The Digestive and Endocrine Systems

Lesson 3

ASSIGNMENT 6

Read in your textbook, *Clinical Anatomy and Physiology for Veterinary Technicians,* pages 358–377, 436, and 474–475. Then read Assignment 6 in this study guide.

Introduction

The *endocrine system* involves the secretion of chemicals called *hormones* by glands within the body. These chemicals control bodily functions, often at locations very distant from the gland that secreted the chemical. The opposite of endocrine is *exocrine,* which involves the secretion of substances into spaces outside the body. The glands in the skin and gastrointestinal tract are examples of exocrine organs. (The lumen of the intestine is a space that technically isn't "within" the body, because it's continuous with the outside environment via the mouth and anus.)

The *pancreas* is unique in being both an endocrine gland and an exocrine gland. The endocrine function is the secretion of substances such as insulin, which metabolizes sugar. The exocrine function involves the secretion of digestive enzymes into the duodenum.

Many endocrine organs exist throughout the body (see Table 15-2 on page 360 of your textbook). While they're all classified as endocrine glands, their anatomy and functions aren't necessarily similar or even remotely related. Therefore, there isn't really a grand organizational scheme to this system as there is with some of the other body systems. The glands are considered together only because their means of secretion is similar.

All endocrine glands secrete hormones in the form of proteins that travel via the blood to the target organ for that particular hormone. The hormone causes changes in the activity, and in some cases the structure, of the target organ. Hormones collectively coordinate the physiology of nearly all activities in the body. In this way, the endocrine system is related to the nervous system. A comparison of the functions of the nervous and endocrine systems can be found on page 359 of your textbook (see Table 15-1).

Some endocrine glands have distinct structures that separate them from other organs. Examples include the pituitary gland, the adrenal glands, the thyroid gland, and the parathyroid gland. Other endocrine cells are incorporated in the tissue of other organs. Examples include the insulin-producing cells of the pancreas, certain cells of the brain and kidneys, and the endocrine sex glands.

Many endocrine glands are somewhat self-regulating via a process called *negative feedback.* Hormone secretion raises the blood level of that hormone or affects the level of specific substances in the blood. The endocrine cells detect the altered levels of the hormone or substance that they monitor and decrease the secretion of their hormone. Breakdown in this self-regulation can lead to disorders of endocrine secretion.

Pituitary Gland and Hypothalamus

A ventral protrusion of the brain called the *pituitary gland* (also called the *hypophysis*) has a multitude of functions, many of which involve control of other endocrine glands. The pituitary gland consists of two parts: the anterior pituitary and the posterior pituitary. Each contains different types of cells that secrete different substances. The *posterior pituitary,* also called the *neurohypophysis,* is an outgrowth of nervous tissue from the hypothalamus in the brain. The epithelial tissue that comprises the anterior pituitary wraps around the posterior pituitary gland.

Two hormones are released by the posterior pituitary gland: *antidiuretic hormone (ADH)* and *oxytocin.* ADH is also called *vasopressin* and acts to improve water uptake in the renal collecting duct by increasing its permeability to water. This ensures the body doesn't excrete too much water and become dehydrated. ADH also causes some smooth-muscle contraction that can lead to blood vessel constriction and a resulting increase in blood pressure. Oxytocin stimulates milk production and is important in stimulating contractions of the uterus during labor. These hormones are actually produced by nerve cells in the hypothalamus and are carried by nerve fibers to the posterior pituitary. The hormones are stored in the ends of these nerve fibers until release is stimulated by nerve impulses traveling from the hypothalamus.

The *anterior pituitary gland* synthesizes the hormones it secretes, including a group of hormones that stimulate growth and secretion of other endocrine cells. It also secretes hormones that act directly on tissues to produce their effects.

Stimulating hormones include

- *Thyroid-stimulating hormone (TSH),* which stimulates thyroid gland growth and secretion
- *Adrenocorticotrophic hormone (ACTH),* which stimulates the adrenal glands to produce various hormones
- *Follicle-stimulating hormone (FSH),* involved in the development and function of the reproductive glands
- *Luteinizing hormone (LH),* involved in the development and function of the reproductive glands

Direct-acting anterior pituitary gland hormones include

- *Growth hormone (GH),* which is very important in the mature development of a person or animal
- *Prolactin,* which stimulates development and secretion of the mammary glands
- *Melanocyte-stimulating hormone (MSH),* which stimulates production of melanin in the skin by special cells called melanocytes

Thyroid Glands

Two small glands located in the neck, one on each side of and just ventral to the trachea, are known as the thyroid glands. The *thyroid glands* secrete *thyroid hormone* and *calcitonin.* Calcitonin helps regulate blood calcium levels.

Thyroid hormone controls cell metabolism and stimulates nervous tissue growth. It also stimulates production of proteins and helps maintain blood glucose levels. The term "thyroid hormone" actually refers to two distinct molecules:

- *Thyroxine,* also known as T_4, contains four iodine molecules.
- *Triiodothyronine,* also known as T_3, incorporates three iodine molecules.

TSH produced by the pituitary gland stimulates secretion of thyroxin from the thyroid glands.

Calcitonin regulates the level of blood calcium by inhibiting the release of calcium from bone. It also stimulates calcium deposition in bone by increasing the activity of osteoblasts. Calcitonin secretion is regulated by the level of blood calcium and is independent of thyroxin secretion.

Parathyroid Glands

Immediately adjacent and just caudal to the thyroid glands are a pair of very small glands called the *parathyroid glands.* The parathyroid glands secrete a hormone called *parathyroid hormone (PTH),* also called *parathormone*. *Parathormone* causes the blood calcium level to rise. Phosphorus levels decline in the face of parathormone because the renal reabsorption of phosphorus is inhibited and excretion is increased. Regulation of phosphorus in conjunction with calcium is important. If calcium and phosphorus levels are above a certain level, crystals of calcium and phosphorus are deposited in tissues, causing tissue damage. Secretion of parathyroid hormone is regulated by the level of blood calcium detected by the parathyroid cells. As blood calcium decreases, the secretion of parathyroid hormone increases, and vice versa.

Adrenal Gland

Cranial to each kidney in the abdominal cavity is an adrenal gland. The *adrenal gland* is a small, oval-shaped, somewhat flattened gland. The adrenal glands have two sections—an outer layer of tissue called the adrenal cortex and an inner core of tissue called the adrenal medulla. The *adrenal medulla* secretes epinephrine and norepinephrine. The *adrenal cortex* secretes *mineralocorticoids,* including aldosterone; a group of hormones known as *glucocorticoids;* and some sex hormones, particularly androgen and estrogen.

Aldosterone stimulates the uptake of sodium and water as well as the excretion of potassium in the renal tubules. It's important in regulation of blood pressure. Glucocorticoid hormones are a type of steroid that has many metabolic effects throughout the body. These hormones primarily affect carbohydrate metabolism via effects on starch metabolism in the liver and regulation of insulin.

The adrenal medulla is derived from nervous tissue. It's controlled by the sympathetic nervous system. Epinephrine and norepinephrine work to stimulate the body in response to a threat, so the animal can fight and overcome the threat or flee and escape it. The heart and lungs are stimulated to work faster, so the muscles have plenty of oxygen supply. Digestion is halted temporarily so blood and oxygen can be diverted to the muscles—after all, digestion won't be needed anymore if the animal is eaten by a lion.

Endocrine Pancreas

We discussed the pancreas in some detail in the unit on the digestive system, where its exocrine function was examined. The pancreas is also an endocrine organ, secreting several hormones into the blood. Scattered among the exocrine pancreatic cells, and located near blood vessels, are clumps of cells called the *islets of Langerhans.* The primary hormones secreted by the pancreatic islet cells are insulin and glucagon.

Insulin enables cells, especially liver, muscle, and fat cells, to take glucose from the blood to be used for generating energy for cellular functions. Insulin also inhibits synthesis of glucose from starch stored in the liver.

Glucagon opposes many of the effects of insulin by decreasing uptake of glucose by cells. Glucagon also stimulates the synthesis of glucose from glycogen in the liver.

The pancreas also secretes the hormone *somatostatin.* This hormone has many effects, but it primarily inhibits secretion of insulin and glucagon.

Problems associated with endocrine pancreatic function are relatively common. The most common disorder is diabetes mellitus. *Diabetes mellitus* is a deficiency of insulin secretion, or in some cases, a lack of responsiveness to the presence of insulin. The cause of diabetes mellitus, in most cases, is damage to the beta cells in the islets of Langerhans. Lack of insulin results in cellular inability to take in glucose and leads to *hyperglycemia* (excessive levels of glucose in the blood). Weight gain or weight loss, increased appetite, and increased thirst and urination are all signs of diabetes mellitus.

Gonads

One of the many functions of the reproductive organs, the testes and ovaries, is production and secretion of sex hormones. Within the testes, hormones from the anterior pituitary stimulate the continuous production of androgens by clumps of specialized cells. *Androgens* are a group of hormones involved in the development of male secondary sex characteristics.

Cells in the ovaries produce the female sex hormones on a cyclical timetable when stimulated by the hormones FSH and LH from the anterior pituitary. The ovaries actually produce two groups of hormones, the estrogens and the progestins. The *estrogens* function to prepare the female for breeding. The primary progestin, *progesterone,* is involved in preparing the uterus for pregnancy.

Miscellaneous Endocrine Organs

Various other hormone-producing cells exist in tissues throughout the body. These include cells in the kidneys, stomach, small intestine, thymus, placenta, and pineal body. A variety of organs also produce the hormone-like compounds known as *prostaglandins.* These compounds are organized into nine groups, designated by the letters A through I, and act within the area where they're produced.

Kidneys

Cells in the kidneys secrete the hormone *erythropoietin.* This hormone is released in response to tissue hypoxia and results in stimulation of the bone marrow to produce red blood cells.

Stomach

Cells in the stomach produce the hormone *gastrin,* which acts to stimulate the production of digestive enzymes in the stomach.

Small Intestine

The small intestine contains cells that secrete the hormones *secretin* and *cholecystokinin (CCK).* These hormones stimulate gallbladder contraction and the release of other digestive enzymes.

Placenta and Thymus

The placenta and thymus are endocrine organs active only during specific life-cycle stages. The *placenta* encloses the fetus during pregnancy and forms the interface between the fetal and maternal circulations. It secretes the hormone *chorionic gonadotropin,* which functions in maintenance of pregnancy. Small amounts of sex hormones are also produced in placental tissue. The thymus gland is active in infancy and secretes the hormones *thymosin* and *thymopoietin.* These hormones act to stimulate the development of T-lymphocytes and strengthen the immune system.

Pineal Body

The small *pineal body* is seated within a fluid-filled space in the third ventricle of the brain. The cells in the pineal body secrete the hormone *melatonin.* The function of melatonin isn't well understood, but it appears to play a role in regulating sleep and wakefulness. Secretion of melatonin may be influenced in part by the amount and duration of sunlight in the environment.

Summary

The endocrine system, much like the nervous system, is concerned largely with the regulation of the body's internal environment. Many aspects of the endocrine system work in conjunction with the nervous system to govern the internal environment. The endocrine system secretes substances directly into the blood or other internal fluids of the body and is somewhat self-regulating via negative feedback mechanisms. Extremely precise control of various aspects of the internal environment can be achieved by the endocrine system. Breakdowns in the normal operation of the endocrine system can have disastrous consequences for the animal.

Birds, Reptiles, and Amphibians

The endocrine system of birds, reptiles, and amphibians is similar to that seen in mammals. Hormonal control of molting and ecdysis, as well as courtship and mating rituals, occurs.

Before proceeding to the next assignment, take a moment to complete *Self-Check 6.* Remember, you can check your answers by turning to the back of this study guide.

Self-Check 6

Questions 1–10: Match the terms in the left-hand column with their definitions in the right-hand column.

_______ 1. Diabetes mellitus

_______ 2. Calcitonin

_______ 3. Melatonin

_______ 4. Prolactin

_______ 5. Islets of Langerhans

_______ 6. Vasopressin

_______ 7. Gastrin

_______ 8. Cortisol

_______ 9. Parathyroid gland

_______ 10. Thyroxine

a. Steroid hormone secreted by the adrenal gland

b. Hormone produced by follicular cells

c. Stimulates acid secretion in the stomach

d. ADH

e. Stimulates mammary gland development

f. Secreted by the pineal body

g. Disease caused by lack of insulin secretion

h. Pancreatic endocrine tissue

i. Produced by thyroid gland

j. Controls blood calcium level

11. Secretion of TSH by the pituitary gland is controlled by the secretion of ________ by the hypothalamus.

12. List two hormones that influence the blood calcium level.

____

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(Continued)

Self-Check 6

13. The most common thyroid disorder in the dog is _______.

14. The primary hormone produced by the kidney is _______.

15. List two hormones produced by the adrenal medulla.

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Check your answers with those on page 133.

ASSIGNMENT 7

Read in your textbook, *Clinical Anatomy and Physiology for Veterinary Technicians,* pages 264–281, 436–439, and 465–469. Then read Assignment 7 in this study guide.

Introduction

Your body is constantly using energy, even when you're at rest. Your cells use energy to carry out the normal functions of protein synthesis, cell maintenance and repair, and their particular functions. On a larger scale, processes like breathing, pumping of the heart, maintenance of normal levels of substances within the body, and elimination of waste products are vital to life. These processes continue while you're sleeping. Because your body can't manufacture energy, it must obtain that energy from outside sources. In all animals, this energy comes from food. Food also provides the body with fresh raw materials for the growth, maintenance, and repair of body structures. The *digestive system* deals with the intake, physical breakdown, chemical digestion, and absorption of food, along with the elimination of the waste products created by this process. The digestive system also eliminates certain toxic substances and secretes hormones it uses to regulate itself.

The digestive system is also known as the *digestive tract,* the *gastrointestinal (GI) tract,* the *alimentary canal,* or simply the *gut.* Numerous organs are involved in the processes of digestion and absorption of nutrients (see Figure 11-1 on page 265 of your textbook). Anything within the GI tract is actually located outside the body. The GI tract begins with the mouth and ends at the anus. For materials to pass into the body from this tube, they must pass through the lining epithelium.

The specific structure and physiology of the digestive system varies among different species. *Herbivores* (plant-eating animals, such as cattle, sheep, and goats), *carnivores* (meat-eating animals, such as cats), and *omnivores* (animals that eat plant material and meat, such as pigs and humans) all vary in the specific mechanisms of intake, digestion, and absorption of nutrients. Some species of animals have simple, single stomachs (*monogastric* animals), while others have complex organs designed to mix and ferment food *(ruminants).*

The basic functions of the GI tract are

1. *Prehension*—Grasping food with the lips or teeth
2. *Mastication*—Mechanical grinding and breaking down of food (a.k.a. chewing)
3. *Digestion*—Chemical breakdown of food
4. *Absorption*—Movement of nutrients and water into the body
5. *Elimination*—Removal of waste materials

Structure of the GI tract

The intestinal tract is suspended from the dorsal body wall by the *mesentery.* These sheets of connective tissue also contain blood vessels, lymph vessels, and nerves that supply the GI tract.

The walls of the GI tract contain four layers of tissue (see Figure 11-2 on page 266 of your textbook).

1. *Mucosa*—Consists of epithelium and some loose connective tissue that lines the tube
2. *Submucosa*—Dense connective tissue layer located just below the mucosa
3. *Muscle layer*—Thick muscles outside the submucosa
4. *Serosa*—Consists of a thin, tough layer of connective tissue

The digestive tract contains both stratified squamous epithelium and simple columnar epithelium. The mouth, pharynx, esophagus, and anus are lined with stratified squamous epithelium. The stomach and intestines are lined thin simple columnar epithelium. Muscles of the digestive tract include both skeletal and smooth muscle. The mouth, pharynx, cranial area of the esophagus, and the external anal sphincter contain skeletal muscle under voluntary control. The remainder of the digestive tract walls contains involuntary smooth muscle. *Peristaltic* contractions of the muscles within the walls of the intestines are responsible for movement of materials through the GI tract while segmental contractions result in mixing of the food within the tract (see Figure 11-3 on page 267 of your textbook).

Oral Cavity

Your mouth, or *oral cavity,* consists of the lips, teeth and gums, tongue, *oropharynx* (ventral digestive passageway), and associated salivary glands. Your lips are a zone of transition from the skin of the face to the *mucous membrane* (a general term denoting the surface of an organ lubricated by moisture) lining your gums and the inside of your cheeks. The lips have small salivary glands that help moisten their surface and soften and partially digest food in the mouth.

Several layers of muscle help the lips grab food and retain food and water within the mouth. These muscles allow us to whistle and kiss.

Different animals have different degrees of lip muscle development. Grazing animals like cattle, sheep, and horses have muscular lips that are *prehensile* to grasp plant material. Most other mammals tend to have less well-developed lip muscles. The lips are used more for facial expressions (e.g., snarling). The mucous membranes start at the lips, fold in, then reverse course and cover the surface of the gums. The gums attach to the teeth or travel between the teeth to line the inner gums. The inner gums are continuous with the roof of the mouth, underside of the tongue, and eventually with the lining of the pharynx.

Types and Anatomy of Teeth

Teeth are the most specialized organs within the mouth. They're responsible for the breakdown of food *(mastication),* which serves to increase the surface area of the food and thus enhance digestion. The crown is the visible portion of the tooth that projects above the gumline. Below the gumline, embedded in the jaw, is the *root;* some teeth have two or more roots. Between the root and crown, some teeth have a slight narrowing called the *neck,* which is approximately where the gums attach to the tooth. The gum that surrounds the neck of the tooth is called the *gingiva.* Inside each tooth you'll find three or four layers of tissue (see Figure 11-6 on page 269 of your textbook).

The innermost layer of each tooth is called the *pulp*. The pulp contains connective tissue, blood vessels, and nerves. This layer is the sensitive part of the tooth that becomes painful when you develop a cavity. Covering the pulp cavity is a material called *dentine* (or *dentin*), a material somewhat like the inorganic material in bone; dentine constitutes the bulk of the tooth.

The outermost layer of the crown of the canine and feline tooth is made up of *enamel.* Enamel is extremely hard—it's the hardest substance in the body. Enamel usually looks white and somewhat translucent. The tooth's root is embedded into a socket in the jaw called an *alveolus* with *cement* (or *cementum*), which forms a fourth layer over the roots. In constantly erupting teeth, this fourth layer is found over the entire tooth. The cement attaches to a thin periodontal ligament, which forms the attachment to the bone of the alveolus, the tooth socket.

The basic arrangement of features in teeth varies somewhat among animals (see Figure 11-4 on page 268 of your textbook). The teeth of horses and the *cheek teeth* (i.e., premolars and molars) of ruminants lack a definite neck, have very long roots, and feature a layer of cement that covers the enamel from the root to the top of the tooth. As the animal ages, the socket below the root fills with bone and pushes the tooth upward; the tooth stays approximately the same height above the gum because of the constant wearing down from the process of grinding food.

The teeth in some horses wear unevenly due to *occlusion*—the way the upper and lower teeth come together, how the animal chews, and how fast the individual teeth erupt. As a result, the teeth may develop sharp edges that become painful to the lips and gums when the horse chews. This requires the teeth to be *floated,* a process in which a file is used to grind the sharp edges of the teeth down enough to make them less painful.

Teeth in most animals come in two sets—a temporary (or *deciduous*) set and a permanent set. In general, deciduous teeth are smaller, less numerous, and softer than permanent teeth. Deciduous teeth are often present below the gum line at birth and erupt during the first six months to three years of life, depending on the species. As the animal matures into an adult, the permanent teeth, which have been developing in the alveoli of the bone, erupt. They gradually push the deciduous teeth out of the jaw. In some animals, an abnormal condition occurs in which a deciduous tooth isn't shed. This condition is called a *retained deciduous tooth,* which causes problems with occlusion and chewing. The solution is to pull the deciduous tooth.

Most domestic animals have four types of teeth, which are classified as follows:

1. *Incisors*—Cut food
2. *Canines*—Tear food

3. *Premolars*—Grind food into smaller particles for swallowing
4. *Molars*—Grind food into smaller particles for swallowing

You'll find all four types of teeth in carnivores, horses, and pigs. Ruminants lack upper incisors and all canine teeth. The teeth are arranged in two arches called *dental arcades,* one on the upper jaw and one on the lower jaw. Refer to your textbook for the dental formula for each species (page 269, Table 11-1).

As just mentioned, ruminants lack upper incisors; instead, a *dental pad* consisting of hardened mucous membrane tissue is present in the rostral upper jaw opposite the lower incisors. The teeth of each species are adapted to the type of diet eaten by that species. For example, dogs and cats are carnivores that need to cut and tear their food; thus incisors and canine teeth are important. Cows, on the other hand, eat plant material that must be ground up before being swallowed, so the molars and premolars are their most prominent teeth. Pigs and people are omnivores, eating both animal and plant material, so all types of teeth are present and equally prominent in the mouth.

Tongue

The *tongue* is a muscular organ used for manipulating food within the mouth. It includes taste buds, which allow you to taste food. The interior of the tongue is composed of many interlocking muscle bundles. These allow the tongue to move in many directions. The muscle fiber bundles are held together by connective tissue. Scattered throughout the connective tissue are blood vessels, nerves, and small accessory salivary glands.

The tongue's surface is covered with squamous epithelial tissue just like the rest of the mouth, but on the surface are small projections called *papillae* (singular: *papilla*) that help the tongue control the food. Some papillae are specially modified to carry the taste buds. In cats, the papillae are especially prominent (if you touch the top of a cat's tongue, you'll note it feels like sandpaper) and are used like the bristles of a brush for grooming.

Salivary Glands

Salivary glands are located throughout the oral cavity—in the tongue, on the inside of the lips and cheeks, below the tongue, and in the walls of the pharynx. Most of these glands are very small, consisting of a cluster of cells that produce saliva and a small tube called a duct. The duct carries the saliva from the secreting cells to the oral cavity's surface.

These smaller glands, called *accessory salivary glands,* secrete saliva in a continuous manner to keep the surface of the mouth moist. A few glands are much larger and more complex in structure; these glands secrete the majority of saliva in response to the presence of food or other stimuli (usually substances that have a bad taste). These reactions are controlled by the nervous system.

Three pairs of the larger salivary glands exist:

1. The *parotid salivary gland* is located in the angle between the ear and the back of the lower jawbone.
2. The *submandibular,* or just *mandibular, salivary gland* is located just inside and forward of the parotid salivary gland between the caudal borders of the mandibles.
3. *Sublingual salivary glands,* located beneath the tongue, may actually be a pair or cluster of salivary glands. Saliva contains water; electrolytes (sodium, potassium, chloride); *mucin* (a proteinaceous material that gives saliva a slimy feel); and in omnivorous species, amylase and lysozyme. *Amylase* is an enzyme that helps begin the process of digesting certain sugars in the food. *Lysozyme* is an enzyme that has some antibacterial activity.

Saliva performs the following functions:

- Moistens food to make it easier to chew and form a *bolus*
- Keeps the lining of the oral cavity moistened
- Washes particles over the taste buds for the sensation of taste
- Kills some, but not many, bacteria

Pharynx

The *pharynx* is a muscular walled area that opens to both the digestive system and the respiratory system. The pharynx opens into the nasal cavity, the oral cavity, the esophagus, and the trachea. The pharynx serves as a conduit to transport food and liquid from the oral cavity to the esophagus. The pharynx also transports air from the mouth or nasal cavity to the trachea.

Monogastric Stomach and Intestine

The *stomach* is similar to the esophagus in basic tubular anatomy, but the similarity ends there. The stomach begins the process of digestion, mixes the food with digestive fluids, and serves as a holding area that delivers its contents into the small intestine in a controlled fashion over several hours. The stomach differs from the esophagus in three important ways:

1. The stomach can expand to a much larger diameter than the esophagus, so the stomach's capacity to store food is much greater.
2. The muscular layers of the stomach differ from those of the esophagus, because the stomach must not only eventually propel food in the aborad direction, but it must also churn and mix the food being stored in it. Accordingly, the stomach has a third layer of muscle in the muscularis (the other layers being the circular and longitudinal muscles) called the *oblique muscle layer.* The oblique muscle fibers lie at an angle to the long axis of the stomach. When they contract, the stomach contracts at oblique angles that help mix the food in the stomach.
3. The *mucosa* of the stomach consists of a variety of glandular epithelial structures that secrete digestive fluids, mucus, and acid and absorb a small amount of the materials in the stomach. Dogs, cats, pigs, and horses have a type of stomach called a *simple stomach.* The mucosa of simple stomachs contains many folds called *rugae*. The rugae flatten out as the stomach expands to accommodate more food.

A *monogastric* (or *simple*) *stomach* is essentially a large dilated tube with the following regions listed in anatomical order from the esophagus to the small intestine:

1. Esophageal region
2. Cardia
3. Fundus
4. Body
5. Antrum
6. Pylorus

The esophageal region of the stomach lies most cranial and contains the *cardia,* a small area near the opening of the esophagus. Just caudal to the esophageal region is the cardiac region, which contains mucous glands that secrete mucus but not digestive enzymes.

The next region, forming the bulk of the simple stomach, is called the *fundic region* (or *fundus*). In the dog, the fundus is a large region that forms a dome that rises above the cardia. The fundus contains most of the gastric glands, digestive glands that produce gastric juice. Gastric juice contains large amounts of hydrochloric acid (HCl) as well as a digestive enzyme called *pepsin* that begins the breakdown of protein. The lining of the stomach secretes a thick layer of mucus that protects it from the harsh acid and pepsin that might otherwise harm it.

The *body* is a distensible area situated in the middle portion of the stomach. The last region of the stomach is the *pyloric region,* sometimes called the *pyloric antrum.* At the aborad end of the stomach is a muscle sphincter, the *pylorus,* which helps regulate the passage of food from the stomach into the small intestine.

Small Intestine

Structure

Next in line is the *small intestine,* which is remarkably similar in all species. You can separate the small intestine into three major divisions according to the order encountered by food: the *duodenum, jejunum,* and *ileum.* Each of these takes the general tubular arrangement already described, including a mucosa, submucosa, muscularis (with only two muscle layers, the circular and longitudinal), and serosa. The small intestinal mucosa is shaped into numerous small folds called *villi* (singular: *villus*). Columnar epithelial cells (also called *enterocytes*) are tall, thin cells lining the surface of villi. These cells have small finger-like projections on their surface called *microvilli.* Microvilli create the appearance of a "brush border" on the villus.

Inside the villi are small blood vessels and *lacteals*—small lymphatic vessels that help absorb certain fats from the diet. The depressions between the villi, called *crypts,* where new cells are constantly produced to replace cells lost from the tips of the villi. As cells are shed, the cells lining the sides of the villus are pushed toward the tip of the villus by new cells made in the crypts.

Interspersed with the enterocytes, which perform the digestive and absorptive functions, are *goblet cells.* These cells secrete mucus to lubricate the intestine and the food contained within it. Digestion is both a physical process and a chemical process. Food must be broken down physically through the process of chewing, the softening of the food by water and acid in the gastrointestinal tract, and the churning action of the stomach and intestines. Physical breakdown makes the food particles smaller. This breakdown, in turn, makes the food easier to pass farther down the digestive system and exposes more of the food to the digestive juices.

Digestive Processes

The *digestive process* must break chemical bonds between molecules in ingested food to retrieve the simplest form of the nutrient. The process by which the carbon bonds are broken is called *hydrolysis,* and is the most basic process of digestion. All forms of digestion use hydrolysis, but the means by which hydrolysis is achieved varies with the type of nutrient being digested.

Enzymes are proteins produced throughout the body. They perform a variety of functions involving the manipulation of other molecules. In the digestive system, enzymes are the key to the chemical digestion of food and are produced by glandular tissue in various parts of the digestive system, including the salivary glands, stomach, intestine, and pancreas.

Digestive enzymes recognize specific molecules or types of molecules in food and act upon those molecules to perform hydrolysis. The three categories of enzymes in the digestive tract are

1. *Proteases*—Break down proteins
2. *Lipases*—Break down fat molecules
3. *Amylases*—Break down carbohydrates

Within each enzyme category are numerous specific enzymes. Some enzymes are *potentiating enzymes.* These enzymes break a chemical bond on another enzyme to convert that enzyme to an active form. An example of a potentiating enzyme is *enterokinase,* an enzyme produced by the intestine. Enterokinase's only known function is to break a chemical bond on the pancreatic enzyme *trypsinogen,* an inactive enzyme, to convert it to *trypsin,* an active enzyme. Trypsin in turn breaks a chemical bond on *chymotrypsinogen,* an inactive enzyme, to convert it to chymotrypsin, an active enzyme.

Trypsin is both a potentiating enzyme and a digestive enzyme because it also acts to break down protein molecules. Without digestive enzymes, the body wouldn't be able to digest food, and the food wouldn't benefit the body.

Digestion can be either a luminal process or a membrane process. *Luminal digestion* occurs in the lumen of the stomach or intestine. Digestive enzymes mix with the food and acid or alkaline fluids to digest free-floating food particles in the lumen. *Membrane digestion* occurs only in the intestine and involves digestion of food particles on the surface of the mucosa. Enzymes are present in the cell membrane of the enterocytes lining the mucosa. These enzymes digest food particles that come in contact with the mucosa but have no effect on particles floating free in the lumen.

The majority of digestion and absorption of food in dogs, cats, and pigs occurs in the small intestine. The presence of villi and microvilli, as well as the extreme length of the small intestine (several feet in length even in the smallest dog or cat), all serve to increase the surface area of intestine exposed to ingested food. This large surface area in the small intestine facilitates the absorption and digestion of food.

Large Intestine

Although the anatomy of the large intestine varies widely depending on an animal's diet, this organ has the same basic features in all domestic animals. The large intestine has three main parts:

1. Colon
2. Rectum
3. Anus

The *cecum* is a blind sac projecting from the colon that technically isn't part of the large intestine.

Structure

The large intestine is similar in structure to the small intestine, with a tubular arrangement and villi. The enterocytes of the large intestine have an absorptive function but not a digestive function, and there are crypts where new enterocytes are produced as older cells are shed.

Goblet cells are present in increasingly larger numbers as you travel down the colon; these cells secrete mucus for lubrication of the developing stool. The terminal portion of the large intestine is the *rectum,* where stool is stored temporarily until defecation occurs. The *anus* is the opening of the gastrointestinal tract for elimination of stool. At the junction of the rectum and anus, the mucosa changes from glandular villi to flattened squamous epithelial tissue similar to that found on the skin. A large-muscle sphincter surrounds the anus to help retain the stool before defecation. In some cases, nervous control of this sphincter deteriorates and the animal becomes incontinent, unable to retain stool.

Function

The large intestine functions mostly as a site for absorption of water and electrolytes (e.g., sodium, chloride) from the ingested material, which is converted to waste material (i.e., feces). The exception to this rule is the horse, which has a very large cecum and a large colon, both of which serve as sites for fermentation very much like the rumen in ruminant animals that we'll cover in the next section. Horses and similar species are thus sometimes known as *hindgut fermenters,* because fermentation occurs in the large intestine (i.e., the "hindgut"). The cecum and large intestine in these species absorb the products of fermentation along with digested bacteria and protozoa.

Sodium is actively reabsorbed in the large intestine of all species, which facilitates the absorption of water and chloride. Mucus is secreted by goblet cells within the mucosa, and this mucus helps lubricate the feces as it passes through the colon, anus, and rectum. The rectum serves only as a waste storage site until the feces are ready to be evacuated, and the anus contains a muscle sphincter that controls fecal evacuation. Contractions of the colon and rectum triggered by distention of the colon are under the influence of the nervous system. When the colon becomes full, the stretching of its wall is detected by various nerve sensors, and this stimulates a reflex series of muscle contractions in the colon as well as relaxation of the anal sphincter, thus emptying the colon.

Accessory Digestive Organs

Several organs lying near the gastrointestinal organs aid in the digestive process. These include the following:

- Pancreas
- Liver
- Gallbladder
- Biliary ducts

These organs secrete, store, or transport substances that promote digestion, lubricate food, and aid in food absorption. The liver also serves a variety of other functions not directly related to digestion.

Pancreas

The *pancreas* is composed mostly of clumps of glandular secretory tissue and tubules carrying pancreatic digestive secretions to the small intestine. Intermixed with the secretory cells of the pancreas are different cells arranged in clusters called the *islets of Langerhans*. Cells in the islets secrete hormones such as insulin and glucagon. The secretory cells carry out an exocrine function (meaning they secrete into a lumen) by secreting digestive enzymes (trypsin, chymotrypsin, lipase, and amylase) that mix with the food in the small intestine. Trypsin and chymotrypsin help digest proteins and are secreted as inactive forms—trypsinogen and chymotrypsinogen, respectively—to prevent them from digesting the proteins of the pancreas itself. Once in the lumen, enterokinase, an enzyme secreted by the duodenal enterocytes, converts trypsinogen into trypsin. This in turn activates chymotrypsinogen into chymotrypsin. Lipase digests fats, whereas amylase digests carbohydrates.

Liver

The *liver* is one of the largest organs in the human body. Located immediately caudal to the diaphragm, the liver is *convex* (bowing out) on the cranioventral surface and somewhat *concave* (bowing in) on the caudal-dorsal aspect. The liver is divided into several *lobes* by clefts; the number of lobes and the subdivisions of the lobes vary with the species.

Liver tissue contains numerous blood vessels and ducts. Each arrangement of the vessels and ducts is called a *portal triad.* Each portal triad contains the following:

1. A *portal vein* that carries blood from the intestines to the liver
2. A *hepatic artery* that carries blood from the heart to the liver
3. A *bile duct* that carries bile from the liver to the gallbladder or duodenum

The liver performs a wide variety of functions, one of which is detoxification of materials in the blood. Blood coming from the intestines often carries bacteria and a large volume of toxic substances produced by bacteria during digestion. The liver filters this blood. The portal vein carries the blood to the liver, where it slowly flows past the *hepatocytes* toward the central vein. As the blood flows past the hepatocytes, the hepatocytes detoxify the portal blood contents. Cells of the immune system reside in the lobules and remove bacteria from the blood.

Blood in the general circulation reaches the liver via the hepatic artery and supplies the hepatocytes with oxygen and nutrients. The hepatocytes in turn detoxify substances in the general circulation. The hepatocytes also synthesize certain substances that are secreted into the blood and break down blood cells or substances no longer needed by the body. The liver and heart are the only two organs that receive both arterial and venous blood. In most organs, only arterial blood enters the organ, and only venous blood exits it.

Hepatocytes also store a starchy compound called *glycogen.* Glycogen acts as an energy supply when blood sugar becomes low; the liver breaks down glycogen into *glucose,* a sugar molecule used by nearly all body cells for energy production. Glucose is secreted into the blood via the central vein that carries blood from the liver to the heart. Many proteins also are synthesized by the hepatocytes for secretion into the central vein.

Another important function of the hepatocytes is to secrete bile into the bile ducts, where it's carried to the gallbladder or duodenum. The hepatic artery and the portal vein carry substances to the hepatocytes, whereas the bile duct carries substances away from the hepatocytes.

With so many functions, it's understandable that a severely damaged liver can cause many serious and sometimes fatal consequences. Among the problems faced by patients with liver failure are exposure to toxins that affect the brain, infections, poor digestion and absorption of fats and vitamins, and an inability to store and use long-term energy sources such as glycogen.

Gallbladder and Bile Ducts

Exiting from the liver on its caudal surface is the *hepatic duct.* This duct is the collective continuation of the millions of small bile ducts in the portal triads. The hepatic duct carries bile from the liver to the gallbladder and duodenum. The *gallbladder* is closely associated with the liver both anatomically and functionally. It's a relatively simple, muscular, thin-walled sac that sits tucked between the lobes of the liver on the right side. When empty, the gallbladder mucosa has many folds; when filled with bile, the folds flatten out.

A small duct, called the *cystic duct,* connects the gallbladder to the hepatic duct. This connection serves as means for bile to enter and leave the gallbladder. The common bile duct starts where the hepatic duct and cystic duct join. This duct ends where the bile duct empties into the duodenum at the major duodenal papilla, where the pancreatic duct empties. Thus, the common bile duct must pass through, or very near, the pancreas before entering the duodenum.

The gallbladder serves as a storage site for bile; while the bile is stored, water is reabsorbed from it by the gallbladder, making the bile more concentrated. Under the right conditions after eating, the gallbladder wall contracts, forcing bile down the common bile duct to the duodenum. Bile aids in the digestion and absorption of fats in the diet. Horses don't have gallbladders.

Food entering the duodenum also stimulates the production of two hormones from endocrine cells interspersed with other cells in the mucosa: *secretin* and *cholecystokinin (CCK).* Secretin and CCK both stimulate secretion of pancreatic enzymes. CCK stimulates contraction of the gallbladder to release bile into the duodenum. Both the pancreatic secretions and bile enter the duodenum through the major duodenal papilla.

The pancreas produces the proenzymes trypsinogen and chymotrypsinogen. The enzyme enterokinase on the intestinal wall activates trypsinogen to trypsin, which in turn converts chymotrypsinogen to chymotrypsin. Both of these enzymes break down proteins and peptides into amino acids. The pancreas also produces *lipase,* which breaks down fats into triglycerides, fatty acids, and glycerol, and amylase, which breaks down starches into sugars. This enzymatic digestion occurs in the lumen and is called *luminal digestion.*

Similar enzymes on the mucosal surface of the enterocytes exist to carry out membrane digestion into the basic components of each nutrient. Bile helps break fat globules into smaller fat globules, a process known as *emulsification.* Emulsification increases the surface area of fat exposed to lipases, increasing the speed and efficiency of fat digestion. Contractions of segments of the intestinal muscularis produce peristaltic mixing motions that blend the contents so there's increased contact between enzymes and the specific materials they digest.

Absorption Process

As digestion is occurring, the intestine absorbs the products of digestion. The anatomic unit most active in the absorption process is the *villus,* whose surface contains many enterocytes possessing microvilli to absorb digestive products. Microscopically, the center of the villus has an array of arteries that supply the villus with oxygen and nutrients, capillaries that capture absorbed food products from the enterocytes, and veins that carry the absorbed products from the villi to the rest of the body. In the very center of the villus is a tubular structure called a *lacteal,* which absorbs certain fats in the diet and carries them to the general circulation via lymphatic vessels. The actual absorption of the digested food occurs at the cellular level in the enterocytes. Absorption occurs in the enterocyte via either passive diffusion or active transport.

Different molecules are absorbed in different ways, depending on the molecule's size, configuration, and electrical charge. Water is absorbed strictly via diffusion, often following other molecules, because the movement of other molecules changes the concentration of water inside the cell membrane. Water can actually move out of the enterocyte if the lumen's concentration is very high relative to the enterocyte's cytoplasm. Electrolytes are absorbed either via diffusion or active transport, depending on the specific ion. Proteins are absorbed primarily in the form of amino acids via active transport. Both sugar and protein transport are linked to sodium transport; as sodium is transported into the cell, sugar or protein molecules also enter the cell. Sugars, proteins, and certain ions passively diffuse through the other side of the enterocyte into the extracellular fluid surrounding all cells and are then picked up by the capillaries to be transported to the general circulation.

Fats are digested into fatty acids, which don't dissolve well in water. To make them soluble in the intestinal fluid, bile provides these molecules with a coating that's electrically charged on the outside and neutral on the inside. The exterior charge makes the complex, called a *micelle,* dissolve in water. When a micelle comes in contact with the enterocyte's surface, fatty acids are released. Fatty acids are very soluble in the cell membrane's lipid, so fatty acids can cross the cell membrane via diffusion. Once in the enterocyte, the fatty acids are converted to triglycerides.

Triglycerides are transported with cholesterol and phospholipids through the enterocyte to the other side, where the triglycerides are released into the extracellular fluid. Triglycerides are absorbed from the extracellular fluid into the lacteals and from there are eventually transported to the general circulation. A few of the shorter fatty-acid chains are relatively soluble in water and aren't converted into trigylcerides by the enterocytes. They're absorbed directly into the blood rather than entering the lymphatic system.

Ruminant (Compound) Stomach

Ruminants are animals that swallow their food and then regurgitate it back through the esophagus into the mouth to chew on it again before swallowing it once more. This process is called *rumination*. Ruminants have compound stomachs (see Figures 11-8 and 11-9 on page 274 of your textbook) that are much more complex than simple stomachs. The functions of the compound stomach are similar to those of the simple stomach, but the diet being digested is much different.

Ruminants ingest plant material, which is more difficult to digest than the animal material ingested by carnivores and omnivores. Plant material's fiber content is much higher than animal material's, and this fiber is the component of food that's the hardest to digest. Therefore, the ruminant stomach is designed to digest plant material, which explains some of the differences between compound and simple stomachs. Ruminants have one stomach with four compartments. These compartments, in order from the esophagus to the small intestine, are the

1. Reticulum
2. Rumen
3. Omasum
4. Abomasum

The first three compartments are sometimes collectively called the *forestomach* (or *proventriculus*). The *reticulum* is the smallest and most cranial part of the ruminant stomach. The reticulum's mucosa has a honeycomb pattern of folds that function to increase the surface area of the organ. This increased surface area provides greater area for absorption of nutrients. Because of the location of the reticulum, heavy objects can drop into the reticulum, where they may pierce the wall of the organ and damage the diaphragm and other nearby organs. This condition is known as *hardware disease* or *traumatic reticulitis.* Sometimes cows are given magnets by mouth to bind to these metal objects and prevent migration through the wall of the reticulum.

The *rumen* is the largest part of the forestomach and takes up most of the abdomen's left side. The rumen is the most important part of the ruminant stomach because it's where fermentation occurs. In the process of *fermentation,* bacteria and protozoa (i.e., one-celled organisms) as well as digestive enzymes act on plant material to break down the polysaccharide cellulose. *Cellulose* is the primary component of plant fiber.

As fermentation occurs, volatile fatty acids (VFAs), proteins, and vitamins are produced that can be used by the ruminant. By-products of fermentation, such as carbon dioxide and methane gases, are released from the liquid as well, and these by-products must be released either through the mouth or the anus. The rumen also digests bacteria and absorbs both the breakdown products of cellulose and those of the bacteria. The majority of cellulose in the ingested food is broken down in the rumen.

An outer groove called the *ruminoreticular groove* and a corresponding interior fold called the *ruminoreticular fold* only partially separate the rumen from the reticulum. The rumen itself is formed somewhat like a blind sac—the cranial sac contains the openings to the reticulum and omasum, whereas the caudal portion, subdivided into a dorsal sac and a ventral sac by internal pillars, leads nowhere and serves only as a vast fermentation vat.

The *omasum* is a ball-shaped cavity with numerous muscular folds. VFAs not absorbed in the rumen are absorbed in the omasum. Bicarbonate ions and some moisture are also removed from the ingesta in the omasum. The *abomasum,* also known as the *true stomach,* is very similar to the simple stomach in organization and function. Both the omasum and abomasum lie to the right of the median plane. Occasionally, the abomasum displaces to the left or right, pivoting at the opening at each end of the abomasum.

As a result of this abomasal displacement, ingested material can't enter or exit the abomasum. This creates an obstruction aborad to the rumen and omasum and leads to abdominal discomfort for the animal. Surgical correction to replace the abomasum, followed by surgical attachment of the abomasal wall to the abdominal wall to prevent future displacement, is required.

An interesting structure can be found in the ruminant stomach. This structure, called the *gastric groove,* consists of the following three parts:

1. *Reticular groove* (or *esophageal groove*), which is in the reticulum
2. *Omasal groove,* which is in the omasum
3. *Abomasal groove,* which is in the abomasum

These grooves can nearly completely close in infant ruminants to form a tubular structure that transports liquids directly to the abomasum from the esophagus. This is important because infant ruminants don't ingest fibrous plant material; instead, they ingest milk from the mother. Therefore, fermentation is unnecessary, and the rumen needs to be bypassed. Milk is delivered directly to the abomasum, where it's properly digested. As the ruminant matures and begins eating a fibrous plant diet, the gastric groove stops closing so food can enter the rumen for fermentation.

Birds, Reptiles, and Amphibians

Birds have high energy demands and therefore have anatomic and physiologic adaptations to allow rapid absorption of nutrients from food. The beaks of birds vary considerably depending on diet and foraging strategies. The mouth may contain an enlargement that serves as a pouch for temporary food storage. In many species, the esophagus expands to form a structure called the *crop.* The crop functions to store, lubricate, and regulate the passage of food. The stomach of birds consists of a glandular portion *(proventriculus)* and a muscular portion *(gizzard).* The process of chemical digestion begins in the proventriculus. The gizzard is comprised of bands of striated muscles that grind food. In some species, paired sacs called *ceca* are located at the junction of the small and large intestine. Excretions from these sacs are released several times per week and appear dark brown and moist. The GI tract ends at the cloaca. The anterior section receives excrement from the intestine, and the posterior sections stores the excrement. Waste is eliminated through the vent.

The structure and function of digestive tract organs in reptiles and amphibians is highly variable. Carnivorous, omnivorous, and herbivorous reptiles all exist. Snakes and crocodilians are strict carnivores, whereas all three categories are represented by the lizards and chelonians. All adult amphibians are carnivores as well. Some species have very specific feeding habits. Accessory organs may also be present that are used for both tracking and capture of prey.

Now, review the material you've learned in this study guide as well as the assigned pages in your textbook for Assignments 6–7. Once you feel you understand the material, complete *Self-Check 7.* Then check your answers with those provided at the end of this study guide. If you've missed any answers, or you feel unsure of the material, review the assigned pages in your textbook and this study guide. When you're sure that you completely understand the information presented in Assignments 6–7, complete your examination for Lesson 3.

Self-Check 7

1. Name the four types of teeth found in most domestic animals.

2. The salivary gland that's located in the angle between the ear and the back of the lower jawbone is the ________.

3. In a newborn ruminant, the ________ diverts milk from the esophagus to the abomasum, bypassing the rumen.

4. List the four compartments of the ruminant stomach in order from the esophagus to the small intestine.

(Continued)

Self-Check 7

Questions 5–9: Match the terms in the left-hand column with their definitions in the right-hand column.

_______ 5. Bile

_______ 6. Gastrin

_______ 7. Lacteal

_______ 8. Pepsin

_______ 9. Lipase

a. Enzyme that begins the breakdown of protein

b. Enzyme that helps break down fats

c. Compound that emulsifies fats

d. Hormone secreted by the stomach

e. Structure in a villus that absorbs fats

10. Which digestive enzymes are released by the secretory cells of the pancreas?

    a. Trypsinogen, enterokinase, amylase, and lipase
    b. Lipase, amylase, pepsinogen, and chymotrypsinogen
    c. Chymotrypsin, trypsin, lipase, and amylase
    d. Chymotrypsinogen, enterokinase, pepsinogen, and lipase

Check your answers with those on page 134.

NOTES

Lesson 3
The Digestive and Endocrine Systems

EXAMINATION NUMBER

39652400

Whichever method you use in submitting your exam answers to the school, you must use the number above.

For the quickest test results, go to http://www.takeexamsonline.com

When you feel confident that you have mastered the material in Lesson 3, go to http://www.takeexamsonline.com and submit your answers online. If you don't have access to the Internet, you can phone in or mail in your exam. Submit your answers for this examination as soon as you complete it. *Do not wait until another examination is ready.*

Questions 1–25: Select the one best answer to each question.

1. The cells in the pancreas that secrete glucagon are called ________ cells.

   A. gamma
   B. beta
   C. delta
   D. alpha

2. Which of the following is caused by glucocorticoids?

   A. Increased blood glucose level
   B. Decreased gluconeogenesis
   C. Stimulated cartilage growth
   D. Worsened rheumatoid arthritis

3. The ________ functions as both an endocrine and exocrine organ.

   A. hypothalamus
   B. pancreas
   C. pituitary
   D. thyroid gland

4. Which of the following is secreted by the pineal body?

   A. Melatonin
   B. Melanin
   C. Pinealatonin
   D. Thymosine

Examination

5. The ________ are endocrine organs active *only* during specific life-cycle stages.

   A. kidneys and pancreas
   B. hypophysis and pineal body
   C. ovary and testes
   D. placenta and thymus

6. Which of the following produces aldosterone, glucocorticoids, and androgen?

   A. Parathyroid glands
   B. Adrenal glands
   C. Pituitary gland
   D. Kidneys

7. Cholecystokinin is secreted by the

   A. stomach.
   B. pancreas.
   C. small intestine.
   D. adrenal cortex.

8. Which of the following is secreted by the adenohypophysis?

   A. PTH
   B. Insulin
   C. ADH
   D. TSH

9. Hormone secretion is *usually* controlled by ________ systems.

   A. target
   B. cortical
   C. portal
   D. negative feedback

10. The pituitary gland is also known as the

    A. hypophysis.
    B. parahypophysis.
    C. lesser hypothalamus.
    D. portalpituitary.

11. Adrenocorticotropic hormone (ACTH) production

    A. is also known as *growth hormone.*
    B. can be released quickly via stimulation of the hypothalamus by other parts of the brain.
    C. is produced by the posterior pituitary.
    D. can trigger oogenesis.

12. In *most* animals, ovulation occurs when which hormone reaches its peak?

    A. Follicle-stimulating hormone (FSH)
    B. Adrenocorticotropic hormone (ACTH)
    C. Luteinizing hormone (LH)
    D. Thyroid-stimulating hormone (TSH)

13. A deficiency of antidiuretic hormone (ADH) in the body causes the disease

    A. diabetes insipidus.
    B. diabetes mellitus.
    C. hypoadrenocorticism.
    D. hyperadrenocorticism.

14. Which of the following best describes calcitonin?

A. It's released by the parathyroid gland.
B. It functions to prevent hypercalcemia.
C. It functions to prevent hypocalcemia.
D. It's released by the adrenal medulla.

15. Horses are unlike dogs and cats in that a large amount of digestion and absorption in these hindgut fermenters occurs in the

A. rectum.
B. cecum.
C. jejunum.
D. ileum.

16. Which structure is the *main* organ responsible for removing bacteria and toxins from the blood?

A. Pancreas
B. Cecum
C. Gallbladder
D. Liver

17. Which ruminant compartment is the *smallest?*

A. Omasum
B. Reticulum
C. Rumen
D. Abomasum

18. The outer layer of the crown of canine and feline teeth is composed of which material?

A. Cement
B. Enamel
C. Dentine
D. Pulp

19. Which compartment of the ruminant stomach is functionally *most* similar to the simple stomach of carnivores?

A. Rumen
B. Reticulum
C. Abomasum
D. Omasum

20. Which structure prevents backflow of duodenal contents into the stomach?

A. Pylorus
B. Antrum
C. Fundus
D. Cardia

21. Instead of upper incisors, ruminants have

A. occlusion.
B. dental pads.
C. retained deciduous teeth.
D. strong gingiva.

22. Without bile, the dog would have trouble digesting which type of nutrient?

A. Proteins
B. Carbohydrates
C. Lipids
D. Cellulose

23. Which structures provide for greatly increased surface area in the small intestine?

A. Lobules
B. Biliary ducts
C. Crypts
D. Villi

24. Which animal doesn't have a gallbladder?

A. Horse
B. Cat
C. Dog
D. Sheep

25. Which structure secretes digestive enzymes that break down carbohydrates, fats, and proteins?

A. Salivary glands
B. Liver
C. Pancreas
D. Large intestine

Self-Check 1

1. c
2. f
3. e
4. a
5. b
6. d
7. transitional
8. 70
9. right and left kidneys, right and left ureters, urinary bladder, urethra
10. Bowman's capsule, glomerulus
11. The juxtaglomerular apparatus provides neural control in the kidney.
12. ADH provides hormonal controls for the kidney.

Self-Check 2

1. Testicle, epididymis, vas deferens, (ampulla in some species), urethra
2. Ovaries, oviducts (Fallopian tubes), uterus, vagina, and vulva
3. Proestrus, estrus, metestrus, diestrus, anestrus
4. spermatogenesis
5. Sertoli
6. FSH
7. seasonally polyestrous
8. ovum; polar bodies
9. keratin; proestrus
10. oviducts

Self-Check 3

1. cleavage
2. blastocyst
3. amniotic fluid
4. parturition
5. oxytocin
6. Colostrum
7. capacitation
8. cotyledonary
9. zonary
10. morula

Self-Check 4

1. c
2. d
3. a
4. e
5. b
6. sulcus, gyrus
7. Sympathetic and parasympathetic nervous systems
8. Pia mater, arachnoid, and dura mater
9. The midbrain, the pons, and the medulla oblongata
10. Neurotransmitters

Self-Check 5

1. c
2. e
3. a
4. b

5. d
6. The external ear, the middle ear, and the inner ear
7. The malleus, the incus, and the stapes
8. proprioception
9. aqueous chamber, vitreous chamber
10. The lens, suspensory ligament, and the ciliary body

Self-Check 6

1. g
2. i
3. f
4. e
5. h
6. d
7. c
8. a
9. j
10. b
11. TSH-releasing factor
12. Two hormones that influence the blood calcium level are parathyroid hormone (parathormone, PTH) and calcitonin.
13. hypothyroidism
14. erythropoietin
15. Two hormones produced by the adrenal medulla are epinephrine and norepinephrine.

Self-Check 7

1. Incisors, canines, premolars, and molars
2. parotid gland
3. gastric groove
4. Reticulum, rumen, omasum, and abomasum
5. c
6. d
7. e
8. a
9. b

10 c