb due to general health problems. Approximately 20 percent of all lambs die between birth and weaning due to general health problems. Approximately 3 percent of all lambs on a finishing ration die for the same reason.

Nearly 15 percent of all bred sows never farrow due to general health problems. Approximately one-fourth of all pigs die between birth and weaning.

Approximately 50 percent of all bred mares abort or have weak foals due to general health problems. This means that it takes two mares to produce one foal! Approximately 6 percent of all foals die between birth and weaning due to general health problems.

There are also hidden costs associated with animal health that are not figured into the $11 billion lost every year. These hidden costs are reflected by infected carcasses, poor meat quality, added labor costs, retarded growth, salaries for inspectors, depreciation of infected land, and many other costs.
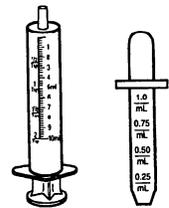
Animal health affects the economics of the average producer, but how does animal health affect the existence of the human race? Some animal diseases can be transferred to humans simply by touching the infected area. There are strict regulations for these diseases because of the effects they could have on humans. Following are some important animal diseases that can be transferred to humans simply through contact and oral ingestion.

Lyme disease - This disease is transmitted usually by a bite from an infected tick or by crushing one on broken skin. The recent increased risk to humans has been caused by more animals bringing the infected ticks closer to human habitations. Human cases of Lyme disease has been reported in the East coast, West coast, Great Lakes, and a few southern states. The closest states to Missouri that have reported human cases of Lyme disease are Arkansas and Tennessee. Human symptoms are a skin lesion around the bite and arthritis in large joints. Sometimes symptoms do not appear until four years after contact. Lyme disease is a curable disease, but there could be some permanent damage to a fetus and some neurological damage, which all can be prevented by early detection.

Brucellosis - Brucellosis is transmitted by touching an aborted fetus, a stillborn fetus, or placental tissues with broken skin; breathing aerosols

containing the organism (prominent in packing plants); or consuming unpasteurized dairy products. This organism cannot survive in dry, arid conditions; exposure to direct sunlight; or extreme hot conditions; but under favorable conditions, it can survive 3-4 months. Human symptoms are continued and intermittent fever, headaches, profuse sweating and chills, depression, body aches, and weight loss. Without proper treatment, these symptoms will persist for several months. This disease cannot be transmitted to other members of the family by human contact.

Rabies - Transmitted through the bite of a rabid animal, rabies is a natural disease occurring in animals to regulate over-population. In humans, 90 percent of rabies cases are from wild animals; the other 10 percent are caused by domesticated pets. Pet vaccination is vital in controlling this disease. In humans, rabies is a curable disease if caught in time, but even the cure is very painful.

Salmonellosisis - Transmitted by eating contaminated foods that are not properly stored or cooked. Salmonellosis can be found in pork, beef, poultry, eggs, milk, and even vegetables grown with infected fecal fertilizers. Human symptoms appear as intestinal infections, fever, abdominal cramps, vomiting, nausea, and diarrhea. Salmonellosis is treatable by simply correcting dehydration and electrolyte imbalances.

Trichinosis - This disease is transmitted by eating infested meat. Main sources of trichinosis are under-cooked pork and wild animals, primarily carnivores such as bears. With proper cooking, this disease can be prevented. Symptoms of trichinosis in humans are inflamed muscles or allergic reactions.

Cryptosporidiosis - Cryptosporidiosis is transmitted by eating contaminated food or water, as well as by working around infected fecal material. Generally, people do not even know they are infected by cryptosporidiosis, since the human body develops immunity and gets rid the disease naturally. Diarrhea is the typical symptom. This disease is more prominent in a population infected

with Acquired Immune Deficiency Syndrome (AIDS), since their immune systems no longer fight off disease.

Approval of Animal Health Drugs

A new drug usually starts with the discovery of a new compound or the need for a new drug. At the very beginning, a manufacturer must decide if it has the research capabilities for developing a new compound and the usefulness of the new compound. Once the manufacturer decides it is worth the time and effort, the compound begins a long journey for approval.

The research and development process ensures that the compound is effective, safe, and convenient to use. In 1988, animal health institutions spent $340 million dollars on research and development of new drugs. Every new compound must go through the following steps for approval and compliance.

The first step in drug approval is the discovery of a new compound that is suitable for the animal health field. This discovery could be accidental or could occur through research and development.

A compound must go through some preliminary trials. Three questions must be answered before an intense development procedure takes place: 1) Does the new drug have any undesirable traits? 2) What are the estimated costs for research and the anticipated demand for this new drug? What is the potential activity of the new compound? 3) Can it be confirmed that the new drug will do what it is supposed to do?

Pre-clinical trials are the next step in drug approval. Pre-clinical trials target animals that the drug can be used for. These trials are usually done in a laboratory on laboratory animals. Exaggerated dosages are given to determine effects on animals. If the manufacturer is still convinced of the effectiveness of the compound, the manufacturer notifies the appropriate agencies.

The INAD (Investigational New Animal Drug) and the EUP (Experimental Use Permit) are notification applications for the FDA and EPA. These

applications show the results of safety, effectiveness, and toxicity studies of the compound. The applications also include plans for continued testing of the compound, as well as small amounts of the compound. After receiving an INAD or EUP file number, the manufacturer makes the final decision to go on with clinical testing, which is the next step in approval.

Clinical trials consist of full-scale field trials. At this point, the manufacturer has made a sizable investment in the compound and has to determine if it will be economical to continue research. Field trials are done on animals targeted for usage. Studies consist of toxicity levels, dosage, residue studies, effectiveness, and blind studies. Studies where the animals are given the compound and the researchers are unaware of which animals received the compound are called blind studies. The data is evaluated to show the effectiveness of the compound.

When clinical studies are completed, a manufacturer can apply for the right to produce the new drug. The manufacturer files for an NADA (New Animal Drug Application) or a pesticide permit, if the compound is a pesticide. A typical NADA application would fill the average volume of an encyclopedia. This application reveals the results of environmental effects, safety to users, animals, and consumers.

Even after the drug or pesticide is approved and marketed, the manufacturer must monitor and report to federal agencies on their findings. Reports are due every six months for the first year, and once a year for the remaining years the drug or pesticide is produced. Further monitoring is done by veterinarians across the country. They report any adverse conditions that occur when using the drug or pesticide.

Population and Individual Medications

It is easy to distinguish between individual and population medications. Individual medications are given to one individual animal. The label verifies the dosage per individual, which is justified by body weight, age, or type of production. Individual medications can be over-the-counter drugs, extra label drugs, or prescription drugs administered by veterinarians. (Extra label drugs

carry a veterinarian-written additional label. This label includes information on drug dosage change, duration change, instructions for a different disease, and administration location.)

Population medications are mixed with feed, a complete feed, or fed by themselves. These medications are usually classified as feed additives and administered to a group of animals.

To deworm a pen of finished cattle, mix the dewormer into the feed and medicate the whole group. Population medications are usually mixed into the feed by a certain percentage, such as 2 percent of a ton or not more than 12 lbs. per ton.

As mentioned previously, individual medications are approved after going through a long, expensive process. Population medications or feed additives go through a totally different process for approval, with some aspects similar to individual medications. For both medications, federal agencies regulate their approval.

Interstate and Intrastate Regulations

It is a "buyer beware" market when purchasing and transporting livestock within the state of Missouri. Livestock can be transported anywhere in the state without health certificates. A buyer can request health papers, but the seller does not have to provide them. If a producer buys livestock at an auction, some health tests will be run at the sale barn. The types of tests are decided by the operator of the sale barn. Most purebred and crossbred operations have health papers on all stock in the operation.

Most other states have similar intrastate regulations. Each state has different regulations on interstate transportation of livestock. If a producer in Missouri sold some cattle to a producer in Kansas, the seller is responsible for finding out Kansas health regulations before the cattle can be transported.

Once the seller finds out the requirements for Kansas, a veterinarian can run the required tests on the cattle being shipped. If the lot of cattle pass the required tests, a health certificate is issued by the licensed veterinarian for that lot of cattle. The certificate stays with that group through the entire process of interstate transportation. If the lot does not pass the required tests, the cattle cannot be shipped to that state. A health certificate is not necessary for each state that the cattle pass through--just the state of destination.

There are other regulations that apply to interstate transportation of livestock. First, livestock cannot be transported on a rail car for more than 28 hours without rest, food, and water. This rest period must last for five hours or longer before being loaded back up for transportation. Second, livestock that travel by truck or trailer cannot be transported more than 24 hours without rest, food, and water. Again, they must rest for five hours or more before being loaded.

Summary

It is important to understand the economic importance of animal health and the costs associated with it. As a consumer, it is vital to understand diseases associated with animals and the possible human effects. Consumers and livestock producers should understand the importance of drugs and how they are approved for animal health.

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Lesson 2:
Immune System of Livestock

Diseases in livestock can cause suffering, death, and loss of income to the livestock producer. Fortunately, many of these diseases can be prevented by proper management and by enhancing the animal's natural ability to fight off disease.

Causes of Diseases in Livestock

A disease is any condition that detracts or interferes with an animal's well-being. Diseases are often classified as infectious or noninfectious, depending on whether another living organism enters the animal's body (infects the animal) and by its activity causes disease.

Noninfectious diseases - These diseases are not caused by infectious organisms. However, there are numerous other causes. Nutritional diseases can occur when the animal receives too little or too much of a particular nutrient in the diet. Obviously, if an animal receives nothing to eat, it will starve. Starvation is a nutritional disease; however, most nutritional diseases are more subtle. A deficiency of certain vitamins and minerals can produce a variety of symptoms, such as poor growth, weak bones, weak muscles, poor eyesight, and a decreased resistance to other diseases.

Metabolic diseases can occur when the animal's organs don't function correctly or when the animal undergoes major changes in its life. For example, when a cow gives birth to a calf, she begins producing milk to feed the calf. The cow normally uses calcium from her body to put into the milk. However, some cows use too much calcium from their bloodstream. Since calcium in blood is necessary for normal muscle function, these cows are weak and unable to stand. This metabolic disease is sometimes called milk fever.

Toxic diseases are caused by exposure to poisonous materials. There is a wide variety of poisonous or toxic materials around homes and farms, and the symptoms of disease will differ with the different poisons. Some of the more common livestock poisonings involve farm chemicals (such as insecticides and herbicides) and automotive products (batteries, antifreeze, etc.). Some poisons form when mold grows on grain or hay that is used for feed. Some plants are poisonous.

Certain diseases result from injury or trauma. Lightning strike is one example of an injury that occurs when livestock are on pasture in a thunderstorm. Most injuries are not this dramatic. Some animals become lame after injuring their feet on rough or rocky surfaces. Predator animals (such as wolves and coyotes) may attack and injure livestock. People caring for livestock need to be aware of things that can injure their animals and protect them as much as possible.

Diseases that are present at birth are called congenital diseases. These are often caused by faulty development of the fetus inside the mother's uterus. Some examples are cleft palate (a hole in the roof of the mouth) and ventricular septal defect (an abnormal opening between two heart chambers). If a female calf is twin to a male calf, her reproductive tract may not develop normally. This congenital condition is known as free-martinism and will result in the calf being sterile (unable to reproduce).

Diseases that are inherited from parents are genetic diseases. Symptoms of genetic diseases may or may not be present at birth. One example is porcine stress syndrome. Pigs affected with this disease will become rigid from muscular contractions, and their body temperatures become very high when they are subjected to stress. Additionally, they may have labored breathing, shaking, and blotchy skin. Breeding pigs can be tested for the defective gene that causes this disease. If the parent pigs are free of this defective gene, their offspring will not be affected.

Infectious diseases - Infectious diseases are caused by other living organisms that infect (live in or on the animal) and cause disease. Organisms that can cause disease are sometimes called pathogens. The way that these organisms cause disease varies. Some organisms actually kill the cells or tissues that they infect. Other organisms produce toxins or poisons that have an adverse effect on the animal's body. Sometimes the body's response in trying to rid itself of the infecting organism will cause pain, discomfort, and loss of normal function. Most infectious diseases of

livestock are caused by bacteria and viruses. Some diseases are caused by fungi or protozoa.

Bacteria - Bacteria are microscopic, single-celled organisms. Bacteria are very common; in fact, millions of bacteria live inside every normal person and animal. Most bacteria are harmless, and some may even be beneficial. However, a few bacteria are pathogenic (disease-causing) and can be harmful to the animal. Pathogenic bacteria require moisture, warmth, and nutrients to grow and multiply. An animal's body provides all of these requirements.

Bacteria cause disease when they grow in places where they are not supposed to grow or when they produce by-products that are harmful to the animal's body. Some examples of bacterial diseases are *E coli* diarrhea in calves and piglets, blackleg in calves, and erysipelas in pigs.

Viruses - Viruses are extremely small particles that typically consist of nucleic acid centers (genes) surrounded by capsules of protein and/or carbohydrates. Viruses are so small that they can only be seen under most powerful electron microscopes. Viruses cannot grow or reproduce unless they infect the cells of another organism. Pathogenic viruses can destroy cells or change their function in such a way that causes disease. Some examples of viral diseases in livestock are infectious bovine rhinotracheitis (IBR or red nose) in cattle and transmissible gastroenteritis (TGE) diarrhea in pigs.

Fungi and protozoa - Fungi share some characteristics with bacteria; however, they are usually more complex in form. Fungi can consist of more than one cell with different functions. Most familiar fungi (mushrooms, molds) do not infect animals. However, some diseases, such as ringworm and thrush, are caused by fungi, which can infect animals.

Protozoa are single-celled animals. As with bacteria, most protozoa are harmless and some are even beneficial. Some protozoa live inside cattle rumens and help them digest grass and hay. Other kinds of protozoa, such as coccidia, infect animals and cause disease. (See Figure 2.1.)

Types of Immunity

Animals are faced with exposure to potentially pathogenic organisms every day and usually do not get sick from these exposures. Fortunately, animals have mechanisms to ward off these threats to their health: natural and acquired immunity.

Animals possess natural barriers to infection with disease-causing organisms. For example, the skin is usually an effective barrier and prevents pathogens from entering the body. Mucus from the nose and tears from the eyes usually trap pathogens before they can infect the body.

Also, animals can protect themselves from specific pathogens. Certain body cells examine everything they contact to determine whether or not it belongs there. If these cells come into contact with a pathogen, they recognize that it does not belong, and they then notify the immune system to produce antibodies against that particular pathogen.

Antibodies are protein molecules that bind with the pathogen and help other cells in the body eliminate it. These cells also remember pathogens that they have seen before, so that they will be even more efficient at removing them the next time.

The immune system can be stimulated to produce antibodies against a pathogen by a natural

FIGURE 2.1 - Protozoa (Pathogens)
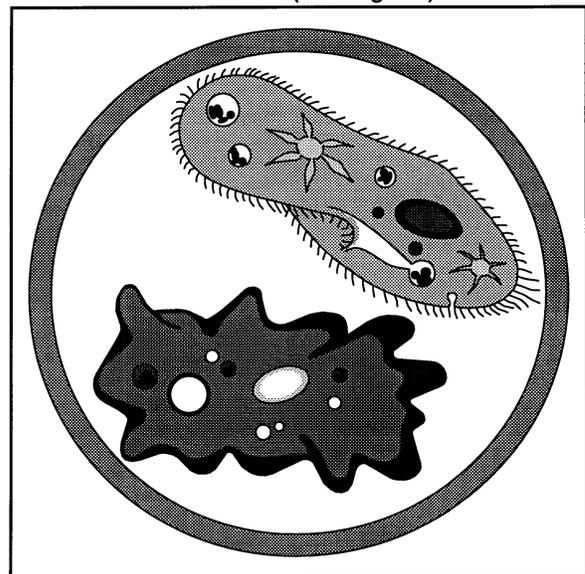
exposure to that pathogen or by vaccination. This process is called active immunity. In passive immunity, animals may also receive antibodies that another animal has made. This occurs when a baby animal receives antibodies from its mother through the colostrum or first milk. It may also occur when blood serum (which contains antibodies) is taken from one animal and injected into another animal.

Types of Immunizing Agents

Although animals form antibodies against a certain pathogen when they are naturally exposed to that pathogen, it is often better if people help them form antibodies *before* they are exposed to the pathogen. This is done by giving them vaccines. Vaccines are basically a modified form of the pathogen that will not cause disease.

Modified live vaccines are live viruses or bacteria that have been changed so that they will not produce disease. These vaccines are usually very effective at stimulating the animal's immune system.

Killed vaccines consist of viruses or bacteria that have been killed, often by treatment with heat or chemicals. Since the pathogens have been killed, they are not capable of producing disease. Killed bacterial vaccines are sometimes called bacterins.

Toxoids are a form of toxin or poison that has been changed so that it no longer has its toxic effects but it will help the animal produce antibodies against the toxin. The most common example of a toxoid is the tetanus vaccine for horses and sheep. The disease symptoms of tetanus are caused by a toxin, which is produced by the tetanus bacteria, *Clostridium tetani*.

Antisera and antitoxins are antibodies to specific pathogens and toxins that have been formed in the blood serum of another animal. While these antibodies give quick protection against certain diseases, this passive immunity does not last as long as the active immunity stimulated by vaccines and toxoids.

Antibiotics

Antibiotics are compounds produced by microorganisms (often fungi) that either kill or inhibit the growth of other bacteria or fungi. These compounds are most often given either by mouth or by injection to help cure or prevent bacterial infections. Many different antibiotics are available.

Two of the most commonly used antibiotics are penicillin and tetracycline. Some pathogens are resistant to the effects of certain antibiotics, so antibiotics should be chosen based on the susceptibility of the pathogen to that antibiotic. Antibiotics have no effect on viruses; therefore, they are not useful for curing viral infections.

Summary

Diseases can be a significant problem in livestock production. Diseases can be either infectious (caused by a pathogenic organism) or non-infectious. Noninfectious diseases can be nutritional, metabolic, toxic, traumatic, congenital, or genetic in nature. Infectious diseases can be caused by bacteria, viruses, fungi, or protozoa. The animal's immune system fights off infectious pathogenic organisms and can be enhanced by giving vaccines or other immunizing agents. Also, antibiotics can be given to help an animal fight off some bacterial infections.

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Lesson 3:
Respiratory Diseases
Affecting Livestock

Livestock producers or those in related occupa-
tions should understand the effects of respiratory
diseases on a single operation *and* the entire
livestock industry. To prevent diseases from
spreading throughout the herd and causing
extreme losses, a producer must be able to
recognize the symptoms of these diseases.
Everyone should understand how outside
influences can trigger respiratory infection within a
herd. Stress can lead to many infections in
livestock. Like humans, animals under stress are
more likely to be invaded by viruses or bacteria
because their bodies are run down.

Swine

Atrophic rhinitis - Atrophic rhinitis is a highly
transmissible disease in swine that causes
distortion of the nasal passages. It is caused by
bacteria *(Bordetella* and *Pasteurella).* Infected
swine have lower levels of production and are
more susceptible to other respiratory diseases.
Atrophic rhinitis is not a fatal disease--just an
unwanted disease. It is transmitted as an aerosol
from an infected hog to a noninfected one.
Carriers besides swine include dogs, cats, rabbits,
mice, turkeys, horses, and humans.

Sneezing and sniffling are the most common
symptoms in swine and are early detections for the
disease. Coughing and snorting are other
symptoms of Atrophic rhinitis. Inflammation of
nose membranes is also a good indication of this
disease. As the disease matures, the shape of the
nose becomes deformed. The nose turns to one
side or the other by as much as 45 degrees.

For prevention, a producer must monitor the herd's
contact with outside animals. A producer must
also correct environmental deficiencies in
sanitation, temperature, humidity, and ventilation.
Control dust, drafts, excessive ammonia, and
overcrowding.

To treat this preventable disease, a producer must
first isolate infected animals to prevent further
spreading. Uninfected animals can be protected

from *Bordetella* and *Pasteurella* organisms by
medicating the feed with sulfamethazine or
oxytetracycline.

Mycoplasma pneumonia - Mycoplasma pneumonia
transmission occurs easily by contact.
Transmission can also occur through infected
clothing, dust, and carrying by the wind from shed
to shed. Young pigs are most susceptible at 3-9
months. Pigs with Mycoplasma pneumonia that
appear to have recovered remain carriers of the
disease. Symptoms can reappear if the pigs come
under stress. The mortality rates of Mycoplasma
pneumonia are relatively low, but secondary
infections can increase the risk of death, so
treatment is important in controlling the disease.

A dry, hacking, repetitive cough in young pigs is a
typical symptom of Mycoplasma pneumonia.
Infected pigs remain alert and have a healthy
appetite, but they also have reduced growth rates,
weights, and feed efficiency. Pigs with acute
cases cough and pant and appear to have a fever,
little appetite, and a staggering gait.

For prevention, isolate and observe outside
animals brought into the herd. This also applies to
animals suspected to be infected. After working
with infected animals, change and wash clothing
worn during the process. Make sure there is
appropriate feed and water so the animals do not
come under further stress. There are vaccines
available to prevent this disease.

There are a wide variety of antibiotics and feed
additives to treat animals. It is a good idea to use
different medications so that the disease does not
become resistant to one specific medication. Keep
infected animals isolated in a dry, warm, well-
ventilated area with appropriate feed and water.

Pasteurella pneumonia - Pasteurella pneumonia is
like most respiratory diseases in that it spreads in
the aerosol form. Younger swine are generally
affected by the disease. Pigs of 8-24 weeks of
age are most susceptible. Mortality rates are high
if effective treatments are not administered. If not
treated, death can occur as quickly as 5-10 days.

Fever, coughing, depression, mouth breathing,
and labored abdominal movements are all typical
acute symptoms of Pasteurella pneumonia.

Chronic symptoms are intermittent coughing and signs of ill thrift.

Chilling, dusty conditions, poor nutrition, ration changes, overcrowding, poor ventilation, and poor hygiene can trigger Pasteurella pneumonia. All these factors are signs of poor management.

Infected animals can be treated by injected antibiotics. Other animals that shared the same airspace can be treated with feed or water additives for 5-7 days. Like most respiratory diseases, Pasteurella pneumonia is very treatable and preventable if caught early enough.

Haemophilus pneumonia - Haemophilus pneumonia affects all ages of swine, but generally weaning-age pigs are most susceptible. Like most respiratory diseases, Haemophilus pneumonia transmits in the aerosol form. Mortality rates are as high as 60 percent if not treated quickly.

Severe respiratory distress, severe abdominal respiration, and bloodstained discharge from the nose and mouth are acute symptoms of Haemophilus pneumonia. This particular disease hits fast. Some infected pigs die within a few hours or in couple of days. Pigs that lie and don't want to move show fatal signs of this disease. Chronic cases are usually non-fatal, but they do show signs of ill thrift, persistent cough, fever, and respiratory distress.

There are some good preventive measures for Haemophilus pneumonia. One is to provide well-ventilated, clean, and uncrowded environmental conditions. Treated, infected pigs usually develop immunity to future outbreaks. Also, sows that have been infected and treated will pass immunity to their offspring by colostrum in the milk. It is also a good idea to isolate outside animals for a while to look for any symptoms.

There are several antibiotics available for treatment of secondary infections in affected pigs. Treatments come in the forms of feed or water additives and administered injections. Haemophilus pneumonia is treatable if animals are isolated quickly to prevent spreading of the disease and secondary infections.

Salmonella choleraesuis - This organism enters the body orally, multiplies in the intestinal tract, crosses the intestinal wall, and spreads throughout the rest of the animal. It undergoes its most rapid growth in the lungs and does the most damage there. This disease is most usually seen in pigs from 40 pounds to finish weight but can occur at any age.

The most common sign is sudden death in pigs that had been doing very well. If observation is frequent enough and detailed enough, one may actually see pigs become somewhat listless, experience difficulty breathing, and progress rapidly to severe respiratory difficulty and death. Animals dying from this disease often have purplish discoloration of the ears, belly, and/or feet and lower legs. Clinically, this disease is nearly impossible to differentiate from *Actinobacillus pleuropneumonia.*

Sanitation efforts are extremely cost-effective in preventing this disease because it is transmitted through the feces. Minimizing stress also helps in prevention; many hogs can be carriers but yet will never have problems if they are not stressed enough to lower their resistance. Stressors include overcrowding, drastic temperature fluctuations, feed/water shortages, movement, mixing, etc. While preventive antibiotic therapy and/or use of vaccines can offer some benefit, their long-range cost-benefit ratio will not be as great as improved sanitation and decreased stress.

In an outbreak, water medication and individual injections with appropriate antibiotics are the best approaches. Feed medications can help in long-term control, but sick pigs will simply not eat enough feed to make it a successful treatment method. Antibiotic selection needs to be based on cultures tested in a laboratory and known successes in the local region.

Porcine Reproductive and Respiratory Syndrome (PRRS) - This disease was first diagnosed in the mid-1980s and was originally known as Swine Mystery Disease. It is caused by a type of virus, which produces two known syndromes: a reproductive herd problem and a respiratory syndrome found primarily in pigs younger than 10 weeks old. The virus is usually transmitted by pig-to-pig contact. The virus is shed from the respiratory

system, in the feces, and in the semen. There may be some transmission through the air.

PRRS presents itself primarily as a difficulty in breathing that often progresses to a deep cough, rough hair coat, poor growth, and an increase in secondary bacterial infections of the respiratory tract (e.g., *Pasteurella, Bordetella, Haemophilus, Streptococcus, Actinobacillus, Salmonella,* etc.). Incidence of the disease is variable. Death losses can often be as high as 25 percent within a group of pigs. Deaths are from secondary infections, not from the virus itself.

The best prevention is maintaining a negative herd through tight biosecurity and obtaining replacement stock from a known negative herd. In addition, making use of all-in, all-out pig flows will help prevent the disease from ever reaching its most severe level. A commercially approved vaccine is available to help prevent the disease. It is approved for use pigs that are 3-16 weeks old.

There is no treatment for the viral disease itself, so treatment efforts are aimed at secondary invaders that complicate and worsen the disease. Treatment, therefore, depends on which secondary problem exists.

Cattle

Infectious Bovine Rhinotracheitis or "Red Nose" (IBR) - IBR is transmitted by infected droplets that spread by coughing and by nose-to-nose contact. (See Figure 3.1.) The disease can also be spread

venereally or by contaminated examination instruments. The virus can be found in infected tissues of aborted fetuses and in nasal or ocular (eye) fluids of infected animals, but it is rarely found in blood. All ages and breeds of cattle are susceptible. IBR can be fatal, but generally it only causes other respiratory and reproductive problems to appear.

Symptoms associated with IBR are: open-mouth breathing, fever, large amounts of nasal discharge, and a fiery red nose. Other prominent signs of IBR are: depression, lack of appetite, labored breathing, and coughing.

Prevention is difficult since the IBR virus is so widespread; it is hard to find a herd that does not have a carrier. Prevention is usually by vaccines and natural immunity. Less-confined environments reduce chances of an outbreak of IBR. Cattle can develop a natural immunity to this disease, but vaccinations prevent secondary infections and spreading.

Antibiotic treatment of severely affected animals helps suppress secondary infection, but antibiotics have little to no effect on the actual virus. The animals have to rid their bodies of the virus naturally to recover.

Pasteurella infections - Pasteurella is a bacterial infection usually affecting feedlot, grouped, or well-confined animals. This disease can affect all ages of cattle. A Pasteurella infection can spread by droplets in the air, contact, coughing, or feeding

Figure 3.1 - Nose-to-Nose Contact
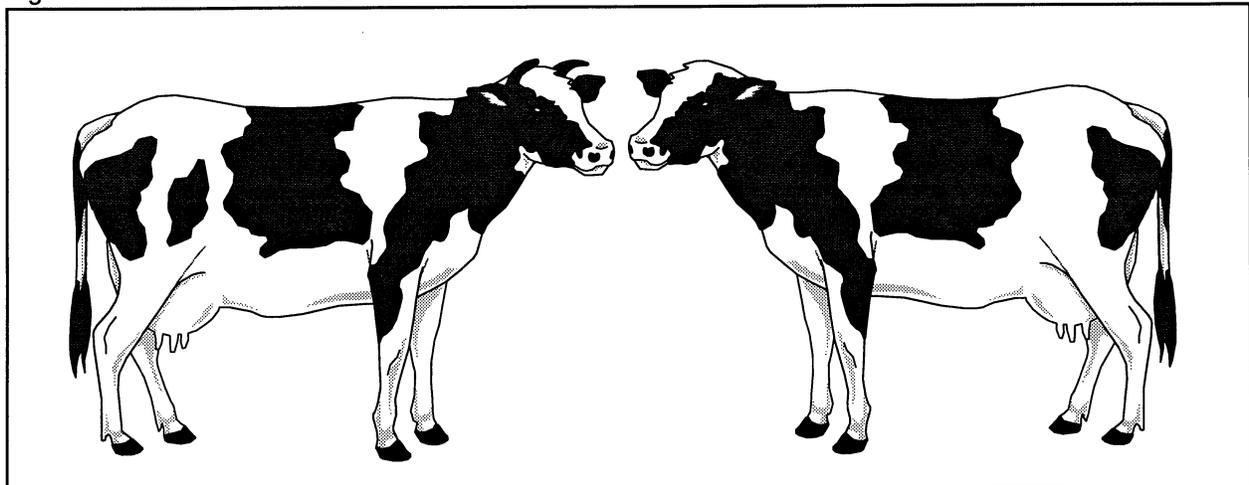
equipment. This is a very treatable disease, especially in older animals. Fatal cases tend to hit the younger population.

Infected animals show signs of fever, persistent cough, nasal discharge, rapid respiration, and sometimes diarrhea. Other symptoms are depression, lowering of the head, and eye discharge.

Prevention depends largely on good management practices to avoid additional stress on animals. Do not make quick ration changes; avoid overcrowding, outside infections, and stressful movement of cattle. Quickly isolate suspected infected animals.

For treatment, keep isolated animals in a dry, warm, well-ventilated area. Use antibiotics and proper environmental conditions to speed up the recovery process.

Bovine Respiratory Syncytial Virus - BRSV usually targets the younger population of cattle in feedlots. Transmission occurs through the aerosol form or by contact. Generally, weaning-age stock is infected the heaviest with the disease. Cattle that are 6-9 months old are most susceptible in feedlot conditions and have high mortality rates. Older cattle can be affected with the disease, but they have much lower fatality percentages.

Coughing, depression, large quantities of nasal discharge, open-mouth breathing, and frothing are true indications of BRSV. Fever, severe respiratory distress, and extension of the neck are other symptoms. The highest number of reported cases are during July through October. Once environmental conditions cool down, the cases decline in number.

For prevention, producers need to keep a watchful eye on weaning-age stock in feedlot conditions, since this is the most susceptible population. Isolate suspected animals as quickly as possible to reduce the spread of the disease. Do not make sudden changes in diet or water supply because this will place extra stress on the animals. Vaccines are available to prevent BRSV.

Antihistamines and vitamins are used for treating animals infected with BRSV. Revaccinating for

IBR has been effective against BRSV. Remember, isolating infected animals and providing proper environmental conditions will aid in treatment.

Bovine Virus Diarrhea (BVD) - BVD infection generally occurs by contact, infected urine, or by the aerosol form. All populations can be affected, but the most susceptible cattle are 6-18 months old. More cases of this disease are reported during the winter and early spring months. A persistently infected bull can spread the disease through his semen to uninfected cows and their fetuses.

Acute cases generally show signs of a fever, depression, weakness, oral and nasal lesions, dehydration, diarrhea, lameness, nasal discharge, and increased salivation. In acute cases, fatalities usually occur 3-4 days after infection. Since the disease is carried through the bloodstream, pregnant cows can abort their fetuses. Chronic cases can linger for 2-6 months and sometimes past a year. These chronic cases remain carriers for the disease and are a detriment to the herd.

Stress, hormonal changes associated with puberty, and the enhancement of an already existing virus can trigger an infection of BVD.

There are vaccines available to control the spread of the disease. Infected animals usually die, and the ones that survive should be destroyed.

Horses (Equine Family)

Strangles - Due to bacterial *Streptococcus equi*, younger horses are particularly susceptible to strangles, but any horse that has not been infected
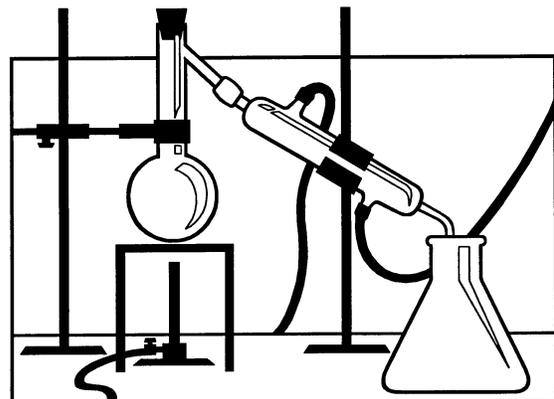
before will be susceptible. Infection spreads by inhaling or ingesting droplets breathed or coughed from infected animals. This very contagious bacterial disease affects the upper respiratory tract in horses. This is a very treatable disease, but it can be fatal and spreads quickly.

Animals infected by strangles have a very high fever, coughing, snorting, and thick mucus discharge. The throat, pharynx, and larynx become inflamed, and the animal has difficulty swallowing. Often when food or water is swallowed, these substances are regurgitated back through the nostrils.

Isolating infected animals helps control spreading of the disease. Cold, poorly ventilated, and very confined conditions can lead to an outbreak. Overworked animals and severe weather conditions can also increase the chances for this disease. Since humans can also spread the disease, disinfect all clothing after working with infected animals.

There are several antibiotics for treatment. Early treatment will help prevent abscesses and secondary infections. Isolation of infected animals is very important in treatment and control.

Rhinopneumonitis - This viral disease is transmitted by droplets in the aerosol form. The virus circulates through the bloodstream and localizes in the respiratory tract. Generally, only younger horses contract the disease. It can only be spread in the aerosol form. Horses and donkeys are the only species that are infected naturally. Rhinopneumonitis is a treatable disease, but it has the tendency to abort foals in pregnant mares.

Generally, an outbreak occurs in the autumn and winter months and is usually mistaken for a cold. Horses infected by the disease will have a fever, congestion, and nasal discharge. Sometimes coughing and loss of appetite can be symptoms. This disease is very difficult for a rancher to diagnosis without the help of a licensed veterinarian.

Isolate infected animals from the herd. A rancher could reduce outbreaks by not confining animals to tight, poorly ventilated areas. Vaccinations can be

used, but they are not proven 100 percent effective.

There are a number of antibiotics that can be used to control secondary infections. Certain antibiotics are used strictly for nursing mares, and others are used for gestating mares.

Equine influenza - Equine influenza is an acute, highly infectious, viral disease in horses. It is transmitted as an aerosol and has very high mortality and abortion rates. Outbreaks usually occur when moving or grouping horses. This disease is so infectious that horse shows require papers stating that the animal has been vaccinated against Equine influenza.

Symptoms are very similar to other respiratory diseases in horses. These symptoms include: fever, nasal discharge, depression, weakness, dehydration, and loss of appetite. This disease is fatal but can be treated if caught quickly. Death and aborted foals are extreme symptoms of Equine influenza.

For prevention, ranchers and owners must be aware of this disease when grouping or moving horses. They also must be aware of outside contact with other horses. As mentioned before, there are vaccinations to prevent this disease.

Isolating infected horses is vital in treating them and preventing the spread of the disease throughout the herd. Keeping the infected animal in a dry, warm, well-ventilated area will also help in treatment. Antibiotics prevent secondary infections.

Summary

It is important for livestock producers and others in the livestock health field to have a good knowledge base of respiratory diseases, their symptoms, and treatments. The producer is the first step in prevention, treatment, and detection of any respiratory disease because he/she comes into contact with the animals more often than any other person. Everyday observations of livestock are critical for prevention, treatment, and detection of respiratory diseases.

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Lesson 4:
Diseases of the Gastrointestinal Tract

Good management practices can greatly reduce the spread of disease. An example of a good practice is when the producer cares for healthy newborns first, then does chores with the other animals. Sanitation and disinfection are also very important in killing disease-causing agents and keeping them from spreading. Following recommended vaccination and deworming schedules will eliminate many parasite-related gastrointestinal problems. For newborns, receiving colostrum within the first few hours of birth helps ensure antibody protection against many diseases.

In some sections of this lesson, the "diseases" discussed are actually conditions or problems, rather than infectious diseases.

Swine

Baby pig diarrhea - *Escherichia coli* (*E coli*), transmissible gastroenteritis (TGE), rotavirus, coccidiosis, *Clostridium perfringens* type C, and various combinations are the causes of diarrhea in baby pigs. Diarrhea is especially a problem in sows with poor milk flow and in unsanitary, continuous flow farrowing areas.

With any of the baby pig diarrheas, it is better to prevent them with vaccination, cleaning, and disinfection to reduce the number of pathogens in the environment. Vaccines are given to the sow before farrowing so that she will pass antibodies to the pigs through her colostrum.

E coli bacteria adhere to the lining of the small intestine and produce toxins, which cause the intestine to secrete excess fluid. The affected pig has diarrhea and becomes ill from dehydration. Sows can be vaccinated against *E coli* before farrowing. In treatment, antibiotics can help, as can oral or injectable fluids.

FIGURE 4.1 -
Oral Syringe
and Dropper
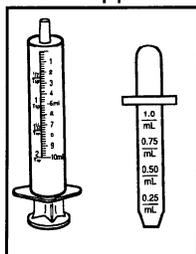
The viruses TGE and rotavirus infect and destroy the lining of the small intestine. This prevents the intestines from absorbing nutrients and fluid. The affected pig is contagious and has diarrhea and vomiting, which produces dehydration and starvation. Vaccines for both TGE and rotavirus are available; dehydration can be treated with oral or injectable fluids.

Clostridium perfringens type C is a toxin-producing bacterium that kills the lining of the small intestine. This prevents proper absorption and digestion. The pig can have bloody diarrhea and can die of dehydration and starvation. For prevention, sows can be vaccinated before farrowing. Pigs with diarrhea can be treated with antibiotics and oral or injectable fluids.

Coccidia is a protozoan that infects the lining of the small intestine and eventually causes death with improper absorption and digestion. As with the other pathogens, this produces diarrhea and results in dehydration and starvation. Pigs can only be treated with oral or injectable fluids.

Adult diarrhea and gastrointestinal disease - Causes of these conditions and diseases are swine dysentery, salmonellosis, proliferative enteritis, whipworms, and gastric ulcers. These diseases usually occur after a pig has been weaned but can also occur in adult breeding animals. Good sanitation and all-in/all-out pig flow management will help control these diseases. All-in/all-out pig flow management is farrowing house scheduling in which sows and pigs are moved in and out as groups so proper sanitation and disinfection can keep TGE from spreading to the next group.

Swine dysentery is caused by bacteria. The disease can also be carried by animals that do not show symptoms. Symptoms include bloody diarrhea and inflammation of the large intestine. For control, add appropriate antibiotics to the feed or water.

Salmonellosis is also caused by bacteria—most commonly *Salmonella choleraesuis*. Besides causing diarrhea and inflammation of both small and large intestines, this bacterium can also cause an infection of the bloodstream. Infected pigs often become very sick with high fevers; the skin around their ears, snout, and flank will turn purple.

Antibiotics can be added to the feed or water for control.

Proliferative enteritis is caused by bacteria. It causes an inflammation and thickening of the intestinal lining. This often results in dark, bloody diarrhea. Antibiotics can help with control.

Whipworms are worm parasites. They cause an inflammation of the large intestine and bloody diarrhea. Deworming medicines are the appropriate treatment for whipworms.

Gastric ulcers are caused by several factors, one of which is finely ground feed. Pigs with gastric ulcers do not eat well and can bleed into their stomach. This can cause their manure to look very dark and tarry. There is little practical treatment.

Cattle

There are four major categories that cause gastrointestinal difficulties in cattle: anatomical problems, mechanical problems, toxins, and infections (viral and bacterial).

Anatomical problems - **Displaced abomasum** occurs when the abomasum (true stomach) gets out of position and becomes twisted, thereby affecting the entire digestive system. The exact cause is unknown. Early diagnosis by a veterinarian is important, as a case of simple displaced abomasum can progress to left displaced abomasum (LDA), right displaced abomasum (RDA), or abomasal volvulus, which is life threatening.

Symptoms include decreased appetite, no cud chewing, decreased milk production, abdominal pain, a sprung rib cage, and a temperature. With calves, the main sign is chronic bloating. Diseases such as ketosis, mastitis, and metritis can occur at the same time.

The best precaution against this condition is good feed management. Do not change feed rations too rapidly just before, or immediately after, parturition. Make sure the dietary fiber needs are met in both quantity and fiber size. With simple displaced abomasum, laxatives or antacids can be effective, as can a "rolling" technique. Surgery is usually

required for valuable cattle with LDA, RDA, or abomasal volvulus.

Vagus indigestion occurs when the main nerve (vagus nerve) controlling gastrointestinal movement (motility) is damaged or pinched. Clinical signs include lack of appetite and lack of intestinal sounds.

Some cases cure themselves spontaneously and a few respond to veterinary treatment, but many never recover and subsequently die.

The most common **dental problem** is the extreme wear or loss of teeth. This occurs naturally with age and can occur very rapidly, depending on the geographic region and feeding practices. Some diseases, primarily nutrient deficiencies or excesses of calcium, phosphorus, and Vitamins D and A, can affect proper dental development.

Intestinal tortions, intussusception and **hernias** can result in loss of appetite, blockage of the intestine, severe pain, and eventual death. With intussusception, part of the intestine slips into a nearby area, causing obstruction. A veterinarian is required to surgically correct these abnormalities.

A **prolapsed rectum** generally occurs as a result of severe coughing/respiratory disease, diarrhea, or straining from constipation. Correction of the slipped rectum and proper healing requires early recognition, surgical repair, and correction of the true cause.

Mechanical problems - **Hardware disease** is most frequently seen with dairy cows, which are the most haphazard eaters among cattle. Debris that is consumed with forage can include wire and nails. The reticulum/first stomach traps most foreign objects, but a sharp object can perforate the reticulum, liver, or nearby heart. Sharp objects can also affect the lungs or cause leakage of digestive fluids.

An animal with hardware disease will lose appetite, prefer to stand quietly with an arched back, have impaired milk and other body functions, urinate frequently, breath with difficulty, and have a slight temperature. A grunting sound might accompany the pain, especially if pressure is applied to the

reticulum area (sternum). With chronic cases, the disease becomes difficult to diagnose because of confusing signs as the hardware moves through the body. An X-ray or exploratory surgery is needed for definite diagnosis.

Hardware disease can be prevented by passing a magnet into the reticulum, where it attracts and holds harmful metal objects. Without the magnet, the animal might heal on its own, or it might have complications and even die. Inexpensive treatment involves reducing feed intake and allowing the animal to remain still. Broad-spectrum antibiotics fight infection. For valuable cattle, surgery to remove the object and drain abscesses is an option.

Bloat occurs when the esophagus becomes blocked where it opens into the rumen; this blockage prevents the animal from burping normal rumen gases. The cause can be something lodged in the esophagus, such as a hedge apple; a cancerous growth; overeating of grain or legumes, such as clover and alfalfa; or injury.

Affected animals are off their feed and have a ballooned left abdominal wall. Severe cases cause both sides of the abdomen to balloon and can result in death due to pressure on the diaphragm and prevention of normal breathing.

Treatment is accomplished by passing a tube down the esophagus to release the gas and by placing supporting medication into the rumen. Severe cases might require surgical release of the gas through the left abdominal wall. This should not be attempted without proper training.

Ulcers can occur at any point along the gastrointestinal tract of cattle. They can be caused by ingested toxins, viruses, or improper diets. True stomach ulcers, like those in people or pigs, occur only in the abomasum. Affected animals are off their feed and can pass dark feces if bleeding is occurring. Treatment usually consists of supportive care and medication until the ulcers heal themselves.

Toxins - Toxins affecting cattle can be from manufactured sources, such as lead, insecticides, herbicides, fertilizer, etc., or naturally occurring plants, such as yew bush trimmings, wild cherry leaves, etc. They are most often taken in orally, but some can be absorbed through the skin.
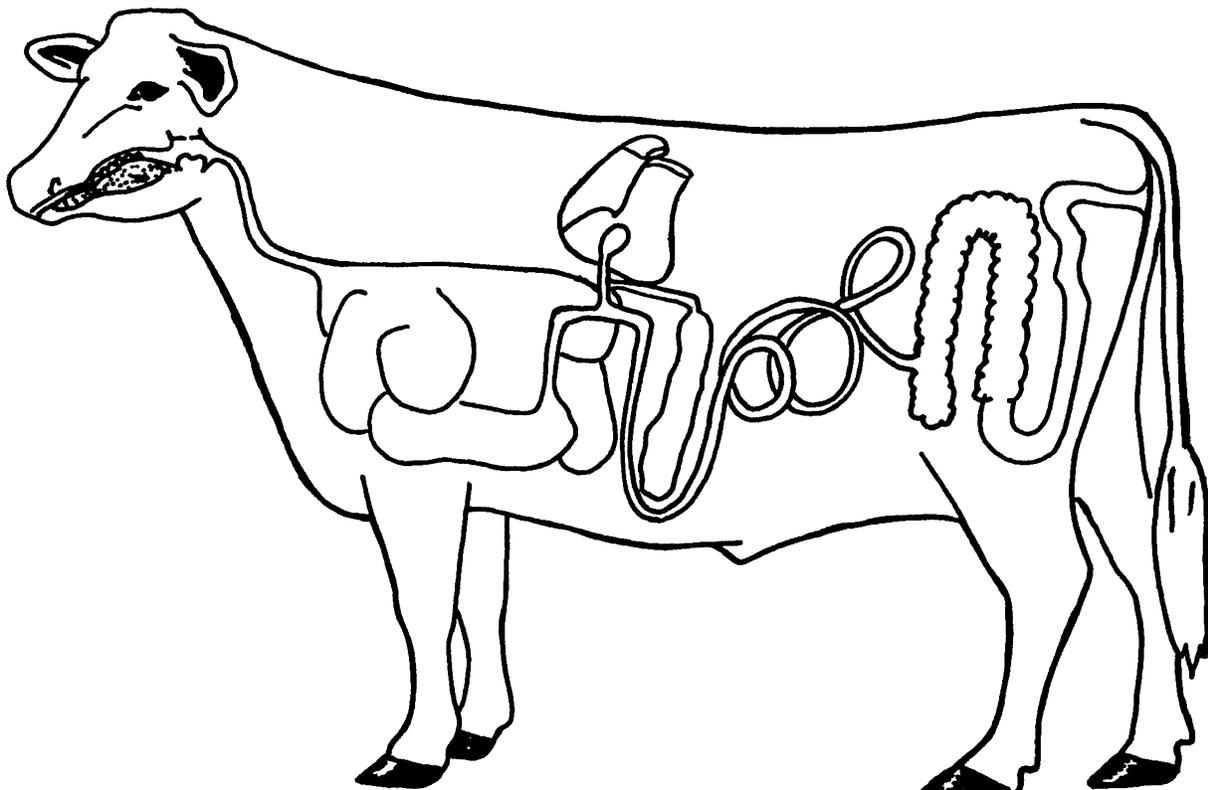
The effect of toxins on the digestive tract of cattle varies, depending on the type of toxin and the amount. Clinical signs vary from mild lack of appetite to severe constipation or diarrhea. In addition, other organ systems can be affected, making treatment and recovery very difficult.

Successful treatment requires the help of an experienced veterinarian. The proper use of antidotes, laxatives, and absorbents requires professional diagnosis and training. The best treatment, of course, is to prevent exposure to toxins.

Infectious problems (viral and bacterial) - **Scours/diarrhea** is a problem for all ages of cattle, but it is particular deadly for calves younger than 10 days old. Three categories are generally responsible for scours: (1) bacteria—*E coli, Salmonella,* and *Clostridium perfringens* types A, B, C, and E; (2) viruses—rotavirus, coronavirus, IBR, and BVD; and (3) contributing environmental factors, such as overcrowding, lack of colostrum, vitamin deficiency, and parasites. *E coli*-triggered diseases are the largest cause of calf death. Determining the specific cause of diarrhea often requires a veterinarian and diagnostic laboratory.

Symptoms include watery feces, weight loss, dry skin, weakness, and depression. Animals that lose 15 percent of body weight from dehydration generally go into a coma and die.

Dehydration is the main damage caused by scours. It can be treated through oral fluids and electrolyte therapy, much like drinks professional athletes consume after hard exercise. Antibiotics are effective for some causes; consult a veterinarian. For sick calves, milk replacer and electrolytes are used to rehydrate and nourish the calf while it fights the infection (with the help of antibiotics).

Proper management is extremely important, both in treating sick animals and eliminating factors that enhance bacteria and virus growth. Infected animals should be isolated and handled last. Keep newborns from having nose-to-nose contact.

Keep birthing pastures or pens clean, treat navels to eliminate infection, and prevent overcrowding.

Many cases of scours can be prevented. Vaccinate pregnant cows against colibacillosis 6-2 weeks before parturition and provide adequate vitamins and minerals. If calves do not receive sufficient colostrum soon after birth, they will not have enough antibodies to fight off infection. Cattle can be vaccinated against *Salmonella, Clostridium,* rotavirus, coronavirus, IBR, and BVD.

Proper internal parasite control is also a must. Parasites (worms and coccidia) cause intestinal irritations that make the occurrence of other infectious diseases much more common. (See Lesson 6 of this unit for more on parasites.)

Horses

Colic - It is the most frequently seen gastrointestinal problem in horses. Colic is not a single disease, but a symptom of pain in the abdomen, usually in the intestines, and is caused by a variety of diseases. Even with the best treatment, some cases of colic can result in death.

Feral or wild horses eat high-fiber/low-energy diets continually as they roam, unlike living conditions in captivity. A horse's relatively small stomach; inability to vomit; and large, free-moving intestines are not well suited to human management, where improper feeding and watering results in colic.

Common causes of colic are sudden changes in feeding or watering, too little forage, overfeeding/overwatering recently worked horses, working horses immediately after a full feeding, moldy grain or hay, and parasite buildup. These factors result in abnormal bowel movements, spasms, or a physical obstruction of the intestine's interior. Spasmodic colic, which accounts for approximately 40 percent of all cases, is a particularly common problem for nervous horses but luckily is the most easily treated.

Symptoms of mild abdominal pain generally include depression, pawing, lack of appetite, decreased bowel movement, yawning, looking toward flanks, excessive lying down, repeatedly getting up and down, frequent attempts to urinate, tail twitching, and kicking at the belly. Moderate

pain is indicated if the horse rolls or thrashes dangerously, has patchy sweating, or has rapid breathing. A horse in severe pain will roll and thrash uncontrollably, have profuse sweating, and ignore attempts at restraint. As a species, horses have a very low pain threshold, but no two horses have the same pain threshold. Therefore, similar causes of abdominal disease can cause widely different levels of pain in two different horses.

The horse *must* be kept on its feet while waiting for the veterinarian so that it does not twist an intestine or injure itself by rolling or thrashing on the ground. Walking the horse slowly might help control the pain. In dealing with colic, the biggest problem is determining whether it is **medical** or **surgical** (less than 4 percent of cases). Medical colics can be treated successfully by administering medication and general nursing care. Surgical colics will cause death without surgery. The veterinarian uses many factors, including circulation and intestinal position by rectal examination in an attempt to make this diagnosis.

Treatment for most cases includes pain relievers, laxatives, withholding feed, and/or a follow-up examination. Second opinions, surgery, intensive care, or putting the animal to sleep (euthanasia) might be needed in severe colic cases. If surgery is necessary, 40 percent of the small intestine and at least 50 percent of the large intestine can be safely removed without special dietary considerations.

Diarrhea - Although it is not as common in horses, diarrhea can result from strongyle infestation, too much milk, bacterial and viral diseases, sudden changes in feed, or at the first normal heat after foaling. Animals with diarrhea can be quite contagious and quickly contaminate the area.

Treatment can involve antibiotics and medicines containing kaolin or pectin. Consult a veterinarian if anything stronger is needed.

Summary

The symptoms and causes of many digestive disturbances are very similar. Correct treatment depends on identifying the specific disease properly. Prevention, through proper sanitation and management, seems to be the key to controlling GI diseases.

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Lesson 5:
Reproductive Diseases in Livestock

Abortions in animals represent genetic and economic losses and often cause a serious disposal problem, especially if abortion resulted from an infectious disease. All reproductive diseases mentioned in this lesson have abortions as one of the symptoms.

Swine

Pseudo-rabies - Pseudo-rabies is an acute, fatal disease occurring in all ages of swine. The most susceptible population consists of pigs less than two months of age. This disease is usually spread by a virus in the sow's milk or in the boar's semen.

Young pigs usually die right away or are aborted by the sow. Older pigs or weaning-age pigs show signs of fever, incoordination, walking sideways, tremors, mouth frothing, eye discharge, and sometimes convulsions. Vomiting, diarrhea, and death will soon follow. Adult swine show signs of fever, vomiting, muscle spasms in limbs, convulsions, or intense itching. Adults might also have respiratory problems. The most prominent sign in female swine is aborting of young.

The only preventive measure is to test all incoming stock for pseudo-rabies. Any stock that tests positively for pseudo-rabies must be destroyed. When restocking the herd, use only stock that tests negatively.

The only treatment is to destroy infected animals to prevent further spreading of the disease.

Leptospirosis - Leptospirosis affects all populations of swine. It is transmitted by wallowing in muddy areas infected by contaminated urine. Other methods of transmission are infected dead pigs and infected outside animals entering confined quarters. The organism usually confines itself to the area of the bladder. The organism can survive for several months in stagnant waters. Infection usually occurs through the nasal and oral passages by nosing at urine or eating contaminated fetus, food, soil, or water.

Reproductive disorders usually appear as abortions, infertility, stillbirths, fever, reduced milk, and neonatal mortality. Acute cases show signs of dullness, diarrhea, hindquarters weakness, incoordination, staggering gait, and stiffness of neck.

Vaccinations are available to prevent leptospirosis. Vaccinations for sows should be given prior to mating and just before farrowing. This method is very beneficial for confined farrowing operations. Animals entering new herds should be isolated, vaccinated, and vaccinated again 4-6 weeks later. Pigs should be vaccinated at weaning and again 4-6 weeks later. Good management practices, such as cleaning pens and eliminating stagnant waters and rodents, are also good preventive measures for leptospirosis.

Feed additives can eliminate carrier animals. Treat the entire herd for 8-11 days. There are several drugs available that are effective in treating infected animals.

Brucellosis - Brucellosis attacks all breeds, classes, and ages of swine. There is no lasting immunity for brucellosis. Infected, recovered animals can be reinfected with the disease later in their lifetime, usually 6-12 months after their first infection. There are several modes of infection. The germ can be present in the urine of both sows and boars, semen, vagina discharges, food and water troughs, sow's milk, and even in the soil. The germ enters the body through the mouth from any of the above sources. The germ can be transferred from pen to pen by human clothing, boots, farrowing crates, and feed buckets. Transmission can also occur when hogs eat or come in contact with infected, aborted fetuses. The disease can be readily transferred from the boar to sow during mating.

In boars, symptoms show up as swelling of one or both testicles. If not caught early enough, the boar generally becomes impotent. An infected sow's symptoms appear in her offspring not in the sow herself. Since each fetus has its own placenta membrane, some pigs are born normally developed, but others might be born dead and underdeveloped. Abortions can occur but are rare in swine. If abortions do occur, the sow generally eats her young.

Isolating and testing sows that have abortions or stillborns are good preventive measures. These measures help prevent further spreading. Good sanitation practices, such as cleaning and disinfecting farrowing crates and other farrowing equipment, are good preventive measures for confined breeding stock. Isolating and testing outside animals entering the herd will prevent an outbreak of brucellosis.

No drugs are available at this time to treat brucellosis. The most effective method of treatment is to destroy them in the proper manner.

Parvovirus - Parvovirus is probably the most infectious virus that affects swine because of its resistance to heat, cold, acidity, alkalinity, and disinfectants. parvovirus affects all breeds, classes, and ages of swine. Infection occurs venereally, by inhalation, and by ingestion. Pigs infected with parvovirus in their adolescent years will develop a natural immunity for the remaining years of production.

Symptoms of parvovirus appear as reproductive problems in swine. Sows have stillbirths, problems conceiving, reduced litter sizes, and mummification of fetuses. Boars will show infertility problems.

Isolate and test suspected infectious animals and outside animals entering the herd. Good sanitation practices are important for prevention because infected animals generally shed the virus in their fecal matter. There are vaccinations available for parvovirus.

Cattle

Brucellosis - Brucellosis is a very contagious bacterial disease in cattle. It is a major concern in the livestock industry because transmission to humans can occur very easily. Bacteria enters the body through the mouth or venereally. Transmission occurs by licking genital organs, infected fetus, infected placenta, or by licking vaginal discharges. Transmission can also occur during natural servicing of females, but is rare. Females are more susceptible than males, and older animals are more susceptible than younger animals. Time of year, climate, and weather have little influence on the brucellosis bacteria.

Abortions in cattle are a significant sign of brucellosis, but this is not always true for every infected female. Other symptoms are weak calves at birth, retained placenta, and vaginal discharge. These symptoms lead to a period of infertility for both the female and male. An infected male will usually have a reduced sex drive and enlargement of one or both testicles.

Calf vaccination is vital in preventing brucellosis from entering a herd. Good sanitary practices and annual brucellosis testing are good additions to a herd management plan.

Isolating infected animals is important in preventing the disease from spreading. Currently, there is no effective means of ridding the disease except through the destruction of positively tested animals.

Mastitis - Mastitis is more common in dairy than in beef cattle because the dairy cow's udder comes in contact with more outside sources. All breeds of dairy and beef cattle are susceptible to mastitis. Mastitis is a reproductive disease because it appears only after birth. Infection usually occurs by bacteria transfer from the milker's hand, milking equipment, flies, or by lying on infected ground. The bacteria enters the body through the hole at the end of the teat. Cows that have been infected with the disease will not build a natural immunity to mastitis; it can reoccur again and again throughout the cow's production lifetime.

Mastitis changes the nature of milk. Infected milk has thick, white, pus-like clots in it. Clots resemble paper spit-wads. The milk usually becomes paler and thinner in nature. Infected milk has a very unpleasant odor since it is infected with pus. The udder becomes hot to the touch, tense, and painful for the animal. The udder might also develop lumps that can be felt by the producer.

There are several teat dips available for prevention of mastitis. Dipping the teats after milking is a good management practice, as are good cleaning procedures in the milking parlor and of milking equipment.

There are several drugs available for treating mastitis. These drugs should be administered to the infected animal until the animal fully recovers.

Infected milk must be disposed of properly. There is usually a waiting period until the milk can be returned to the herd's milk supply.

Metritis - Metritis means inflammation of the uterus or breeding bag. Metritis is not a specific disease but a symptom of a variety of bacterial diseases. Infection can occur venereally, by contaminated obstetrical equipment (calf pullers and chains), by human contact after working with infected animals, and improper clean-up. Predisposing causes for metritis are manually removing or rough removal of afterbirth, and even removing afterbirth before it is ready to be taken away. The retained placenta acts as a wick to the uterus for infection.

Females infected with metritis have inflammation of the mucus membrane lining of the uterus. This inflammation creates outward signs of vaginal discharge in the forms of excess mucus, pus flakes, or excess pus. Breeding problems usually occur, such as conception difficulties, missed heat cycles, and fertilized eggs that cannot attach themselves to the uterus wall. These problems occur because of the inflammation in the uterus. Bulls are usually unaffected by metritis but can be carriers of the disease.

Good sanitation and feeding practices are good preventive measures. If an outbreak occurs, isolate infected animals and make sure equipment and clothing are cleaned after working with them. An outbreak of metritis is more likely to occur in confined areas like calving barns. (There is a higher concentration of infectious diseases than is found outside.)

Several drugs are available for treatment of infected females. Consult a veterinarian for the most effective treatment of metritis.

Leptospirosis - Leptospirosis affects all classes, breeds, and ages of cattle. As with swine, the disease is transmitted through infected urine. Transmission generally occurs by inhaling infected urine droplets that are present in the air. Animals that recover from leptospirosis generally develop a high resistance to reinfection. Low-lying ground with swampy conditions and stagnant bodies of water are predisposing causes of leptospirosis.

Acute symptoms of leptospirosis are fever, depression, failure to eat, and reduced milk production. Some chronic symptoms are abortions, breeding difficulty, death, and retained placenta.

Isolate infected animals to reduce transmission of the disease. If there is an outbreak of leptospirosis in the herd, be aware of any stagnant bodies of water. There are vaccinations available for the prevention of leptospirosis.

Several drugs are available for treatment of cattle. Consult a veterinarian for an effective treatment.

Horses

Metritis - Metritis affects all classes and breeds of equine breeding stock. The most susceptible horses are breeding mares. Infection can occur venereally, by contaminated obstetrical equipment (such as foal pullers and chains), by human contact after working with infected animals, and improper clean-up. Infection generally occurs by retained placenta membranes. The retained placenta acts as a wick for infection directly to the uterus.

Symptoms of metritis are more difficult to detect than other reproductive diseases because they usually appear as breeding problems. Mares show no signs or symptoms of vaginal discharge. The only signs are failure to conceive or maintain pregnancy. Another sign of metritis is repeated service to a known fertile stallion. Sometimes a mare appears to have conceived by missing a heat cycle, but 2-3 months later a fetus is not found (because the fertilized egg could not attach itself to the uterus wall).

If an outbreak occurs, isolate infected animals and make sure equipment and clothing are cleaned after working with infected animals to prevent spreading of the disease.

The following are effective treatments for metritis: local antibiotic therapy, systemic antibiotics, topical antiseptic therapy, uterine flushes, plasma infusion, and a combination of plasma infusions and antibiotics.

Fescue toxicity - Fescue toxicity affects female breeding stock in horses. Infection occurs when gestating mares eat fungi-infested fescue grass. By eating infected fescue, less of the hormone prolactin is produced. Reduced prolactin decreases or eliminates milk production in the mare. This process generally takes place in the last 60 days of gestation.

Fescue toxicity is hard to detect until it is too late. If the mare's diet consists of fescue forage and the mare is gestating, the lack of udder development is a good sign of fescue toxicity. After foaling, signs of fescue toxicity are stillborns and thick, discolored placenta.

A good preventive measure is to take gestating mares off a fescue diet 60 days before foaling to reduce fescue toxicity chances.

Since fescue toxicity is not an infection, treatment for the disease is not necessary to aid in recovery. Good management practices are the most effective way to prevent fescue toxicity.

Summary

It is important for livestock producers and others in the livestock industry to understand the impact of reproductive diseases on the industry. The producer is the first step in detection, prevention, and treatment of reproductive diseases. It is vital that a producer understands the impact of health on the herd.

Credits

Hungerford, T. *Diseases of Livestock.* 9th ed. Sydney, Australia: McGraw-Hill Publishing, 1990.

Taylor, R., and R. Bogart. *Scientific Farm Animal Production.* 3rd ed. New York: Macmillan Publishing Co., 1988.

Abortions can be caused by thousands of factors, so diagnosis of the cause can be very difficult. The diagnostic success rate for abortion is only about 30 percent. Researchers say abortion losses of 2-3 percent can be tolerated without undue concern in well-managed livestock operations. The following factors are obstacles to accurate abortion diagnosis:

1. Abortions generally occur as the result of an event that occurred several weeks or months earlier. If the cause was present at conception, it is usually undetectable by the time of the abortion.
2. The mare usually retains the fetus in the uterus for several hours or days after death.
3. Fetal membranes, which are commonly affected first, are usually unavailable for examination.
4. Toxic and genetic factors can result in abortions but are very hard to discover.
5. Many factors causing abortions are still unknown and are very difficult to detect.

The following factors are considered causes for abortions in livestock:

1. Venereal infections
2. Nonvenereal ascending infection
3. Septicemia - a systemic disease caused by pathogenic microorganisms and their toxic products in the blood
4. Anemia - lack of or reduction in red blood cells
5. Nutritional problems
6. Trauma
7. Genetic defect
8. Toxicity problem
9. Endocrine abnormality
10. Other

Lesson 6:
External and Internal Parasites

Each of the major livestock parasites will be discussed in terms of their hosts, life cycle, damage to the host, symptoms, and control.

External Parasites of Livestock: Their Symptoms and Treatments

Ticks - Ticks attack all classes of livestock but are of greatest concern to cattle and horse producers.

After leaving the host, adults lay eggs that hatch into larvae in 10-21 days. The larva becomes a nymph and attaches to a host until it becomes a mature adult, which ranges from a few days to several months, depending upon the species.

The greatest damage to hosts by ticks is the sucking of blood, which can cause anemia, weight loss, and even death. They also leave a wound that allows for bacterial infection or other injury. Infestations usually are found by visual inspection.

Extreme temperatures and pasture rotation help control ticks. The most effective method of control is chemical treatment.

Louse - Lice are species specific, and only one species affects swine--the hog louse.

In the life cycle, the adult female glues eggs to the host's hairs. The hatching range is 1-2 weeks, when nymphs are produced. In two weeks to a month, the nymphs become mature adults.

Blood-sucking lice can cause the hosts to become anemic. Irritation and discomfort cause rubbing and scratching. This decreases feeding and grazing time, resulting in loss of gains, unthriftiness, and even death. The primary symptoms of lice infestations are rough hair coats, rubbing, and scratching.

Chemical control with pesticide sprays, dips, dust, and self-treatment devices are most effective.

Mites - Mites attack all classes of livestock. They spend their entire life on the host. The adult female lays its eggs on the surface of the host's skin. Eggs hatch in approximately four days and larvae emerge. The larvae molt, become nymphs, molt again later, and become adults. The entire life cycle takes 12 days or less.

The host's hair comes out and the skin becomes rough and crusty. Symptoms are falling hair and rough, crusty, red skin.

Mites can be chemically controlled. Animals having this pest are placed under quarantine.

Screwworm - The screwworm affects all livestock. Infestation usually is only through wounds; however, some infestations have been found without wounds.

A screwworm is the larva stage of a blowfly. They feed on living flesh for 5-7 days, drop to the ground, and pupate. The larvae or maggots live on live flesh and can cause weight loss, permanent injury, or even death.

The primary signs of screwworms in a wound are an unpleasant odor, enlargement of the wound, and seepage of blood serum (mostly plasma) from the wound.

Topical sprays are available for the treatment and prevention of screwworm infestation.

Heel fly or cattle grub - Cattle are the primary hosts for the cattle grub; however, they have been found in other species of livestock.

The adult fly lays eggs on the host's leg hairs and lower parts of the body. Eggs hatch into larvae that penetrate the hair follicles and enter the animal's body. During a period of months, the larvae migrate through fleshy tissues of the animal's body until they reach the back.

The primary damage is to the hides by causing decreased values from the holes. During the grub's migration to the back, animals can injure themselves trying to get rid of the grubs. There is

also damage to meat that must be trimmed away as waste. Egg laying is the most visible symptom of the heel fly. There are visible swellings of the grubs once they arrive in the animal's back.

The best control method is with systemic insecticides before heel flies reach the animal's back.

Horn fly - Cattle are the main hosts, but horn flies will attack other species.

The adult female lays her eggs in manure, where they hatch in nearly 24 hours. Larvae mature in 5-10 days and then pupate. Young flies emerge from the pupae in 3-7 days and become adults in a few days.

The adult fly bites and sucks blood from the head, neck, back, and belly of cattle. The biting results in the transmission of disease, annoys the animal, and indirectly causes weight loss. Horn flies are easily seen on infested animals. Unless they are controlled, horn flies will cover the backs and necks of cattle during spring and summer.

Chemical control is the best method. Feed additives and ear tags are available for controlling horn flies.

Other flies - Flies are parasites of all classes of livestock.

The adult female lays eggs in manure, debris, and other dead and decaying organic matter. Eggs hatch into larvae in approximately 24 hours. The larvae mature and pupate in 5-10 days. Flies emerge from the pupae in 5-7 days, becoming adults in only a few days.

Besides biting, sucking blood, and transmitting diseases, flies annoy animals, indirectly causing lowered feed gains and weight loss. Flies are easily seen, and heavy infestations are common around lots and barns.

Most flies can be controlled with chemical sprays and dusts or feed additives. Because most species build up an immunity to nearly all chemicals, rotation in the use of chemicals is recommended.
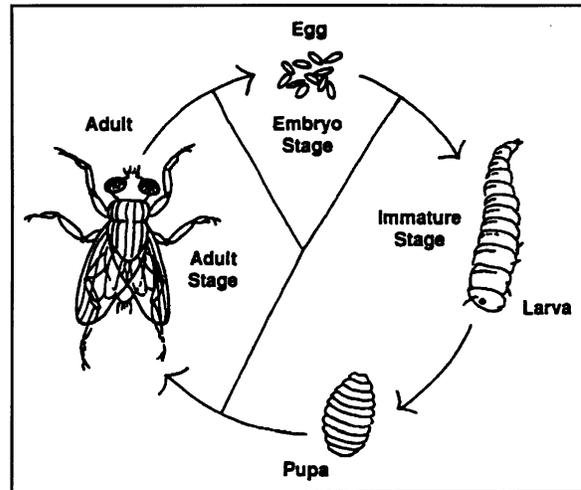
Nose bots - The nose bot is a parasite of horses and sheep and is closely related to the heel fly.

The adult fly emerges from the pupae, which lies dormant in the feces and other debris until the first warm days of spring, late summer, and early fall. While grazing, animals rub their noses against the ground, and the fly deposits eggs on the nose and chin of the animals.

Damage results when large bot infestations in the animal's stomach reduce digestion and usually leave an ulcerated area. The presence of the adult fly is very obvious because of the irritation it causes the animal.

Chemical control through deworming is the only method of control.

Internal Parasites of Livestock:
Their Symptoms and Treatments

Internal parasites affecting livestock are divided into three major groups: roundworms, tapeworms, and flukes.

Roundworms - From an economic standpoint, roundworms are the most important parasites. There are many types of roundworms, which affect almost every species of livestock. Although there are species that attack every system in the body, the ones of greatest concern are found in the digestive system, mostly the stomach and intestines.

Stomach worms - There are several species of stomach worms, but the twisted stomach worms and the brown stomach worms are most important. Stomach worms are found in all classes of livestock but commonly affect cattle, sheep, and horses.

In the adult stage, stomach worms live as blood-sucking parasites attached to the stomach wall. Eggs pass in the host's feces and hatch into larvae in 15-20 days, depending on temperature and humidity. The larvae crawl up a blade of grass, are eaten by the animal, and travel to the stomach lining until they mature.

While penetrating the stomach lining before maturing, stomach worms cause severe damage by reducing the host's digestion of nutrients and producing poisons. Young, undernourished, or disease animals are hardest hit.

The most common symptom is anemia. In light infestations, the animal will have a dull hair coat, an unthrifty appearance, and will sometimes have scours. In severe infestations, there will be persistent scouring, weight loss, anemia, weakened condition, and possible death.

Sanitation and pasture rotation are good control measures. Chemical dewormers are used to treat infested animals. The type of dewormer used is dependent upon the class of livestock. Drenches and injectable dewormers are most used in cattle and sheep. Feed and water additives are generally used for swine. Liquid dewormers, administered by tubing, are the most effective treatment for horses. Feed additives are also effective.

Strongyles (bloodworms) - There are several species of strongyles, which normally inhabit the small intestine but also are found in the abomasum of ruminants. Strongyles attack all species. They have a greater affect on young animals in each species. After cattle and horses reach an age of 4-5 years, they build up a partial immunity and are less affected.

In the adult stage, bloodworms live as blood-sucking parasites attached to the lining of the intestines. Eggs pass from the host in the feces and hatch into larvae within five to 20 days,

depending upon temperature and humidity. The larvae then attach to a blade of grass, are eaten by an animal, pass through the stomach, and attach to the wall of the intestine. The larval stage can live for months in the grass before being eaten. Larvae pass through the arteries and other internal organs, sometimes causing irreparable damage.

Strongyles (bloodworms) are the most detrimental of all internal parasites. Besides sucking blood, which results in anemia, their presence and the scar tissue left by them greatly reduce digestion in the intestines. They are the major cause of colic in horses. Chronic infestations result in unthriftiness, poor feed conversion, weakened condition, and even death.

The most common symptom is anemia. Weight loss, rough hair coats, scouring, loss of appetite, colic, and weakness are seen in moderate and severe infestations.

Sanitation and pasture rotation are effective control measures. The use of chemical dewormers in a regular deworming program is the best method of control. When deworming cattle and sheep, boluses, drenches, and injectable dewormers are the most effective. For swine, water and feed additives are most often used. For horses, tubing at regular intervals plus feed dewormers between tubings give the best results.

Ascarids - Ascarids are primarily parasites of cattle, sheep, hogs, and horses. Younger animals are most often affected.

Eggs are passed in the feces and contaminate pastures, lots, and stable areas, where they are ingested by susceptible hosts. The larvae burrow into the wall of the intestines and migrate through the liver, heart, and finally the lungs, where they are coughed up and swallowed. After reaching the intestines the second time, they develop into the adult stage. Here, they reach a length of 8-15".

Affected animals can develop pneumonia and lung damage due to the larval migration through the lungs. Unthriftiness, weight loss, and colic due to intestinal blockage are common in heavy infestations. Symptoms include weight loss, dull hair coat, general unthriftiness, and colic.

Ascarids are generally controlled by the same means as other stomach and intestinal roundworms. Pasture rotation, sanitation, and deworming programs are the best control measures.

Pinworms - Pinworms are small roundworms usually found in the colon and rectum of horses.

Adult females lay eggs around the anus of the horse. These eggs drop off and contaminate pastures, stables, and watering and feeding areas. After eggs are ingested by the host, they pass to the colon and rectum, where they mature.

Damage by pinworms is minor. However, they do cause severe irritation around the tail area, which causes horses to rub their tails. Tail rubbing is the most noticeable symptom. Also, white scaly deposits are visible around the anus.

The chemical worming programs used to control other species of roundworms will control pinworms. Sanitation measures around barns and lots are effective in reducing infestations.

Habronema stomach worm - The horse is the major host of the *Habronema* stomach worm, but the house fly is an intermediate host.

This species affects the host in two stages. The adult stage is found in the horse's stomach, where little damage occurs other than an occasional tumor. Larvae are passed in the feces, which are ingested by house fly maggots. The *Habronema* stomach worm remains in the fly when it emerges from the pupal stage. The larvae of the *Habronema* are deposited on the lips of the horse by the fly, are swallowed, and mature in the horse's stomach.

Real damage of the *Habronema* does not involve its normal life cycle. If the larva is deposited on an open wound, a summer sore develops. These summer sores are difficult to heal and are the result of the migration of *Habronema* larvae throughout the wound. They can permanently disable or disfigure horses. These sores also develop around the medial canthus (corner of the eye nearest the bridge of the nose), especially in stabled horses.

A summer sore is easily detected by a seepy, hard-to-heal crusty sore. In the eye there is excessive tearing and running, which later forms an open sore. The larvae can be seen upon close inspection.

As with other roundworms, disruption of the life cycle is necessary. The best control is a regular deworming program. Sanitation is important, along with a fly control program in and around the stable area.

Lungworms - These roundworms affect the circulatory system and lungs. Lungworms affect all species of livestock.

Eggs are laid in the lungs, then coughed up and swallowed. The eggs hatch in the stomach or intestine, and the larvae are passed in the feces. After a period of development in moist earth or water, the larvae are ingested by the host and pass to the intestine. There, they burrow through the intestinal wall into the lymph nodes and are carried to the lungs, where they mature into the adult stage.

In heavy infestations, there can be mechanical blockage of the lungs, causing a collapse of the infected area. This furnishes an ideal location for the invasion of other organisms. Lungworms can also cause blockage of the windpipe and bronchia.

Coughing is the first indication of this parasite; it is accompanied by faster and more forceful

breathing. In severe cases, the animal breathes with its mouth open and its tongue protruding. It is reluctant to move, usually develops a fever, goes off feed and water, and becomes gaunt.

Sanitation and pasture rotation are the best control practices. Chemical control is relatively effective.

Broad tapeworm - In general, tapeworms are far less important than roundworms. The broad tapeworm is a parasite of all classes of livestock, as well as humans.

The adult lives in the small intestine, where it can reach a length of 10' or more. Tapeworm segments containing eggs break off continuously and pass out in the feces. Eggs are eaten by the oribatid mite, which lives in grass and weeds and serves as an intermediate host. The eggs develop in these mites, then are eaten by livestock and hatch in the small intestines. They feed on foodstuff eaten by the animal and grow to maturity.

There is no physical damage to the host. However, the tapeworm is in competition with the host for food. Unthriftiness, loss of weight, diarrhea, and emaciation are the major symptoms. Chemicals can rid the host of tapeworms.

Beef tapeworm - Although the beef tapeworm is a parasite of cattle, humans are the necessary intermediate host.

Beef tapeworm eggs contaminate the feed of cattle and pass down into the intestines. There, the eggs hatch out, bore through the intestinal wall, and lodge in a muscle, causing a cyst. Beef affected by these cysts are called measly beef. The parasite is then passed to humans when infected, undercooked beef is eaten.

There is little economic damage to cattle by the parasite; however, it is a problem for humans. Adult beef tapeworms only live in humans and can reach a length of 25'. There are almost no visible symptoms in cattle except in the carcasses of slaughtered animals.

Since humans are the necessary intermediate host and the beef tapeworm is transferred through the meat, the best control is eating only well-cooked beef.

Pork tapeworm - This tapeworm is the same as the beef tapeworm, except that the larvae live in the muscle tissue of pork.

Liver fluke - The liver fluke is a parasite of cattle, sheep, goats, and humans. It is especially damaging to young animals.

The adult lives in bile ducts, where eggs are laid, pass down into the intestines, and leave in the feces. Eggs must land in water to hatch. The larvae that hatch from these eggs swim about seeking a snail, which is necessary to complete the liver fluke's life cycle. Larvae develop for a period in the snail, then emerge and attach to plants along the water. Livestock eat the water plants and become infested. The young flukes pass to the intestines and burrow through the abdominal cavity and into the liver, where they live principally on blood. Egg production begins about three months after entering the animal.

The fluke causes irritation, thickening of the bile duct, and fibrosis of the liver, making it unfit for human consumption. The usual symptoms are anemia and weight loss. Highly infested animals might die.

Pasture rotation and using water troughs help in control. Chemical treatment will kill adult flukes in the animal. Control of snails will break the cycle, but that is difficult to do.

External Parasites of Poultry: Their Symptoms and Treatments

Poultry producers lose millions of dollars annually to damage caused by external parasites. These parasites transmit pathogens or kill birds, decrease egg production, increase feed costs, reduce weight gains, and lower carcass quality.

Lice - Lice are more abundant in summer than in winter months. Lice are permanent parasites of their hosts. They spend all life stages on the same bird. Sometimes, they will pass from one bird to another, particularly from an older bird to a younger bird.

Although lice eggs are laid singly, they can be abundant enough to form dense clusters on the fluffy area of a bird's contour feathers.

Eggs cemented to the bird's feathers are oval, white, and sometimes beautifully ornamented with fine spines. Eggs hatch in a few days or weeks. Young nymphs immediately begin running about and feeding on the host. After a few weeks, they gradually become adult sized in form and color.

All lice infecting poultry are sucking and chewing types. Lice irritate, cause weight loss, reduce egg production, decrease carcass quality, and can even kill birds. Several species of lice attack poultry. These include: body lice, head lice, wing lice, and fluff lice.

Mites - Mites vary in size and structure. Poultry are susceptible to many types of mites.

Mites usually occur on or under the bird's skin or feathers. A few can exist in body tissues, feather quills, or nasal and respiratory passages such as the air sac. Mites feed by piercing the bird's skin or tissue, sucking blood or body fluids, or by biting bits of skin or feathers.

Mites slow the growth of birds, reduce egg production, lower vitality, damage plumage, and even kill birds. Much of the injury, consisting of constant irritation and loss of blood, is unapparent unless one examines the bird.

Ticks - Several species of ticks affect poultry. These include the fowl tick, Lone Star tick, and Gulf Coast tick. The tick is a bloodsucker and injures poultry by transmitting disease, causing weight loss, lowering egg production, and causing skin blemishes that reduce market value.

Ticks are difficult to eradicate. Houses and surrounding areas require thorough pesticide treatment.

Mosquitoes transmit poultry diseases, including malaria and fowlpox.

General parasite control - Many pesticides exist to control external parasites of poultry. Because the list of approved material changes rapidly, consult a poultry specialist for a recommendation.

Besides applying pesticides, producers can apply good management practices to their operations. Poultry houses and surrounding areas should be free of foreign materials, including manure and stagnant water.

Internal Parasites of Poultry: Their Symptoms and Treatments

Various worms are major internal parasites of poultry. The number of worms that occur in any given bird depends upon the number of infectious eggs that the bird ingests. Worms do not multiply within the host bird. The three major types are roundworms, tapeworms, and flukes.

Large roundworms - Chickens, turkeys, ducks, geese, and pigeons are susceptible to large roundworms.

The large roundworm has a simple and direct life cycle. The female lays thick, heavy-shelled eggs in the bird's intestines. Eggs are expelled in the feces. Poultry eat the eggs, the eggs hatch, and the larvae develop into mature worms to complete the life cycle.

Heavily infested birds exhibit droopiness, emaciation, and diarrhea. Very heavy infestations result in death. Primary damage is reduction in efficiency.

Cecal worm - These exist in the ceca of chickens, turkeys, and other birds. A cecal worm's cycle is similar to that of the large roundworm. This common worm parasite does not affect the bird's health seriously. There are no marked symptoms or pathology occurrences due to the presence of cecal worms.

Capillary worms - Capillary worms occur in the bird's crop and esophagus. The life cycle is direct or bird-to-bird. Worms lay their eggs in the bird's feces. Poultry eat the infected eggs.

The worm produces a mucous membrane inflammation and sometimes causes hemorrhaging. The bird's intestinal lining might erode extensively and result in death. Heavy infestations, especially in houses with deep litter, reduce growth, egg production, and fertility of birds.

Tapeworms - These differ from roundworms because they are flat, ribbon-like, and segmented. They also differ from other worm parasites by

having both male and female sexual organs on each segment.

Worms attach to the intestinal lining by suction cups located on the worm's head. Symptoms of tapeworm infestation in poultry include weakness, unthriftiness, and poor growth. Diarrhea develops in some cases.

Tapeworms affect young birds more severely than older birds.

Flukes - Flukes are leaf-like flatworms that affect various parts of a bird's body. Flukes do not cause significant losses in poultry.

Parasite control - Prevention and control of worm infestations involves more than treatment. Proper diet, sanitation, and medication are essential. Poultry should receive feed rations adequate in vitamins A and B complex. Rations lacking these vitamins make poultry more susceptible to worm infestations.

Sanitation practices are essential to prevention and control of worms. Remove poultry litter regularly. Avoid overcrowding birds. Treat infected birds with commercial drugs.

Summary

Proper management and sanitation are the best control measures for both internal and external parasites in all species of livestock and poultry. Proper identification of parasites leads the way to appropriate prevention and treatment. There are many drugs available commercially to help control parasites.

Credits

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

The Merck Veterinary Manual. 7th ed. Rahway, NJ: Merck & Co., 1991.

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

Gillespie, James R. *Modern Livestock and Poultry Production.* Albany, NY: Delmar Publishers, Inc., 1989.

Lesson 7:
Quality Assurance Programs

Livestock associations have developed programs to ensure quality in animal products. Quality animal products start on the farm with the producer; producers should be responsible for their products. This responsibility will instill consumer confidence in animal products and (hopefully) increase demand for these products.

Pork Quality Assurance Program

The pork industry's Quality Assurance Program was developed into three levels. A swine producer interested in the Quality Assurance Program can request information about the program from the National Pork Producers Council (NPPC). The producer must begin on level I and work through the system. The NPPC will send the producer a booklet to read. Afterward, the producer takes an evaluation at the end of the booklet. Once the producer has taken the evaluations for levels I and II and understands the idea of quality assurance, he/she sends the self-addressed card back to the NPPC. The producer will then receive the level III booklet. The producer must follow the guidelines in the level III booklet to qualify for the Quality Assurance Program.

Ten critical control points are outlined in level III for "Quality Assured Pork Production."

Herd health management plan - A producer must establish an efficient, effective herd health management plan. A swine producer should provide a clean, healthy environment, as much as possible. A checklist helps ensure management practices are in line for a healthy swine herd. The herd health management plan also sets up a vaccination program for the herd and compares it to recent trends in the swine industry. The herd health management plan should be completed in the presence of the producer's veterinarian.

Veterinarian/client/patient relationship - A valid relationship exists when three conditions are met: (1) The client or swine producer agrees to the instructions provided by the veterinarian on judgments of animal health and medical treatments; (2) The veterinarian has sufficient knowledge of the client's livestock to make proper judgments on medical treatments; and (3) The veterinarian is readily available for follow-up evaluation on infected livestock to observe any adverse conditions that still exist.

Drug storage - Store all drugs correctly, follow label instructions, and pay close attention to expiration dates. If the label reads, "use the entire bottle," do so or discard the remainder. Store leftover medications in a cool, dry, dark place (preferably a refrigerator). A pick-up dashboard is unacceptable. Clean syringes and discard used needles. Do not store medications in syringes. Keep medications out of reach of children. Keep water or feed additives dry to prevent caking or clumping.

FDA-approved drugs - A producer must always use FDA-approved OTC (over-the-counter), extra label, or Rx (prescription) drugs with professional assistance. Remember, prescription medications can only be given by a licensed veterinarian. Over-the-counter medications can be administered by anyone after carefully reading label directions. Extra label medications require extra instructions from the vet The producer must follow the guidelines on dosage, withholding times, mixing, safety, and efficacy. Producers are discouraged from buying unapproved FDA medications and buying drugs from uninformed suppliers.

Drug administration - A producer must administer all injectable drugs and oral medications properly. Injectable drug administration guidelines follow. Use the smallest recommended needle to reduce stress, minimize tissue and skin damage, and reduce leakage. There are four types of delivery systems for injectable medications. Intramuscular (IM) medication is given in the muscle, subcutaneous (SQ) is given under the skin, intraperitoneal (IP) is given in the abdominal cavity, and intravenous (IV) is given in the vein.

If a producer cannot answer the following questions correctly, he/she must seek assistance from his/her veterinarian to inject medication. Should drugs ever be injected in the muscle of the ham? Are the syringes adjusted correctly to give proper dosages? Do you follow label directions for quantity of medication and site selection? Do you

restrain animals to prevent needle breakage and inappropriate dosages?

The producer also needs know how to give water medications. When are water medications used? How do you calibrate medicators? How often do you calibrate medicators? Where do you store medications? How do you flush the lines if medications are used? Are medications mixed fresh daily, and do you monitor consumptions? What is the recording system for water medications?

Following label instructions - Always follow label instructions when using feed additives. A producer must be able to answer the following questions about feed additives (or seek veterinarian assistance). When is the last time the mixer or scale was calibrated, and what time period does the owner's manual recommend? Do you keep written records on calibration dates? When is the last time you did a feed analysis to check mixer accuracy? How often do you check the mixer for wear? How often do you clean your mixer or mill? How do you handle spills of medicated feeds? Do you flush your mixer after mixing medicated feeds? How do you store feed additives? Do you follow label directions and withdrawal times carefully?

Records of treated animals - A producer must maintain proper treatment records and adequate identification of all treated animals. A swine producer is responsible for keeping accurate records on all health-related events associated with livestock. These records must include the identification of animals, what medications were administered, times treated, and withdrawal times.

Drug residue tests - A producer must use residue tests when appropriate. Consider residue testing when sows are culled directly from the farrowing house for selling or marketing. Animals that receive extra label medications should be tested. Consider residue testing swine shown at fairs or livestock shows. Consider residue testing pigs sold to individuals for roasting or for slaughter at private slaughter houses. Newly purchased animals entering the herd should be residue tested since it is rare to receive treatment records for these animals.

Staff medication awareness - A producer must implement employee/family awareness of proper drug use. Swine producers, employees, and family members involved with administering medications should be educated on proper administration techniques and product labeling. Remember, the swine producer is ultimately responsible for those hogs!

Annual checklist - A producer must complete the "Quality Assurance Checklist" annually with the residing veterinarian. Consider this checklist a minimum for swine health programs. This checklist will point out a producer's attitude, knowledge, and commitment to the pork industry.

Beef Quality Assurance Program

The Beef Quality Assurance Program is unlike pork and dairy programs. State associations, rather than the national association, are responsible for setting up quality assurance programs. There are several other differences between quality assurance programs. The Missouri Beef Quality Assurance Program has a code of ethics for producing beef in Missouri. The Missouri association also has set up beef management practices that should be followed by beef producers. Instead of 10 critical control points, the Missouri beef association has five "beef tips" that producers should follow to ensure quality beef products. These tips follow.
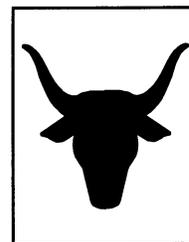
Processing cattle - Handle cattle in a way that minimizes bruising when administering injections. Avoid injecting cattle during wet weather to prevent contaminants from entering the injection site. Make sure the injection site is dirt- and manure-free. Avoid using disinfectants when using any modified live virus product. Consider needle size when administering medications. Use smallest needle possible to prevent abscesses. Wet down the work area around the chute to reduce dust or other foreign materials. Secondary infections could result from these materials entering the body at injection sites and open incisions.

Select injection sites carefully. Consider injecting medications in the neck or lower thigh to prevent loss of expensive cuts of meat and market docks. Consider the volume of medication injected at one site. There are limitations on the amount given at a selected injection site. Know the differences between intravenous (IV), intramuscular (IM), and subcutaneous (SQ) injections. Inject these medications appropriately and follow label directions. Always properly place implants to avoid excess trimming of meat. Keep the working area, equipment, and employees clean to avoid any secondary infections when working with cattle.

Current Good Manufacturing Practices - Manufacturers need to follow the following practices to ensure quality beef products. Building, grounds, work and storage areas, and equipment should be routinely maintained, metered, cleaned, and properly stored to ensure purity and intended potency. Manufacturers must keep accurate records of all lab tests done on product testing.

Proper storage for different medications should be designed and maintained. Use proper clean-out procedures on equipment to prevent contamination of products. Use adequate labeling of products to prevent mix-ups and assure that correct labels are used on medicated feed. Production records must be kept on formulation, mixing dates, and shipping dates to ensure quality assurance.

Violations and inspections - If a residue is detected in an animal, the inspector will report the finding to the USDA's Food Safety and Inspection Service. They assign a case number and identification number to the owner of the cattle. The producer will then be asked questions about the incident and why the animal(s) tested positive. Every time the producer ships animals to market, he/she must notify the USDA office of shipments. This monitoring will continue until the USDA office is satisfied that this occurrence will not happen again.

The USDA office reports to the FDA. The FDA then decides whether a follow-up visit is needed. If the violation only occurs once, there will probably not be a visit. If there are several violations, there will be a visit to the facility. The FDA has the legal right to inspect any facility they desire, so producer cooperation is critical.

If you do not cooperate with the FDA during their inspection of the facility, the FDA has several options, all of them serious. The FDA can get a federal court injunction against the facility to halt all further activities. The FDA can file civil or even criminal charges against the producer for not complying with regulations. Also, the FDA can seize all cattle that remain at the facility. Producers must understand label directions about residue withdrawal times or pay the consequences.

Record keeping and inventory control - Beef producers must keep accurate records on all aspects of animal health. To maintain market share and consumer confidence, producers must prove, through effective documentation, that they have a tight control on risk factors associated with animal health. This maintains consumer confidence and strengthen the demand for beef. Inventories on animal health products are also important for beef producers to control. Knowing the amounts of medications and the amounts used are important in maintaining tight control over risk factors.

Feed ingredient quality control - A beef producer must be aware of the implications associated with residues found in feed ingredients. If a producer buys medicated feed from a supplier, which is then fed to the producer's cattle and cause a residue violation, who is responsible? If the producer does not have accurate records verifying that the load of medicated feed was received on a certain date and its contents, the producer is responsible. If the producer has accurate records of all incoming feed ingredients and withdrawal times, the producer can pass the liability to the supplier. Accurate records keep the producer free of any implications related to residue violations from purchased feedstuffs.

Dairy Quality Assurance Program

The National Milk Producers Federation and the American Veterinary Medical Association have produced 10 critical control points for "Quality Assured Dairy Production." The 10 critical control points are as follows.

Preventive health program - A producer must have a preventive herd health management program

established. A dairy producer should maintain the herd in a clean, healthy environment, as much as possible. The nutritional program should meet growth, maintenance, and lactation needs of animals. A producer should have the veterinarian implement a health program that encompasses preventive medical procedures and monitoring of reproductive status of breeding stock. Healthy livestock are more profitable and less likely to require drug therapy. Good management practices and health programs keep animals producing efficiently; therefore, they are less dependent on medical therapy.

Veterinarian/client/patient relationship - A valid veterinarian/client/patient relationship exists when the following conditions are met. The client or dairy producer agrees to the instructions provided by the veterinarian on judgments about animal health and medical treatments. The veterinarian needs sufficient knowledge of the client's livestock to make proper judgments. The veterinarian must be readily available for a follow-up evaluation on infected livestock to observe any adverse conditions that still exist.

FDA-approved drugs - Dairy producers should use FDA-approved drugs, whether they are prescription or over-the-counter drugs. The producer must follow label guidelines. Guidelines on dosage, withholding times, mixing, safety, and efficacy are also important.

Grade A requirements - All drug labels must comply with "Grade A" milk control labeling requirements. Over-the-counter drugs used by the dairy producer must have the following requirements specified on the label: (1) the manufacturer's label with indications for use on lactating cows and withholding times and (2) the manufacturer's label with indications for use on non-lactating cows. If used according to label directions, no further instructions are needed.
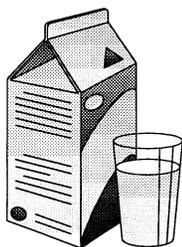
Prescription drugs used by the dairy producer must have the following requirements specified on the label:

1. The prescribing veterinarian's name and address, in addition to the manufacturer's label indicating milk withholding time on lactating animals
2. The prescribing veterinarian's name and address, in addition to the manufacturer's label indicating use for non-lactating cows

Prescription drugs are given by the veterinarian, and the medication should be used up totally. There shouldn't be any left over; if there is, return it to the vet. It should not be stored at the producer's facility.

Extra label drugs used by the dairy producer must have the following on the label: veterinarian's name and address, active ingredient, directions, and cautionary statements as necessary.

Drug storage - Store all drugs according to "Grade A" milk control labeling requirements. All drugs used in a dairy operation must be stored properly. Storage must not contaminate the milk supply, equipment, or utensils. Drugs used for lactating animals must be stored separately from drugs used for non-lactating animals. Drugs for lactating animals must be labeled for "lactating animals," and the name and address of veterinarian is required if the medication is Rx. Drugs for non-lactating animals must be labeled for "non-lactating animals."

Drug administration - A producer must be sure that all drugs are administered properly and treated animals are properly identified. Before administering or dispensing drugs to any animal, consider the following. What FDA medications are approved for all classes of cattle on the farm? (Use labels.) Do you follow label directions on proper dosages? Do you follow approved routes of administration? Do you follow withholding times? If a dairy producer does not understand any of these questions, he/she should seek assistance from the residing veterinarian.

Treatment records - A producer must keep treatment records and identify treated animals. A dairy producer is responsible for keeping accurate records on all health-related events associated with livestock. These records include identification of animals, what drugs were administered, times treated, and withholding times.

Drug residue testing - Proper drug residue testing capabilities are readily available to producers for on- and off-farm usage. Producers must test milk and urine by appropriate tests for best results.

A dairy producer must consider the following factors to prevent drug residue from entering the milk supply or slaughter residue testing. Consider testing milk from sick animals that have received medication to detect any drug residues. Remember, withholding times on labels are based on healthy animals, so sick animals might have longer withholding times. Consider testing milk on animals that have been given extra label drugs, because extra label drugs do not have official withholding times.

Dry animals returning to the milking herd that have been given any type of medication during dry period should be tested. Consider testing any newly purchased lactating animals, since it is rare to receive treatment records for newly purchased animals. Before sending animals to the sale barn, consider testing the urine of any culled animals and calves that were weaned from treated cows. Urine testing detects any drug residues present in the animals. Calves can be infected by milk from a treated cow. Consider urine or milk testing on animals intended for slaughter to ensure that there are no residue violations during slaughter.

A dairy producer must know and understand precautions and misuses of residue testing. *Never* use residue testing to shorten a withholding time. *Never* test the bulk tank to test milk from individual cows. Treated cows should be tested individually, not with the entire population. *Never* add milk that has tested residue-positive to the bulk tank to dilute it!

Staff medication awareness - Dairy employees must demonstrate a knowledge of proper medication usage and methods to avoid marketing adulterated products. Dairy producers and employees who administer medications should be educated on proper administration techniques and understand product labeling.

Annual checklist - A producer must complete a "Quality Assurance Checklist" annually with the residing veterinarian. Consider this checklist a minimum for dairy health programs. Each dairy

operation should be customized to fit the "Quality Assurance Checklist."

Summary

Quality assurance programs help alleviate consumer apprehension about medication usage, placements of injections, drug residues, and environmental conditions. Producers need to make a conscious effort to reevaluate procedures and practices to realign them with these program guidelines. Student awareness of these programs will reenforce the importance of quality production and give them the tools required to defend the industry against opposition or misinformation.

Credits

Milk and Dairy Beef Quality Assurance Program. Stratford, IA: Agri-Education Inc., 1991.

Missouri Beef Quality Assurance Program. Ashland, MO: Missouri Beef Producers, 1990.

Pork Quality Assurance Program. Des Moines, IA: National Pork Producers, 1991.