Please do not write on these : Return them in good condition. Write your answers on a separate piece of paper.

11

Animal Reproduction

Key Terms

Ampullary-isthmic junction
Artificial vagina (AV)
Atresia
Blastocyst
Broad ligament
Colostrum
Corpus luteum (CL)
Donor
Dystocia
Embryo transfer
Epididymis
Episodic
Estrous cycle
Estrus
Flow cytometer
Flushing
Follicle-stimulating hormone
Folliculogenesis
Freemartin
Gametes
Generation interval
Gonads
Hypothalamus
In vitro
Libido
Lordosis
Luteinizing hormone
Luteolysis
Monoestrus
Morula
Oocyte
Ovulation
Parturition
Passive immunity
Pituitary gland
Placenta
Polyestrus
Postpartum
Postpartum interval
Pregnancy disease
Progesterone
Prostaglandin
Puberty
Recipients
Secondary sex characteristics
Semen
Testosterone
Zygote

Learning Objectives

After you have studied this chapter, you should be able to:

- Describe how the endocrine system drives the production of gametes.
- Identify the various anatomical features of female and male reproductive systems.
- Compare and contrast the functions of the male and female gonads.
- State how conception, pregnancy, and parturition occur.
- Discuss the considerable influence of the environment on reproductive function.
- Describe the uses and advantages of the technologies recently employed in animal reproduction.

INTRODUCTION

Reproduction is required for propagation and continuation of a species, and as such, is an essential process in all species. Producers of domestic animals are particularly concerned with reproduction, as the production of young is the primary determinant of income for most livestock species. Even dairy producers, who generate the majority of their income through milk sales, require reproduction to occur to initiate lactation. In fact, increases in reproductive efficiency are considered to have a much greater impact on profitability than does progress in general production methods. A 3% improvement in birthrate would result in an additional 1 million beef calves born per year, 3.2 million pigs born per year, and

3.7 million gallons of milk produced per year. Considering these numbers, efforts to increase reproductive efficiency in domestic animal species are typically well rewarded financially. Likewise, selection against poor reproductive efficiency is similarly rewarding.

Reproduction in all animals, both male and female, requires tremendous coordination between the hypothalamus, the pituitary gland, and the gonads. Because these individual endocrine glands behave in concert with one another, they are often referred to as a single entity, the hypothalamo-pituitary-gonadal axis, which acts to coordinate and carry out the processes involved with germ cell development and maintenance, fertilization, pregnancy, and **parturition**, the process of giving birth. These processes, although critical to produce offspring, are active only during certain phases of the life cycle. These phases are typically age dependent. In addition, many other factors come into play, including season (day length), presence of the opposite gender, and level of nutrition. Knowing which factors affect reproductive function and determining how to minimize the negative effects of those factors are critical to successful reproduction.

Parturition Process of giving birth.

At the basis of the reproductive system is the **gonad**. The female gonad is the *ovary* and the male gonad is the *testis*. The gonads have two primary functions: steroidogenesis, or the production of the sex steroids, and gametogenesis, or the production of **gametes**. Both of these functions are hormonally controlled and require absolute coordination for proper activity to be expressed. The hormones responsible for proper function of the gonads are produced by the brain (hypothalamus) and **pituitary gland**. Because the gonad is directly responsive to the action of the hypothalamus, environmental factors including nutritional status, length of daylight, and emotions have a profound influence on reproductive function. Some reproductive terms and other information of general value about some species are listed in Table 11–1.

Gonads Sex organs; testis in male, ovary in female.

Gametes Mature sperm in the male and the egg or ova in the female; the reproductive cells.

Pituitary gland Gland sitting directly below the hypothalamus.

PUBERTY

Before an animal of either sex is capable of reproduction, it must go through the process of **puberty**. The signals for puberty differ by species, but the most important factors influencing the onset of puberty are age and weight. However, nutritional stress, season of the year, and other factors can also affect the onset of puberty. Puberty is simply the process of maturing from a nonfunctional endocrine and physiological reproductive state into a state of functional gamete and hormone production. After puberty, an animal is said to be *reproductively competent*. Puberty is associated with the **secondary sex characteristics** commonly associated with each sex. The transition through puberty is characterized by inconsistent reproductive competency.

Puberty Transitional state through which animals progress from an immature reproductive and hormonal state to a mature state.

Secondary sex characteristics Characteristics that differentiate the sexes from each other; occur most profoundly during and after puberty.

Examples of secondary sex characteristics in males include such things as humps on the necks of bulls, beards on men, increased musculature in the male of most species, and changes in the sound of vocalization (for instance, the voice change in boys that happens at puberty). For females this includes the many characteristics lumped together that we refer to as femininity: added body fat that creates curves where once angles were visible, mammary development, smoother hair coats, and so on. Behavioral characteristics such as "marking" territory (both sexes) or aggression in males are also part of the complex.

Table 11–1
REPRODUCTIVE TERMS BY SPECIES

	Cats	Cattle	Dogs	Goats	Horses	Chickens	Sheep	Swine
Mature male	Tom	Bull	Dog	Buck	Stallion	Cock[1]	Ram	Boar
Mature female	Queen	Cow	Bitch	Doe	Mare	Hen	Ewe	Sow
Young male	—	Bullock	Puppy dog	Buck kid	Colt	Chick[2]	Ram lamb	Boar[3]
Young female	—	Heifer	Puppy bitch	Doe kid	Filly	Chick[2]	Ewe lamb	Gilt[3]
Newborn	Kitten	Calf	Pup	Kid	Foal	Chick[2]	Lamb	Pig
Unsexed male	Gib	Steer	Castrate	Wether	Gelding	Capon	Wether	Barrow
Groups	Bevy	Herd	Pack	Band	Herd	Flock	Flock	Herd, drove, or sounder
Genus	*Felis*	*Bos*	*Canis*	*Capra*	*Equus*	*Gallus*[4]	*Ovis*	*Sus*
Act of parturition	Littering	Calving	Whelping	Kidding	Foaling	NA	Lambing	Farrowing
Duration of heat	6–7 days	14 hrs	2–21 days (6–12 avg)	42 hrs	6 days	NA	30–35 hrs	2–3 days
Length of estrous cycle (average; range)	18; 14–21 days	12; 18–24 days	3 1/2–13 months; (6 months avg)	21; 15–24 days	21; 16–30 days	NA	16; 14–20 days	21; 18–24 days
Time of ovulation in (days) relation to heat	Stimulated by mating	10–14 hrs after end of estrus	Usually 1–3 days after first acceptance of male	Near end of estrus	1–2 days before end of estrus	NA	1 hr before end of estrus	18–60 hrs after estrus begins
Gestation period (average; range) (days)	63; 62–64	281; 274–291	63; 58–68	151; 140–160	336; 310–350	21-day incubation	150; 140–160	113; 111–115
Age at puberty (months)	4–18 (much breed variability)	8–14	5–24	4–8	10–12	4–6	4–8	5–7

[1]Called a tom in turkeys.
[2]Called a poult in turkeys, a gosling in geese, and a duckling in ducks.
[3]Shoat refers to a young pig of either sex under one year of age.
[4]Genus for chicken.

ENDOCRINOLOGY

Hypothalamus Area of the brain responsible for many homeostatic functions.

Episodic The pulsatile manner in which the gonadotropic hormones are secreted by the anterior pituitary gland. Controlled by the pulse-generating center of the brain.

Luteinizing hormone Gonadotropic hormone primarily responsible for providing the signal to disrupt the mature follicle in females, and the production of testosterone by the Leydig cells of the testes in the male.

Follicle-stimulating hormone Gonadotropic hormone responsible for growth, development, and maintenance of follicles in females, and the production of sperm in males.

Testosterone Male steroid sex hormone.

Atresia The degeneration of follicles that do not make it to the mature stage, otherwise known as the Graafian stage.

Ovulation Release of the ova or egg from the ovary.

The endocrine functions involved in reproduction are initiated by the **hypothalamus**, a small area of the brain, which plays a critical role in the body's ability to adapt to the environment. The hypothalamus releases a hormone called *gonadotropin-releasing hormone* (GnRH). Release of this hormone is the first step in a cascade of hormonal events that must proceed in a coordinated manner to result in successful action by the gonads. Interestingly, GnRH is released in a pulsatile manner, causing all of the hormones and actions to be **episodic** (Figure 11–1). This action maintains a high degree of sensitivity in the system. The stimulation for GnRH release is controlled by a center referred to as the *pulse-generating center*. This center is under control of various parts of the brain and, in fact, integrates the many environmental signals to produce a driving force in the endocrine cascade.

GnRH travels a short distance to the anterior pituitary gland, which sits directly below the hypothalamus. The anterior pituitary gland, in turn, responds to GnRH by releasing two other hormones: **luteinizing hormone** (LH) and **follicle-stimulating hormone** (FSH). These two hormones enter the bloodstream and travel to the gonads of both males and females. Again, these hormones are released into the bloodstream in a pulsatile manner so that the gonads are only exposed to high levels of the gonadotropins (LH and FSH) intermittently.

Testosterone, the primary male hormone, is produced by the testes. In the male, release of LH is the signal to the testes to produce testosterone. If LH is not present, testosterone is not produced in adequate quantities for expression of the secondary sex characteristics associated with males. FSH in males is required for the production of sperm, the male gamete.

In the female, FSH is responsible for growth and maintenance of the developing follicle that is destined to produce the ova, which is the female gamete. Without adequate FSH support, the follicle undergoes death in a process referred to as **atresia**. As the follicle grows and develops, it produces estrogen (Figure 11–2). The increased level of estrogen causes a surge of LH to be released from the pituitary gland. This surge of LH initiates the breakdown of the follicle wall, thereby releasing the ova from the ovary and making it available for fertilization (Figure 11–3). This release of the ova from the ovary is called **ovulation**.

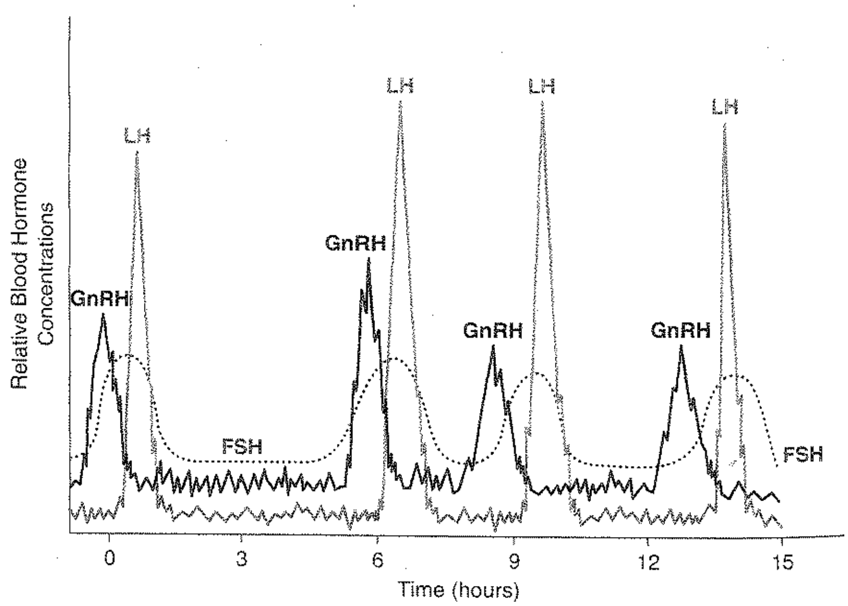


Figure 11–1
Episodic release of the hormones of reproduction in response to the release of gonadotropin-releasing hormone (GnRH). LH = luteinizing hormone; FSH = follicle-stimulating hormone. (Source: Senger, 2003, p. 216. Used with permission.)

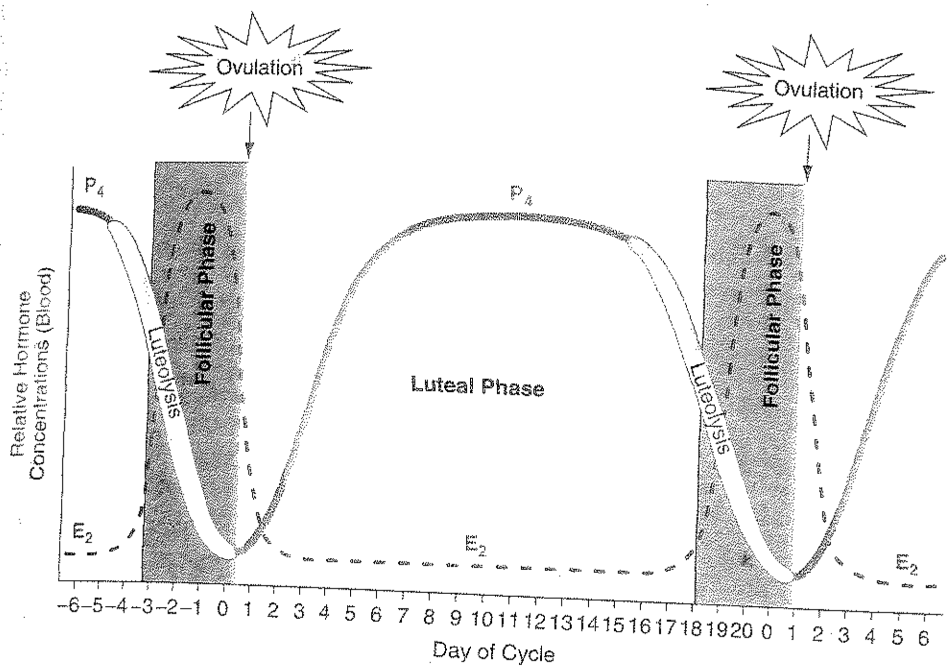


Figure 11–2
Phases of the estrous cycle. P = progesterone; E = estrogen. (Source: Senger, 2003, p. 148. Used with permission.)

After ovulation, the follicle is transformed into a **corpus luteum (CL)**. This structure's primary responsibility is to produce the hormone **progesterone**, which is required to support pregnancy. Progesterone inhibits LH and FSH release, prevents behavioral **estrus**, and decreases the motility of the muscles in the uterus. In some species (goat, rabbit, and sow), the CL is required throughout gestation to maintain

Corpus luteum (CL) Ovarian structure responsible for the production of progesterone for the support of pregnancy.

Progesterone Female sex steroid produced by the corpus luteum or the placenta.

Estrus The period when a female is receptive to mating. Synonymous with *heat*.

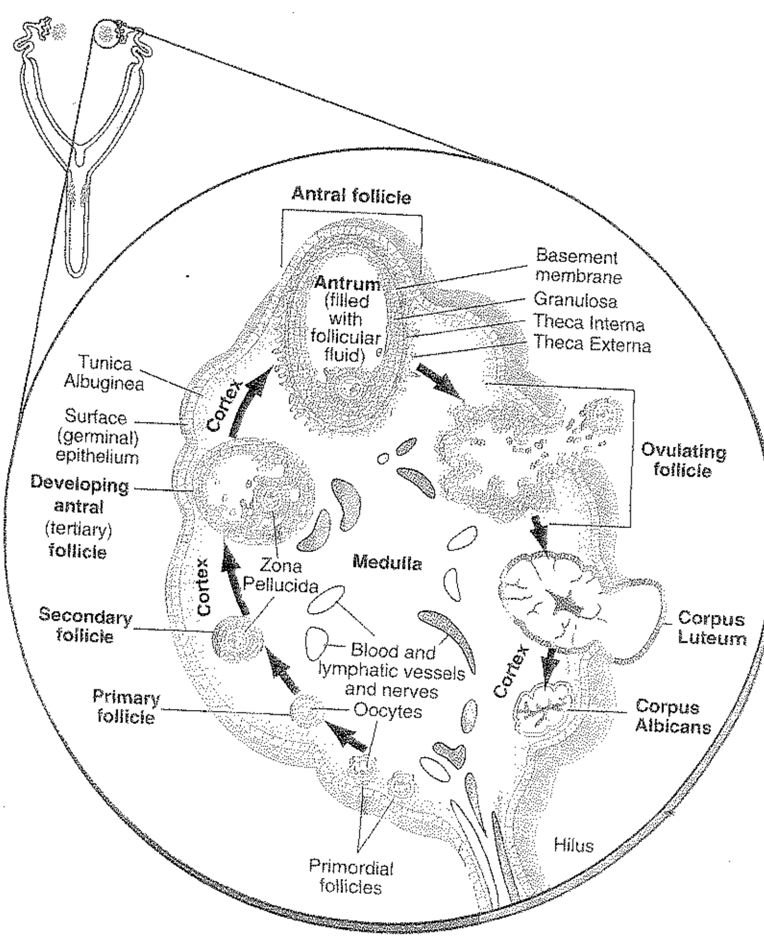


Figure 11–3
Illustration of the ovary. (Source: Senger, 2003, p. 25. Used with permission.)

a successful pregnancy. In other species (cow, mare, and ewe), the CL provides adequate progesterone during early pregnancy, but becomes unnecessary because the **placenta**, the organ that surrounds the fetus and attaches to the female uterus during pregnancy, begins to produce enough progesterone to support pregnancy sufficiently. The placenta is the organ through which oxygen and nutrients are passed to the fetus from the female and waste is passed from the fetus to the female.

Placenta The organ that surrounds the fetus and unites it to the female while it develops in the uterus.

ANATOMY

Female

The female reproductive tract consists of the ovaries (female gonad), oviducts (also called Fallopian tubes), uterus, cervix, vagina, and external genitalia (Figure 11–4). In most domestic animal species, the reproductive tract is suspended below the rectum by the broad ligament. The ovaries occur in pairs, are attached to the ligament at the hilus, and are responsible for the development, and release of the ova. In addition, the ovaries produce the female sex steroid hormones progesterone and estrogen, depending on the stage of the reproductive cycle.

The ovaries of the newborn female contain all of the **oocytes** (gametes) the female will ever have. The functional oocytes are sequestered in primordial follicles before birth, which remain in a quiescent state until recruited into a growing pool that enter folliculogenesis, the growth and development of the primordial follicle in the ovary, during the monthly **estrous cycle** of the female. During folliculogenesis, follicles will continue to develop or die through atresia. The few follicles that survive to sufficient size produce the high levels of estrogen required to result in the surge of LH that ultimately causes the release of the ova from the follicle. It is not yet clear

Oocyte The gamete from the female.

Estrous cycle The time from one estrus (heat) to the next.

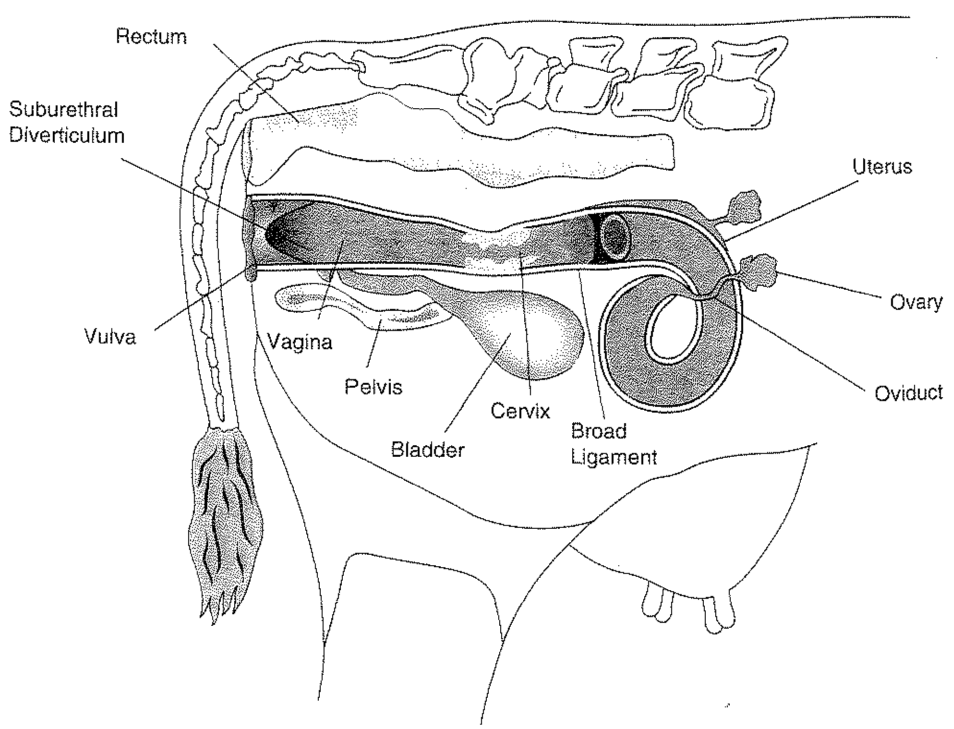


Figure 11–4
Female reproductive tract. (Source: Oklahoma State University. Used with permission.)

how the follicle that survives to ovulation is chosen among the 100 or so that begin to grow each month.

The ovum is released from the follicle and is "captured" by the *infundibulum*, a funnel-shaped structure at the end of the oviduct that surrounds the ovary. The thin membrane directs the ovum into the oviduct, preventing it from entering the abdominal cavity. The upper portion of the oviduct is the ampulla, and it connects with the isthmus, the lower portion of the oviduct. The isthmus connects the oviduct with the uterine horn. The area where the ampulla and isthmus connect, the ampullary-isthmic junction, is considered the site of fertilization. The oviduct is glandular, providing nutrients and a transport medium in the secretions. The eggs remain in the oviduct for approximately 3 to 6 days, depending on the species.

Species differ greatly in the type of uterus configuration present, as indicated in Figure 11–5. The primary difference between types of uteri is the presence of uterine horns. The uterus functions to provide a passageway for sperm cells from the cervix to the oviducts, to provide glandular secretions to nourish the embryo prior to development of the placenta, to provide a proper environment for the development of the fetus, to provide nutrients and eliminate waste products for the developing fetus through the placental–uterus junction, and to expel the fetus during parturition. The uterus is a very muscular organ, and contractions aid in the expulsion of the fetus. However, this contractility of the uterus must be suppressed to allow the embryo to implant to the wall of the uterus for a successful pregnancy. After ovulation, the development of a functional CL ensures that adequate progesterone is produced and secreted. Progesterone suppresses the contractility of the uterus, which allows the embryo to implant.

The uterus is connected to the cervix, which acts as a gatekeeper from the vagina into the uterus. The cervix has five primary functions:

1. To act as a passageway for sperm cells.
2. To act as a storage reservoir for sperm cells. In this way there can be a more consistent release of sperm into the uterus. This increases the chances that viable sperm will be present at the same time the ova is prepared for fertilization.

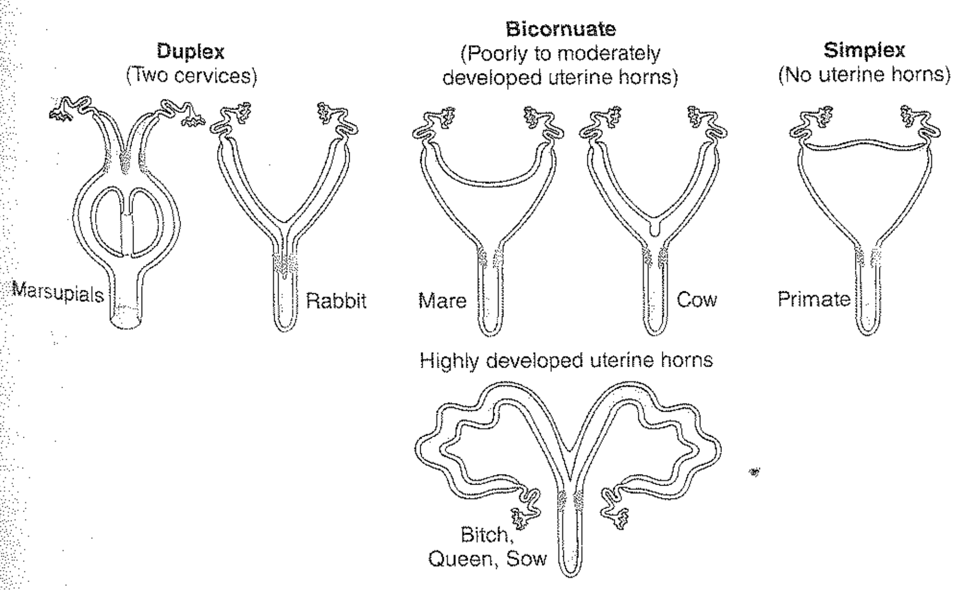


Figure 11–5
Types of uteri. (Source: Senger, 2003, p. 30. Used with permission.)

3. To act as the primary barrier between the external and internal environments.
4. To provide lubrication.
5. To act as a passageway for the fetus at parturition.

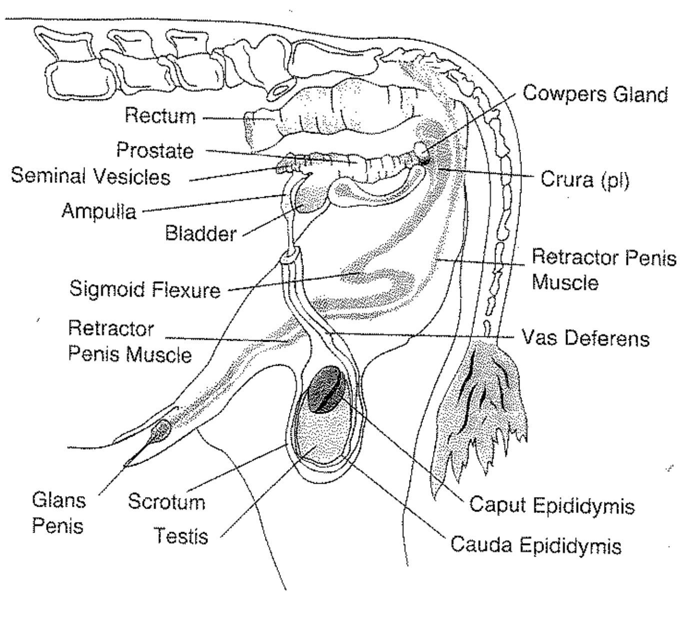
The cervix, a very thick-walled, sphincter-like organ, has a canal with many crypts and folds through which the sperm must travel (except for the mare and sow in which the sperm is deposited directly into the uterus). This canal becomes occluded, or shut off, from the vagina by viscous secretions that are produced under the influence of high progesterone. The viscous secretions are referred to as a *cervical seal* or *cervical plug*. Its function is to prevent the entrance of any contaminants when the embryo or fetus may be present. In fact, if the cervical seal is broken during pregnancy, spontaneous abortion generally follows. Under the influence of high estrogen, the cervix produces copious amounts of mucus to lubricate the vagina. This secretion also aids in preventing microorganisms from gaining entrance to the uterus by flushing the contaminants out.

The vagina serves a dual function, first, as the copulatory organ in most species, and second, it serves as a birth canal to expel the fetus. Unlike the uterus, the vagina is not a muscular organ. The vagina connects the cervix with the vulva, or the outside anatomical feature of the female. The vulva consists of two labia (inner and outer), which, under normal circumstances, provide a closure protecting the female reproductive tract against entry by microorganisms.

Male

The primary structures of the male reproductive tract are the testes, penis, duct system, and accessory sex glands (Figure 11–6). The testes, which are analogous to the ovary in the female, are responsible for both gamete (sperm) production and production of the male sex steroids. Because the production of sperm is very temperature dependent, occurring at temperatures 4–6°C cooler than normal body temperature, the body has developed several mechanisms to maintain proper temperature control. The testes begin development in the abdominal cavity but descend from the abdomen to the scrotum, usually during fetal development, through the inguinal canal. Infrequently, one or both of the testes may not descend and instead remain in the abdomen in a condition referred to as *cryptorchidism*. Because testosterone production can occur at body temperatures, a bilateral cryptorchid (neither

Figure 11–6
Male reproductive tract.
(Source: Oklahoma State University. Used with permission.)



testis descended) male will exhibit secondary sex characteristics of a normal male. However, sperm production requires cooler temperatures, so the affected male is generally infertile. With unilateral cryptorchidism (one descended testis), the descended testis is fertile and often compensates for the lack of sperm production by the undescended testis. Therefore, the males are typically fertile. The condition appears to be hereditary, and, therefore, cryptorchid males should not be used for reproductive purposes.

The testes are suspended by the spermatic cord into the scrotum. The scrotum protects the testes and allows quick cooling for the testes to maintain proper temperature. The scrotum contains many thermosensors, which determine the outside temperature and cause several reactions, including scrotal sweating to dissipate the heat. In addition, neural connections from the scrotal thermosensors to the brain can affect the respiration of the male during heat stress. The increased respiration rate again dissipates the heat, thereby lowering testis temperature. The spermatic cord also connects the testis to the abdominal cavity through the inguinal canal. The spermatic cord contains the blood supply to the testes, neural connections, and a muscle that is capable of raising and lowering the testes. When the testes become cold, the external cremaster muscle raises the testes closer to the body to warm them. The cremaster muscle works in concert with the tunica dartos muscle, a smooth muscle layer underneath the skin of the scrotum. The tunica dartos muscle is capable of holding the testes close to the body for sustained periods of time. When the testes become too warm, the external cremaster muscle and tunica dartos muscle relax, thereby allowing the testes to descend. In bulls and rams, the scrotum may become very pendulous during hot summer days. This is an example of how the body tries to compensate for environmental conditions to maintain processes such as sperm production. Another unique feature for temperature control is a specialized vascular system called the *pampiniform plexus,* a network of veins surrounding convoluted segments of the testicular artery, which acts as a countercurrent heat exchange that cools arterial blood as it travels from the body to the testes, and warms the blood traveling from the testes to the body. If the body is not able to disperse enough heat and the testes become too warm, sperm production may halt and pregnancy rates can be depressed.

The testes are responsible for sperm and testosterone production. Testosterone is responsible for the secondary sex characteristics in males. In contrast to females, which have limited ova production, the male has tremendous gamete production potential. Sperm is produced continuously, as opposed to females, who are born with the total number of gametes they will ever have. Sperm are produced by seminiferous tubules within the testis capsule, and are then transported through the **epididymis** for further development and storage. Sperm collected from the head of the epididymis are typically immature and nonfertile. However, offspring have resulted from fertilization of eggs with sperm collected from the tail of the epididymis. Prior to ejaculation, the sperm travel from the epididymis through the ductus deferens to the urethra. The ductus deferens (vas deferens) can be cut in a procedure called a *vasectomy.* This almost certainly results in sterility but leaves sexual function intact. It is occasionally used to produce a male called a *teaser* to aid in estrus detection. The sperm in the ductus deferens are suspended in a fluid from the testes. However, several other organs add fluid to the sperm to make up the final product, **semen**. Boars and stallions produce gelatinous fractions that act to seal the cervix after breeding to prevent loss of semen back through the cervix. The seminal vesicles, prostate gland, and bulbourethral glands (Cowper's gland) all produce secretions that increase the volume of the semen, add nutrients to the semen, and aid in coagulation of the semen after ejaculation.

Epididymis Duct connecting the testis with the ductus deferens. Responsible for sperm storage, transport, and maturation. It consists of a head, a body, and a tail.

Semen Fluid from the male that contains sperm from the testis and secretions from several other reproductive organs.

The penis is the organ that deposits the semen in the vagina or cervix, depending on the species. The penis can be either vascular (stallions) or fibroelastic (bulls, boars, rams). The vascular penis enlarges during sexual excitement by retaining blood in specialized erectile tissue. The increased blood volume under high pressure causes erection. Following ejaculation, the blood is allowed to leave the organ, thereby decreasing blood pressure and volume in the penis.

With the exception of the stallion, the common farm animal species have a fibroelastic penis that exists in an S-shaped configuration inside the body until erection. During sexual excitement, the muscles responsible for retaining the penis in the sigmoidal flexure relax, allowing the penis to extend through the sheath. There is minimal increase in diameter of this type of penis. One modification of the penis is noted with the boar. The glans penis (the end of the penis) of the boar is corkscrew-shaped, such that it engages into the analogous corkscrew-shaped cervix of the sow. Therefore, the boar deposits the semen in the cervix rather than the vagina.

Because the penis is such a vascular organ, trauma can cause severe hemorrhaging. It is a fairly common injury for bulls to suffer a "broken penis," in which the penis is bent or kicked while extended. The blood from the penis leaks out and pools in the surrounding tissue. Many times the damage is irreparable and prevents the bull from ever mating naturally again. Semen can still be collected using an electroejaculator, which is explained later.

PREGNANCY

Successful timing of ovulation and mating should result in pregnancy. During estrus, the female becomes receptive to the male, thereby encouraging copulation (the physical mating). The ova, recently released from the ovary and traveling down the oviduct, becomes fertilized in the ampullary-isthmic junction of the oviduct. The window of opportunity for fertilization is very narrow. If fertilization has not occurred within approximately 12 hours, the oocyte begins to degenerate, and the chance for successful fertilization decreases drastically. Fortunately, sperm travels to the ampulla very rapidly, as soon as several minutes after ejaculation. In addition, the cervix and uterus have numerous crypts and crevices that hold sperm. Thus sperm deposited for several hours or even days before ovulation have an opportunity to reach the oocyte.

Once the oocyte is fertilized, it becomes a one-celled embryo called a **zygote**. Cell division begins soon after fertilization and the zygote becomes a multicelled **morula** embryo. Further development transforms the morula embryo into a **blastocyst**. The blastocyst embryo is free-floating as it moves down the oviduct toward the uterine horns and body of the uterus. The day of implantation varies by species, but generally occurs between 14 and 40 days in farm animals. The blastocyst continues to develop, and cellular partitions become evident. The inner cell mass is the initial fetus, and the trophoblast partition develops into the placenta (Figure 11–7).

Zygote Cell resulting from the fusion of the sperm and oocyte.

Morula Early-stage embryo, after cell division multiplies cell numbers in the zygote.

Blastocyst More differentiated embryo consisting of an inner cell mass, blastocoele, and a trophoblast.

Prostaglandin A group of fatty acid hormones, one of which is prostaglandin $F_{2\alpha}$, which breaks down the corpus luteum allowing the female to return to estrus.

Relatively high levels of progesterone are required for maintenance of the pregnancy, and the CL supplies the progesterone during the early phases of pregnancy in all species. However, for pregnancy to be maintained, degradation of the CL must be prevented. The pregnancy must first be recognized by the female. If pregnancy is not recognized in time, the CL degrades, thereby removing the source of progesterone required to support the pregnancy. In the cow, ewe, and mare, the nonpregnant uterus produces **prostaglandin** $F_{2\alpha}$ ($PGF_{2\alpha}$), which travels to the

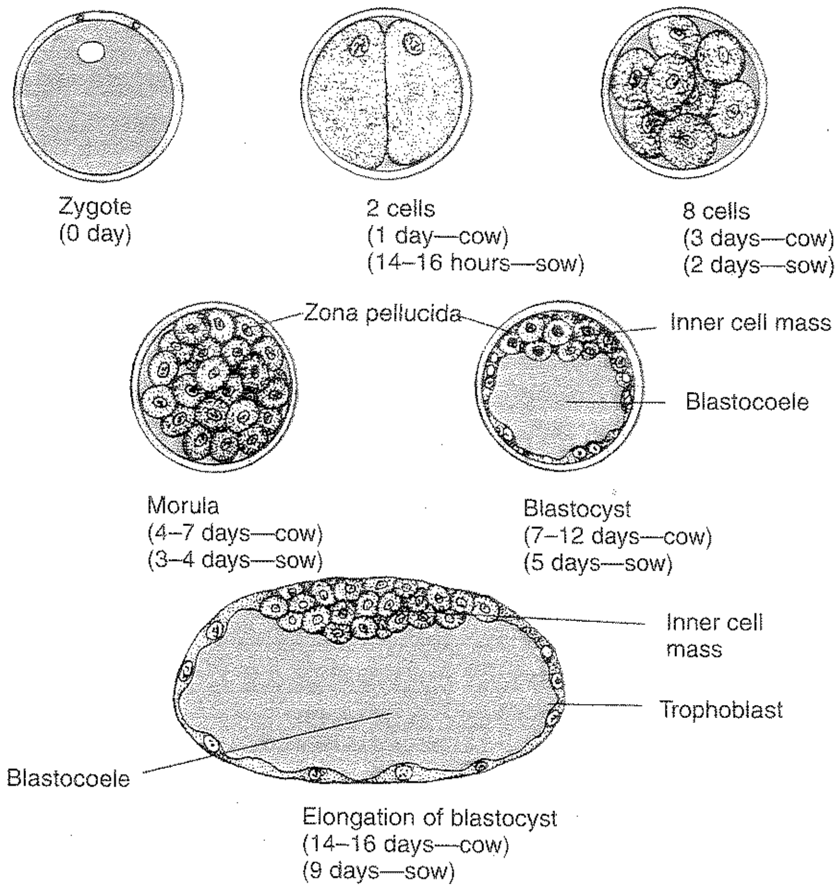


Figure 11–7
Specific cleavage stages at given times after fertilization in the cow (281-day gestation) and the sow (114-day gestation). (Source: Bearden and Fuquay, 1997, p. 91. Used with permission.)

ovary and causes **luteolysis**, or breakdown of the CL. The blastocyst of the species, however, produces proteins that block the production and release of $PGF_{2\alpha}$, thereby preventing luteolysis.

The trophoblastic cells of the blastocyst give rise to the various layers of the placenta. The fetal membranes are made up of the amnion, the chorion, the allantois, and the yolk sac (Figure 11–8). The amnion surrounds and cushions the fetus in

Luteolysis Breakdown or degeneration of the corpus luteum. Occurs at the end of the luteal phase of the estrous cycle if pregnancy is not detected.

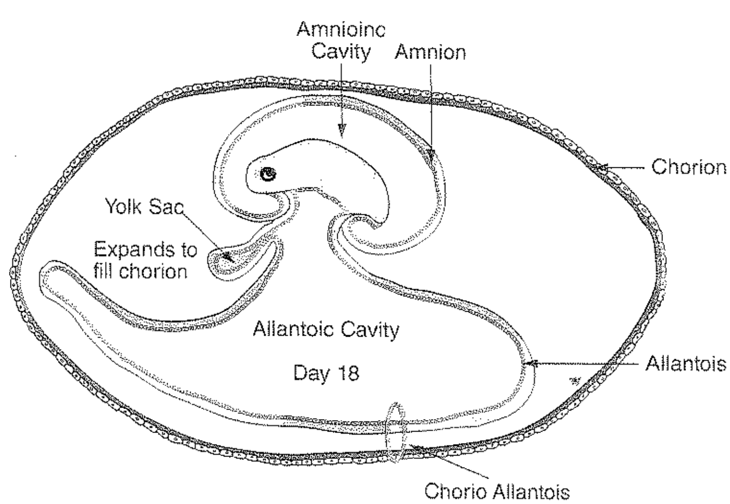


Figure 11–8
Fetus with placenta. (Source: Geisert, 1999.)

amniotic fluid. In case of severe trauma, this amniotic fluid protects the fetus. The allantochorion, a fusion of the allantois and chorion, is in contact with the endometrium of the uterus. The yolk sac provides nutrients to the developing embryo/fetus. In some species such as birds, the yolk sac is prominent. In others, the yolk sac develops early but degenerates early in the pregnancy. In total, the placenta regulates the exchange of oxygen, nutrients, waste, and in some species, antibodies, between the mother and fetus. The actual connection between the uterus and placenta to facilitate these exchanges varies greatly by species, from a very diffuse connection as in the sow, to very localized connections seen in ruminants.

When more than one fetus is present, the membranes of the multiple fetuses typically fuse together. This is a normal occurrence and has no bearing on development, except in the cow. In cattle, the blood supplies for the multiple membranes fuse as well, allowing hormones to transfer from one fetus to the other. If the twins are of the same sex, development continues normally. However, if the twin combination is a bull and heifer, the male hormones from the bull disrupt the development of the female. For this reason, about 10 out of 11 heifers born as a twin with a bull are sterile owing to incomplete reproductive tracts, a condition called freemartinism. A relatively inexpensive blood test has been developed to determine whether a newborn heifer is normal or a **freemartin**. The incidence of multiple births in beef cattle is relatively low but is about 6% in dairy cattle and has been increasing with higher milk production levels.

Freemartin Condition in cattle in which a female calf is born as a twin with a bull calf and as a result is infertile.

As a rule of thumb, approximately two-thirds of fetal growth occurs in the last trimester of the pregnancy. Therefore, energetic demands of the female are greatest during this period and can create special nutritional requirements, which must be met. For example, ewes carrying more than a single fetus are susceptible to a condition called **pregnancy disease** in which the female is not capable of providing, or is not provided, enough nutrients to support the high demand of the fetuses. Likewise, cows and horses must be fed adequately such that energy reserves are appropriate at birthing. If not, the female is faced with high nutrient demands to support lactation without the necessary resources to draw on. Typically, these females are late to return to estrus, and subsequent breeding is delayed.

Pregnancy disease Also referred to as *pregnancy toxemia.* A form of ketosis in females that occurs in late pregnancy because the female cannot eat enough of the feed she is provided or is not provided enough feed. Usually occurs in cases of multiple fetuses; common in sheep.

Parturition

Parturition, the process of giving birth, is the culmination of pregnancy. Parturition is initiated by hormones secreted by the offspring. It is also possible to induce parturition using a cortisol-type drug such as dexamethasone. As the young move up the pelvic cavity and begin to push against the cervix, a neural connection from the cervix to the brain stimulates the release of oxytocin from the posterior pituitary gland. Oxytocin travels to the muscles of the uterus, causing contractions that aid in expelling the fetus. Most births occur naturally with no assistance. However, malpresentations and inappropriately sized offspring may necessitate intervention. Difficulty in birthing is called **dystocia**. The leading cause of dystocia is a fetus that is too large for the birth canal. This situation can be virtually eliminated by selecting for low-birthweight sires and by using pelvic dimensions as a selection tool in the females.

Dystocia Birthing difficulty.

Females preparing for an impending parturition display behavioral changes that vary from species to species. They generally become restless, may separate from other animals, and show extreme discomfort. The vulva swells and the udder becomes engorged. In the mare, **colostrum** may ooze from the teats in the few days prior to parturition. The ligaments around the tailhead relax, and the tail becomes relaxed.

Colostrum First milk given by the female after birth of the young.

Birth is preceded by expulsion of part of the allantochorion (referred to as the *waterbag*), which usually breaks as it releases fluid. As the fetus moves through the pelvic cavity, the placenta becomes detached from the uterus. This leads to a loss of connection for oxygen and nutrients to the fetus. Therefore, it is essential that labor progresses fairly rapidly to ensure that the young has adequate oxygen. In cows, mares, ewes, and does, the position of the fetus is normally front feet first, with the head lying between the two front legs. In pigs, either head- or tail-first presentation is normal.

The last phase of parturition is expulsion of the fetal membranes. This typically happens within a reasonable period of time after birth. In some circumstances, the placenta does not pass, resulting in a condition called *retained placenta*. Retained placenta in cattle used to be removed manually by a veterinarian, and the cow would be treated with antibiotics to prevent infection. However, the current dogma is to allow the placenta to slough off on its own, even up to a week after parturition. In horses, however, a retained placenta results in a serious health problem and should be treated as an emergency.

Following parturition, some species lick their young to clean and invigorate it, as well as to develop an identification bond with it. Others do not clean their young. Most farm animal species are relatively precocious and able to stand within minutes of birth. It is critical for the young to nurse as soon as possible after birth to obtain the antibodies contained in the milk. Colostrum, or first milk, differs from normal milk in that it is higher in protein, vitamin, mineral, and antibody concentrations. The antibodies, which are large protein molecules capable of fighting disease, are passively transferred to the young by being absorbed from the digestive tract. This confers **passive immunity** to the young. However, the gut begins to close to passage by the antibodies soon after birth. Therefore, if the young has not nursed soon after birth, it is incapable of taking advantage of the immunity of its mother. Many producers keep frozen colostrum in the event that a calf, lamb, or foal is born and has not nursed within 2 to 3 hours of birth. The frozen colostrum can be thawed and fed to the young through a tube placed in its stomach. Because the antibodies in the colostrum reflect the immunity of the mother, the more diseases the mother has been exposed to or vaccinated against, the more antibodies the young will gain. Therefore, it is better to collect colostrum from older, rather than young, animals.

Passive immunity Immunity conferred to an animal through preformed antibodies it receives from an outside source.

The period between parturition and the onset of estrous activity is referred to as the **postpartum** period or **postpartum interval**. Management during this period is particularly important in cattle, which must become pregnant again within 80 days after calving to maintain the desired 12-month calving interval. In seasonal breeders, such as sheep and goats, this period has a much lower importance because season (actually, day length) has an overriding suppressive effect on reproduction. The females do not exhibit estrous activity until several months after parturition, regardless of other environmental factors. The postpartum interval is greatly affected by poor nutrition and by the presence and suckling of offspring. In combination, these two factors severely limit the onset of estrus. In swine, the suckling effect is so strong that producers wean the young early to stimulate the onset of estrus in a timely fashion. Beef cattle producers are now experimenting with short-term weaning to stimulate the onset of estrous activity, combined with increased feed intake to decrease the postpartum interval. Dairy cattle producers have a more difficult time managing the postpartum interval because the cows must continue producing high volumes of milk.

Postpartum After parturition.

Postpartum interval Period of time from parturition to first estrus in the female.

ENVIRONMENTAL INFLUENCES ON REPRODUCTION

Many environmental conditions can have profound influences on reproductive function. The nutritional status of an animal greatly affects a female's ability to become pregnant, and it also influences a male's ability to exhibit the **libido** (sexual drive)

Libido Sexual drive.

and necessary sperm production to impregnate females. The nutritional effect can be divided into two categories:

1. Nutritional status: The long-term energy, protein, vitamin, and mineral regimen the animal has been exposed to; often reflected by how much body fat the animal is carrying.
2. Nutritional balance of an animal: The day-to-day consumption of proper nutrients in the proper amounts to support reproduction.

All nutrient groups can affect reproduction in animals; however, the primary nutritional limitation is energy. As a female loses body condition, or fat, her ability to become pregnant is limited. All species have a body condition level below which a female will not conceive. However, obesity can also become a limiting factor in reproductive function. Separation of nutritional status and nutritional balance is important, particularly in breeding females. For example, cows with questionable energy reserves (fat content) may be encouraged to ovulate and exhibit estrus by increasing energy intake for a short period prior to and during the breeding season. This process, called **flushing**, is commonly used in sheep, swine, and goats to increase ovulation rate.

Flushing Feeding extra feed to stimulate estrus and ovulation rates.

Stress has a significant negative influence on fertility, although the mechanisms are not entirely understood. As increased knowledge of animal behavior is gained, increasing reproductivity by decreasing stress becomes an important concept for producers to adopt. Mixing unfamiliar animals together during the breeding season can present enough stress to decrease the incidence of estrus and reduce conception rates, particularly when combined with other environmental factors. (See Chapter 13, "Animal Behavior.")

Many species exhibit a very strong reproductive response to the length of day. This is not limited to the female. In sheep, the weight of the testes in the ram fluctuates throughout the year, being greatest in the fall during the breeding season, and the least in the nonbreeding season. However, the most significant effect of season is on the estrus of females during the breeding season and the lack of estrous cycles during the nonbreeding season. The mare is an example of a long-day seasonal breeder, so named because estrus is observed as days are becoming longer. Sheep, deer, elk, and goats are short-day breeders and onset of estrus is observed in the fall, as days become shorter. The exact mechanisms for seasonality are not known. However, the amount of sunlight present during the day is detected by the brain and transmitted to the pulse generator in the hypothalamus, which turns on the release of GnRH to start the endocrine cascade. Likewise, in the nonbreeding season, the pulse generator is shut down, and the ovary does not receive the gonadotropic support from the anterior pituitary gland for adequate development and maintenance of the follicles. Because seasonal breeders respond to length of light during the day, reproductive function can be manipulated by using artificial light to simulate the changing seasons. Therefore, it is possible to have ewes lambing in the fall, rather than the spring, and have mares foaling in late summer, rather than the spring. In addition, some breeds of season-breeding species are much less affected by day length than are other species. For example, most whiteface breeds of sheep have longer breeding seasons than those of blackface breeds. Also, the closer to the equator one goes, the less seasonal the species become because of a more consistent day length throughout the year. Although cows are not recognized as being seasonal breeders, there is increasing evidence that fertility is higher at certain times of the year.

Polyestrus Exhibiting more than one estrous cycle.

Monoestrus Exhibiting only one estrous cycle; for example, the bitch is seasonally monoestrus.

Species such as the sheep, goat, and mare can be described as being seasonally **polyestrus** because they exhibit more than one estrous cycle during a breeding season. However, some species such as the dog are seasonally **monoestrus** because they exhibit only one estrus during the breeding season.

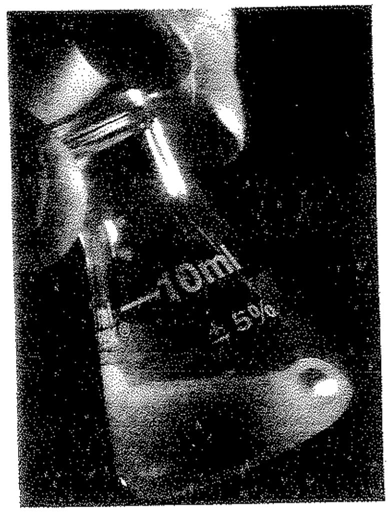


Figure 11–9
USDA-Agricultural Research Service-developed techniques for turkey semen (shown here) have been used to increase populations of endangered species such as the bald eagle and whooping crane. (Photo by Keith Weller. Courtesy USDA-Agricultural Research Service.)

TECHNOLOGY AND REPRODUCTION

Artificial Insemination

Artificial insemination (AI) was one of the first biotechnologies employed in the livestock industry to improve the reproduction and genetics of farm animals. In 1899, Russian scientist E. I. Ivanoff initiated efforts to establish AI as a practical procedure and was the first to develop methods as we know today. The first AI cooperatives were established in 1938 with significant growth of AI industry occurring through the 1940s. Today, inexpensive techniques have been developed, and artificial insemination (AI) is now a common procedure in many species and is used, to some degree, in virtually all species (Figure 11–9). For example, in dairy cattle, approximately 80% of the calves born result from artificial insemination. This procedure allows dairy producers to use semen from proven sires to improve herd genetics. Artificial insemination is used on nearly 100% of the commercially grown turkeys because modern large-breasted turkey males are incapable of mating naturally. Several horse breed associations have recently changed registration rules so producers can take better advantage of this technology.

Successful insemination requires the acquisition of high-quality semen from a male, the detection of estrus in the female, and the ability to deposit the semen properly in the reproductive tract of the female. Semen is usually collected by stimulating the male to ejaculate into an **artificial vagina (AV)**, which has a receptacle to receive the sample (Figure 11–10). Another method of collecting semen in bulls, rams, and boars is to use an electroejaculator. The use of an electroejaculator is often preferred with males who refuse or are incapable of mounting a female naturally because of injury or age. This instrument consists of an electrical prod placed in the rectum of the male. The electrical current stimulates contraction of muscles causing sperm

Artificial vagina (AV)
Device used to collect semen from a male. Following erection, the penis is directed into the artificial vagina and the male ejaculates, capturing the ejaculate in a reservoir of the AV.

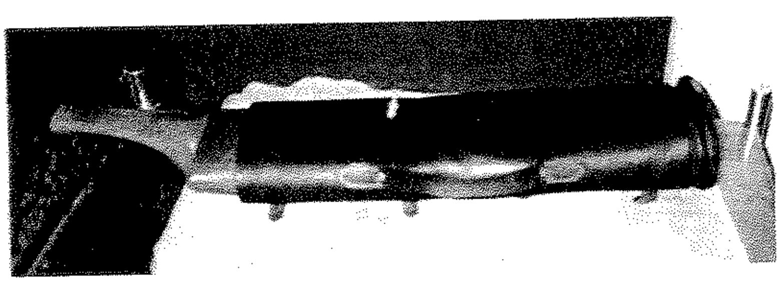


Figure 11–10
Photo of an artificial vagina.

Table 11–2
Characteristics of Semen from Farm Animals

Characteristics	Cattle	Goats	Horses	Sheep	Swine
Volume of ejaculate (ml)	2–10	.2–2.5	20–300	.5–2.0	150–500
Sperm concentration (10^9/mL)	.3–2.0	1–5	.03–.8	–5	.02–.35
Motile sperm (%)	70	80	70	75	60
Ejaculates/week	4	20	3	20	3
Motile sperm (AI)	10	60	100	120	1,200
Females inseminated/ejaculate (AI)	350	25	60	20	20

Source: Compiled from Bearden and Fuquay, 1997, Cole and Garrett, 1980, and Cupps, 1991.

to be expelled. With either method of collection, the sample is generally extended with a solution that contains proteins and buffers, and frozen in liquid nitrogen (for bulls and rams), or cooled sufficiently to prolong the life of the sperm (for boars and stallions). Frozen semen can be stored indefinitely. In fact, bull semen collected and frozen in the 1950s still retains enough fertile sperm to result in acceptable pregnancy rates. Characteristics of semen from various farm animal species are presented in Table 11–2.

In the late 1980s, a breakthrough in semen-sexing technology led to the development of a flow cytometer capable of differentiating and separating X- and Y-chromosome-bearing sperm in amounts suitable for AI. This technology is based on the ability to accurately differentiate the 2.8–4.2% difference in DNA content between the X and Y chromosome. In 1992, the first sex-selected calf was produced utilizing in vitro fertilization. Further advances in flow cytometry allowed for the first sex-selected calf to be born by means of AI in 1997. In 2003, the commercialization of this technology led to the availability of sexed semen for many different species worldwide.

Detection of estrus is one of the most difficult tasks in successful artificial insemination. Placement of the semen in the reproductive tract of the female must be coordinated with the timing of ovulation of the egg from the follicle on the ovary to ensure that fertilization can occur while the sperm is still alive and in the proper location. Fortunately, many species present specific behavioral activities that are characteristic of estrus. In the cow, a female allows other females, and males, to mount her approximately 12 hours prior to ovulation. Therefore, when a cow is standing to be mounted, she will be ready to be artificially inseminated in approximately 12 hours. The difference in timing between artificial and natural breeding is to accommodate for the placement of the semen. In natural breeding in the cow, semen is deposited in the vagina, and sperm must traverse through the cervix before entering the uterus. In artificial insemination, the sperm is deposited directly into the uterus, thereby bypassing the cervix. Mares have a characteristic "winking" of the vulva following urination when in estrus. Sows exhibit **lordosis**, a steadfast posture when pressure is applied to the back, and a swollen vulva that turns red in color. Therefore, to detect estrus in the sow, all one must do is press heavily on the back. If the sow walks away, she is not in estrus. If the sow not only stands but also refuses to move when pressure is applied, she is likely in estrus. The ewe presents a particular problem. Ewes do not exhibit overt signs of estrus and, therefore, are very difficult to identify for breeding. The female dog sloughs the lining of the uterus, losing blood and tissue for the duration of estrus. Cats typically exhibit marked behavioral changes.

Lordosis Posture assumed by females in estrus such that they resist pressure applied to the back.

Estrous Synchronization

To combat the problem of estrous detection, and to minimize the labor involved in artificial insemination in cattle, drugs have been developed to synchronize estrous cycles in females. In this manner, several females can be given the proper drugs to provide a tight estrous synchrony so animals come into estrus in a narrow window and can be bred at the same time. There are three basic approaches to synchronizing estrus.

One approach is to give injections of prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) during the luteal phase causing regression of the corpus luteum. (Federal law restricts this drug to use by or on the order of a licensed veterinarian, and it is not for human use. Women of childbearing age, asthmatics, and persons with bronchial and other respiratory problems should exercise extreme caution when handling this product.) $PGF_{2\alpha}$ is a hormone naturally produced and released by the uterus when pregnancy is not recognized by the dam. The regression of the CL removes the inhibitory effect of progesterone on the release of LH and FSH allowing the levels of LH and FSH to increase dramatically, permitting the development of the follicles for ovulation. Therefore, females with a functional CL ovulate approximately 72 hours after the injection of $PGF_{2\alpha}$. If there was no functional CL present, the cow may be given another injection approximately 11 days after the first. The second injection is usually effective in evoking estrus.

A second method of estrous synchronization is the use of progesterone, which can be fed orally or administered as a vaginal insert. EAZI-BREED™ CIDR® Cattle Inserts contain 1.38 grams of progesterone in elastic rubber molded over a nylon spine and are administered intravaginally. Melengestrol acetate (MGA), a medicated feed additive (feed additives are limited to use exactly as labeled; use of the product in any fashion other than as labeled is illegal), is a synthetic progestin (progesterone-like in action) used primarily for the suppression of estrus in feedlot heifers. The actions of the progesterone block the release of LH and FSH, thereby interrupting the estrous cycle of the female. Upon removal of the implant, the inhibitory effects of progesterone are removed, and the female exhibits estrus.

Another popular method incorporates the use of GnRH (federal law restricts this drug to use by or on the order of a licensed veterinarian) into the synchronization regime to time not only estrus, but ovulation as well. The use of GnRH is popular with dairy cattle producers.

Embryo Transfer

Embryo transfer (ET) is the process of collecting fertilized embryos from one female (donor) and placing them in another (**recipient**) for further development (Figure 11–11). This technology became available to livestock producers in the 1970s. The value of embryo transfer is that it allows for the production of many more offspring from genetically superior females. ET is similar to, but less extensive than, the increased breeding potential from males using artificial insemination. Although used to some extent in several species, it has been most widely used in the cattle industry. There is less incentive for ET use with swine because they are litter producers and have a much shorter **generation interval**. With sheep and goats, there is less incentive for ET use because it is more difficult to make the procedure cost effective. The following discussion focuses on the cow for that reason.

The process of embryo transfer begins with the superovulation of the female. Superovulation is the process of administering exogenous FSH such that the ovary receives the gonadotropic support so more than the normal number of follicles reach the preovulatory stage. In fact, the FSH prevents follicles that would normally

Embryo transfer The process of transferring fertilized embryos from one female to another female.

Recipients Females used to carry the embryos of a donor animal throughout gestation.

Generation interval The average age of animals within a species when they bear their first offspring.

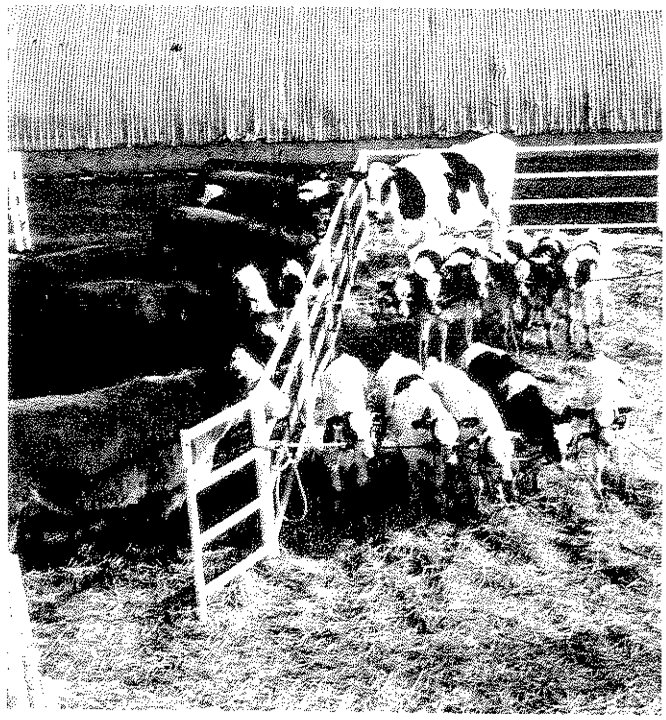


Figure 11–11
The dairy cow (upper right) is the genetic mother of the 10 calves. She was superovulated, and the embryos were recovered from her uterus 1 week after conception. After 3 to 10 hours of culture in vitro, the embryos were transferred to the uteri of the 10 recipient cows (left) for gestation to term. (Photo courtesy of George E. Seidel, Jr., Colorado State University.)

undergo atresia from dying. Therefore, the FSH does not increase the number of eggs being produced, it just keeps the follicles in a productive and developing state, therefore resulting in more ovulating, fertilizable eggs. As the donor cow is being superovulated, the cows being used to receive the embryos—the recipients—receive hormone injections to synchronize their estrous cycles with that of the donor cow. The synchronization of the recipient's estrous cycle with the donor is critical to the success of the procedure. Multiple inseminations of the donor cow are timed so that the majority, if not all, of the eggs will be fertilized.

The embryos stay in the donor cow for about seven days, which is the most viable stage for transfer,and are then flushed out of the oviducts, as they have not yet implanted. The embryos are identified under a microscope and placed, one by one, into a recipient female. If all goes well, the embryo develops into a fetus in the recipient, who produces a calf that carries the genetics of the sire and the donor female. Commercial embryo transfer companies boast greater than 60% pregnancy rates with good-quality embryos. In addition, if more embryos are collected than there are available recipients, it is possible to freeze the embryos indefinitely. The producer thereby has more flexibility in planning calvings, can hold on to frozen embryos to determine the quality of full siblings, and can maximize the use of recipients. Embryo transfer greatly increases the genetic impact that a cow can have on a herd by increasing the number of offspring born each year.

"In Vitro" Fertilization

Although embryo transfer is used extensively across the United States in cattle, it does have disadvantages. For example, ET can only be performed when a cow is open. Therefore, it is necessary to keep a superior cow nonpregnant for long periods to complete the procedure of superovulation, breeding, and flushing of the embryos. Second, some cows do not respond to the hormones as expected. When the ovaries are understimulated, no eggs are produced. When they are overstimulated, too many eggs are often produced and all may be nonfertile.

Recent technology allows the collection of the eggs directly from the ovary, before the follicles have fully developed. These ova are then fertilized **in vitro** and allowed to develop to stages appropriate for placement into recipients. This method has many advantages, including these:

In vitro In a test tube or other environment outside the body.

- Collection of ova during pregnancy
- Use of different sires on the ova from each collection
- Frequent collections, as often as weekly

There are some drawbacks to collecting eggs directly from the ovary. The technology is not perfected. In addition, it is relatively expensive and time-consuming. However, in vitro pregnancy rates are approaching the success observed with embryo transfer. Increased pregnancy rates will be expected with advances in the technology and when more people become proficient at the procedure.

REPRODUCTION IN POULTRY AND BIRDS

Hen

The goal of reproducing young is the same in poultry as in mammalian species. However, the method varies in that the young are not carried inside the body. Rather, the eggs are laid outside the body where they are incubated until the young are ready to emerge (hatch) from the shell. Figure 11–12 shows the reproductive tract of the hen. The discussion focuses on the hen; however, the process is similar for other avian species.

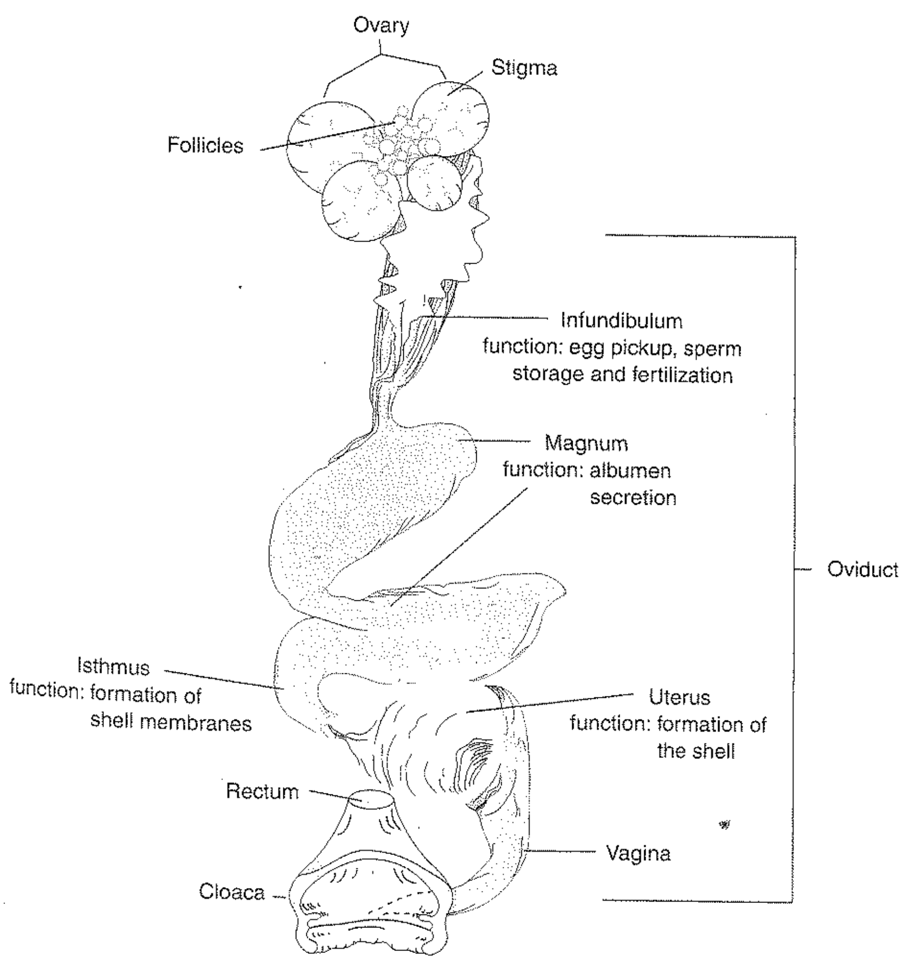


Figure 11–12
Avian reproductive tract. The avian oviduct is adapted into different sections: infundibulum, magnum, isthmus, uterus, and vagina. Although these parts have the same names as parts of the mammalian reproductive tract, their functions are quite different. (Source: Adapted from Geisert, 1999.)

Poultry females (hens) have only one functional ovary, unlike mammals, which have two. Only the left ovary in the hen is functional. When a female chick hatches, approximately 4,000 ova are attached to the ovary, each enclosed in a follicle. The follicle contains the blood vessels that will nourish the egg when it is time for it to mature. The ova begin maturing at sexual maturity. Each mature ovum is successively released from its follicle by rupture of the follicle wall. This release from the follicle is called *ovulation*. The rupture occurs along a line called the *stigma*. The ovum (yolk) moves into the oviduct where the additional parts of the egg are added.

In the oviduct, the egg moves from region to region where very specific steps in egg formation occur (Figure 11–13). The first section of the oviduct, the infundibulum, captures the yolk from the body cavity after ovulation. In the infundibulum, fertilization occurs if sperm are present. Sperm can remain viable for up to several weeks in some species. The total time the yolk spends in the infundibulum is 30 minutes or less. The yolk moves into the second portion of the oviduct, the magnum. The yolk stays in the magnum for 2 to 3 hours, during which time the thick portion of the albumen, or white, of the egg is added. The albumen is deposited around the yolk. In the next portion of the oviduct, the isthmus, the shell membranes are added. During the 1.5 hours that the egg is in the isthmus, it takes up water and mineral salts and the inner and outer membranes of the shell are added. Calcification of the shell occurs in the uterus, or shell gland, which is the next portion of the oviduct. In addition, the remainder of the albumen is added in the uterus. Early in the 18 to 20 hours the egg is in the uterus, it undergoes *plumping*, a process of adding water and minerals to the egg through the previously formed membranes. Once the plumping process is over, the calcification of the shell takes place and shell pigment is added. After the shell formation is complete, the egg moves from the uterus, through the vagina, where the bloom or cuticle is added, through the shell and then through the cloaca for oviposition, which is expulsion to the outside of the hen's body. This process is commonly referred to as laying the

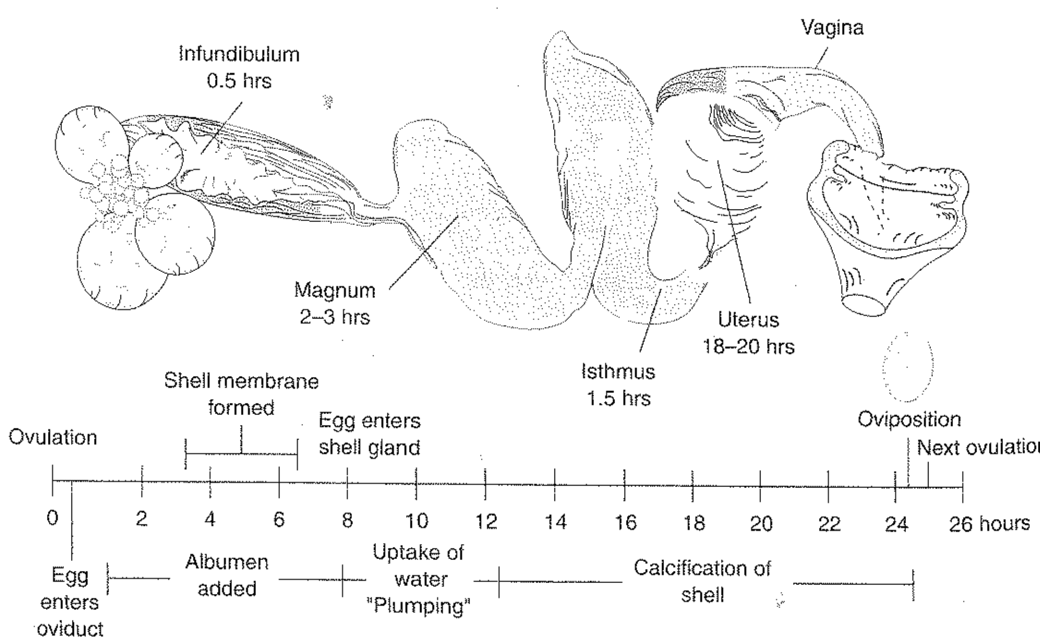


Figure 11–13
Steps in egg production. (Source: Adapted from Geisert, 1999.)

egg. The total time from ovulation to the laying of the egg is slightly more than 24 hours. Approximately 30 minutes after the egg is laid, another ovulation occurs and the process is repeated. Fertile eggs may be incubated by the hen or collected for artificial incubation. In the case of the vast majority of eggs laid by chickens, the eggs are not fertile and are processed as a food source.

Cock

Figure 11–14 shows the reproductive organs in the male bird. Hens lay eggs in the absence of males, and it is not necessary for sperm to be present in the female's reproductive tract for an egg to form. For this reason, no males are found with chickens in commercial laying houses.

However, if reproduction of the species is desired, sperm must be present in the infundibulum during the process of egg formation. As observed for the hen, there are substantial differences in the reproductive tract of male birds as compared to that of mammals. The differences begin with the testes, which are found inside the body cavity rather than outside it. The sperm cells move from the testes into the vas deferens, which leads to the cloaca and terminates in small papillae found in the wall of the cloaca. The male bird has a phallus, but it is rudimentary compared to that of the mammalian species. During copulation, the sperm are transferred from the papillae to the phallus and deposited in the oviduct via the cloaca of the female.

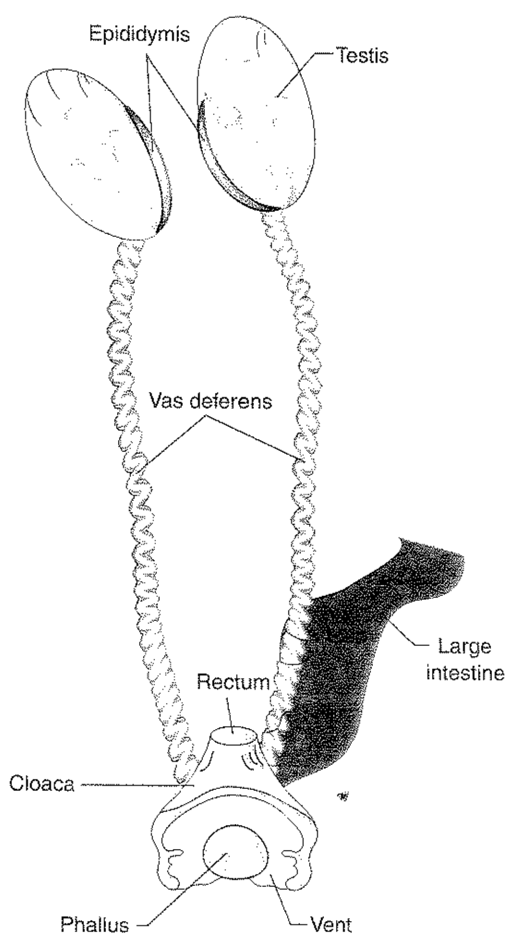


Figure 11–14
Reproductive organs in the male avian. (Source: Adapted from Geisert, 1999.)

SUMMARY AND CONCLUSION

Maintaining reproductive function is central to the success of livestock enterprises that rely on the production of young. The success of reproduction relies on absolute coordination among many systems of the body. Environmental factors may radically influence the expression of reproductive behavior, release of critical hormones, success of implantation of the embryo, and maintenance of pregnancy. Only when environmental factors are most favorable are animals able to express reproductive success fully.

Many tools of modern technology are improving our ability to manage the reproductive process. However, producers must also work diligently to increase the genetic potential for high reproductive function. A conflict can arise for the producer because of the advent of some of the emerging technologies. For example, it is not in the long-term best interest of the producer or the industry to use embryo transfer on a "good" cow that is not capable of maintaining a pregnancy. Likewise, using a stallion with a low sperm count may eventually decrease the fertility of numerous offspring, a defect that may take generations to correct. Opportunities for increasing production through advances in reproductive technology are tremendous. However, producers wishing to pursue this strategy have the responsibility to use it wisely.

STUDY QUESTIONS

1. Why is reproduction so important to the producers of domestic livestock?
2. Describe the interplay among the many factors that affect animal reproductive function.
3. What are gonads? What are their main categories of function? What does the brain have to do with the proper function of the gonads?
4. What is puberty, and what does it have to do with secondary sex characteristics?
5. What does it mean for a hormone to be episodic? What are two examples of episodic hormones?
6. What is the hypothalamus? What does it have to do with reproduction? What is the anterior pituitary? What does it have to do with reproduction?
7. Make a table. Down the side of the table, list each of the hormones that has a function in reproduction of the female. Across the top, make categories for origin, target, and function. Fill in the table.
8. Make a table. Down the side, list each of the hormones that has a function in reproduction of the male. Across the top, make categories for origin, target, and function. Fill in the table.
9. Describe the different types of uteri of different species of animals.
10. List and briefly discuss the functions of the parts of the female reproductive tract.
11. List and briefly discuss the functions of the parts of the male reproductive tract.
12. What is the difference in the type of penis a horse has compared to that of a bull and a boar?
13. Why is it so important for the testicles to be outside the body cavity? Discuss temperature regulation of the testes.
14. What is cryptorchidism, and what are its consequences to fertility?
15. Why would it not be good for a bull to produce a gelatinous fraction in his semen like the boar and stallion do?
16. What can be the consequences of a male animal getting kicked during mating? What is the likely outcome of this? Is there any way to still retain the breeding services of the male, especially a bull?
17. Depending on the species, it is possible for mating to take place as much as 2 to 3 days before ovulation and a pregnancy still ensue. However, a natural service that takes place 2 to 3 days after ovulation will not result in a pregnancy. What is the difference?
18. Describe the role of the CL in pregnancy. Do you think it would be possible for a physical mishap to cause a disruption of the CL and therefore terminate a pregnancy? Can you think of what such a mishap might be?
19. Describe the role of the placenta. What happens to the placenta in multiple births? In what species does this cause a problem? What is the problem and what is it called?
20. Describe the reproductive and environmental interaction that leads to pregnancy disease, especially in sheep.
21. What are the steps in parturition?
22. Describe the value of colostrum to baby animals. Why must it be consumed soon after birth?
23. What is important about the management of the postpartum period in livestock? What are the major factors that affect it?

24. Describe the difference between nutritional status and nutritional balance. What effect does each have on reproduction?
25. What effect does stress have on reproduction in livestock? Do you think this could mean that handling systems for managing open females should be designed with stress reduction in mind?
26. What effect does season of the year have on reproduction? Is this more of an issue with some species than with others? If yes, which species?
27. What is the value of artificial insemination to a breeding program? How is semen collected for use in artificial insemination? How long will it last if properly processed, frozen, and stored? What are the challenges to successful AI?
28. What are some of the signs that various species display during estrus?
29. What is the value of estrous synchronization? Describe the three methods of estrous synchronization discussed in the text.
30. What is the value of embryo transfer? Can it be used on all the common livestock species? On what species is it most commonly practiced? Why?
31. Describe the procedure for embryo transfer in cattle.
32. What are the differences and similarities between embryo transfer and in vitro fertilization?
33. What is the caution that producers must exercise in order to protect the long-term integrity of the genetic pool of livestock if they use technology to enhance reproduction?

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