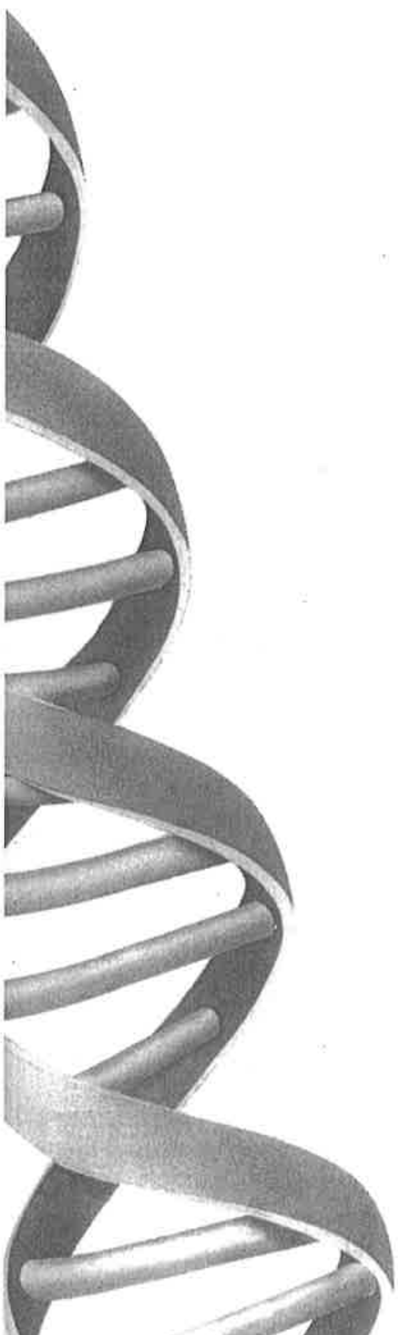
CHAPTER ◆ 15

Animal Nutrition



Student Outcomes in Basic Science

As a result of studying this chapter, you should be able to

1. Explain why animals must have nutrients.
2. List the six nutrients essential to life.
3. Discuss the role water supplies in supporting life.
4. Discuss the relationship between proteins and amino acids.
5. Distinguish between a carnivore, omnivore, and a herbivore.
6. Discuss the importance of protein in the diet of animals.
7. Discuss the importance of carbohydrates.
8. List the types of common sugars.
9. Distinguish between a starch and a sugar.
10. Discuss the importance of fats in the diet of animals.
11. Discuss the role minerals play in sustaining life.
12. List the vitamins that are important in the diet of an animal.
13. Discuss the function of vitamins.
14. Distinguish between a monogastric and a ruminant digestive system.
15. List and define the function of the organs of the monogastric digestive system.
16. List and define the function of the organs of the ruminant digestive system.

Student Outcomes in Agricultural Science

As a result of studying this chapter, you should be able to

1. Explain the sources from which protein is obtained for feeds.
2. List the common grains that are used as a source of carbohydrates.
3. Distinguish between a concentrate and a roughage.
4. List the sources of fats in animal rations.
5. List the sources of minerals in animal feeds.
6. List sources for the various vitamins that are of use to animals.
7. Explain the differences in the feed used by monogastrics and feed used by ruminants.

In order for an animal to go on living, growing, reproducing, and preforming all of the body functions, it must have nourishment. All movement and body processes of the animal require the use of energy. There are only two places where an animal can obtain energy: one is from the food it ingests; the other is from the energy stored by its body in fat cells. Obviously even for the animal to store energy in the fat cells, it must have an intake of food.

In the wild, animals must spend most of their time in search of food to sustain themselves. Most agricultural animals are given their food every day. The nutrients obtained from their feed can go into growing and producing the products desired by the producers. Therefore producers carefully balance the diets to fit the needs of the animals.

A certain level of nutritional needs, known as the **maintainence ration**, must be met first. This is the level of nourishment needed by the animal to maintain its body weight and not lose or gain weight. Nourishment over that amount can be used for growing, gestating, and producing milk or other products, Figure 15–1.

In the wild, most animals eat a variety of foods. This variety gives the animals the nutrients they need to support their bodily functions. In agricultural operations, producers balance the feeds of their animals to ensure that the proper nutrients are consumed. In confinement the animals have to eat what the producer gives them. A lot of research has gone into the development of feeds that give animals exactly what they need to remain healthy and to perform at their peak, Figure 15–2. One type of feed may supply several of the needed nutrients, but usually a certain **feedstuff** contains a certain concentration of a particular nutrient. A feedstuff is generally a feed component that producers would not normally give by itself, but combined with other types of feedstuffs, it helps comprise the animal's feed.

Animals must have nutrients in each of six major classes: water, protein, carbohydrates, fats, vitamins, and minerals. Each of these classes of nutrients serves a specific function in the metabolism of the animal. Metabolism refers to all of the chemical and physical processes that take place in the animal's body. These processes provide energy for all of the functions and activities of the animal's body. Metabolism that builds up tissues is called **anabolism**. Examples are the maintenance of the body, growth, and tissue repair. Metabolism that breaks down materials is called

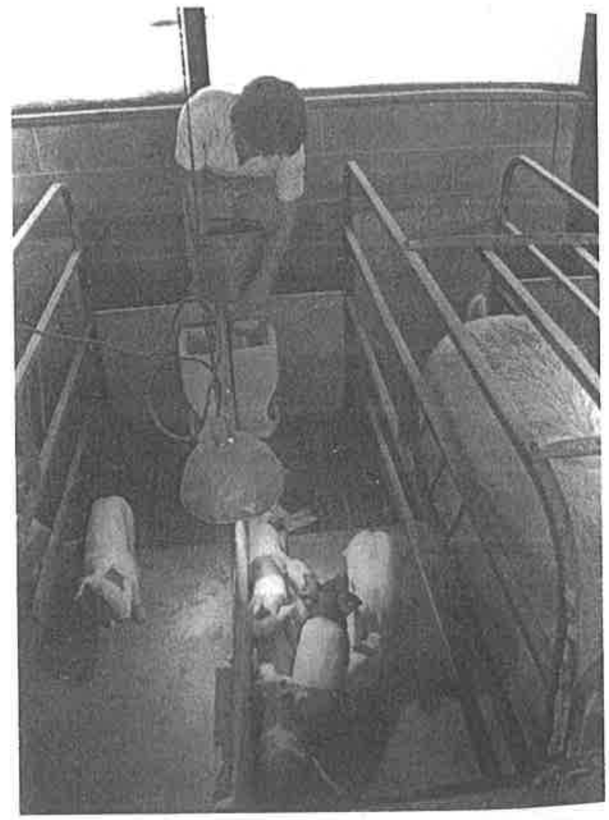


Figure 15-1. Animals must have nourishment above the maintenance level in order to grow, gestate, and/or produce milk. *Rick Jones, Cooperative Extension Service, The University of Georgia.*

Figure 15-2. A lot of research has gone into developing feeds that provide animals with the proper nutrients. *Dr. Frank Flanders, Agricultural Education, The University of Georgia.*

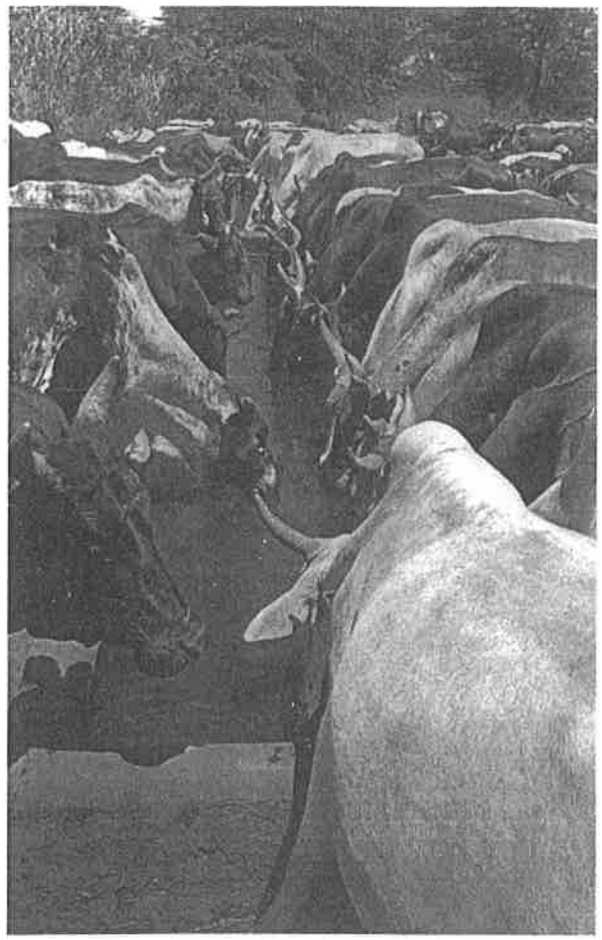


Figure 15-3. Water is an essential nutrient needed to provide all the bodily fluids. *United States Agency for International Development.*

catabolism. An example is the breakdown of food within the digestive system.

WATER

Water is the most abundant compound in the world. Over two-thirds of the world's surface is covered with water. Since this nutrient is essential for sustaining life, animals must have frequent intakes of water to remain alive, Figure 15–3. Even animals such as llamas and camels, which can go for long periods of time without drinking, have to have water. This nutrient provides the basis for all of the fluid of the animal's body. The bloodstream must be a liquid in order for circulation to occur. Digestion requires moisture for the breakdown of the nutrients and the movement of the feed through the digestive tract. Water is needed to produce milk. It is needed to provide fluid for the manufacture of all of the bodily fluids. It provides the cells with pressure that allows them to maintain their shape. It helps the body maintain a constant temperature. Another vital function of water is that of flushing the animal's body of wastes and toxic materials. This nutrient is so vital that over half of the animal's body is composed of water. A loss of 20 percent of this water will result in the death of the animal.

Using ballpark figures, animals generally need about three pounds of water for every pound of solid feed they consume. Some of this water comes in the feed itself. For instance, animals that graze obtain water from the succulent green forages they eat. Some water can be obtained in feeds such as silage that have a relatively high water content. However, most of the water an animal needs comes from the water it drinks. Since water is so essential, producers make sure that animals are given a constant supply of clean water.

Animals may require more water at some periods than at others. A horse that is working hard in hot weather will sweat profusely and will need more water intake to replenish the fluid lost from its body. Likewise a sow that is nursing a litter of twelve pigs requires a lot of water to produce milk for the young, Figure 15–4.

PROTEIN

Protein can make up to around 15-16 percent of an animal's ration and may be the most costly part of the ration. Proteins are composed of compounds known as **amino acids**. Amino acids are often said to be the building blocks of life because they go into the formation of tissues

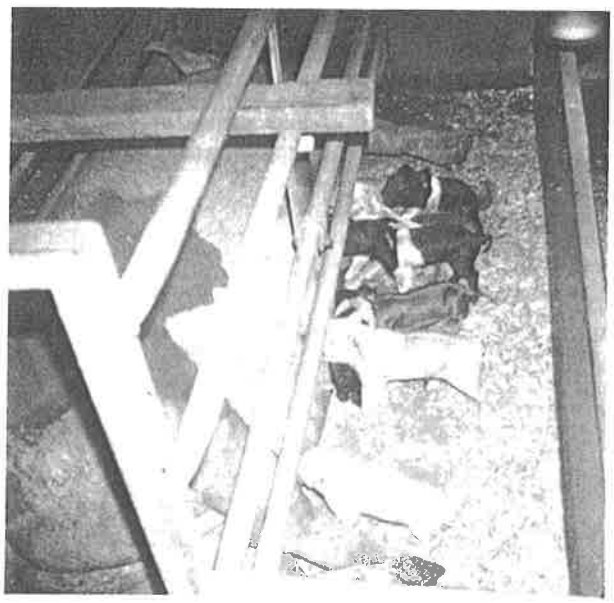


Figure 15-4. A sow nursing a litter of pigs needs a lot of water.

that provide growth for the animal. Muscle production in particular is dependent on the amino acids found in proteins. All of the enzymes and many of the hormones in the bodies of animals are composed of protein. To a certain degree, protein is also used to provide energy.

Like water, some animals need larger amounts of protein than others. Young, rapidly growing animals need more protein than mature animals. This is because the amino acids in the protein are needed to build muscles, skin, hair, bones, and all of the other cells that go into the growth process, Figure 15–5. A cow that is giving large amounts of milk needs more protein than an animal that is not lactating.

In all there are over twenty different types of amino acids that an animal's body uses. Of these, there are ten essential amino acids that the animal must obtain from its feed. The other amino acids can be synthesized by the animal's digestive tract. This means that the thirteen nonessential amino acids can be made from the ten that the animal consumes. In this sense, the ten are essential in that they cannot be manufactured by the animal and must be consumed. The following table lists the **essential amino acids** and **nonessential amino acids**.

Essential	Nonessential
Arginine	Alanine
Histidine	Aspartic acid
Isoleucine	Citrulline
Leucine	Cystine
Lysine	Glutamic acid
Methionine	Glycine
Phenylalanine	Hydroxyproline
Threonine	Proline
Tryptophan	Serine
Valine	Tyrosine

Animals may not be able to digest all of the protein in a particular feed. The total amount of

Figure 15-5. Animals use protein to grow muscle, hair, and other tissues. *USDA photo.*

protein in a feed is called the **crude protein content**. The amount of crude protein in a feed is calculated by analyzing the nitrogen content and multiplying that percentage by 6.25. Digestible protein is the protein in a feed that can be digested and used by the animal. The digestible protein is usually about 50-80 percent of the crude protein.

Of all the ingredients in an animal's feed, protein is usually the most costly. Although protein can be found in most of the feedstuffs, some have a much lower content than others. For example, yellow corn has a protein content of around 8 percent. A growing pig may need a ration that consists of 16 percent protein. Being fed corn alone will not give the pig an adequate amount of protein to provide for the building of the body cells to sustain growth. This means that a feedstuff that is higher in protein content will have to be added.

Protein can come from basically two sources: animal and plant. **Carnivores** (animals that eat other animals), such as dogs, cats, and foxes, get almost all of their protein from meat. After all, the muscles in an animal's body are primarily composed of protein and can serve as food for another animal. Omnivores (an animal that eats both plants and animals), such as humans and pigs, can get protein from both plants or animals. Animals that eat only

Figure 15-6. Soybeans provide protein for animal rations. *John Deere and Company.*

plants are called **herbivores**, and they must get protein exclusively from plants.

Most feedstuffs that are rich in protein come from plant sources. Pigs were once fed slaughterhouse by-products such as **tankage** and blood meal. Recent research has shown that these protein sources are inferior to plant sources in terms of protein that is usable to the animal. Some dried fish meal is fed to hogs as a supplement. Much of plant protein that goes into the feed of animals comes from the vegetable oil industry. Cooking oil is usually pressed from cottonseed, soybeans, peanuts, or corn, Figure 15–6. These seeds are run through huge presses where the oil is squeezed out. The material that is left is in the form of a cake composed of the seeds minus the oil. It is dried and ground into a meal for feed. This material is usually 40-45 percent crude protein and can greatly increase the percent of protein in a feed. This feedstuff is then mixed with the other feedstuffs in the proper ratio to give the desired protein content for the feed.

The protein source used is often determined by the animal that is being fed. For instance, pigs are not fed cottonseed meal because this feedstuff contains a substance known as gossypol that is toxic to them. Other needs of the animal also determine the protein source that is used. Modern livestock opera-

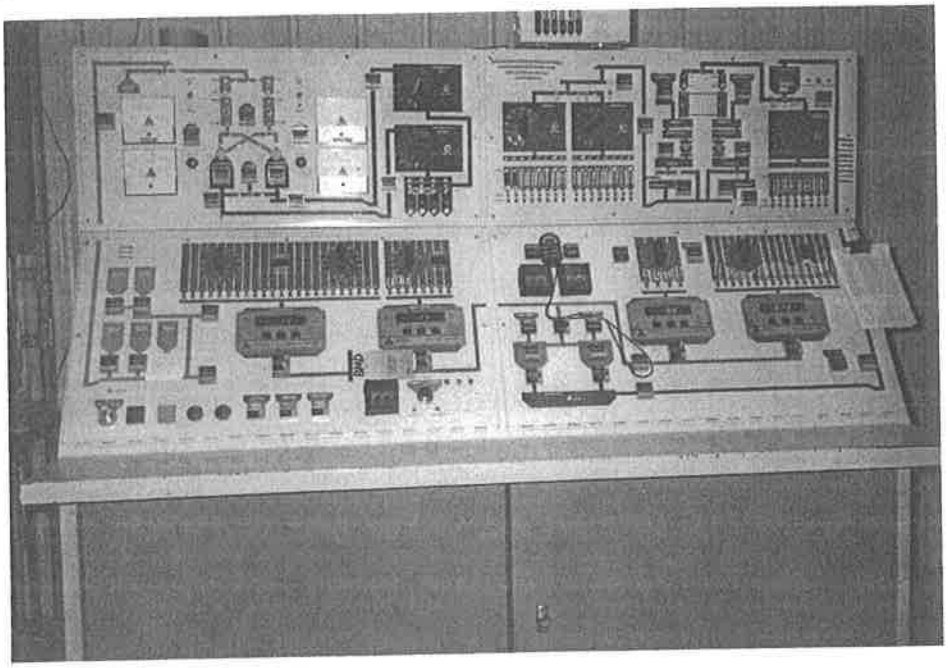


Figure 15-7. Feeds are balanced using computers. This is a computer control panel of a large, modern feed mill. *Dan Rollins, ConAgra Feed Mill, Falkville, Alabama.*

tions no longer just balance a feed ration based on the percent of protein. Now the feed formulas are based on the types and amounts of amino acids that are needed by a particular group of animals. The process of balancing feed rations based on amino acid contents is so complicated that it is done by computers. Large modern feed mills have computers that control the formulating and blending of the different types of feed, Figure 15–7. Two feedstuffs may have the same percentage of protein and have different percentages of the essential amino acids. Different amino acids are needed for different body functions. For example, a different amino acid is needed for growth than is needed for milk production. Growing animals need a different type of protein supplement than a lactating dam needs. Feeds balanced on the type of amino acids needed by the animal are more cost-efficient, Figure 15–8.

CARBOHYDRATES

The main source of energy from animals comes from carbohydrates. Carbohydrates are compounds made up of carbon, hydrogen, and oxygen. They include sugars, starches, and **cellulose** and are the major organic compounds in plants. Almost all carbohydrates come from plants and are developed by photosynthesis. By weight, plants are composed of about 75 percent carbohydrates. As will be discussed later, some animals are more efficient than others at making use of these carbohydrates.

Starch is generally found in grain. It is used by the plant as energy storage for the seed. Grains such as wheat and corn contain a lot of starch and therefore a lot of energy for the animal to use. Starches are composed of sugars, and as digestion occurs, the starch is broken down into the component sugars.

Figure 15-8. Feed samples are constantly monitored to ensure the proper balance and quality of the feed. *Dan Rollins, ConAgra Feed Mill, Falkville, Alabama.*

There are several different types of sugars. Two broad groups are **monosaccharides** (the simple sugars) and **disaccharides** (the more complex sugars). Simple or complex refers to the chemical composition of the sugar and the different ways the molecules are formed.

There are several common simple sugars (monosacchrides); among these are **glucose**, **fructose**, and **galactose**. Glucose is the simplest of all the sugars and is found in a low concentration in plant materials. It is also the major energy source found in an animal's blood. The animal's body breaks down some of the other sugars into glucose.

Fructose is found in fruits and honey and is the sweetest of all the sugars. Common table sugar (**sucrose**) is a disaccharide composed of fructose and glucose. Galactose is obtained from the breakdown of the disaccharide **lactose** (milk sugar).

Cellulose is the portion of cell walls that gives the plant its rigid structure. The enzymes in an animal's digestive system cannot break down cellulose. However, some animals have microorganisms in their digestive system that break down the cellulose fiber so the enzymes can digest the material. (This will be discussed later in this chapter.)

The most important source of carbohydrates for agricultural animals is grains. Most of the millions of tons of corn grown in this country each year go into the production of livestock feed, Figure 15–9. Other grains such as wheat, oats, and barley are also used. Feeds that are high in grain content are known as concentrates because of the high concentration of carbohydrates.

For horses and ruminant animals, forages grown for grazing and for hay are valuable sources of feed. These food sources are referred to as roughages because of the amount of fiber in the diet. Sometimes a combination of grain and forage is used in the form of silage or similar types of feed, Figure 15–10.

Figure 15-9. Most of the millions of tons of corn grown each year go into the production of animal feeds. *John Deere and Company.*

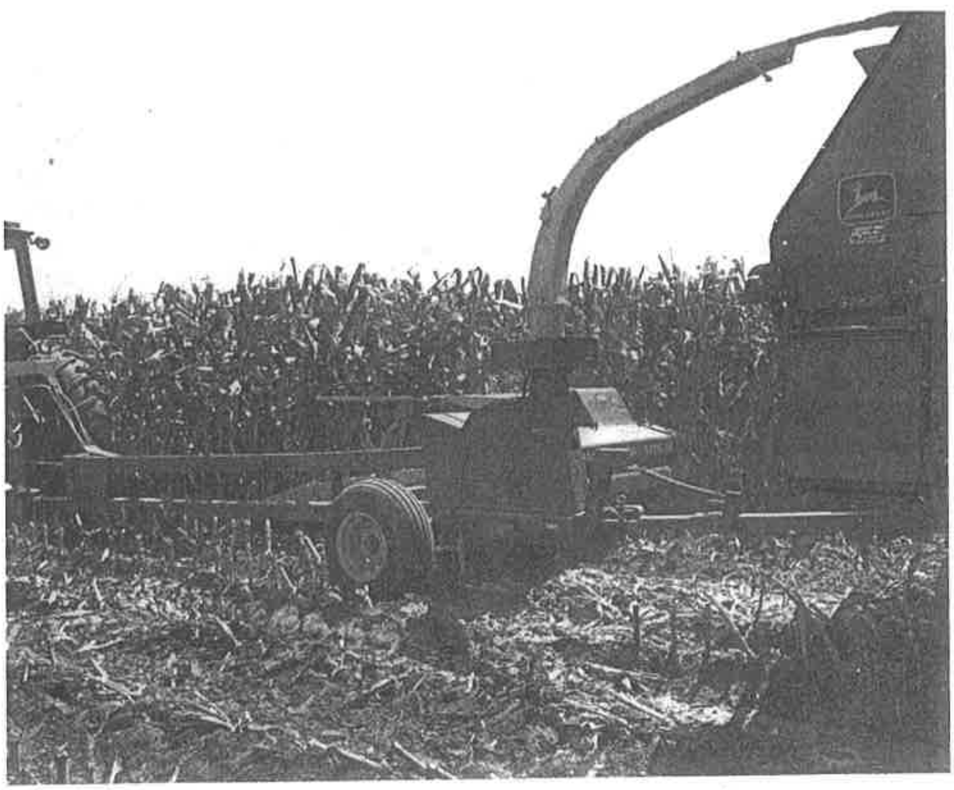


Figure 15-10. Corn is chopped to create silage, which is a combination of roughages and concentrates. *John Deere and Company.*

FATS

Fats are part of a group of organic compounds known as **lipids**. These compounds will not dissolve in water but will dissolve in certain organic solvents. Besides fats and oils, lipids also include cholesterol. Fats are found in both plants and animals. They serve as concentrated storage places for energy. Oil within seeds such as peanuts and soybeans is an example of plant fats, Figure 15–11.

Fats serve the purposes of providing energy for the animal and of storing excess energy. When an animal consumes more energy (especially in the form of fats) than it needs to provide for all the needed bodily functions, the excess is stored in the form of fat. When the body does not take in enough energy to perform the normal bodily functions, these reserves of fat are used.

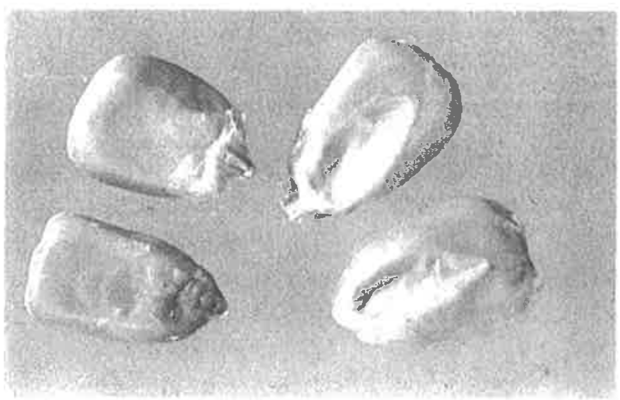
Certain acids, referred to as the essential fatty acids, are also derived from fats. These acids are necessary in some animals for the production of some hormones and hormonelike substances.

The most important sources of fats in feeds for agricultural animals are the grains that contain oil. Corn and most of the other feed grains contain oil that is used as a fat source by the animals. Some types of animals, pigs for example, may have problems if fed too much oil. Hogs fattened on oily feeds such as whole peanuts may produce soft, oily pork that is not acceptable to the consumers.

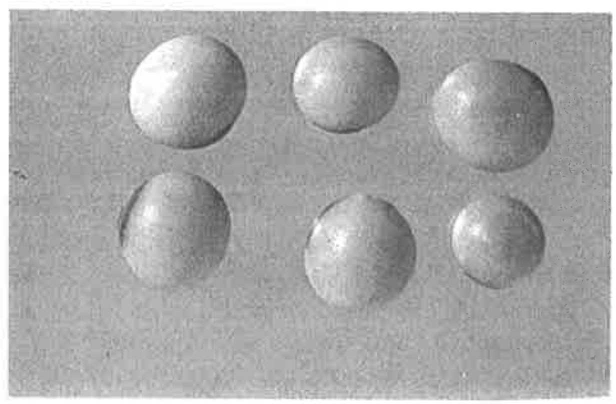
MINERALS

Minerals are the only group of nutrients besides water that are **inorganic**. Although they provide only a small portion of the total feed intake, they are vitally important. This group serves the important role of providing structural support for the animal. Bones are formed by a combination of calcium and phosphorus. Another example is eggshells, which are mainly composed of calcium, Figure 15–12. Eggshells are ground up and added to chicken feed as a source of calcium. Animals must have a sufficient intake of these inorganic materials to provide the building materials for their body structure.

In addition to building bones, minerals provide other essential needs. They aid in the construction of muscles, blood cells, internal



(A)



(B)

Figure 15-11. Oil within seeds such as corn (*A*) and soybeans (*B*) is an example of plant fats. *American Association of Feed Microscopists.*

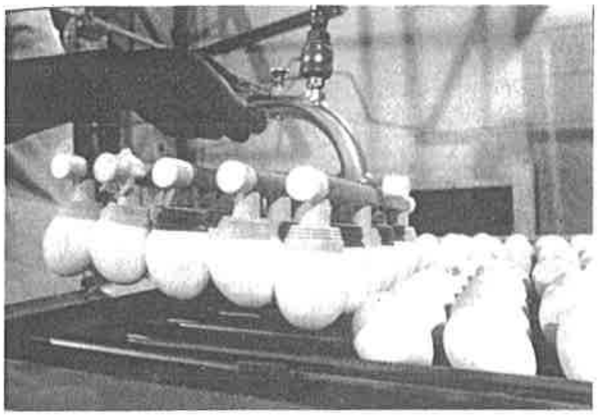


Figure 15-12. The shells of eggs are mostly composed of the mineral calcium. *Dr. Nicholas Dale, Cooperative Extension Service, The University of Georgia.*

organs, and enzymes. Animals with a deficiency in minerals never develop properly and are more susceptible to disease.

The mineral elements required by animals include seven **macrominerals** (required in relatively large amounts in the diet) and nine **microminerals** or **trace minerals** (required in very small amounts in the diet). The macrominerals are calcium, chlorine, magnesium, phosphorus, potassium, sodium, and sulfur. The microminerals are cobalt, copper, fluorine, iron, iodine, manganese, molybdenum, selenium, and zinc. These inorganic, crystalline, solid elements make up 3-5 percent of the body on a dry-weight basis, with calcium (approximately one-half the body mineral) and phosphorus (approximately one-fourth the body mineral) accounting for the largest portion of the total mineral content.

Minerals are usually added to the feed of animals in their chemical form. Calcium is sometimes added from other animal sources. For example, ground up oyster shells are fed to laying hens to provide materials for their bodies to create strong eggshells. Ground eggshells can also be used as a calcium source for animal feed.

Figure 15-13. Cattle are fed minerals "free choice." This mineral box turns with the wind to help keep out the rain

Minerals are often fed **free choice**. This means that the animals are given free access to the minerals and are allowed to eat all they wish. For cattle, this is done by a mineral box or trough, or by the use of a salt block, Figure 15–13. Essential minerals are in the block, and the animals get them as they lick the block for salt.

Vitamins

Vitamins are considered to be micronutrients. This means that the body needs them in very small amounts. Even though only small amounts are required, vitamins are essential for life. They are essential for the development of normal body processes of growth, production, and reproduction. They are also vitally important in providing the animal with the ability to fight stress, disease, and to maintain good health.

Some animals are able to synthesize certain vitamins in their body tissues. Other vitamins cannot be created by the animal from other nutrients and must be obtained from the diet or by microbial synthesis in the digestive system.

There are sixteen known vitamins. The B vitamins and vitamin C are water soluble. Fat-soluble vitamins are A, D, E, and K.

Vitamin A is not found in feeds, but it is converted by the animal's body from the provitamin **carotene**, which is found in green, leafy forages from pastures, hay, silage, and dehydrated legumes (alfalfa). Other sources include yellow corn, fish liver oils, and whole milk. Vitamin A can be stored in fats and the liver for several months, to be used when forage quality is low or stress conditions increase the body's demand for vitamin A. Supplementation is usual for ruminants and swine.

Vitamin D is sometimes referred to as the "sunshine vitamin" since both animal and plant sources depend on ultraviolet light to make a form of vitamin D. This form of the vitamin is converted by the liver and kidneys to forms that are usable. Animals make their own vitamin D, and diets of sun-cured forages, yeast, and certain fish oils provide the basis for synthesis, Figure 15–14. Commercial vitamin D is available and generally is made from irradiated yeast. Excessive amounts of vitamin D can

Figure 15-14. Sun-dried forages can provide the basis for the synthesis of vitamin D. *John Deere and Company.*

reduce an animal's efficiency and is **toxic** in some incidences. Animals in total confinement often receive supplements of vitamin D.

The cereal grains, germ oils, and green forage or hay supply vitamin E. Vitamin E is found in several forms of a complex organic compound called tocopherol. Commercially produced vitamin E is available for supplemental feeding. There are no known toxic effects from excessive levels in the diet.

Vitamin K is utilized to form the enzyme prothrombin, which in turn helps to form blood clots. Deficiencies rarely occur because vitamin K is synthesized in the **rumen** and in the **monogastric** intestinal tract. Green forages, good-quality hays, fish meal, and synthetic forms of vitamin K can be used to increase the level in the diet.

The B Vitamins

Thiamine is essential as a coenzyme in energy metabolism. Dietary sources of thiamine include green forage or well-cured hays, cereal grains (especially seed coat or bran), and brewer's yeast. Heat processing of grains reduces the amount of available thiamine. Thiamine is usually synthesized in the rumen. The diet of monogastric animals usually provides enough thiamine. However, thiamine is commercially available in vitamin premixes.

Riboflavin is important as a part of two coenzymes that function in energy and protein metabolism. Sources include green forages, leafy hays, or silage; milk and milk products; meat; fish meal; and distiller's or brewer's by-products, Figure 15–15. Commercially available, riboflavin is generally added to swine rations and may be needed in ruminant rations.

Pantothenic acid is a component of coenzyme A, which is important in fatty acid and carbohydrate metabolism. Sources include brewer's yeast, liver meal, dehydrated alfalfa meal, molasses, fish solubles, and most feedstuffs. Commercial sources should be included in the diets of confined animals.

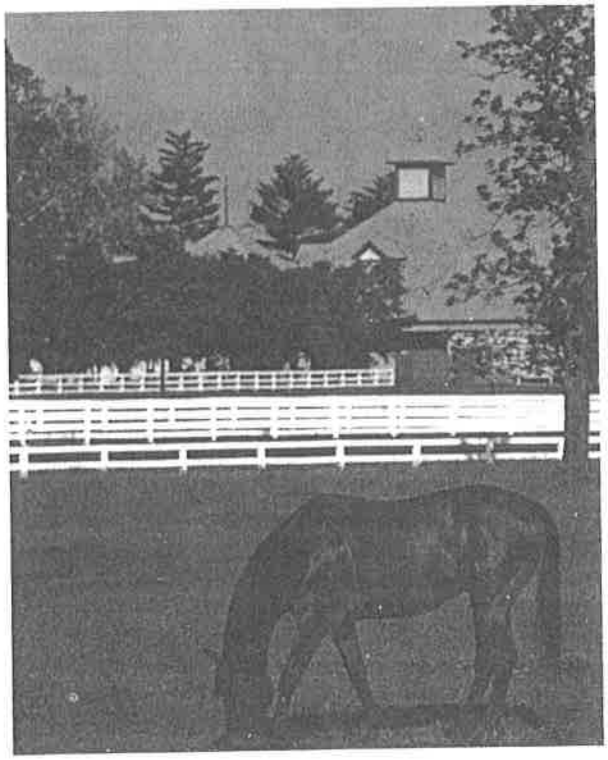


Figure 15-15. Green forages are a good source of vitamins such as vitamin K, thiamine, and riboflavin. *Kentucky Horse Park.*

Niacin is part of an enzyme system essential in the metabolism of fat, carbohydrates, and proteins. Niacin is found in animal by-products, brewer's yeast, and green alfalfa. There is some present in most feeds, but the niacin in grains is largely unavailable to nonruminants and supplementation is often needed.

Pyridoxine is important as a coenzyme component needed for fatty acid and amino acid metabolism. Most feedstuffs are fair-to-good sources of pyridoxine, including cereal grains and their by-products, rice and rice bran, green forages and alfalfa hay, and yeast. Supplementation in animal diets is usually not needed.

Biotin is widely distributed. It is found in large quantities in egg yolk, liver, kidney, milk, and yeast. Biotin is a part of an enzyme involved in the synthesis of fatty acids. It can be readily synthesized by animals and is not deficient in normal farm animals.

Folic acid is needed in body cell metabolism. Folic acid is found in green forages, such as alfalfa meal, and in some animal proteins. The animal body synthesizes some folic acid, and although it is available in synthetic forms, supplements are not greatly needed in farm animals.

Choline is found as a component of fats and nerve tissues and is needed at greater levels than other vitamins. Most commonly used feeds are good sources of choline. Choline is synthesized in the animal body when other vitamins such as B_{12} are abundant.

B_{12} functions as a coenzyme in several metabolic reactions and is an essential part of red blood cell maturation. Synthesis of vitamin B_{12} requires cobalt. Sources of B_{12} include protein feeds of animal origin and fermentation products. Most swine rations are supplemented with vitamin B_{12}.

Inositol is found in all feeds and synthesized in the intestinal tract, so is not generally needed as a supplement.

Although the function is not well known, paraaminobenzoic is synthesized in the intestine and is usually not deficient in livestock rations.

Vitamin C is essential in the formation of the protein collagen. Vitamin C is found in citrus fruits; green, leafy forages; and well-cured hays. Animals normally can synthesize sufficient quantities of vitamin C to meet their needs.

THE DIGESTION PROCESS

Animals use feed nutrients on a cellular basis—all of the different nutrients that an animal takes in must be converted to a form that the cells in the body can use. Once this conversion (digestion) is completed, the nutrients must be transported to the cells where they are needed. The system that performs this task is referred to as the digestive system. The organs that make up this system are known as the **gastrointestinal tract** (GI tract).

The gastrointestinal tract is also referred to as the **alimentary canal**. This is the tract reaching from the mouth to the anus, through which feed passes following consumption and where it is exposed to the various digestive processes. The digestive system includes the various structures, organs, and glands involved with the procuring, chewing, swallowing, digestion, **absorption**, and excretion of feedstuffs. Although there are similarities in the digestive systems, farm animals are often classified according to the nature of their digestive system. There are basically two types of digestive systems. One is known as monogastric (single-compartment stomach), Figure 15–16; and the other is known as ruminant (multicompartment stomach). Following are descriptions of processes in the two digestive systems in the order of occurence.

Monogastric Digestive Systems

Monogastric systems are those that have only one-compartment stomachs. These include the pig, horse, dog, cat, and birds. The horse has an enlargment, known as a **cecum**, that enables it to utilize high-fiber feeds by means of microbial fermentation, much as do ruminants, Figure 15–17. This means that the horse is not typical of monogastric animals. Simple-stomach (monogastric) animals are not capable of digesting large amounts of fiber and are usually fed concentrate feeds.

The digestive process begins in the mouth, which is the first organ of the digestive tract. Within the mouth the tongue is used for grasping

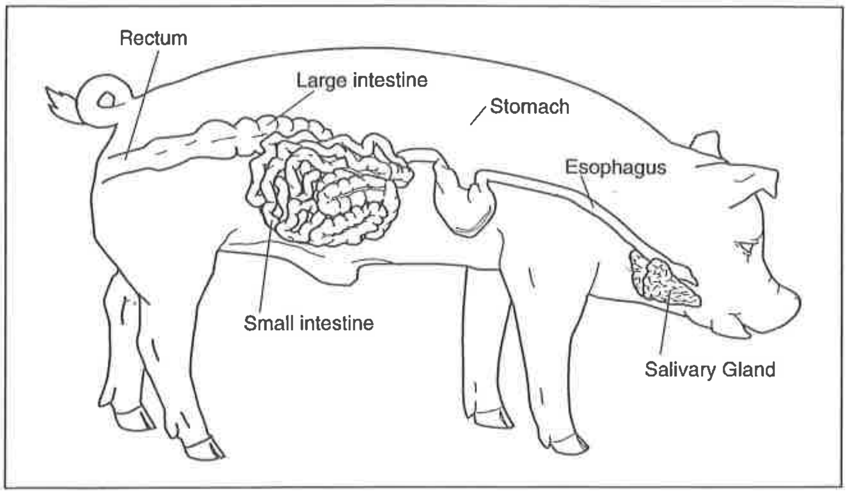


Figure 15-16. The pig has a monogastric digestive system.

the food, mixing, and swallowing. The teeth are used for tearing and chewing the feed. This is the first step in the process of breaking down the feed into fine particles. The mouth also contains salivary glands, which consist of three pairs of glands that excrete saliva. Saliva contains several substances: water to moisten, mucin to lubricate, bicarbonates to buffer acids in the feeds, and the enzyme amylase to initiate carbohydrate breakdown.

The **esophagus** is a hollow, muscular tube that moves food from the mouth to the stomach. This is accomplished by muscular contractions that push the food along.

The stomach is a hollow muscle that causes further breakdown of foods by physical muscular movement. The food is pressed together and massaged by the movement of muscles in this area. In the stomach, food is also broken down by chemical action. The walls of the

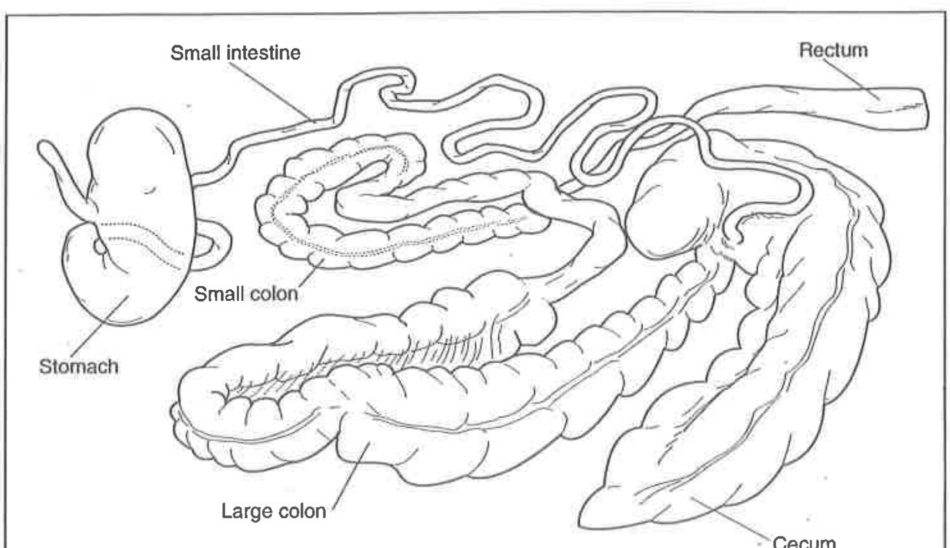


Figure 15-17. Horses have a large pouch called a cecum that helps digest high-fiber feeds such as hay.

stomach secrete hydrochloric acid that begins to dissolve the food. Another secretion, **pepsin**, begins to break down proteins into the amino acids. The secretion rennin acts to curdle the casein in milk. Gastric lipase causes the breakdown of fats to fatty acids and glycerol.

The small intestine is a long, hollow tube that leads from the stomach to the large intestine. This organ is made up of several parts: the **duodenum**, the **jejunum**, and the **ileum**.

The entrance to the small intestine is controlled by a sphincter muscle that helps move food into and through the tract.

The first segment of the small intestine is the duodenum. The duodenum receives secretions from the pancreas, which act to break down proteins, starches, and fats. Here the intestinal walls secrete intestinal juices that contain enzymes that further the process of breaking down the food.

The next segments of the small intestine are the jejunum and the ileum. These are the areas of nutrient absorption. Absorption is the process by which the nutrients are passed into the bloodstream. The villi (small fingerlike projections) in these areas facilitate absorption into the bloodstream and/or lymph system through membranes that surround the villi, Figure 15–18. This type of membrane is called a **semipermeable membrane**. This means that the membrane will allow particles to pass through in a process called **diffusion**.

The last organ of the digestive tract is the large intestine. This organ is divided into three sections. The first section is the cecum, which is a blind pouch. A cecum is of little function in most monogastric animals. However, in some animals, such as the horse, this area is where fibrous food such as hay and grass is broken down into usable nutrients.

The second segment of the large intestine is the colon, which is the largest part of the organ. Its function is to provide a storage space for wastes from the digestive process. Here water is removed from the wastes and some microbial action begins on fibrous materials.

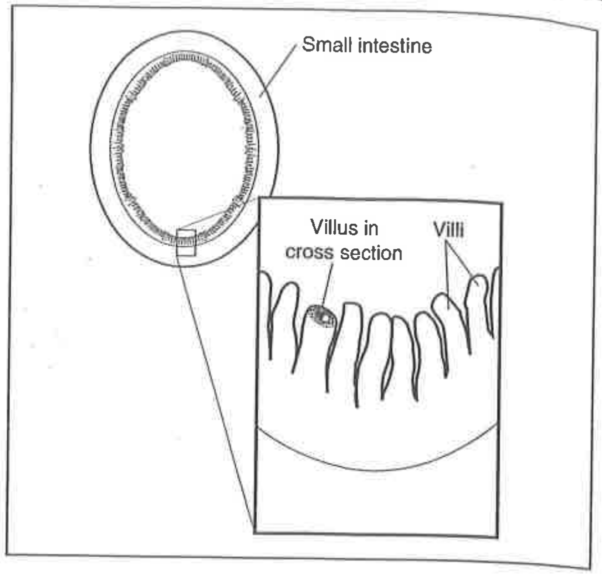


Figure 15-18. The small intestine is lined with fingerlike projections, called villi, that absorb nutrients into the bloodstream.

The rectum is the final segment of the large intestine and the final part of the digestive system. It serves to pass waste material through to the anus where it is eliminated.

Ruminant Digestive System

Animals such as cows and sheep have multicompartment stomachs that allow them to use high-fiber feeds such as grasses and hays, Figure 15–19. These animals are often called "cud chewers" because they regurgitate **boluses** of feed, consumed earlier, and remasticate (chew) and reswallow. The digestive systems of ruminants differ from monogastric systems in several ways.

In the mouth of ruminants there are no upper front teeth. Instead there is a dental pad that works with the lower incisors for tearing off

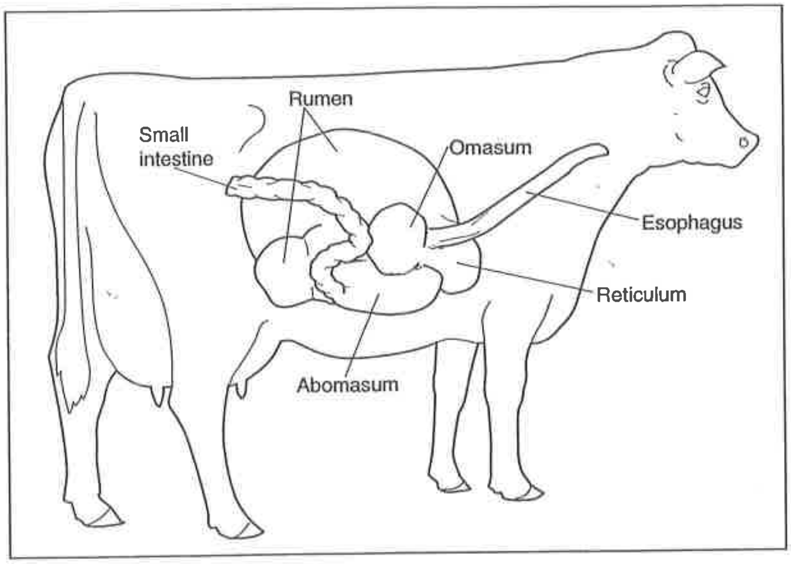


Figure 15-19. Cattle have four compartments to their stomachs. This allows them to use large amounts of roughages.

forages and other feedstuffs. The upper and lower jaw teeth (molars) enable the animal to chew on one side of the mouth at a time. Large quantities of saliva are produced. This saliva is highly buffered and provides phosphorus and sodium for the rumen microorganisms. Unlike most monogastric animals, there are no enzymes in the saliva, but there is some urea released that provides nitrogen for the bacteria in the rumen.

The stomach has four compartments. It consists of the **rumen** (paunch), **reticulum** (honeycomb), **omasum** (many piles), and the **abomasum** (true or glandular stomach). In the young ruminant animal an esophageal groove or heavy muscular fold allows milk from the suckling animal to bypass the rumen and reticulum to the omasum.

Compartments of the Ruminant Stomach

The esophagus leads to both the reticulum and the rumen. As ruminants graze, they tend to pick up hard, indigestible objects such as small stones, nails, and bits of wire. These heavy materials fall into the reticulum. The walls of the reticulum are made up of **mucous membranes** that form subcompartments with the appearance of a honeycomb. These small compartments trap and provide a storage place for "hardware" that does not float, Figure 15–20. This prevents dangerous objects from proceeding through the rest of the digestive tract.

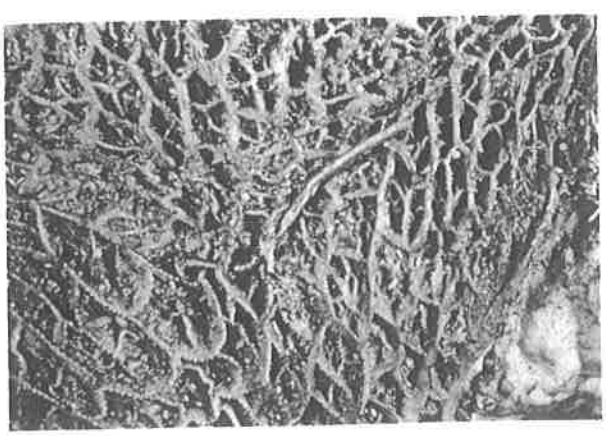


Figure 15-20. The reticulum collects hard indigestible objects. Note the nail. *North Dakota Department of Education.*

The reticulum also functions to store, sort, and move feed back into the esophagus for regurgitation or into the rumen for further digestion. The process of breaking down roughages begins with a contraction of the reticulum and muscles in the esophagus to move roughage and fluid to the mouth. Excess fluid is squeezed out and the material is reswallowed.

After the material is reswallowed, it moves to the rumen. The rumen functions as a storage vat where food is soaked, mixed, and fermented by the action of bacteria. The hollow, muscular paunch fills the left side of the abdominal cavity and contains two sacks, each lined with papillae (nipplelike projections) that aid in the absorption of nutrients. Bacteria thrive in the rumen environment and function to break down fibrous feeds. Carbohydrates are broken down into starches and sugars. Volatile fatty acids are released as the carbohydrates are broken down, and these fatty acids are absorbed through the rumen wall to provide body energy.

Bacteria also use nitrogen to form amino acids and eventually proteins. The bacteria can also synthesize water-soluble vitamins and vitamin K. Byproducts of the microbial activity include methane and carbon dioxide. A small portion of these gases is absorbed by the blood, but much of the gas is eliminated by belching. Belching occurs when the upper sacs of the rumen force gases forward and down so the esophagus can dilate and allow gases to pass. If gases are not eliminated due to froth or foam blocking the esophagus, a condition called **bloat** (an inflation of the rumen) will sometimes occur.

After leaving the rumen, the food material passes through to the omasum. The omasum is a round organ on the right side of the animal and to the right of the rumen and reticulum. The omasum grinds roughage using blunt muscular papillae that extend from many folds of the omasum walls.

The last compartment of the ruminant's stomach is the abomasum. The abomasum is the only glandular (true stomach) stomach of the ruminant. The abomasum is located below the omasum and extends to the rear and to the right of the rumen. This compartment functions similarly to the stomach of monogastric animals. By the time food materials reach the abomasum, the fiber of the roughages have been broken down to the extent that they can be handled by the abomasum. The small and large intestines of the ruminant animal function much the same way as they do in the monogastric animal.

◆ Review Exercises

TRUE OR FALSE

1. A feedstuff is generally a feed component that producers would not normally give to an animal exclusive of other feedstuff. ______.
2. Water, although an essential nutrient, is needed only in small amounts and makes up only a tiny fraction of the animal's body. ______.
3. Protein, composed of amino acids, may be the most costly part of the animal's ration. ______.
4. Digestible protein, that protein in a feed that can be digested and used by the animal, makes up about 20–25 percent of the crude protein. ______.
5. Carnivores get almost all their protein from meat, omnivores can get protein from meat and plants, and herbivores get protein exclusively from plants. ______.

6. The main source of tissue-building proteins is carbohydrates. ______.
7. Photosynthesis accounts for almost all carbohydrate development. ______.
8. Of all the millions of tons of corn grown in this country each year, only a small amount is used for feed grain. ______.
9. Fats can only be obtained from animals. ______.
10. Animals with a deficiency in minerals never develop properly and are more susceptible to disease. ______.
11. Both animal and plant sources depend on ultraviolet light to make a form of vitamin D. ______.
12. It is possible for animals to ingest too many vitamins, and harm can result. ______.
13. The terms gastrointestinal tract and alimentary tract refer to the same system. ______.
14. The small intestine consists of three parts called the duodenum (which breaks down the food), the jejunum, and the ileum (both of which are areas of absorption). ______.
15. Ruminant animals do not have small and large intestines. ______.

FILL IN THE BLANKS

1. The maintenance ration is the level of ______________ needed by the ______________ to maintain ______________ weight and not ______________ or gain weight.
2. Metabolism refers to all of the ______________ and ______________ processes that take place in the ______________ body.
3. Metabolism that builds up tissue (such as growth and ______________ repair) is called ______________; metabolism that breaks down material (such as the breakdown of ______________ within the ______________ system) is called ______________.
4. Young, rapidly growing animals need more protein than ______________ animals because the ______________ acids are needed to build muscles, ______________, ______________, bone and all of the other calls that go into the ______________ process.
5. Feed formulas are now based on the ______________ and ______________ of ______________ acids that are needed by a particular group of ______________.
6. Carbohydrates are compounds made up of ______________, hydrogen, and ______________ and include sugars, ______________, and ______________.
7. Simple or complex sugars refer to the ______________ composition of the sugar and the different ______________ the ______________ are formed.
8. When an animal consumes more energy (especially in the form of ______________) than it needs to ______________ for all the necessary bodily ______________, the excess is stored in the form of ______________.
9. Although minerals provide only a small portion of the total ______________ intake, they are vitally important in providing ______________ support for the ______________.
10. Although vitamins are ______________—needed only in small amounts—they are essential in the development of normal body ______________ of health, ______________, production, and ______________.
11. Good sources for pyridoxine include ______________ grains and their by-products, ______________ and rice bran, ______________ forages and ______________ hay, and ______________.
12. Choline is found as a component of ______________ and ______________ tissues and is needed in ______________ levels than other ______________.
13. Simple-stomach or ______________ animals are not capable of ______________ large amounts of ______________ and are usually fed ______________ feeds.

14. Ruminants such as the cow and ______________ have ________________ stomachs that allow them to use high-____________ feeds such as grasses and ____________.

15. The esophagus in a ruminant animal leads both to the reticulum (which serves to store ________________ and functions to store, sort, and ___________ feed back into the esophagus for _______________ or into the rumen for further ____________) and the rumen (which functions as a storage ________ where food is soaked, ________, and __________).

DISCUSSION QUESTIONS

1. What is the difference between a feed and a feedstuff?
2. Define metabolism.
3. List at least four functions water plays in sustaining life.
4. Explain why a young animal needs more protein than a mature animal does.
5. List the sources of protein for livestock feeds.
6. From what source do all carbohydrates come?
7. What purpose do fats serve?
8. What essential needs do minerals provide?
9. List the vitamins that are needed by animals.
10. List the parts of the monogastric digestive system and briefly describe the function of each.
11. List the compartments of the ruminant stomach and describe the function of each.

STUDENT LEARNING ACTIVITIES

1. Locate and report on an article telling about research that has been completed on livestock feeds. Explain what practical differences you feel this research will make.
2. Obtain the tag from a bag of feed. Make a list of the ingredients and tell which nutrients are derived from each component.
3. From a slaughterhouse, obtain the digestive tract of a monogastric animal (pig) and a ruminant (sheep or cow). Dissect the tract and identify all of the parts. Be sure to wear latex gloves when the organs are handled.