The Genitourinary Systems

Lesson 1

ASSIGNMENT 1

Read in your textbook, *Clinical Anatomy and Physiology for Veterinary Technicians,* pages 374–386, 449–450, and 469–470. Then read Assignment 1 in this study guide.

Urinary Organs

The primary function of the *urinary system* is removal of waste products and excess water from the body. The mammalian urinary system is composed of right and left kidneys and ureters, the urinary bladder, and the urethra (see Figure 16-1 on page 375 of your textbook). Urine begins forming in the kidneys, passes through the ureters to the bladder, and then exits the body through the urethra.

The abdominal cavity is also known as the *peritoneal cavity* and contains all of the abdominal organs except the kidneys. The kidneys lie adjacent and connected to the peritoneal cavity, in the *retroperitoneal space.* They're located cranially and dorsally in the abdominal cavity, with the right kidney slightly more cranial to the left.

The kidneys receive blood from the *renal arteries,* which are short branches off the abdominal aorta. Blood returns from the kidneys to the rest of the body through the *renal veins,* which connect to the caudal vena cava. Each kidney is covered with a tough, transparent outer membrane called the *renal capsule.*

Urine leaves each kidney through a single draining tube, the *ureter,* which transports urine to the urinary bladder. The ureters are composed of three layers. Urine is moved through the ureters by peristaltic contraction of the muscular layer. The ureters travel caudally and ventrally and then enter the neck of the bladder. In males, the ureters enter the bladder just cranial to the connecting ducts of the prostate gland. The bladder is located in the caudo-ventral aspect of the abdominal cavity and is lined with transitional epithelium. The bladder wall contains smooth muscle bundles that contract to expel the urine. The neck of the urinary bladder contains circular “sphincter” muscles composed of skeletal muscle fibers. The muscles are under voluntary control and open and close the passageway into the urethra.

The process of *urination,* also referred to as *micturition* or *uresis,* involves several steps. The first step involves triggering of stretch receptors in the bladder wall as the bladder becomes full. This leads to the activation of a reflex that causes the muscles in the bladder wall to contract. Relaxation of the sphincter muscles allows urine to move into the urethra. The function and size of the urethra is different in females and males. In females, the urethra is essentially straight and short and has no other function but to transport urine. In males, the urethra is often curved and longer and functions to transport both urine and genital secretions.

Kidneys

There are many anatomic and functional divisions to the kidney. The kidneys of most mammals are bean-shaped. There’s a small indentation in the medial aspect called the *hilus,* which is where the kidney’s blood supply (the renal artery and vein) attaches to the kidney. The hilus is also the external boundary of the *renal pelvis,* a funnel-shaped structure that transports urine into the ureter.

Kidneys of rats, mice, dogs, cats, and other small mammals have only a single lobe *(unilobar),* while larger mammals, such as cattle, can have between 25 and 30 lobes *(multilobar).* Lobes are obliterated in small mammals due to the compression of the smaller renal capsule (see Figure 16-2 on page 376 of your textbook). The two main divisions of the kidney are the *medulla* (the inner layer) and the *cortex* (the outer layer). The medulla is divided into inner and outer medullary zones. The *inner medullary zone* has faint radial striations and is colored pinkish-yellow to red. The *outer medullary zone* is dark red and has striations that project radially to penetrate the cortex. These striations are called the *medullary rays,* and they extend variable distances into the cortex while never quite reaching the outer surface.

The cortex lies between the outer medullary zone and the capsule. It's formed from reddish-brown tissue of granular consistency and contains most of the secretory elements of the kidney. The capsule is the thin, translucent, and tough outermost covering of the kidney. External to the capsule is the *perirenal fat,* literally the "fat around the kidney." This fat is abundant in mature animals, but becomes minimal in animals that are severely diseased, aged, or starved. The perirenal fat acts as an insulator to absorb shock and provide stability for the kidney in relation to other body structures.

Renal Arteries and Veins

The *renal arteries* supply blood to the kidneys, and the *renal veins* drain blood from the kidneys. The renal arteries are direct branches off the abdominal aorta; therefore, the kidney normally receives nearly 70 percent of aortic blood pressure. Such high pressure improves the filtration efficiency.

The renal artery enters the kidney at the hilus, then enters the renal pelvis, and branches out into a fanlike collection of smaller arteries. These arteries keep branching repeatedly to form a connecting network of *afferent glomerular arterioles.*

The afferent glomerular arterioles then enter the Bowman's capsule and form the *glomerular capillary system.* This is where the blood filtration takes place. The granular appearance of the cortex is due to the glomeruli and Bowman's capsules. The glomerular capillaries meet to form the *efferent glomerular arteriole,* which divides into capillaries again to supply the kidney cells with oxygen and nutrients. These capillaries eventually lead to the *efferent veins,* which empty into larger veins. These veins unite to form the renal vein, which returns blood from the kidney to the caudal vena cava.

Nephron

The basic unit of the kidney is the *nephron,* which begins with Bowman's capsule and empties into the *proximal convoluted tubule.* The proximal convoluted tubule continues as the descending limb of the *loop of Henle* and penetrates into the medulla. It then constricts and bends back on itself to form the ascending limb of the loop of Henle. The ascending limb increases in diameter to become the distal convoluted tubule. The raylike appearance of the medulla is due to the straight parts of the collecting tubules and the distal portions of Henle's loop. In Bowman's capsule, much of the blood's fluid is forced out of the capillaries because of the blood pressure. Left behind are the blood cells, large proteins, and enough fluid to allow the blood to keep flowing. In the proximal convoluted tubule, a considerable amount of reabsorption occurs. Small proteins, glucose, and ions are returned to the blood by active transport, followed by the *osmosis* (passive transport) of water. About 75 percent of the filtrate is returned in this section of the nephron. Salt is actively transported back into the blood in the loop of Henle. In the *distal convoluted tubule,* wastes are concentrated and passed into the collecting ducts, and from there into the ureter and bladder.

There are many specialized cells in the nephron that contribute different functional capabilities to the entire unit. *Brush border cells* in the proximal convoluted tubules have many closely arranged microvilli on the surface of the cells, which project into the lumen of the tubule. These *microvilli* are involved in extracting and further processing materials from the tubules. Brush border cells have protoplasmic "feet" that interconnect with the basement membrane of an adjacent capillary. Additionally, there are many deep folds in the cell membrane. Some folds pass almost completely through the cell, allowing the cell to act as a semipermeable membrane to permit osmotic fluid interchange between the capillary lumen and outer surface of the tubule.

Transitional epithelial cells line the entire urinary tract, from the renal pelvis to the opening of the urethra, and give the urinary tract the ability to rapidly accommodate changes in size. The kidney and other associated organs can enlarge to accommodate an increase in excretory load, and then shrink back to normal size. (*Excretory load* is the need for elimination of excess water and wastes from the bloodstream.) This ability allows an animal to survive with only one kidney—the remaining kidney takes over the function of the missing or diseased organ.

In males, the termination of the urethra occurs in an opening at the tip of the penis. There are some unique qualities of the urethra in species such as the ram and the boar. The ram has a long urethral process, composed of excess duct tissue that extends farther than the tip of the penis. The boar has a *urethral diverticulum,* a small sausage-shaped sac opening at the dorsal cranial aspect of the prepuce. The urethral diverticulum has lymph glands that produce an unpleasant odor in uncastrated males.

In females, the termination of the urethra occurs as a longitudinal slit in the vestibule of the vagina. Unique variations in urethral endings can be observed in the bitch and cow. The bitch's external urethral opening occurs at the apex of a small mass of tissue called the *urethral papilla,* located on the vaginal floor. The terminus of the cow's urethra appears as a transverse slit in the anterior aspect of a tissue pouch called the *suburethral diverticulum,* found about four inches inside the vaginal opening.

Renal Physiology

The kidney's most important function is to extract waste material from the blood and excrete the wastes in the form of urine. Additionally, the kidney sustains the body's internal environment in a state of equilibrium known as *homeostasis* by modifying the rate and nature of fluid excretion. Kidneys can increase and decrease in size based on the demands affecting homeostasis. The kidney depends on constant physical, hormonal, neurohormonal, and enzymatic adjustments to maintain homeostasis.

Physical Aspects of Kidney Function

The excretion of dissolved nonprotein plasma constituents occurs through a unit formed by Bowman's capsule. The normal unit is unable to filter out large molecules like proteins. Approximately 20 percent of the mineral salts, urea, water, sugar, and other products in the plasma are removed from the blood and pass into the nephron. As this fluid mixture passes through the nephron tubules, selective reabsorption occurs as nutrients and liquids needed by the body are removed and returned to the blood. The cells of the tubule walls actively transfer useful substances from the tubule lumen while retaining the waste products.

Once excretory products reach the arched collecting tubule, there's no additional substrate transfer, and the waste products can be classified as urine. At this point, water may still pass through the walls to adjust the concentration of urine. The urine is carried through the tubules to the ureters and then the urinary bladder. The transitional epithelium lining the bladder and urethra make the structures distensible and aid in storing urine until it can be voided.

Formation of Urine

The amount of urine produced depends on the flow of blood through the kidneys. Approximately one-fifth of total cardiac output passes through the kidneys every minute. Therefore, in five minutes, the animal's total blood volume will have passed through the renal circulation. Approximately 90 percent of the renal blood flow directs itself outward into the cortex and glomerular tufts to be filtered. The remaining 10 percent perfuses and nourishes the kidney tissues.

Nervous stimulation can alter the blood flow through different parts of the kidney, so urine formation may also be affected. If nourishing blood flow to the tissues is shut off, the nephrons may be unable to perform their functions. A prolonged decrease in renal blood flow can cause *reflex anuria,* which may result in damage to the nephron and possible kidney failure. Reflex anuria occurs in situations of shock or sudden stress and may persist despite a return of normal blood flow.

The glomerular tufts within Bowman's capsule perform the function of filtering water and dissolved solutes from the blood plasma. The tubular portions of the nephron perform the function of selective reabsorption, which produces urine.

The energy for these processes comes from the high blood pressure in the kidneys. Since the kidneys have a short connection to the abdominal aorta, approximately 70 percent of aortic pressure reaches the glomeruli. The capillaries in the kidneys must withstand blood pressure that's about two and one-half times the pressure in other capillaries in the body. The normal renal capillaries differ from other capillaries in that they prevent the passage of proteins through their walls, while allowing the passage of water and solutes.

The high pressure of blood in the glomerular capillaries forces water out of plasma. This high pressure is countered by pressures that tend to retain water, such as the pressure of plasma proteins, interstitial pressure, and required pressure to move fluid through kidney tubules. The difference between the pressures is the *effective filtration pressure.*

The quantity of filtrate emerging from the glomerulus depends on the effective filtration pressure and the quantity of renal blood flow. These usually remain fairly constant despite changes in blood flow to other areas of the body. The renal arterioles and arteries are able to adjust their resistance rapidly and accurately to compensate for changes in blood pressure.

Conditions affecting filtration of blood will have subsequent effects on production of urine. Hydrostatic, hemodynamic, and glomerular changes (individually or in combination) can all alter urine production. *Hydrostatic* changes occur when there's an increase or decrease in arterial pressure and/or the pressure that counters filtration. *Hemodynamic* changes occur when there's a decrease in blood flow to the kidney secondary to constriction of blood vessels, shock, or congestive heart disease. *Glomerular* changes arise when the glomerular tufts become diseased, negatively affecting their function.

Physiology of the Nephron

The nephron structurally and functionally begins with Bowman's capsule, which surrounds the glomerular tuft; it then continues as the proximal convoluted tubule, Henle's loop, and the distal convoluted tubule (see Figure 16-3 on page 377 of your textbook). The nephron can be divided into two regions of differing functions: the *passive secretory region* and the *active secretory region.* The proximal convoluted tubule and descending limb of Henle's loop function passively, using osmotic pressure to transfer fluids between the interstitial tissue surrounding the tubule and the protourine within each tubule. Active secretion takes place in the ascending limb of Henle's loop and the distal convoluted tubule, which transports substances from the protourine back into the blood. The portions of the nephron that are involved in active secretion are lined by epithelial cells that have large numbers of the energy-producing mitochondria necessary for active processes.

The end of the distal convoluted tubule is the point where urine enters the collecting duct system, which then transports it out of the kidney to the ureters. From this point on, there will normally be no change to the chemical composition of the urine, as chemical change occurs only in the nephron. Urine concentration may change, however, as water may still be transported through the wall of the excretory duct.

The reabsorption of glucose occurs in the proximal convoluted tubule. Glucose leaves the tubule lumen and enters the interstitial space, where it then enters the capillaries of the medullary plexus. If the glucose concentration in the nephron is exceedingly high, some glucose may not be reabsorbed and may remain in the tubule lumen. The nephron has a specific reabsorptive capability (that is, the amount of substance the nephron is able to reabsorb) for each substance, known as the *renal threshold.* This means that the nephron is able to reabsorb X molecules of glucose, which is enough for normal function. When there's more than that amount of glucose in the blood, the nephron can still reabsorb only X molecules, so some glucose remains behind. Glucose that isn't reabsorbed travels through the remainder of the nephron, enters the collecting ducts, and will result in *glycosuria* (glucose in the urine). The renal threshold may vary between species.

Selective reabsorption of mineral salts, which is essential in maintaining the acid-base balance in the body, occurs in the ascending limb of Henle's loop and in the distal convoluted tubule. The regulation of the amount of sodium in the body is also important to normal bodily function. Excretion of sodium from the nephron is an active process. The volume of water that's excreted in urine is less than 1 percent of the volume that originally entered the kidney. Reabsorption of water occurs throughout the entire nephron and depends largely on the difference between the osmotic pressure within the tubule and the interstitial pressure surrounding the tubule. This pressure gradient is primarily generated by the concentration of sodium ions in the interstitial fluid and causes the passive transfer of water through osmosis. Two-thirds of the water that enters the nephron at the glomerulus returns to the capillaries of the medullary plexus by the end of the proximal convoluted tubule.

In mammals, the length of Henle's loop corresponds to the concentration of urine. Animals that have concentrated urine, such as dogs, cats, camels, sheep, and goats, all have predominantly long loops. Humans, cattle, and swine void relatively dilute urine and have few long loops.

The thin portion of Henle's loop is permeable to water. This allows water to passively transfer from the tubule to the capillaries. In the thicker-walled ascending limb, sodium is actively moved out of the tubule and into the interstitium. This part of the tubule is less permeable to water. Mineral salts are returned to the bloodstream in the distal convoluted tubule, which is again water-permeable. As protourine passes through the collecting tubules, water is pulled out of the tubules into the interstitium, while waste products are retained and excreted in the urine.

The kidneys maintain the electrolyte and chemical balance of the body fluids at a very constant level in normal mammals. The ability of animals to endure stress depends in large part on the proper function of the kidneys. Stress can affect body chemistry, placing more demand on the kidneys. Diseased kidneys can't keep up with the increased demands. Clinical signs of kidney failure often don't appear until some strain has been made upon the kidney that it can't correct.

Neural and Hormonal Regulation of the Kidney

Neural and hormonal kidney regulation determines the rate of urine production by affecting the number of nephrons involved and the activity of epithelial cells in the nephrons. Neural regulation occurs through the *juxtaglomerular* *apparatus,* which determines the quantity of blood passing through the glomerulus. Hormonal control occurs through the activity of *antidiuretic hormone (ADH).* ADH is stored in the posterior pituitary gland and enters the bloodstream when osmotic pressure in the blood increases. The release of ADH results in increased water reabsorption into the bloodstream, and thus less water is excreted. When osmotic pressure returns to normal, the release of ADH is inhibited. *Diabetes insipidus,* a condition in which the release of ADH is inhibited, can occur secondary to tumors of the pituitary gland and hypothalamus. Such tumors don't respond to the negative feedback caused by an increase in osmotic blood pressure. Therefore, ADH release and water reabsorption into the bloodstream are maintained.

Enzymatic Regulation of Kidney Function

In response to stress or increased levels of metabolic wastes in the blood, the kidney can release enzymes to increase blood pressure and heart rate. The purpose of this response is to increase the flow of blood through the kidneys, and thus increase the production of urine. A series of events, called the *renin-angiotensin-aldosterone mechanism,* moderate the increase in arterial pressure.

Renin, an enzyme, is released into the bloodstream from the renal cortex. Renin activates other enzymes that are normally found in the blood, producing angiotensin. *Angiotensin* causes vasoconstriction, an increase in heart rate and contractility, and the production of aldosterone by the adrenal cortex. *Aldosterone* then affects parts of the nephron, increasing sodium return to the bloodstream.

The activity of these enzymes is normally negated by an inhibitory enzyme system when the stimulus that caused the activation has stopped. The inhibitory enzymes destroy the angiotensin, so that the body returns to normal. Improperly functioning kidneys may lack such a negative feedback loop, leading to kidney failure through *renal hypertension syndrome.* (That is, the blood pressure remains at unsustainably high levels, damaging the kidneys.)

Juxtaglomerular Apparatus

The *juxtaglomerular apparatus* is part of the kidney's neural regulatory system. There are two main functions of the juxtaglomerular apparatus:

1. Maintaining nerve stimulation in the afferent and efferent glomerular vessels, which regulates blood flow to and from the glomeruli
2. Shutting off the blood supply to certain glomeruli, which decreases urine production

The juxtaglomerular apparatus is therefore another mechanism that controls the regulation of body water and the function of the kidneys.

Endocrine Aspects of the Kidney

The kidney also acts as an endocrine organ, producing hormones or hormone-like substances that affect other organs in the body. These substances include some prostaglandins and erythropoietin (EPO).

Erythropoietin has two important functions:

1. Stimulation of red blood cell production by the bone marrow
2. Enrichment of iron levels in the blood cells

Avian, Reptile, and Amphibian Urinary System

The urinary system organs of birds are similar to those of mammals. However, the kidneys of birds don't contain a renal pelvis. Urine moves through the ureters into the cloaca. From there, the urine may be moved upward to the colon and ceca for further reabsorption of water or propelled outward through the bird's vent. The composition of urine in birds is very different from mammals, with the primary component being uric acid. The final waste product is excreted along with a small quantity of fecal material as a paste referred to as a *mute*.

In most reptiles, the kidneys are oblong structures and are located in the caudal coelomic cavity. The kidneys of snakes are lobulated. In most reptiles, the ureters empty into the urodeum area of the cloaca. A urinary bladder may be present in some species and is connected to the urodeum by the urethra. The distal collecting tubules join to form collecting ducts. Those ducts come together and form the ureter. The reptile nephron doesn't have a loop of Henle comparable to what's found in mammals. Reptiles can't produce urine that's more concentrated than their blood due to the lack of loops of Henle in the nephron. Water conservation is accomplished by absorption of water from the urine through the wall of the urinary bladder, rectum, or cloaca. As in birds, the primary component of the urine of most reptiles is uric acid.

The kidneys of amphibian species filter blood and coelomic fluid via openings called *nephrostomes* that connect the coelomic cavity to the renal tubules. The kidneys of amphibians are usually lobulated, and all amphibians have urinary bladders. The primary component of urine in larval and aquatic amphibians is ammonia. In other amphibians, urea is the primary waste product excreted in urine.

Self-Check 1

At the end of each section of *Animal Anatomy and Physiology 2,* you'll be asked to pause and check your understanding of what you've just read by completing a "Self-Check" exercise. Answering these questions will help you review what you've studied so far. Please complete *Self-Check 1* now.

Questions 1–6: Match the terms in the left-hand column with their definitions in the right-hand column.

_______ 1. Renin

_______ 2. Erythropoietin

_______ 3. Ureter

_______ 4. Urethra

_______ 5. Aldosterone

_______ 6. Nephron

a. Tube carrying urine from the bladder to the external environment

b. Hormone secreted by adrenal glands

c. Hormone causing angiotensin production

d. Functional unit of the kidney

e. Tube carrying urine from the kidneys to the bladder

f. Hormone stimulating red blood cell production

7. The cells lining the transport and storage portions of the urinary system are called ________ epithelium.

8. About ________ percent of the aortic blood pressure reaches the kidney.

9. The four major structures that make up the mammalian urinary system are the ________, ________, ________, and ________.

10. The two structures that act as a filter to remove plasma elements, besides proteins, from the blood are the ________ and the ________.

11. What is the function of the juxtaglomerular apparatus in the kidney?

    ____

12. What is the function of antidiuretic hormone (ADH) in the kidney?

    ____

Check your answers with those on page 131.

ASSIGNMENT 2

Read in your textbook, *Clinical Anatomy and Physiology for Veterinary Technicians,* pages 387–404, 450–452, and 474. Then read Assignment 2 in this study guide.

Reproductive System

The function of the reproductive system is the production of offspring. The cellular components of the reproductive system include *spermatozoa* in males and ova in females. The production of these cells is accomplished through the process of *meiosis.*

Meiosis

Mitosis and meiosis are the processes through which cellular division takes place. The process of meiosis involves two stages: the *primary phase (meiosis I)* and the *secondary phase (meiosis II).* Meiosis I includes all of the phases of mitosis but differs in the process of chromosomal division. During prophase in meiosis I, chromosomes form pairs before the formation of the aster spindle, and each pair replicates to form a *tetrad* (essentially, a pair of pairs). There are one-half as many tetrads as there are chromosomes in the parent, but each tetrad has four chromosomes; therefore, the number of chromosomes in the new cell is doubled. For example, say a cell has 20 chromosomes. During prophase in meiosis I, it will form 10 tetrads, giving it a total of 40 chromosomes.

During metaphase in meiosis I, tetrads line up along the equator of the cell and are then pulled apart by the *aster spindle.* The divided tetrads now have two chromosomes and are called *dyads.* The dyads have the same chromosome number of the parent cell, but each daughter cell has a different chromosomal identity, with one-half of the chromosomes originally present in the parent cell. Using our previous example, each daughter cell has 20 chromosomes, but 10 of the parent cell's chromosomes weren't passed down to that daughter cell. Ten of the daughter cell's chromosomes are duplicates. The other daughter cell will have the other 10 chromosomes from the parent, again duplicated for a total of 20 chromosomes.

Anaphase and telophase in meiosis I are very similar to those seen in mitosis, except for the reformation of chromatin. In meiosis, the dyads become chromatin without first forming thin threads. At the end of the primary phase, the cells produced are called *secondary spermatocytes* or *secondary oocytes* but are collectively termed *daughter cells.* Meiosis further differs from mitosis in that there's no resting phase in meiosis.

Meiosis II is a maturation phase in which the cell divides twice, but the chromosomes divide only once. During prophase in meiosis II, chromosomal dyads re-form. In metaphase, the dyads line up along the cell's equator. In anaphase and telophase of meiosis II, the dyads are pulled apart into two cells without longitudinal division of the cells. Two daughter cells (called *spermatids* or *ootids*) are formed. The daughter cells are *haploid,* meaning that they contain one-half the number of chromosomes of the species. The end result of meiosis II is the formation of four haploid cells that come from diploid parent cells. In our example, the parent cell, with 20 chromosomes, produces four haploid daughter cells, with 10 chromosomes each. Thus, in meiosis, cells divide twice, but the chromosomes divide only once. As a result, when the cells of the male and female combine, the offspring's cells have the correct number of chromosomes, half derived from each parent.

The processes that produce the reproductive cells are referred to as *spermatogenesis* and *oogenesis* (see Figure 17-1 on page 390 of your textbook).

Spermatogenesis

Spermatozoa (singular: *spermatazoon*) are the mature reproductive cells of the male, produced through the process of *spermatogenesis.* They consist of a "head," which contains the genetic information, and a flagellum, or "tail," which propels them toward the egg (see Figure 17-6D on page 392 of your textbook). Spermatozoa develop from *spermatids,* which are present in the embryo but remain in a dormant state until puberty. Spermatids and spermatozoa are contained within the *seminiferous tubules.* Structurally, spermatozoa (often called *sperm* for short) are composed of four parts: the head, the neck, the middle piece, and the tail. The head is made up of nuclear material, including one-half the species' number of chromosomes. The head is covered with a capsule, called the *acrosome,* which contains the digestive enzymes necessary for the sperm to penetrate through the layers of the ovum. The neck is positioned between the head and the middle piece. The middle piece is composed of strands of protoplasm, an inner and outer fibril sheath, that attach the neck to the tail. A large concentration of mitochondria are also present and provide the energy needed to propel the cell forward. The tail allows movement through a whiplike motion of the flagellum.

Oogenesis

Oogenesis is the generation of female germ cells *(ova)* in the cortex of the ovary. *Oocytes,* the immature cells from which the ova evolve, are present from birth. The oocytes cluster into the connective tissue of the cortex in structures called *ovigerous cords* or *egg nests.* The ovary lies dormant until the animal becomes sexually mature and follicular structures begin to form in the cortex of the ovary. Production of the follicular structures depends on nutrition, climate, and *follicle-stimulating hormone (FSH).* FSH induces ovulation and the formation of secondary sex characteristics. As oocytes develop into ova, the number of oocytes steadily reduces to none during the female's life span.

Inside the ovary, an egg nest develops into a *follicle,* which is the site of ova maturation in the majority of species. As a functional ovum develops, other cells within the egg nest become *sustentacular cells,* which are nutritive support cells. The mature ovum emerges from the ruptured follicle at ovulation. Maturation of ova in the bitch, cow, and ewe differs from that of other species in that it takes place in the *oviduct* instead of the follicle.

As the follicle develops, the ovum undergoes its first maturation (meiosis I) to form two secondary oocytes. One of the secondary oocytes contains almost all the cell's cytoplasmic contents. The other secondary oocyte becomes the *first polar body,* essentially a waste cell. The secondary oocytes undergo a second maturation (meiosis II), forming two polar bodies (developed from the first polar body) and two *ootids.* Each ootid has one-half the chromosome count of the parent. Again, one of the ootids receives the majority of the cell's cytoplasmic contents. The other ootid becomes another polar body. The polar bodies disappear. The remaining secondary ootid then matures to form the ovum.

Anatomy of the Male Genital System

The male genital system consists of five main parts:

1. The *testes,* or *testicles* (normal mammals have two), and their associated systems of transport ducts
2. The blood supply and associated tissues
3. The nervous supply
4. The accessory glands
5. The penis

Testes

The testes have two main functions:

1. The production, maturation, transportation, and storage of spermatozoa
2. The production of androgens (male sex hormones)

The testicle is shaped like an egg and, like the kidney, has a dent in the middle called the *hilus.* The testicle is covered by a layer of tough, white connective tissue called the *tunica albugenia.* At the hilus, the tunica albugenia penetrates the testicle to divide it into pyramid-shaped *lobules*. Each lobule has its base at the outside border of the testicle and its apex at the hilus.

Temperatures within the body are typically too high to allow for the development of mammalian male germ cells, the spermatozoa. Therefore, most mammalian species have testicles that are situated external to the body, in a sac called the *scrotum.* Exceptions are beavers, elephants, and whales, for example, which have internal testicles. Rodents have testicles that are kept inside the body, becoming functional only when they descend to the outside during the breeding season.

Testicles are formed from two clusters of germinal tissue, each of which lies external to the embryo's peritoneal cavity. Each cluster connects to a spot on the floor of the peritoneal cavity via a cord of connective tissue called the *gubernaculum testis.* The gubernaculum testis remains proportionally the same length, causing the testicle to move backward and downward in the body as the developing embryo grows away from it. The testicles, along with their blood and nervous supply, then are covered by two layers of peritoneum. Once the testicle has completely descended, the gubernaculum testis becomes the *scrotal ligament.* The scrotal ligament functions to attach each testicle to the scrotum (refer to Figure 17-7 on page 393 of your textbook).

In some individuals, the testicle may not descend properly into the scrotum. Animals are called *cryptorchid* if both testicles fail to descend properly, or *monorchid* if one testicle fails to descend.

Scrotum

The *scrotum* contains the testicles and is made up of skin, muscle, and fibrous tissue. It's lined on the inside with the two layers of peritoneum mentioned above, the *common vaginal tunic* and the *proper vaginal tunic.* The scrotum is constructed to maintain the testicular temperature between four and seven degrees Celsius cooler than the body temperature, to allow for production of sperm. Therefore, the scrotal skin is thin, has sweat glands, and lacks subcutaneous fat. Cold temperatures aren't good for sperm production, either, though, so in cold seasons heat must be conserved.

Testicular temperature is maintained through the following mechanisms:

1. The *cremaster muscle* draws the testicles closer to the body when it's cold.

2. Smaller muscles can contract to gather the scrotal skin, keeping the testicles closer to the body and reducing heat loss through the skin.
3. A scrotal thermal regulation reflex elicits shivering (to raise the body temperature) or rapid breathing (to lower the body temperature).

Spermatic Cord and Vas Deferens

The *spermatic cords* connect the testes to the body and consist of blood vessels, nerves, lymphatic vessels, and the *vas deferens* (also known as the *ductus deferens*). The spermatic cord enters the abdominal cavity through a small opening in the abdominal wall called the *inguinal canal.* (This is the same opening through which the testes descended from the abdomen.) As the spermatic cord enters the abdominal cavity, the vas deferens breaks away and attaches to the urethra, which is adjacent to the neck of the bladder. In some species, the vas deferens enlarges before attaching to the urethra to form a spindle-shaped structure called the *ampulla.* The vas deferens is the muscular tube that connects the epididymis and the urethra.

Blood Supply, Nerves, and Lymph

There are two main structures that regulate the testicular blood flow:

1. The testicular artery
2. The testicular vein

The blood supply to the testicle is primarily supplied by the *testicular artery.* The testicular artery arises from the abdominal aorta, just caudal to the cranial mesenteric artery. The testicular artery is covered by the proper vaginal tunic and descends to the testicle as part of the spermatic cord. The *testicular vein* originates from capillaries and venules within the testicle. Like the testicular artery, the vein is enclosed by the proper vaginal tunic and is considered part of the spermatic cord. The testicular vein returns blood from the testicle to the caudal vena cava. The testicular artery provides blood to the testicle that's cooler than the blood inside the body, due to a cone-shaped mass of venules called the *pampiniform plexus* (see Figure 17-9 on page 394 of your textbook). The venules in the plexus surround the testicular artery, so the arterial blood is cooled by the blood coming back into the body. The blood in the venules is in turn warmed by the arterial blood, so it's closer to body temperature. The testicular vein then returns blood to the caudal vena cava. The venules of the pampiniform plexus thus serve to conserve body heat.

The *testicular nerve* conducts motor, sensory, sympathetic, and parasympathetic nerve fibers to and from the testicle. The nervous supply arises from the cranial mesenteric ganglion and runs adjacent to the testicular artery in the spermatic cord.

The testicular lymphatic system functions to drain fluids from the testicular interstitium and transport androgens from the testicle. The lymph system originates in the lobular interstitial tissue, the tunica albugenia, and the epididymis. The larger vessels travel adjacent to the testicular vein. Inhibition of lymphatic drainage can cause significant enlargement of the testicles and the scrotum.

Duct System

The *seminiferous tubules* make up the substance of the testicles. They're where the formation of spermatozoa takes place. During development, the spermatids are attached to the *Sertoli cells* in the seminiferous tubules. Once development is complete, the sperm detach from the Sertoli cells and enter the system of tubules called the *rete testis.* The rete testis then converges to efferent ducts, which exit the testicle at the hilus and lead to the epididymis. The *epididymis* functions to store, concentrate, mature, and transport spermatozoa. Sperm require a period of several weeks to progress from their site of production to the area from which they'll be ejaculated. A slow current of positive pressure of fluids in the testes transports nonmotile sperm to the tail of the epididymis, or the *ampulla,* where they're stored. The sperm become motile only when they're activated by the mildly alkaline fluids of the semen during ejaculation.

Sperm that haven't yet left the epididymis are infertile. There are three parts to the epididymis:

1. The head
2. The body
3. The *tail*—the site of spermatozoa storage

The head connects to the body, which then connects to the tail. During copulation, spermatozoa are propelled from the tail through the vas deferens into the urethra.

Accessory Glands of the Male Genital System

The accessory reproductive glands contribute the majority of the volume of semen in the form of various fluid secretions.

There are three accessory glands of the male genital system:

1. The *prostate*
2. The *seminal vesicles*
3. The *bulbourethral glands* or *Cowper's glands*

The dog has only a prostate gland, while the cat has both the prostate and the bulbourethral glands. Both animals lack seminal vesicles; therefore, they have shorter copulating times (see Figure 17-11 and Table 17-2 on page 396 of your textbook).

Penis

The *penis* is the male organ of reproduction that provides passage for the products of the urinary and genital tract. The penis is composed of muscle, erectile, and connective tissues. The three main parts of the penis are the roots, the body, and the glans. Additional structures are present in some species, such as the os penis in the dog. The *os penis* is a bone that aids in maintaining an erection in species where erectile tissue is absent or deficient. The *glans penis* contains sensory nerve endings and may also contain erectile tissue. There are many species-specific variations of the glans. The glans penis of the horse becomes largely engorged due to the presence of much erectile tissue. Conversely, the glans penis of the bull and ram is considerably smaller; it contains a smaller quantity of erectile tissue and therefore becomes minimally engorged during erection. The glans penis of the cat is covered by small spines and becomes moderately distended. Other species, such as the boar, completely lack a glans penis.

The penis also contains the *urethra,* which is the shared excretory pathway of the urinary and genital system. There are variables between different species. For example, the ram's urethra is structured so that it extends beyond the glans penis.

The body of the penis contains spongy erectile tissue that becomes stiff when engorged with blood. It's formed by two structures, the *corpus cavernosum penis* and the *corpus cavernosae urethrae (corpus spongiosum),* which lie dorsal to and enclose the urethra. Together, they fill with blood to enlarge during sexual excitation, producing an erection. The erectile tissue is supplied by three arteries.

The bull, the ram, and the boar all have erectile tissues that are enclosed within fibrous connective tissue. In these males, the corpus cavernosa makes up a smaller portion of the penis near its root. The penis in these species is rather firm even in its flaccid state and enlarges minimally during erection. Instead, the flaccid penis forms an S-curve called the *sigmoid flexure,* which straightens during erection to allow for penetration to occur. Those species with a sigmoid flexure have well-developed erectile tissue muscles, such as the extensor penis and the retractor penis.

The *prepuce* acts as a protective sheath to cover the glans penis. During erection, the prepuce retracts out of the way.

Penis of the Dog

The dog's penis is very different from that of other species in having only one accessory sex gland—the prostate gland. The prostate gland completely encircles the urethra; therefore, diseases that affect the prostate also affect the urethra. The long corpus spongiosum extends from the root of the penis to just behind the glans, forming the *penile bulb* (called *bulb of* *the glans* in your text). This bulb becomes engorged with blood during mating and prevents the male from withdrawing the penis until several minutes after mating is finished. This period of time is called the *tie* and appears to be necessary for conception.

The glans penis contains a central bony support structure, the os penis. The glans penis contains much venous-based erectile tissue and is divided into the following two parts:

1. The *cranial section,* which is relatively long, comes to a point and covers the cranial end of the penis.
2. The *caudal section* (also called the *penile bulb*)—The act of ejaculation is a prolonged process in the dog, likely due to the lack of seminal vesicles and Cowper's glands.

Ejaculation

Ejaculation is a neuromuscular reaction during which spermatozoa emerge from the body. Ejaculation begins in nervous receptors in the glans penis and ends via rhythmic contractions of the urethra's muscular walls. During ejaculation, sperm are suspended within *semen,* a composite fluid produced by the prostate and bulbourethral glands and the seminal vesicles. The prostate and bulbourethral glands produce a mildly alkaline fluid, which induces motility. The seminal vesicles produce seminal fluid, which makes up the majority of the transport fluid.

Semen contains high levels of choline, citric acid, fructose, bicarbonate, and protein. Semen helps to maintain a neutral acid/base balance (pH) to counter the acidic environment of the female reproductive tract and increase the likelihood of conception.

Anatomy of the Female Reproductive System

In most species, the reproductive system is considerably more complicated in the female than the male. The reproductive organs are suspended within the abdominal cavity by the broad ligaments, which contain the nerves and blood vessels that supply the reproductive organs. The following five basic female sex organs are seen in all species, with some anatomical and physiological variations:

1. The *ovaries,* which produce eggs, or *ova* (singular: *ovum*)
2. The *oviducts (Fallopian tubes),* which carry the eggs to the uterus
3. The *uterus,* which nourishes and protects the developing fetus
4. The *vagina,* which is the opening to the outside
5. The *vulva,* the external structures of the reproductive system

Ovaries

The ovaries are paired, irregularly oval-shaped organs. Ovaries are analogous to the male's testicles in that they produce germ cells (*ova,* instead of sperm) and sex hormones (*estrogens,* instead of androgens). The location of the ovaries within the abdominal cavity varies among species, but they're predominantly positioned caudally and dorsally. The production of ova is primarily directed by the action of two hormones, *follicle-stimulating hormone (FSH)* and *luteinizing hormone (LH).*

As the ovum develops, it's enveloped by an expanding fluid-filled sac called the *follicle.* The follicle is lined with *granulosa cells* that secrete estrogen hormones. Once the follicle and ovum mature, the follicle ruptures to expel the mature ovum into the oviduct. The ruptured follicle then fills with blood, to form the *corpus hemorrhagicum.* The granulosa cells multiply, forming the *corpus luteum,* which produces *progestins* to maintain pregnancy. If the ovum isn't fertilized, the corpus luteum degenerates into the *corpus albicans,* which is composed of scar tissue and has no function.

All species (except the bovine) produce a corpus hemorrhagicum. The corpus luteum occurs in both pregnancy and estrus.

There's a sensory, motor, and sympathetic nervous supply to the ovary through the *utero-ovarian nerve.* The nervous supply originates from the lumbar spinal nerves and the posterior mesenteric ganglion.

Ovulation takes place with the rupturing of the follicle, which moves the mature ovum into the oviduct. The ovum enters the infundibulum of the oviduct, then moves down the oviduct into the uterus. This process takes approximately three days in domestic animals. If the ovum isn't fertilized within a week, it will degrade and die. The possibility exists that the ovum may not pass into the oviduct and will enter the abdominal cavity. If fertilization occurs in that area, it's termed an *ectopic pregnancy.* Ectopic pregnancy is fatal unless the embryo is removed from the abdomen.

The mature ovum is large and spherical. The ovum contains a well-defined nucleus and a dark-staining nucleolus. The granular cytoplasm is contained by the *zona pellucida,* which is a carbohydrate capsule that forms near the end of the maturation process.

Pre- and Postovulation Changes in the Ovary

The maturation of the ovum requires the development of support structures in the surrounding tissue. There's an increase in the number of granulosa or sustentacular cells, and they change from a flattened layer to a columnar arrangement. At this time, the ovum and the associated cells are collectively termed the *primary follicle.* The granulosa cells continue to increase in number, while each cell becomes both smaller and more spherical.

After the follicle is structurally complete, it continues to enlarge. An increase in follicular fluid causes the follicle to take on a cystlike structure. Immediately prior to ovulation, the number of cells and connective tissue fibers on one site on the outer surface of the follicle is reduced. This is where the follicle ruptures and the ovum emerges during ovulation.

Oviducts

The *oviducts* (also called the *Fallopian tubes* or the *uterine ducts*) are convoluted structures that transport mature ova from each ovary to the uterus. In the majority of mammals, fertilization takes place in the oviducts. Like the ovaries, the oviducts lie within the *mesovarium.* The end of the oviduct closest to each ovary expands to form the funnel-shaped *infundibulum.* The free edge of the infundibulum is fringed with *fimbriae,* finger-like structures that entirely surround the ovary. The point at which the infundibulum attaches to the hilus of the ovary is the sole contact point between the ovary and the other structures of the reproductive tract.

The end of the oviduct opposite from the ovary opens into the *horn of the uterus.* Species variations exist, as the uterus of humans and primates lacks horns, so the oviducts open into the uterine body. The interior of the oviduct is lined with a thin layer of ciliated columnar epithelium. The beating of the cilia aids the ova in passing from oviduct to uterus.

Uterus

The uterus consists of three main groups of components:

1. The *cornu* (horns), which are paired
2. The *corpus* (body)
3. The *cervix* (neck)

Variations of the uterine structures exist both between and within species, with the majority of domestic animals having a *bicornuate* uterus (that is, one with two horns). The fetuses develop in the horns of the uterus. The fertilized ovum implants in the lining of the uterus and is nourished and protected by the placenta, which forms and grows around it. You'll learn more about the placenta in the next assignment.

Cervix

The *cervix,* or neck of the uterus, is a muscular separation between the uterus and the vagina. The cervix is normally closed but dilates during physiologic changes such as estrus and labor. Mechanical manipulation, such as that used in artificial insemination, may also dilate the cervix.

Vagina and Vulva

The *vagina* is a muscular tube through which the penis enters during copulation and the fetus passes during labor. The vagina is a secretory organ lined with mucous-secreting vestibular glands and a stratified squamous epithelium. The vagina lies ventral to the anus in all domestic animals.

The exterior portion of the female reproductive tract is called the *vulva.* The vulva is divided into three portions:

1. The labia, or "lips"
2. The clitoris
3. The vestibule

The *labia* are the external structures of the female reproductive tract. The *clitoris* is a small collection of erectile tissue that's derived from the same embryologic cells as the penis in the male. The clitoris contains many sensory nerve endings that contribute to the sexual excitation of the female during copulation. The *vestibular glands* secrete mucus that aids in copulation. The vestibule and the vagina are separated by the *hymen,* a thin membrane that's penetrated during copulation.

In the cow, mare, and bitch there are variations in vaginal structure, such as in the position of the urethral opening in the ventral wall of the vestibule. In the cow, the urethral opening lies in a depression termed the *crypt.* In the mare, the urethral opening opens directly into the vestibule. In the bitch, the urethral opening is in a raised fleshy structure called the *papilla.*

Estrous Cycle

The *estrous cycle* is a physical alteration that occurs in normal adult females and accompanies ovulation. The estrous cycle is often called “heat.” Four basic types of estrous cycles are seen in different species: the monoestrous, diestrous, polyestrous, and seasonally polyestrous. The classification of the type of cycle is based on the number of cycles per year, as follows:

1. In *monoestrous* animals, ovulation occurs once per year. This pattern is seen in foxes, deer, and minks.
2. In *diestrous* animals, ovulation occurs twice per year. This pattern is seen in the dog.
3. In *polyestrous* animals, ovulation occurs multiple times per year. This pattern is seen in cattle and swine. The length of estrus varies from four days to four weeks.
4. In *seasonally polyestrous* animals, ovulation occurs multiple times per season. This pattern is seen in horses, sheep, and cats.

The estrous cycle is divided into five phases:

1. Proestrus
2. Estrus
3. Metestrus
4. Diestrus
5. Anestrus

Proestrus is characterized by growth of the follicle, secondary to production of estrogen-rich follicular fluid. Estrogens such as estradiole cause changes in the female reproductive tract, including

1. Thickening of the submucosa in the vaginal wall and uterine wall
2. *Cornification* (“toughening”) of the vaginal epithelium
3. Oviduct epithelial cell production

Proestrus readies the female reproductive tract for ovulation and copulation. To detect proestrus, a vaginal smear can be taken from an animal and evaluated for the presence of cornified cells.

Estrus is also known as a *"heat"* or *"season."* Estrus typically involves postural, behavioral, and voice changes that are conducive to breeding and engorgement of the external genitalia.

Estrus typically ends when the ovum passes from the ovary to the oviduct upon the rupture of the follicle. Species such as cats, rabbits, minks, and ferrets don't undergo ovulation until copulation occurs, causing a persistence of observable estrus behavior. Estrus is the period in which most species are receptive to copulation.

Metestrus involves the development of the corpus luteum from the corpus hemorrhagicum. The corpus luteum is a large mass of yellow tissue that produces *progesterone.* Progesterone is a female hormone with three functions:

1. Suppression of follicular growth to prevent another estrus cycle and a new ovum from being released
2. Preparation of the uterine endothelium to support a fertilized ovum
3. Reduction of vaginal epithelial cells and leukocytes

Diestrus is the longest period in polyestrous or seasonally polyestrous species. During diestrus, there are two possible outcomes for the corpus luteum:

1. Fertilization takes place, causing a persistence of the corpus luteum and production of progesterone. The estrous cycle is consequently interrupted during pregnancy.
2. Fertilization doesn't take place, so the corpus luteum regresses and the effects of progesterone don't persist. The corpus luteum becomes the *corpus rubrum* or "red body" in polyestrous and seasonally polyestrous animals, which induces the growth of a new follicle. As the corpus luteum becomes the corpus rubrum, the uterine lining is expelled. The corpus luteum may persist in monoestrous and diestrous species, causing a *pseudopregnancy,* or

"false pregnancy." A pseudopregnancy involves the physical changes of pregnancy, without the production of offspring. *Anestrus* is the phase in which no ovarian activity occurs. Estrous cycles continue throughout the female's fertile life and can be influenced by diet and confinement.

Before proceeding to the next assignment, take a moment to complete *Self-Check 2.* Remember, you can check your answers by turning to the back of this study guide.

Self-Check 2

1. Trace the pathway a sperm must pass through to get from its place of origin in the testicle to the external environment.

2. Name the five structures that make up the female reproductive tract.

3. Name the five stages of mammalian estrous cycles.

(Continued)

Self-Check 2

4. The process that results in the formation of mature spermatozoa is ________.

5. ________ cells provide nutritional support to developing spermatozoa.

6. The primary hormone involved in initiation of the ovarian cycle is ________.

7. Species that have continuous ovarian cycles only at specific times of the year are called ________.

8. The process of oogenesis produces one ________ and three ________.

9. Cornification of vaginal epithelial cells involves a layer of ________ on the surface of the cells and occurs during the ________ stage of the estrous cycle.

10. Fertilization normally occurs in the ________.

Check your answers with those on page 131.

ASSIGNMENT 3

Read in your textbook, *Clinical Anatomy and Physiology for Veterinary Technicians,* pages 405–413. Then read Assignment 3 in this study guide.

Fertilization and Pregnancy

Copulation

Copulation is the act by which the male animal deposits semen into the vagina or uterus of the female, typically resulting in a pregnancy. With the exception of rabbits and primates, female mammals don't allow copulation at any time except during the estrus phase of the estrous cycle.

Sperm are transported to the oviducts as a result of uterine contraction and action of cilia in the oviducts. The sperm undergo a series of changes as they travel to the site of fertilization. These changes, referred to as the process of *capacitation,* prepare the sperm to penetrate the ovum.

Fertilization

In most species, spermatozoa are deposited in the female's vagina or uterus and ascend to the oviduct to fertilize an egg. Although many sperm may swarm around the ovum, only one spermatozoon will fertilize the egg. The sperm tunnels into the egg with the aid of digestive enzymes released from the acrosome. Once fertilization takes place, the ovum is no longer receptive to penetration by other sperm. The addition of the chromosomes from the sperm causes the egg's haploid chromosome number to become *diploid* (in other words, it now has the correct number of chromosomes for the species). The combined sperm and egg form a *zygote,* which then begins to divide mitotically.

Developmental Stages of the Zygote

There are several basic stages in development of the zygote as it becomes an embryo.

Rapid mitotic divisions, known as *cleavage,* begin as soon as the haploid nuclei of the egg and sperm have fused. The cells don't grow between mitotic divisions. As cleavage continues, a solid mass of cells, known as the *morula,* is formed. The zygote moves toward the oviduct during the entire process of cleavage. By the time the zygote reaches the uterus, it has formed into a *blastocyst.* This is hollow ball of cells with a cavity in the center (see Figure 18-2 on page 407 of your textbook). The blastocyst implants into the uterine wall. The blastocyst secretes hormones that stimulate the uterine wall to develop a dense bed of capillaries to feed the growing embryo.

The growing *blastula* becomes the *gastrula,* a two-layered mass of cells. The gastrula grows toward the uterine lumen as the cells deposit more quickly on one side of the gastrula than the other. Differentiation of cells into blocks of tissue that will develop into different organ systems (muscular, skeletal, and neural, for example) begins.

The placenta develops, joining to the embryo via the umbilical cord. The placenta consists of two membrane structures (see Figure 18-3 on page 408 of your textbook). All mammals have some form of these two structures during development:

1. The *amnion* surrounds the developing embryo and contains *amniotic fluid.* Amniotic fluid is derived from tissue fluid, has an alkaline pH, and is composed of water, protein, carbohydrates, fat, salts, and urea.
2. The *allantois* surrounds the amnion and contains allantoic fluid. *Allantoic fluid* is composed of excretory fluid from the fetal kidneys. An embryo is called a *fetus* once essential structures develop and the species form is attained.

Placenta

The *placenta* is the vascular organ that unites the fetus to the maternal uterus and provides life support to the developing fetus. During pregnancy, the development of the placenta varies among species. The portion of the uterine wall that attaches to the placenta may or may not be shed during labor. If it is shed, it's called *deciduate;* if not, it's said to be *nondeciduate.*

There are four patterns of attachment *(placentation)* between the placenta and the uterine lining (see Figure 18-4 on page 408 of your textbook).

1. *Diffuse*—Placental attachment occurs over the entire uterine wall. This type of pattern is seen in the mare and sow. Animals with this pattern are nondeciduate.
2. *Cotyledonary*—A button-like placental attachment occurs via multiple cotyledons that attach to caruncles on the uterine wall. This pattern is seen in the cow, ewe, deer, goat, and other ruminants. Animals with this pattern are nondeciduate.

3. *Zonary*—A fixed, adherent placental attachment to the uterine wall occurs via a thin cylindrical zone. This pattern is seen in the dog, cat, and other carnivores. Animals with this pattern are deciduate.

4. *Discoidal*—A fixed, adherent placental attachment to the uterine wall occurs via a single disc-shaped area. This pattern is seen in primates and rodents. Animals with this pattern are deciduate.

Monotremes are rare, egg-laying mammals like the platypus. *Marsupials* are mammals that have a short gestation period, lack a placenta, and give birth to underdeveloped young that do most of their development in the mother's pouch. Kangaroos and opossums are marsupials.

Pregnancy and Parturition

The time from *conception* (fertilization) to *parturition* (birth) is termed the *gestation period* or *pregnancy.* Variations exist among species and individuals of identical species (see Table 18-1 on page 409 of your textbook). The gestation period is divided into three basic time periods of unequal length:

1. The first trimester, which is the *embryonic period*
2. The second trimester, which is the *fetal period*
3. The third trimester, which is the *growth period*

Parturition

Parturition is the process of birth, which occurs at the end of the gestation period. Parturition is initiated by the following hormonal changes in the fetus and mother and uterine and fetal size and weight. During parturition, the fetus is expelled from the uterus into the birth canal by the contraction of uterine and abdominal muscles and pressure from the abdominal organs. The cervical and vaginal muscles first relax, causing both the cervix and vagina to dilate. Once the fetus has entered the birth canal, the cervical and vaginal muscles rhythmically contract to expel the fetus from the birth canal into the environment.

The fetus usually passes through the placenta on its way to being born. After the fetus is expelled, the placenta follows, pushed out by weaker uterine contractions. The mother licks the newborn's face to remove any remaining placental membranes, which might block its ability to breathe. This stimulates the newborn's first breaths. The mother also often eats the placenta. In the wild, this would serve to hide the evidence that there's a vulnerable newborn animal in the area, so predators aren't attracted to it.

Postparturient Changes in the Mother

Uterine involution, returning the uterus to its approximate prepregnancy state, takes place over a period of one to two months. However, the postparturient (after birth) uterus will always be slightly larger than it was before, with less muscle tone. Several months are required for abdominal muscle, skin, and other structures altered by pregnancy to return to the prepregnancy state.

Mammary Glands

The *mammary glands* are specialized skin glands that produce colostrum and milk. They're present in both male and female animals and appear differently in different species. The number of mammary glands and their locations is also highly variable among different species (see Table 18-2 on page 411 of your textbook).

Lactation is the process of milk production that begins toward the end of pregnancy. The milk-secreting units of the mammary gland are small structures called *alveoli.* Each alveolus secretes milk into an alveolar duct. The small alveolar ducts empty into progressively larger ducts, and those empty into sinus spaces where milk accumulates. Milk is released into the sinuses in response to the hormone *oxytocin.* The mammary glands initially produce a secretion called *colostrum.* Colostrum has a different appearance and a different composition from normal milk. It contains larger amounts of proteins, lipids, and amino acids than milk and also contains high levels of various essential vitamins. High levels of maternal antibodies are also present in colustrum and impart a temporary immunity to specific pathogens to the developing newborn. Lactation is sustained as long as the mammary gland is physically stimulated and emptied regularly. The physical stimulation and emptying of the gland activate the nervous system, which controls milk production hormonally. When the physical stimulation stops and the gland is no longer emptied regularly, the hormonal control ends and lactation is discontinued.

Avian, Reptile, and Amphibian Reproduction

The gonads of birds are normally quite small. Hormones stimulate enlargement of the gonads at the start of the breeding season. Copulation in some species of birds involves attachment of the grooved erectile penis to the cloaca to transfer sperm into the female's vagina. However, in most species vaginal penetration doesn't occur, and sperm transfer occurs when the male and female bring their cloacae into close proximity.

Anatomical variations of the male reptile reproductive systems include internal testes and copulatory organs that form a trough to transfer sperm. In some reptiles, the copulatory organ is a phallus of erectile tissue. In other reptiles, the copulatory organs are paired structures called *hemipenes.* Amphibian copulation may be internal, or the male may deposit sperm onto a substrate that's then picked up by the female. In some species, the female lays eggs, and the male then deposits sperm onto the eggs. In frog and toad species, males fertilize the eggs as they're laid while grasping the female in an embrace called *amplexus.*

Reptiles and amphibians may be *viviparous* (giving birth to live young) or *oviparous* (egg-laying). Some lizards possess true placentas.

Now, review the material you've learned in this study guide as well as the assigned pages in your textbook for Assignments 1–3. Once you feel you understand the material, complete *Self-Check 3.* 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 1–3, complete your examination for Lesson 1.

Self-Check 3

1. Rapid mitotic divisions that begin when the sperm and egg nuclei fuse are called ________.
2. The zygote stage characterized as a hollow ball of cells with a cavity in the center is the ________.
3. The inner sac surrounding the fetus is filled with ________.
4. The process of giving birth is called ________.
5. The hormone that stimulates contraction of structures in the female reproductive tract is ________.
6. ________ is a premilk substance secreted by mammary glands that contains proteins and maternal antibodies.
7. The process that prepares sperm to penetrate the ovum is called ________.
8. The button-like placental attachment seen in the cow, ewe, deer, goat, and other ruminants is described as ________.
9. The fixed, adherent placental attachment seen in the dog and cat is described as ________.
10. The initial development of the zygote during which no cell growth occurs forms the ________.

Check your answers with those on page 132.

NOTES

Lesson 1
The Genitourinary Systems

EXAMINATION NUMBER

39652200

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 1, 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. Which of the following is the type of epithelium that lines the urinary tract?

   A. Transitional
   B. Squamous
   C. Columnar
   D. Stratified

2. Which of the following is one of the accessory glands of the male genital system?

   A. Thyroid gland
   B. Adrenal gland
   C. Bulbourethral gland
   D. Pituitary gland

3. Which type of placentation is found in dogs and cats?

   A. Diffuse
   B. Cotyledonary
   C. Discoid
   D. Zonary

4. The blood in which of the following vessels contains the *least* amount of waste in the body?

   A. Efferent glomerular arterioles
   B. Renal vein
   C. Peritubular capillaries
   D. Afferent glomereular arterioles

Examination

5. In animals that are diestrous, such as the dog, ovulation occurs
   A. once per year.
   B. twice per year.
   C. four times per year.
   D. several times per season.

6. Transitional cells differ from epithelial cells in that they
   A. can stretch more.
   B. have a thinner cell membrane.
   C. can't withstand acids as well.
   D. lack tight junctions between the cells.

7. In the male, the two functions of the testicles are to produce
   A. urine and spermatozoa.
   B. spermatozoa and white blood cells.
   C. white blood cells and urine.
   D. androgens and spermatozoa.

8. The blood vessels that take blood directly to and from the kidney are the
   A. abdominal aorta and renal artery.
   B. arcuate arteries and intralobular arteries.
   C. renal artery and caudal vena cava.
   D. renal artery and renal vein.

9. Sodium cotransport involves the movement of amino acids and ________ from the tubular lumen into epithelial cells on the same protein as sodium.
   A. ammonium
   B. glucose
   C. potassium
   D. chloride

10. Which structure maintains testicular temperature at a level cooler than the body temperature?
    A. Scrotum
    B. Vas deferens
    C. Urethra
    D. Prostate

11. The ova passes to the uterus through which structure?
    A. Follicle
    B. Oviduct
    C. Vagina
    D. Cervix

12. Which hormone helps transport spermatozoa to the oviduct inside the uterus?
    A. Estrogen
    B. Oxytocin
    C. Leutinizing hormone
    D. Testosterone

13. Which of the following occurs during capacitation?

A. Decreased rate of use of simple sugars for energy production
B. Involution of the uterus
C. Delivery of the placenta
D. Release of digestive enzymes from the acrosome

14. Which structure is responsible for the storage, concentration, maturation, and transportation of sperm from the testicle to the vas deferens?

A. Spermatic cord
B. Cremaster muscle
C. Hilus
D. Epididymis

15. From which portion of the nephron is glucose reabsorbed?

A. Bowman's capsule
B. Distal convoluted tubule
C. Proximal convoluted tubule
D. Ascending Henle's loop

16. In which process does the uterus gradually return to its nonpregnant size?

A. Parturition
B. Stage three of labor
C. Involution
D. Gestation

17. In the female, the two *most* important products of the ovaries are

A. estrogens and ova.
B. ova and androgens.
C. polar bodies and estrogens.
D. estrogens and androgens.

18. The secretory duct that connects the kidney and urinary bladder is the

A. urethra.
B. nephron.
C. renal vein.
D. ureter.

19. What is the name of the bony structure that supports the erectile tissues of the dog?

A. Glans bone
B. Os penis
C. Pubic bone
D. Glans penis

20. Which hormone keeps the myometrium calm and quiet during gestation?

A. Prostaglandin $F_2\alpha$
B. Oxytocin
C. Progesterone
D. Glucocorticoids

21. Which structure allows for passage of the offspring during birth and entrance of the penis during copulation?

A. Cervix
B. Vagina
C. Oviduct
D. Placenta

22. The three accessory glands of the male genital system are the

A. prostate, seminal vesicles, and bulbourethral (Cowper's) glands.
B. seminal vesicles, thyroid gland, and adrenal glands.
C. seminal vesicles, pituitary gland, and prostate.
D. prostate, bulbourethral (Cowper's) glands, and adrenal gland.

23. The two *main* structures that make up a kidney are the

A. hilus and cortex.
B. cortex and medulla.
C. area cribrosa and cortex.
D. renal pelvis and medulla.

24. Which structure contains the capillaries responsible for filtering blood into the nephron?

A. Henle's loop
B. Bowman's capsule
C. Nephron
D. Proximal convoluted tubule

25. After fertilization, the ________ implants in the uterine wall.

A. ovum
B. morula
C. placenta
D. blastocyst