SISTEM REPRODUKSI

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SUB BAHASAN

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2 Reproductive Systems and Genetics

3 Male Reproductive Physiology

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1 Introduction: Reproductive Processes

- Animals may reproduce asexually or sexually
  - **Budding** or **fission,** in which an animal produces a "copy" of itself without embryonic development; for example, some sea anemones split in half to produce two adults from one.
  - **Parthenogenesis,** in which an unfertilized egg develops into an embryo
  - **Sexual reproduction,** which depends on the union of male and female **gametes** (reproductive, or **germ,** cells), each with a single set of chromosomes (*haploid*), to form a new individual with a unique *diploid* (that is, twice haploid) set of chromosomes
- Animals may reproduce physiologically by oviparity, ovoviviparity, or viviparity
- Animals use various strategies to ensure breeding at the appropriate time
  - Seasonal Breeding
  - Synchronization and Mating Behaviors

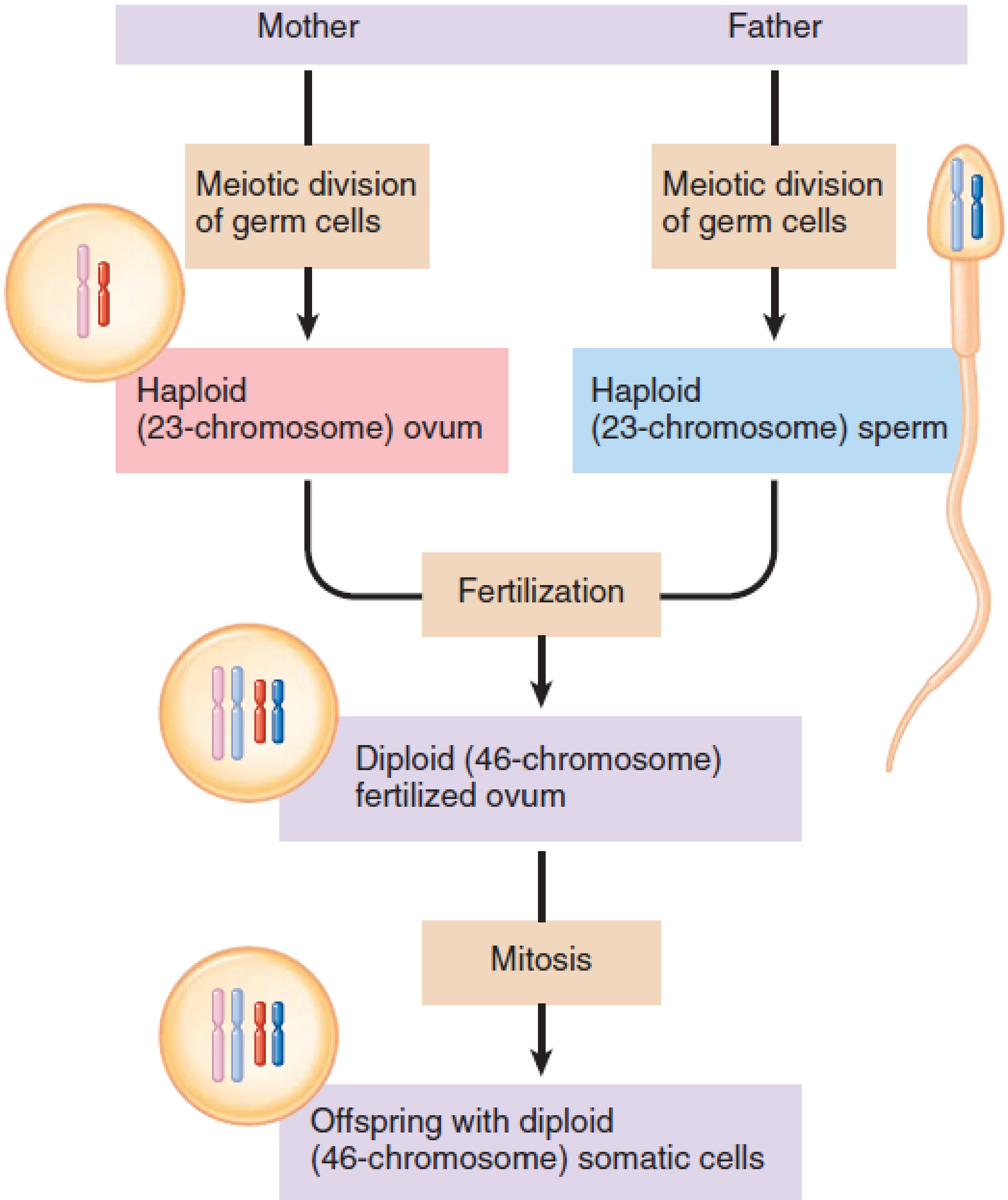


FIGURE 16-1 Chromosomal distribution in sexual reproduction.

FIGURE 16-2 Reproductive strategies in animals. (a) Snails are oviparous, meaning they release eggs from which the young later hatch. (b) Many snakes and lizards, and some fi shes, are ovoviviparous. Their fertilized eggs develop inside the mother, and then off spring are born alive. Yolk reserves sustain development in the egg. In this fi gure, the live born copperhead off spring are still encased in their egg sacs. (c) Birds are ovoviviparous because there is some internal development in the female. Their fertilized eggs contain large yolk reserves, and they develop and hatch outside the mother's body. (d) Most mammals are viviparous; their young are born live. The young of the opossum complete development in a pouch on the mother's ventral surface. The juvenile stages continue to draw nourishment from mammary glands in the mother's pouch.

2 Reproductive Systems and Genetics

- The reproductive system of vertebrates includes the hypothalamus, gonads, and reproductive tract (plus **accessory sex glands)**
- In both sexes in vertebrates, the mature gonads are found in pairs and perform the dual function of
  1. producing gametes (**gametogenesis**), that is, **spermatozoa (sperm)** in the male and **ova (eggs)** in the female, and
  2. secreting sex hormones, primarily *testosterone* in males and *estrogens* (the major form being *estradiol*) and *progesterone* in females

Overview of Male Reproductive

- Overview of Male Reproductive Functions and Organs The essential reproductive functions of the male are as follows:
  1. Production of sperm (*spermatogenesis*) continuously in huge numbers, since only a small percentage survive the hazardous journey to the site of fertilization, and many spermatozoa may be needed to break down the barriers surrounding the female gamete (oocyte).
  2. Delivery of sperm to the female.

- The male reproductive system is designed to deliver sperm to the female reproductive tract in a liquid vehicle, **semen,** which is conducive to sperm viability. In mammals, secretions from the major male accessory sex glands, the **seminal vesicles, prostate gland,** and **bulbourethral glands** (Figure 16-3) provide the bulk of the seminal fluid.
- The **penis,**or **hemipenis** (in avian drakes), is the organ used to deposit semen in the female. Sperm exit the mammalian testes through the **vasa efferentia, epididymis, ductus (vas) deferens, ejaculatory duct,** and **urethra,** the latter being a canal that runs the length of the penis. Instead of an epididymis, in birds the *vasa efferentia* conduct sperm from the testis to a short epididymal duct that is continued as the vas deferens, where it eventually opens into an enlarged area prior to entering the **cloaca.** Both the vas deferens and enlarged region serve as sperm storage sites.
- Lacking the accessory glands of mammals, birds derive seminal fluids from the *seminiferous tubules* and the *vasa efferentia.*

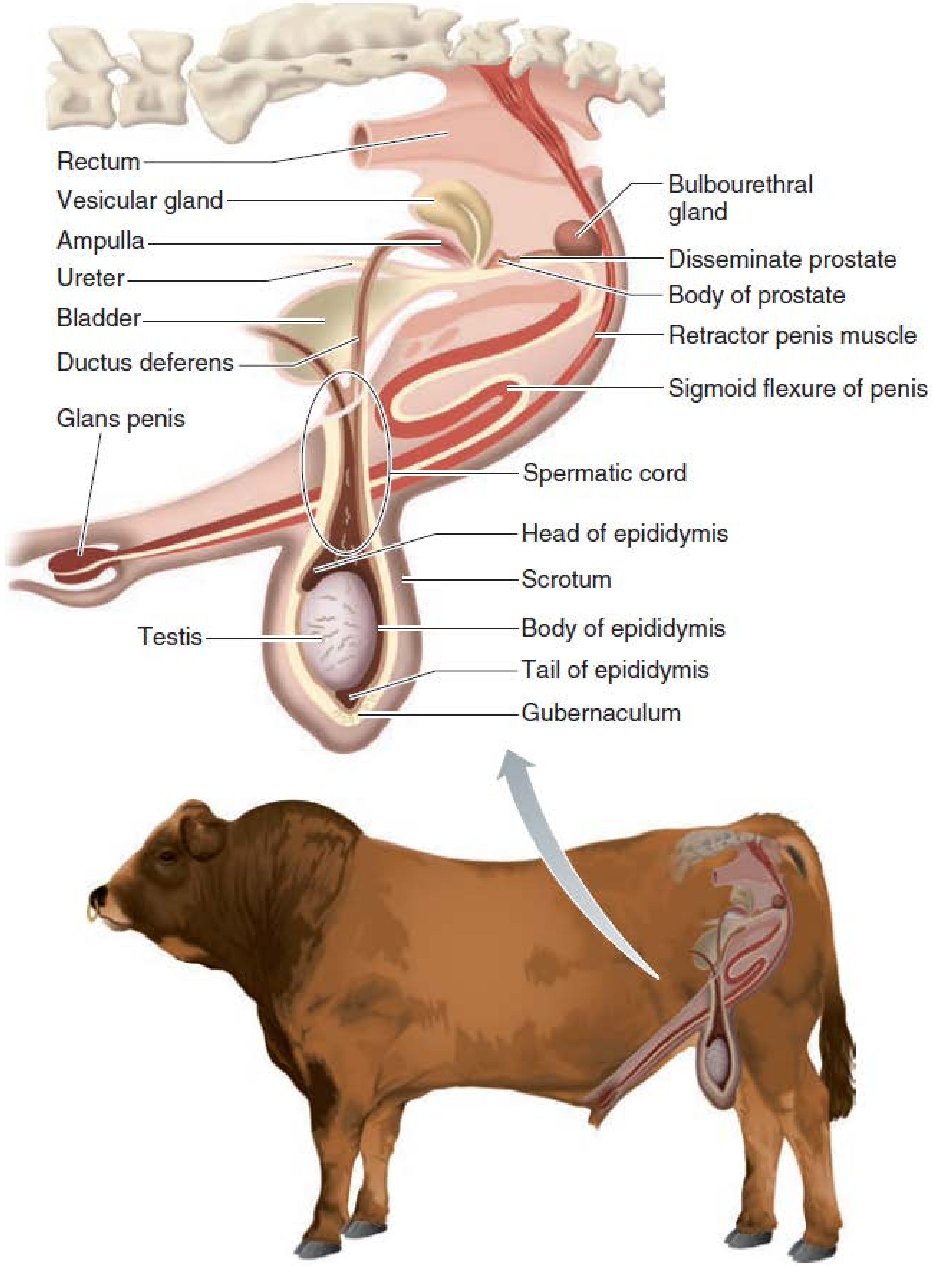
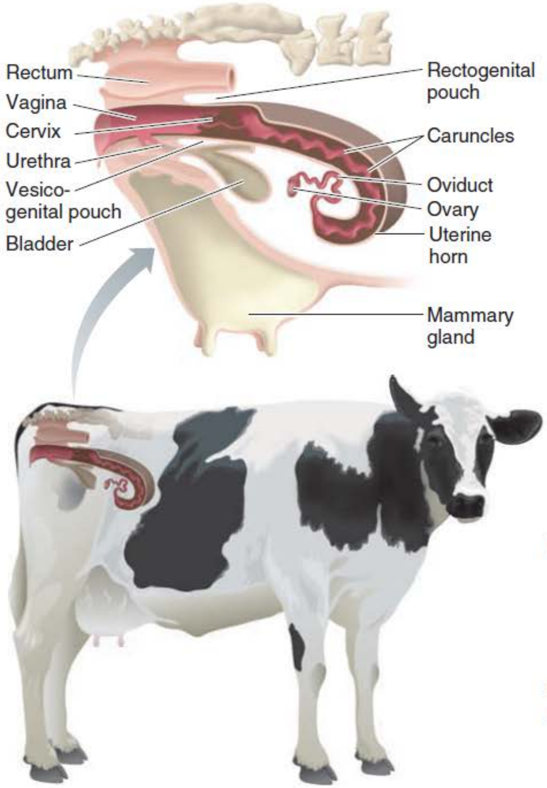


FIGURE 16-3 Reproductive tract of a bull. Sagittal view of the bull reproductive tract.

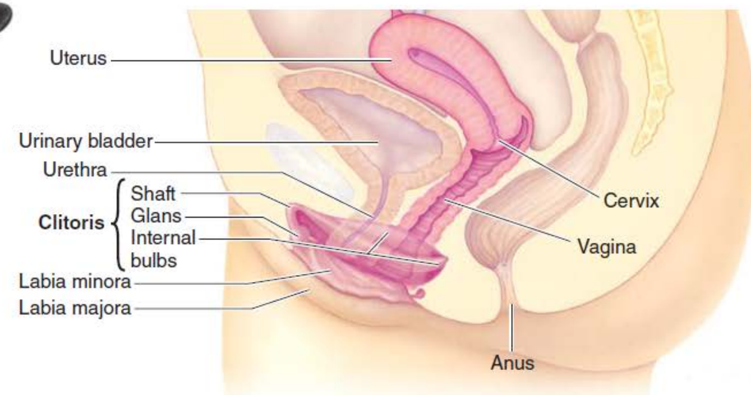
Source: P. L. Senger. (2003). *Pathways to Pregnancy and Parturition*, 2nd ed. Current Conceptions Inc., Washington State University Research & Technology Park, pp. 48, 49.

Overview of Female Reproductive Functions and Organs

- The major structures of the female reproductive tract in reptiles including birds and mammals include the **vagina, cervix, uterus, oviducts,** and external genitalia with internal extensions. These and the **ovaries** lie within the pelvic and abdominal cavity (Figure 16-4a). The essential female reproductive functions include:
    1. Production of ova **(oogenesis)** and ovulation in the **ovaries** (although management of the ovulated oocyte depends on species).
    2. Reception of sperm.
    3. Transport of the sperm and ovum to a common site for *fertilization* (or *conception*).
    4. Giving birth to the young **(parturition)** in a viviparous animal, or laying eggs in an oviparous animal.
    5. Nourishing the offspring by milk production **(lactation)** in mammals. Placental and marsupial mammals have an additional role: nourishment of the developing fetus internally until it can survive in the outside world (**gestation,** or **pregnancy**) via a **placenta** (structurally different in the two mammalian groups) a vascular structure that supplies the fetus with nutrients in exchange for waste products generated by the fetus.
- In oviparous and ovoviviparous vertebrates, the oviducts are the site for deposition of nonembryonic egg materials (albumin). In birds and reptiles, the uterus serves as a **shell gland** for calcification of the egg's outer layer.



(a)



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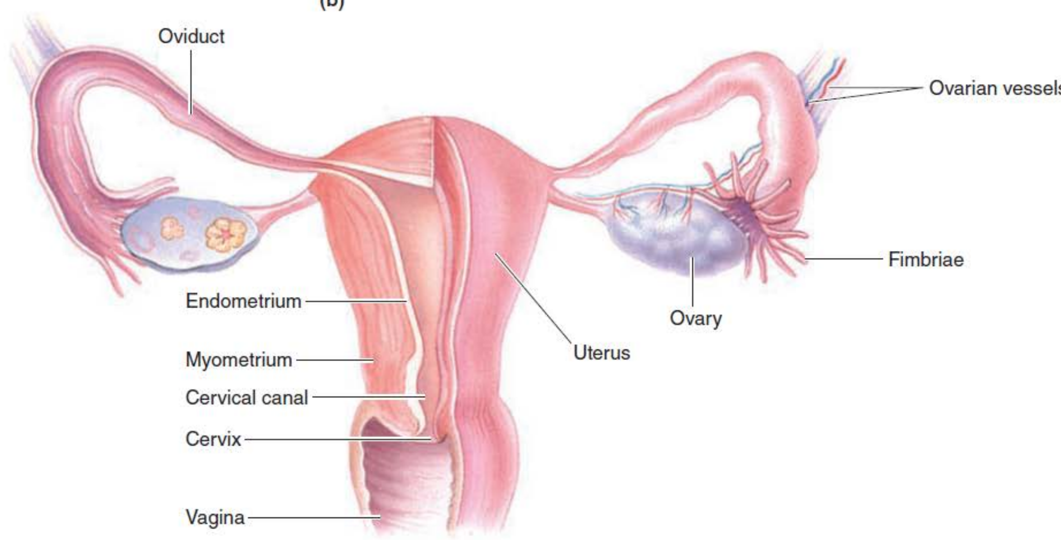


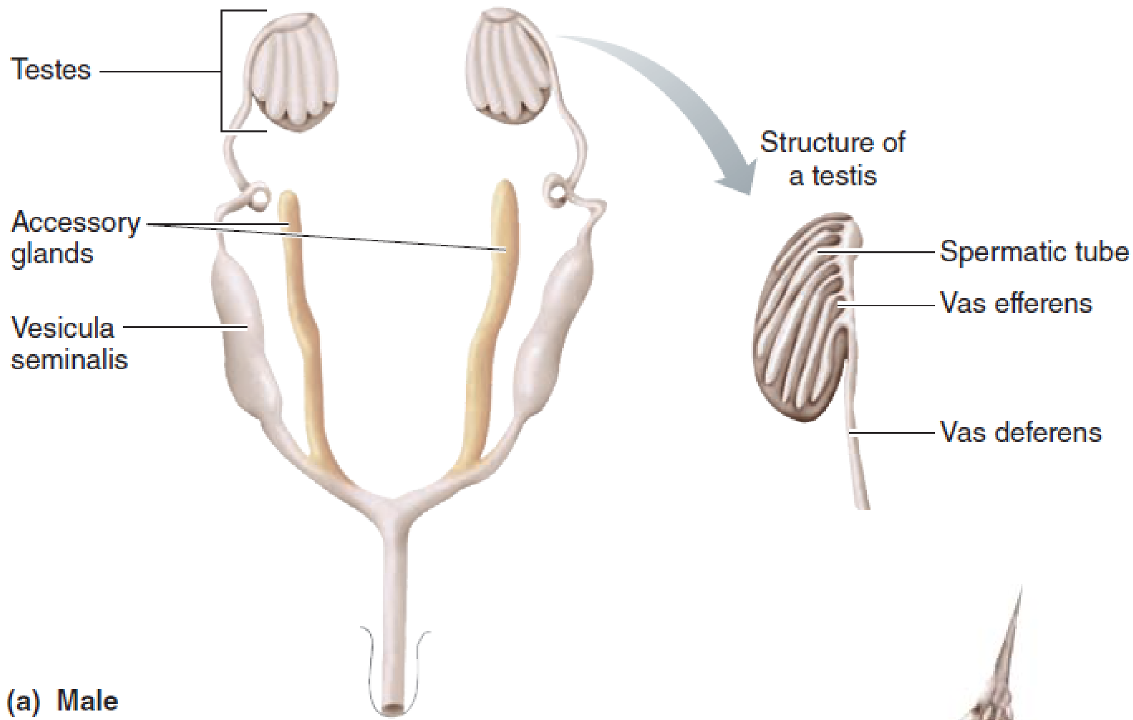
(c)

FIGURE 16-4 **Reproductive tract of two mammalian females.** (a) Lateral view of a cow reproductive tract. (b) Lateral view of a human female, showing recently described internal structures of the clitoris. (c) Posterior view of human female reproductive tract.

Sources: (a) P. L. Senger. (2003). *Pathways to Pregnancy and Parturition*, 2nd ed. Current Conceptions Inc., Washington State University Research & Technology Park, pp. 16, 17. (b) Adapted from H. E. O'Connell, K. V. Sanjeeva, & J. M. Hutson. (2005). Anatomy of the clitoris. *Journal of Urology* 174:1189–1195. (c) © Cengage Learning, 2013

Reproductive systems in insects include the neuroendocrine organs, gonads, and reproductive tract

- The reproductive system of male insects consists of a pair of testes, seminal vesicles, and accessory glands (Figure 16-5a)
- In many species such as bumblebees, the formation of a temporary **mating** or **copulatory plug** (also found in some vertebrates) after fertilization prevents both loss of semen from the female tract and entry of sperm into the vagina (genital chamber) from a competing male.
- Contraction of the female ducts then transports the spermatozoa to the **spermatheca,** the organ that stores the sperm prior toentry into the vagina (Figure 16-5b).
- The reproductive system of a female insect consists of a pair of ovaries, a system of ducts through which the eggs navigate to the outside, the accessory glands, and the spermatheca (Figure 16-5b).
- There are three types of insect ovaries: the ancestral form, or **panoistic,** those without nurse cells (cells that provide nutrients to the oocyte in the early stages of development by cytoplasmic processes called **nutritive chords**); and **meroistic,** those ovaries with nurse cells.



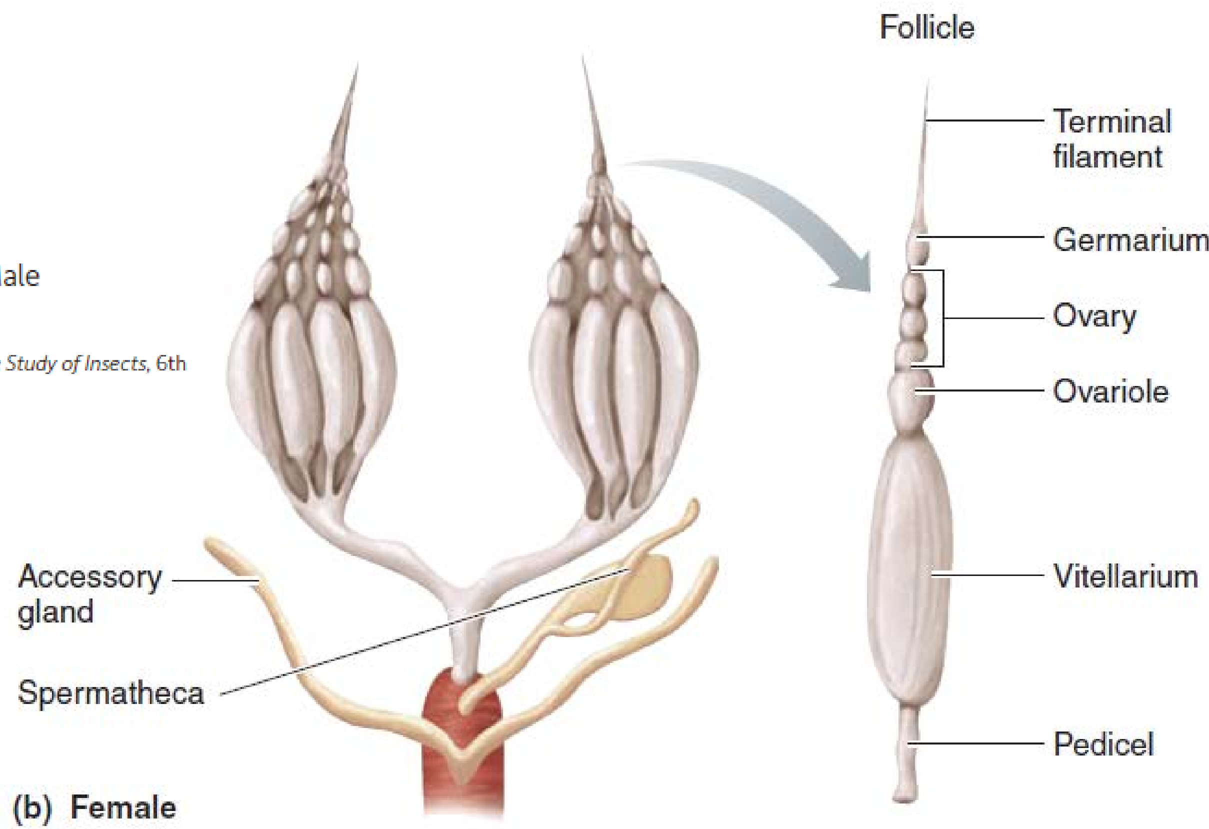


FIGURE 16-5 Reproductive systems of insects. (a) Male reproductive system. (b) Female reproductive system.

Source: C. A. Triplehorn, D. J. Borrer, & N. F. Johnson. (1989). *Introduction to the Study of Insects*, 6th ed. Belmont, CA: Thomson/Brooks/Cole, p. 57, Figure 3-31.

Reproductive systems in insects include the neuroendocrine organs, gonads, and reproductive tract

- There are two subdivisions of meroistic ovaries: **telotrophic,** in which the nurse cells are found in the germarium, and **polytrophic,** where the nurse cells are enclosed in the follicle.The **germarium** forms the anterior portion of the ovariole and it is in this egg-producing portion of the ovary that cystocytedivisions occur and the clusters of cystocytes become enveloped by follicle cells.
- Externally, female insects have an **ovipositor,** an extension of the abdomen, used to lay eggs, for example, by insertion into the ground or into a host animal (as is done by parasitic wasps)
- Recall that in insects it is the *quantity of juvenile hormone* (*JH*) released at each molt that determines the *quality* of the molt, that is, the time to maturity (p. 281). JH plays a role in oogenesis in some species, primarily to initiate **vitellogenesis** (deposition of yolk in an oocyte, including the protein *vitellogenin* made in the fat body
- In other species, egg development is delayed until the adult stage, when the release of another brain hormone stimulates ecdysone release from the prothoracic gland in response to environmental cues such as temperature, photoperiod, or even specific input such as ingestion of a blood meal in mosquitoes

Reproductive cells each contain a half set of chromosomes

TABLE 16-1 Haploid Number of Chromosomes in the Gametes of Some Animal Species

Cat	19	Mouse	20
Chicken	39	Pigeon	31
Cow	30	Pig	19
Dog	39	Rat	21
Goat	30	Sheep	27
Horse	32	Turkey	41
Mink	15		

Gametogenesis occurs by meiosis, resulting in genetically unique sperm and ova

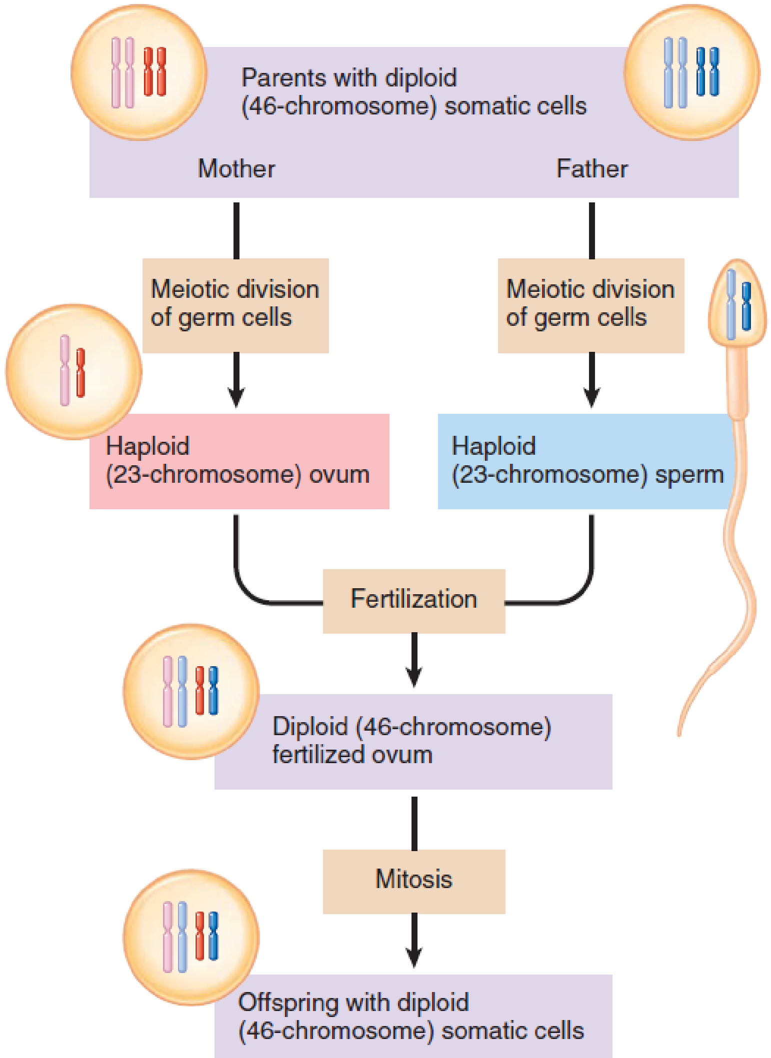


FIGURE 16-1 Chromosomal distribution in sexual reproduction.

The sex of an individual is determined by the combination of sex chromosomes or by environmental stimuli

- In some vertebrates, including all mammals and birds, individuals are destined to become males or females by **genetic sex determination (GSD**), in which a sex is determined by the *sex chromosomes* they inherit.
  - Mammals: XX/XY Mammals have GSD using a larger **X chromosome** and a smaller **Y chromosome.** Sex depends on the combination of these: **Genotypic males** have both an X and a Y chromosome and are called **heterogametic; genotypic females** have two X chromosomes and are called **homogametic.**
  - Birds: ZZ/ZW Birds use the ZZ/ZW GSD system, with the heterozygote ZW being the female and the homozygote ZZ being the male.
  - Reptiles (Nonavian) Many other vertebrates exhibit *ESD.* In all crocodilians, many turtles and lizards, and a few snakes, sex determination depends on the temperature at which eggs are incubated.
- In contrast, many other vertebrates exhibit **environmental sex determination (ESD),** in which external factors like temperature determine an embryo's sex.

The sex of an individual is determined by the combination of sex chromosomes or by environmental stimuli

- Other Vertebrates Most urodele amphibians (newts, salamanders) have a ZZ/ZW system, whereas anurans (frogs) have an XX/XY system. Fish are even more complex, exhibiting one of the most diverse collections of reproductive strategies in the animal kingdom. Some have diffuse, indiscernible chromosomes, making sex determination cytologically diffi cult. Some exhibit the XX/XY system, others have the ZZ/ZW system, others have ESD based on temperature or social interactions, and some rely on complex combinations of genes; moreover, some are **hermaphroditic** (having both sexes in one individual).
- Insects In most insects the male has one X (sex) chromosome, whereas the female has two. Males are referred to as XO (if only one chromosome in the pair is present) or XY (heterogametic with the Y chromosome being different in size from the X chromosome), whereas the female is XX (homogametic). One exception to this pattern is found in the Lepidoptera (butterfl ies and so forth), where the female is heterogametic.

An unfertilized egg can develop into a male or female in parthenogenesis

- *Parthenogenesis* also occurs in many species including water fl eas, some insects, a few reptiles (such as whiptail lizards), and some fi shes (including occasionally in hammerhead sharks).
- Parthenogenetic development that produces females implies that either the eggs failed to undergo meiosis or that the two cleavage nuclei fused to restore the diploid condition, whereas production of a male involves the loss of an X chromosome.
- Depending on the time of year, gall wasps and aphids produce either males or females parthenogenetically.
- At least one group, the bdelloid rotifers, living in an allfemale world, reproduce only parthenogenetically (spawning cloned daughters instead of using sex). Recently it has been found that they may avoid the low genetic diversity of asexual reproduction by promiscuous gene transfer: Their genomes are riddled with genes of other animals, fungi, plants, and even bacteria!

Sex differentiation in mammals depends on the presence or absence of Y-chromosome masculinizing determinants during critical periods of embryonic development

- Differences between mammalian males and females exist at three levels:
  - genotypic,
  - gonadal, and
  - phenotypic (anatomic and/or physiologic) sex (Figure 16-6).

Genotypic and Gonadal Sex

- **Genotypic sex,** which depends on the combination of sex chromosomes at the time of conception, in turn determines **gonadal sex,** that is, whether testes or ovaries develop.
- The presence or absence of a Y chromosome determines gonadal differentiation in mammals. All mammalian embryos have the potential to differentiate along either male or female lines because the developing reproductive tissues include the precursors of both sexes.
- Gonadal specificity in the human appears during the seventh week of intrauterine life, when the indifferent gonadal tissue of a genotypic male begins to differentiate into testes under the influence of the **sex-determining region** of the Y chromosome **(SRY),** the single gene that is responsible for sex determination. This gene triggers a chain of reactions that leads to physical development of a male.

Genotypic and Gonadal Sex

- The sex-determining region of the Y chromosome "masculinizes" the gonads (induces their development into testes) by stimulating production of **testis-determining factor (TDF)** by primordial gonadal cells.
- TDF, which is a specific plasma membrane protein found only in males, directs differentiation of the gonads into testes. Because genotypic females lack the SRY gene and so do not produce TDF, their gonadal cells never receive a signal for testicular formation, so the undifferentiated gonadal tissue starts developing during the ninth week into ovaries instead.

Phenotypic Sex

- **Phenotypic sex,** the apparent anatomic sex of an individual, depends on the genotypically determined gonadal sex.
- **Sexual differentiation** concerns the embryonic development of the external genitalia and reproductive tract along either male or female lines. As with the undifferentiated gonads, embryos of both sexes have the potential to develop either male or female reproductive tracts and external genitalia.
- Differentiation into a male-type reproductive system is induced by **androgens,** which are masculinizing hormones secreted by the developing testes. Testosterone is the most potent androgen. The absence of these testicular hormones in female fetuses results in the development of a female-type reproductive system.

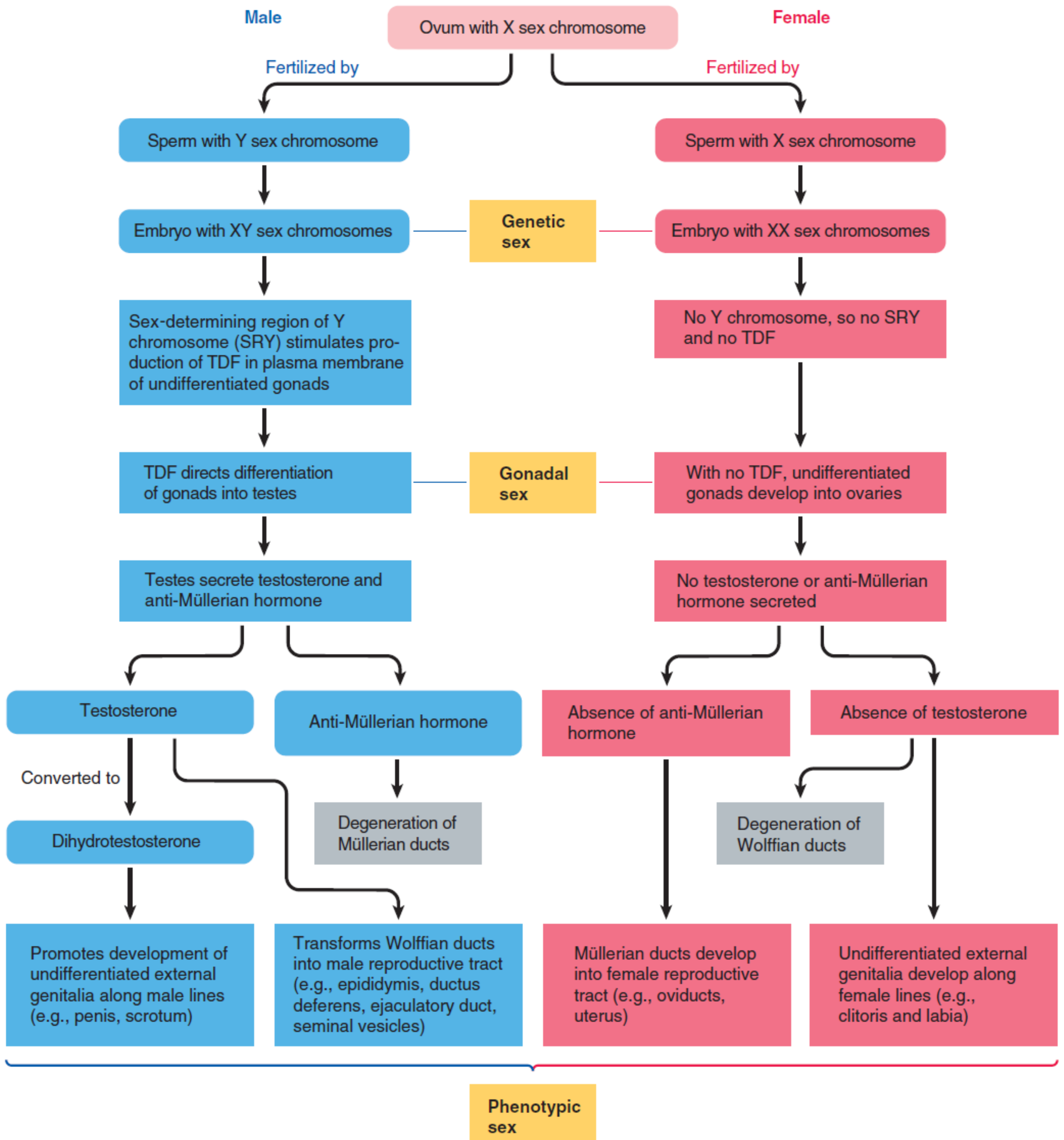


FIGURE 16-6 Sexual differentiation in mammals.

Errors in Sexual Differentiation

- In the usual case, genotypic sex and phenotypic sex are compatible; that is, a genotypic male appears to be a male anatomically and functions as a male, and the same compatibility holds true for females.
- Occasionally, however, discrepancies occur between genotypic and phenotypic sexes because of errors in sexual differentiation, as the following examples illustrate:

Errors in Sexual Differentiation

- In cattle carrying twin fetuses, one of each sex with co-circulation of blood between the two, exposure of the female co-twin to anti-Müllerian hormone regresses the genital reproductive tract (that is, Müllerian duct derivatives), but not the urogenital (that is, posterior vagina and external genitalia), with the consequence that these animals are infertile. Such heifers are termed **freemartins.**
- If testes in a genotypic male fail to properly differentiate and secrete hormones, the result is the development of an apparent anatomic female in a genotypic male, which, of course, will be sterile.

Errors in Sexual Differentiation

- Because testosterone acts on the Wolffi an ducts to convert them into a male reproductive tract but the testosterone derivative DHT masculinizes the external genitalia, a genotypic defi ciency of the enzyme that converts testosterone into DHT results in a genotype with male abdominal (that is, undescended) testes and a male reproductive tract but with female external genitalia.
- The adrenal gland normally secretes a weak androgen, *dehydroepiandrosterone,* in insufficient quantities to masculinize females. However, pathologically excessive secretion of this hormone in a genotypically female fetus during critical developmental stages imposes differentiation of the genitalia along male lines.

REPRODUCTIVE SYSTEMS

ANIMAL PHYSIOLOGY

3 Male Reproductive Physiology

Testes in most mammals descend into the scrotum to become external

- In the mammalian embryo, the testes develop from the gonadal ridge located at the rear of the abdominal cavity.
- In the last phase of fetal life (dependent on the species), they begin a slow descent, passing out of the abdominal cavity through an opening in the abdominal wall called the **inguinal canal** into the scrotum, one testis dropping into each pocket of the scrotal sac.
- Testosterone from the fetal testes is responsible for inducing descent of the testes into the scrotum.

The scrotal location of the testes provides a cooler environment essential for temperature-sensitive spermatogenesis in mammals

- The temperature within the scrotum averages several degrees Celsius less than normal body (core) temperature.
- Descent of the testes into this cooler environment is essential because spermatogenesis in most mammals is temperature sensitive and cannot occur at normal body temperature. This is why a cryptorchid (“hidden testis”) is unable to produce viable sperm.
- In those mammals without a scrotum, alternative mechanisms associated with temperature regulation are found. For example, whales and elephants have countercurrent exchange mechanisms for cooling the testes despite their abdominal location.
- In some mammals, including the rat and rabbit, the testes move into and out of the body cavity seemingly at will through an opening in the inguinal canal.
- The position of an external scrotum in relation to the abdominal cavity can be varied by a spinal reflex mechanism that plays an important role in regulating testicular temperature. Reflex contraction of the *external cremaster muscle* on exposure to a cold environment raises the testicles and the contraction of the *tunica dartos muscle* decreases the scrotal surface area to bring the testes closer to the warmer abdomen. Conversely, on exposure to heat, muscle relaxation permits the scrotal sac to become more pendulous, moving the testes farther from the warm core of the body.

The testicular Leydig cells secrete masculinizing testosterone during the breeding season

- The majority of vertebrate testicular mass consists of highly coiled **seminiferous tubules** within which spermatogenesis takes place (Figure 16-8).
- The endocrine cells that produce testosterone—the **Leydig,** or **interstitial, cells**—are located in the connective tissue (interstitial tissue) between the seminiferous tubules. Thus, the portions of the testes that produce sperm and secrete testosterone are structurally and functionally distinct. During the breeding season, the testes perform the dual function of producing sperm and secreting testosterone.
- Most but not all of testosterone's actions ultimately are directed toward ensuring delivery of sperm to the female.
- The effects of testosterone can be grouped into five categories:
  1. effects on the reproductive system before birth,
  2. effects on sex-specific tissues after birth → puberty
  3. other reproduction-related effects,
  4. effects on secondary sexual characteristics, and
  5. nonreproductive actions (Table 16-2).

TABLE 16-2 Effects of Testosterone

Effects before Birth

Masculinizes the reproductive tract and external genitalia
Promotes descent of the testes into the scrotum of most mammals

Effects on Sex-Specific Tissues

Promotes growth and maturation of the reproductive system at puberty
Essential for spermatogenesis
Maintains the reproductive tract throughout adulthood

Other Reproduction-Related Effects

Develops the sex drive at puberty (sexual maturity)
Controls gonadotropic hormone secretion

Effects on Secondary Sexual Characteristics

Induces the male pattern of hair or feather growth
Causes the voice to deepen because of thickening of the vocal cords
Promotes muscle growth responsible for the male body configuration

Nonreproductive Actions

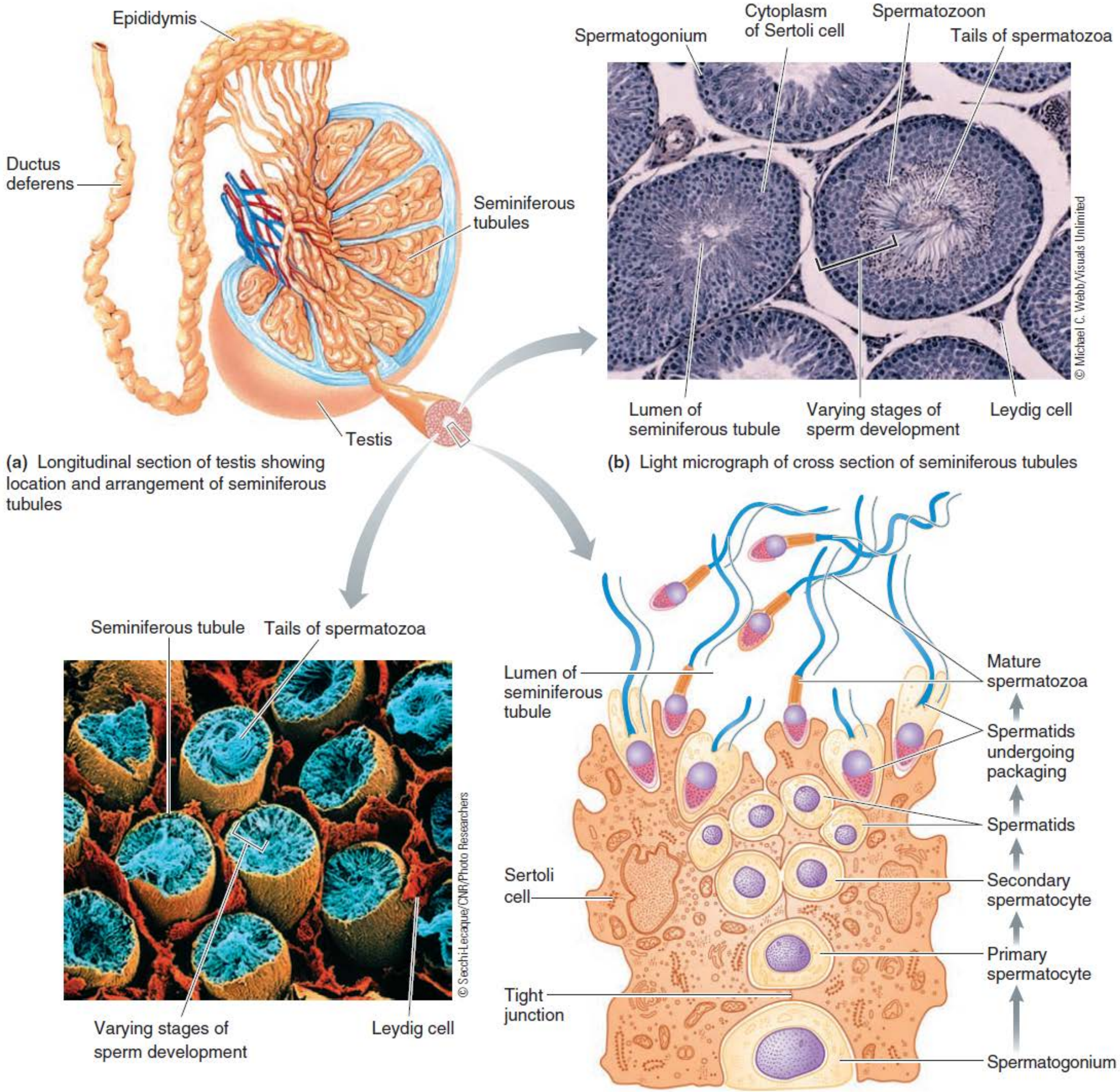
Exerts a protein anabolic effect
Promotes bone growth at puberty (sexual maturity)
Closes the epiphyseal plates after being converted to estrogen by aromatase
Induces aggressive behavior

TABLE 16-3 Average Age (Range) of Puberty in the Male and Female of Various Mammals

Species	Male	Female
Cat	9 months (8–10)	8 months (4–12)
Cow	11 months (7–18)	11 months (9–24)
Camel	3–5 years	3 years
Dog	9 months (5–12)	12 months (6–24)
Sheep	7 months (6–9)	7 months (6–16)
Swine	7 months (5–8)	6 months (5–7)
Horse	14 months (10–24)	18 months (12–19)
Elephant	13–15 years	11–14 years

Spermatogenesis yields an abundance of highly specialized, mobile sperm

- In fact, many of the original descriptions of spermatogenesis were obtained from insect models.
- Two functionally important cell types are present in the mammalian sperm-producing seminiferous tubules (Figure 16-8a):
  - **germ cells,** progenitors that are mostly in various stages of sperm development, and
  - **Sertoli cells,** which provide crucial support for spermatogenesis (Figure 16-8b, c, and d).
- Spermatogenesis encompasses three major stages: *mitotic proliferation* (*spermatocytogenesis*), *meiosis,* and p*ackaging* (*spermiogenesis*) (Figure 16-9).



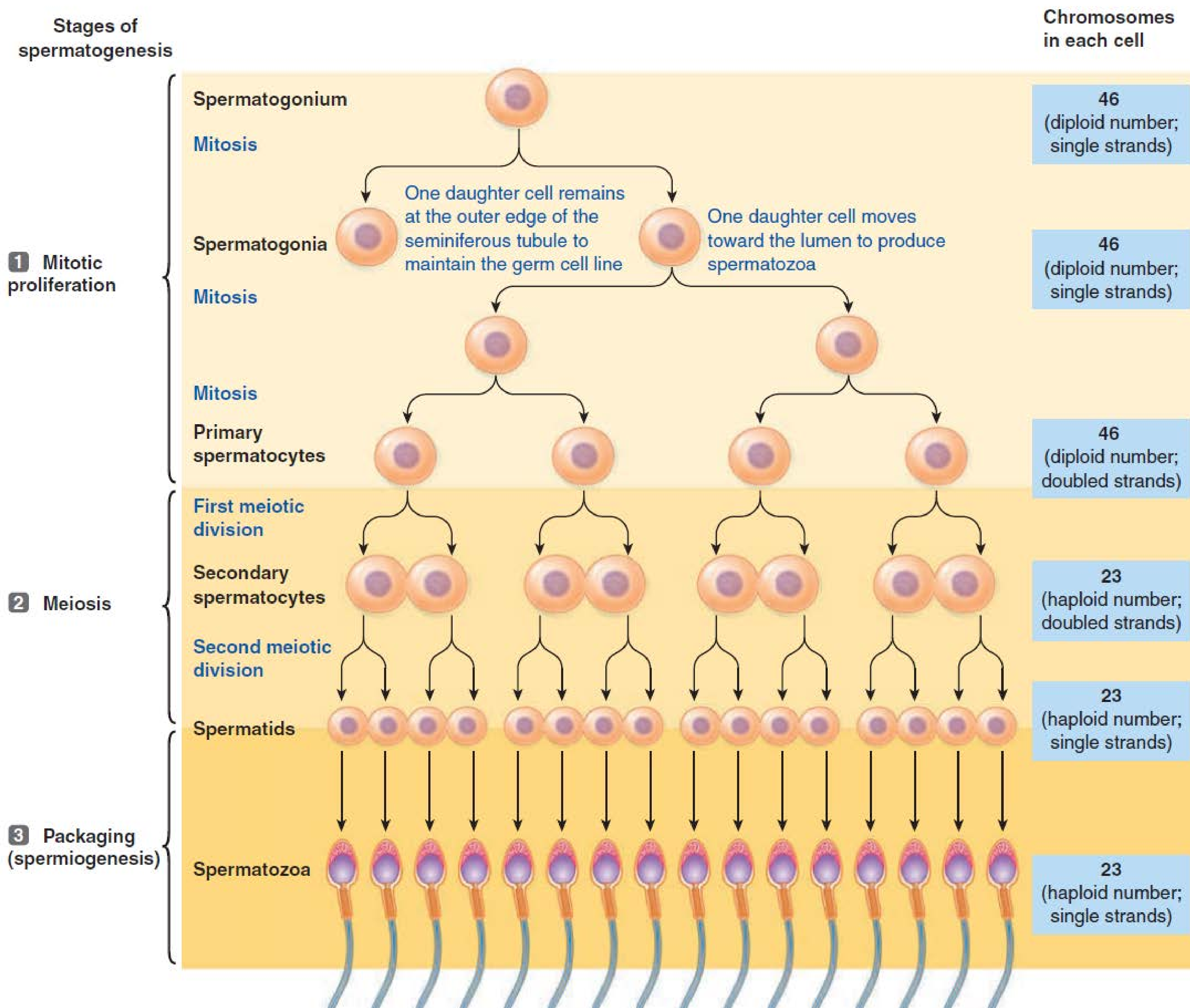
(a) Longitudinal section of testis showing location and arrangement of seminiferous tubules

(b) Light micrograph of cross section of seminiferous tubules

(c) Scanning electron micrograph of cross section of seminiferous tubules

(d) Relationship of Sertoli cells to developing sperm cells

FIGURE 16-8 Anatomy of testis depicting the site of spermatogenesis. (a) The seminiferous tubules are the sperm-producing portion of the testis. (b) The undifferentiated germ cells (the spermatogonia) lie in the periphery of the tubule, and the differentiated spermatozoa are in the lumen, with the various stages of sperm development in between. (c) Note the presence of the highly differentiated spermatozoa (recognizable by their tails) in the lumen of the seminiferous tubules. (d) Relationship of the Sertoli cells to the developing sperm cell.



Stages of spermatogenesis
Chromosomes in each cell
1 Mitotic proliferation
Spermatogonium
Mitosis
46 (diploid number; single strands)
One daughter cell remains at the outer edge of the seminiferous tubule to maintain the germ cell line
Spermatogonia
One daughter cell moves toward the lumen to produce spermatozoa
46 (diploid number; single strands)
Mitosis
Mitosis
Primary spermatocytes
46 (diploid number; doubled strands)
2 Meiosis
First meiotic division
Secondary spermatocytes
23 (haploid number; doubled strands)
Second meiotic division
Spermatids
23 (haploid number; single strands)
3 Packaging (spermiogenesis)
Spermatozoa
23 (haploid number; single strands)

LH and FSH from the anterior pituitary control testosterone secretion and spermatogenesis

- The vertebrate testes are controlled by the two gonadotropic hormones secreted by the anterior pituitary, **luteinizing hormone (LH)** and **follicle-stimulating hormone (FSH),** both of which are produced by the same cell type, the gonadotrope.

Feedback Regulation of Testicular Function

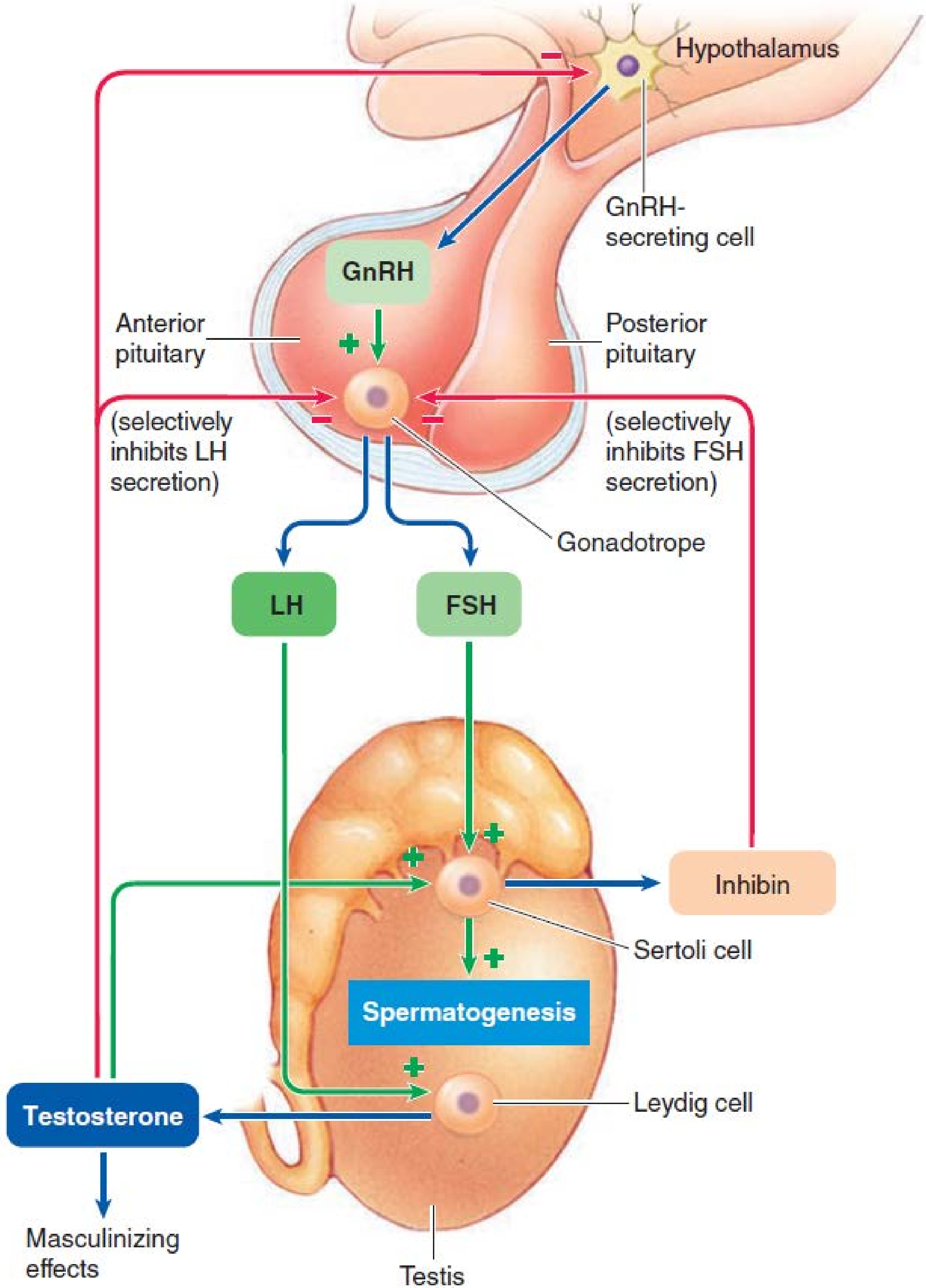
- LH and FSH act on separate components of the testes (Figure 16-11). Luteinizing hormone acts on the Leydig (interstitial) cells and regulates testosterone secretion. Follicle-stimulating hormone acts on the Sertoli cells to enhance spermatogenesis.
- Secretion of both LH and FSH from the anterior pituitary is stimulated in turn by a single hypothalamic hormone, **gonadotropinreleasing hormone (GnRH)** or inhibited by a **gonadotropininhibiting hormone (GnIH).**

Roles of Testosterone and FSH in Spermatogenesis

- Both testosterone and FSH play critical roles in controlling spermatogenesis, each exerting its effect byacting on the Sertoli cells. Testosterone is essential for both mitosis and meiosis of the germ cells, whereas FSH is required to initiate spermatogenesis before puberty as well as for spermatid remodeling.
- Testosterone concentration is much higher in the testes than in the blood because a substantial portion of this hormone produced locally by the Leydig cells is retained in the intratubular fl uid, complexed with androgen-binding protein secreted by the Sertoli cells. Only this high concentration of testicular testosterone is adequate to sustain sperm production.

Conversion of Testosterone to Estrogen in Males

- Although testosterone is classically considered to be the male sex hormone and estrogens to be female sex hormones, the distinctions are not as clear-cut as once thought.
- In addition to the small amount of estrogens produced by the adrenal cortex, a portion of the testosterone secreted by the testes is converted to estradiol outside of the testes by the enzyme *aromatase* which is widely distributed) but most abundant in adipose tissue.
- The boar and the stallion testicle both have significant aromatase activity in the Sertoli cells and as a result secrete substantial quantities of estradiol. Because of this conversion, it is sometimes difficult to distinguish effects of testosterone itself and testosterone-turned-estradiol inside cells.



Hypothalamus
GnRH-
secreting cell
GnRH
Anterior
pituitary
Posterior
pituitary
(selectively
inhibits LH
secretion)
(selectively
inhibits FSH
secretion)
Gonadotrope
LH
FSH
Inhibin
Sertoli cell
Spermatogenesis
Leydig cell
Testosterone
Masculinizing
effects
Testis

Gonadotropin-releasing hormone activity increases at puberty

- Even though the fetal testes secrete testosterone, which directs masculine development of the reproductive system, after birth the testes become quiescent. Subsequently, in response to the increasing secretion of gonadotropins, there is a gradual increase in the secretion of testosterone until puberty.
- Early in the prepubertal period, GnRH secretory pulses occur (at about four-hour intervals in humans), causing brief increases in LH secretion and accordingly, testosterone secretion. The frequency of episodic GnRH secretion gradually increases until the adult pattern of GnRH, FSH, LH, and testosterone secretion is established. Under the influence of the rising testosterone concentrations, particularly in the peripubertal period, the physical changes that encompass the secondary sexual characteristics and reproductive maturation become evident.

The accessory sex glands contribute the bulk of the semen

- The **seminal vesicles** or **vesicular glands** (1) supply fructose, which serves as the primary energy source for ejaculated sperm; (2) secrete *prostaglandins,* which stimulate contractions of the smooth muscle in both the male and female reproductive tracts, helping to transport sperm from their storage site in the male to t he site of fertilization in the female oviduct; (3) provide more than half the semen volume, which helps wash the sperm into the urethra and also dilutes the thick mass of sperm, thus enabling them to develop motility; and (4) secrete fibrinogen, a precursor of fibrin, which forms the meshwork of a clot
- The **prostate gland** (1) secretes an alkaline fluid that neutralizes the acidic vaginal secretions, an important function because sperm are more viable in a slightly alkaline environment; (2) provides clotting enzymes; and (3) releases **prostate-specific antigen (PSA)**.
- During sexual arousal, the **bulbourethral glands** secrete a mucus-like substance that neutralizes the acidic pH in the urethra, provides lubrication, and causes the seminal plasma to coagulate following ejaculation.

4 Mating

- Ultimately, union of male and female gametes often requires *mating* behavior to accomplish delivery of sperm-laden semen to mature ova. In species with internal fertilization, sperm enter the female vagina through the **sex act,** also called **sexual intercourse, coitus,** or **copulation.**
- In most vertebrates, mating occurs at the peak of female fertility, which is *estrus* in most mammals

- In addition to these strictly reproduction-related components, the **sexual response cycle** also encompasses broader physiological responses that can be divided into four phases:
  1. The *excitement phase,* which includes erection (and heightened sexual awareness in humans, at least).
  2. The *plateau phase,* which is characterized by intensification of these responses, plus more generalized body responses, such as steadily increasing heart rate, blood pressure, respiratory rate, and muscle tension.
  3. The *orgasmic phase,* which includes ejaculation as well as other responses that culminate in a burst of stimulating neural signals in pleasure centers of the brain.
  4. The *resolution phase,* which returns genitalia and body systems to their pre-arousal state.

Oxytocin has several roles in mating and other social interactions

- **Oxytocin** is a pituitary hormone most closely associated with labor, lactation, and other female reproductive processes that you will see in detail later. But it is also found in males. Why?
- Oxytocin appears to play roles in mating-related behaviors in both sexes. It is released during arousal and orgasm, and may stimulate orgasmic muscle contractions in both sexes. Oxytocin has been localized in the testes and semen of several mammalian species and may be a paracrine factor inducing contraction of the seminiferous tubules during ejaculation.
- Oxytocin’s actions go beyond mating: Human males who sniffed an experimental oxytocin spray were much more likely to trust other males in their own group, while simultaneously becoming more antagonistic toward strangers. Though oxytocin is popularly dubbed the “trust hormone,” its affects are thus more complex.

5 Female Reproductive Physiology

- In some vertebrates, female reproductive physiology is more complex than the male's.

Complex cycling characterizes female reproductive physiology in many vertebrates, including estrous cycles in most mammals

- As in the vertebrates male, female reproduction involves interactions of internal and environmental factors mediated by the hypothalamic–pituitary–gonadal axis.
- However, unlike the continuous sperm production and relatively constant testosterone secretion in males, the release of ova or deposition of eggs is intermittent, and secretion of female sex hormones displays wide cyclical swings.
- In mammals, there are two separate but coordinated cycles:
  1. The **ovarian cycle,** in which an oocyte matures in the ovary and is *ovulated* to travel to the uterus. As the primary female reproductive organs, ovaries perform the dual function of producing ova (*oogenesis*) and secreting the female sex hormones estrogens and progesterone.
  2. The **uterine cycle,** in which the uterine lining is prepared for a fertilized egg to implant (primarily due to the ovarian hormones).

Complex cycling characterizes female reproductive physiology in many vertebrates, including estrous cycles in most mammals

- The ovarian and uterine cycles together constitute an **estrous cycle** in most mammals, defined as the time from one period of sexual receptivity to the next.
- Sexual receptivity is called **estrus** (a noun, not to be confused with the adjective *estrous*) or **heat,** which occurs periodically under certain specified conditions (often at the time of ovulation).

Complex cycling characterizes female reproductive physiology in many vertebrates, including estrous cycles in most mammals

- Ovarian cycles are very similar among mammals, but uterine cycles differ in two versions. In the *estrous* type, if there is not a pregnancy, the uterine lining that has been prepared for an embryo is reabsorbed.
- In contrast, some primates, including humans, have a **menstrual cycle,** in which uterine lining is sloughed off periodically (*menstruation*). The cycle begins at the end of each menstruation and occurs uniformly throughout the year.
- These primates also usually have distinct *estrus* (receptivity) periods, although human females are considered to be continuously receptive.

- The duration of estrous and menstrual cycles is species specific but variable within a species (Table 16-4).
- In general, the principles governing reproduction are the same for the different species, but there are notable differences. For example, the frequency of estrous cycles differs between species:
  - Cattle, swine, and rodents are **continuously polyestrous** (cycles occuring uniformly throughout the year),
  - while others are **seasonally polyestrous** (estrous cycles are restricted to a particular time of year). Deer, sheep, and goats are examples of **short-day breeders** because they exhibit estrous cycles as day length decreases, whereas bears, hamsters, and horses are **long-day breeders;** that is, they come into estrous as day length increases.
  - **Seasonally monoestrous** females (most carnivores, including bears, dogs, foxes, and wolves) are characterized as having a single estrous event followed by a long period of **anestrus** (period of time without regular cyclic activity). For example, most female dogs have about two estrus periods in a year. In these animals the period of estrus is prolonged and lasts for several days, thus increasing the probability of securing a mate.

TABLE 16-4 Reproductive Cycles of Various Mammals

Genus species[a]	Cycle Type[b]	Cycle Length[c]	Duration of Estrus	Ovulation Type[d]	Time	Luteal Phase in Absence of Coitus
Felis domesticus (cat)	S, P	14	4 days	I	24–30 hr after coitus	No
Bos taurus (cow)	C, P	17–27	13–14 hr	Sp	12–16 hr after end of estrus	Yes
Canus familiaris (dog)	S, M	60	7–9 days	Sp	1–3 days after onset of estrus	Yes
Ovis aries (sheep)	S, P	15–18	30–36 hr	Sp	12–14 hr before the end of estrus	Yes
Mustelo fero (ferret)	S	—	Continuous	I	30 hr after coitus	No
Vulpes vulpes (red fox)	S, M	90	1–5 days Seasonally	Sp	1–2 days after onset of estrus	Yes
Capra hirca (goat)	S, P	20–21	39 hr	Sp	30–36 hr after onset of estrus	Yes—shorter cycles in some breeds
Cavia porcellus (guinea pig)	C, P	16	6–11 hr	Sp	10 hr after onset of estrus	Yes
Mesocricetus auratus (hamster)	C, P	4	20 hr	Sp	8–12 hr after onset of estrus	No
Homo sapiens (human)	C, Mn	28	None	Sp	14 days before the onset of menses	Yes—extremely variable cycle
Equus caballus (horse)	S, P	19–23	4–7 days	Sp	5–6 hr after the onset of estrus	Yes
Macaca mulatta (rhesus monkey)	C, Mn	28	None	Sp	11–14 days after the onset of menses	Yes
Mus musculus (mouse)	C, P	4	10 hr	Sp	2–3 hr after onset of estrus	No
Oryctolagus cuniculus (rabbit)	C	—	Continuous	I	10–12 hr after coitus	No
Rattus norvegicus (rat)	C, P	4–5	13–15 hr	Sp	8–10 hr after onset of estrus	No
Sus scrofa (pig)	C, P	18–23	2–3 days	Sp	36 hr after onset of estrus	Yes

[a]Domesticated or in captivity.
[b]C = continuous; S = seasonal; P = polyestrous; M = monoestrous; Mn = menstrual.
[c]Length of cycle in days.
[d]I = Induced (reflex) ovulators; Sp = spontaneous ovulators (male not necessary).

Source: H. E. Kidder and R. Cochrane, West Virginia University.

Complex cycling characterizes female reproductive physiology in many vertebrates, including estrous cycles in most mammals

- Reproductive capability begins at puberty in mammalian females, but reproductive potential of many primates, some rodents, whales, dogs, rabbits, elephants, and domestic livestock, ceases gradually during middle age (unlike males, who typically have reproductive potential through the remainder of life, although it gradually declines).
- In primates with menstrual cycles, this cessation is called **menopause** due to the complete cessation of **menses** (the outflow uterine materials during menstruation).

Complex cycling characterizes female reproductive physiology in many vertebrates, including estrous cycles in most mammals

- Although ovarian cycles are similar in many ways among vertebrates, differences can be found in the type of ovulation.
  - Most animals are **spontaneous ovulators** that ovulate with a regular frequency and do not require copulation. Some species of birds, for example, ovulate daily for extended periods of time without any contact with the male.
  - **Reflex (induced) ovulation** has been described for a large number of mammals including the cat, mink, ferret, rabbit, and camel. In this strategy ovulation is induced by stimulation of sensory receptors in the vagina and cervix during coitus, either mechanically or by semen components (camelids). Although the strategy is considered a more primitive condition than spontaneous ovulation, very few examples have been described in any taxa other than mammals.
- Exceptions include some reptiles including the whiptail lizard (*Cnemidophorus inornatus*), red-sided garter snake (*Thamnophis sirtalis parietalis*), and loggerhead sea turtle (*Caretta caretta*).

Complex cycling characterizes female reproductive physiology in many vertebrates, including estrous cycles in most mammals

Functions of Estrogens and Progesterone

- As we noted earlier, the ovaries synthesize estrogens and progesterone. These sex hormones act together to promote the opportunity for fertilization of the ovum and, in mammals, to prepare the female reproductive system for pregnancy. Estrogens in the female govern many functions similar to those carried out by testosterone in the male, such as maturation and maintenance of the entire female reproductive system and establishment of female secondary sexual characteristics. In general, the actions of estrogens are important to preconception events. Estrogens are essential for the female to become sexually receptive and permit copulation, ova maturation and release, and transport of sperm from the vagina to the site of fertilization in the oviduct.
- Estrogens in mammals contribute to mammary gland development in anticipation of lactation. The other ovarian steroid, progesterone, is important in preparing a suitable environment for nourishing a developing embryo/fetus and for contributing to the mammary glands ability to produce milk

The steps of gametogenesis are the same in both sexes, but the timing and outcome differ sharply

- **Oogenesis** contrasts sharply with spermatogenesis in several important aspects, even though the identical steps of chromosome replication and division take place during gamete production in both sexes.
- During the last part of fetal life, the oogonia begin the early steps of the first meiotic division but do not complete it. Known now as **primary oocytes.** Until puberty, all the follicles that start to develop
- undergo atresia (degenerate) in the early stages without ever ovulating. Until puberty.
- At the end of the female's reproductive life, only a few follicles remain in the ovaries, and soon even these succumb to atresia.
- This limited gamete potential, which is thought to be determined at birth in mammalian females, is in sharp contrast to the continual process of spermatogenesis in males. (Although in rabbits at least, there is evidence of some new oocytes forming after puberty.)

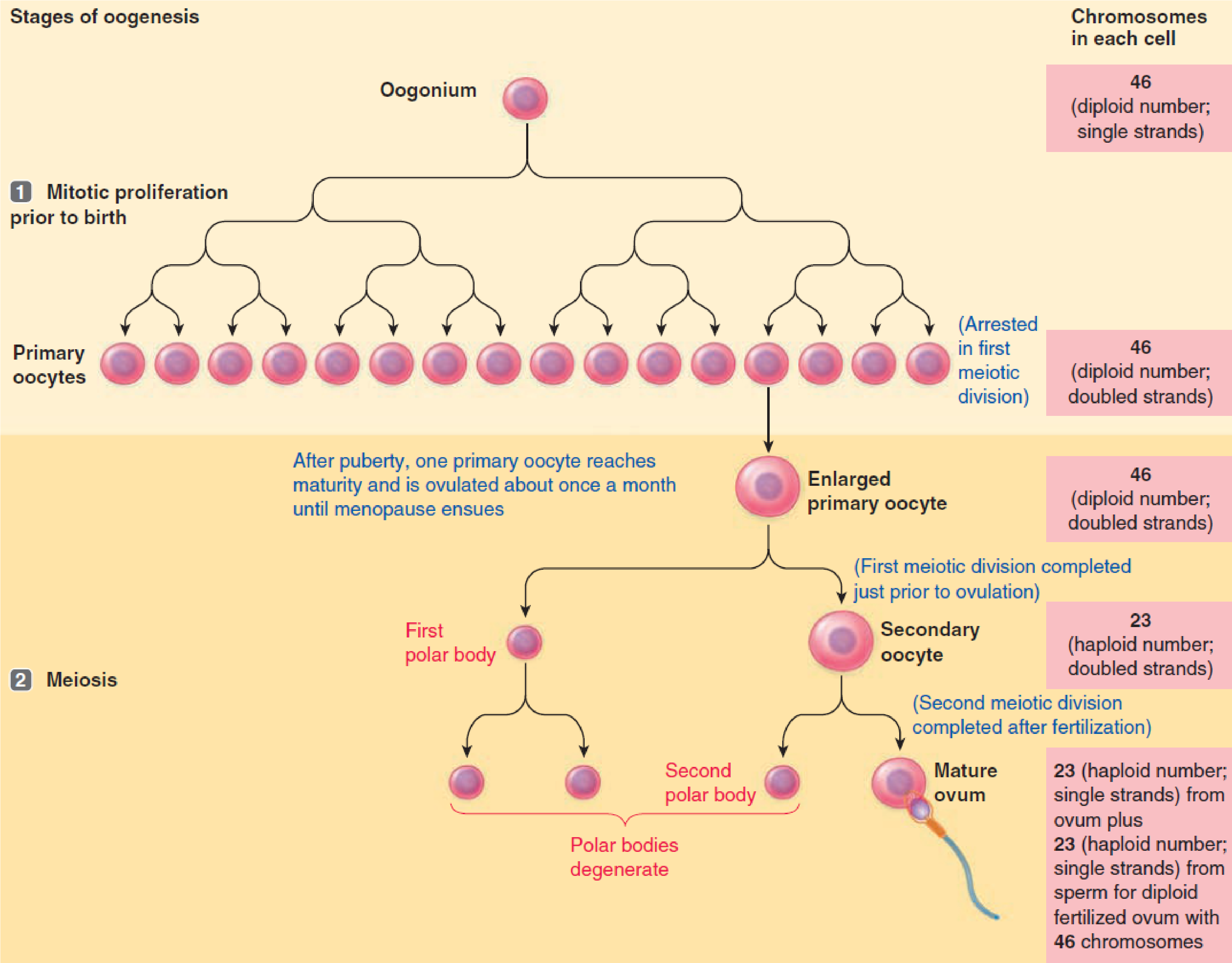


FIGURE 16-15 Oogenesis. Compare with Figure 16-9, p. 774, spermatogenesis.

The ovarian cycle of mammals consists of alternating follicular and luteal phases

- After the onset of puberty, the mammalian ovary alternates between two phases:
  1. The **follicular phase,** which is dominated by the presence of maturing follicles, which produce a mature egg ready for ovulation and the steroids responsible for maturing the oocyte. The follicular hormones also govern the development of the reproductive tract and facilitate sexual receptivity.
  2. The **luteal phase,** which is characterized by the presence of the *corpus luteum* (to be described shortly), the dominant ovarian structure during this phase. It secretes progesterone and, in so doing, prepares the female reproductive tract for pregnancy if the released egg is fertilized.
- In estrous mammals, the follicular phase is comparatively reduced, usually encompassing no more than 20% of the estrous cycle, with the luteal phase encompassing the remaining 80%. In primates with menstrual cycles, the phases are more equal.

The follicular phase is characterized by the development of maturing follicles

- The luteal phase is characterized by the presence
- of a corpus luteum and secretion
- of progesterone

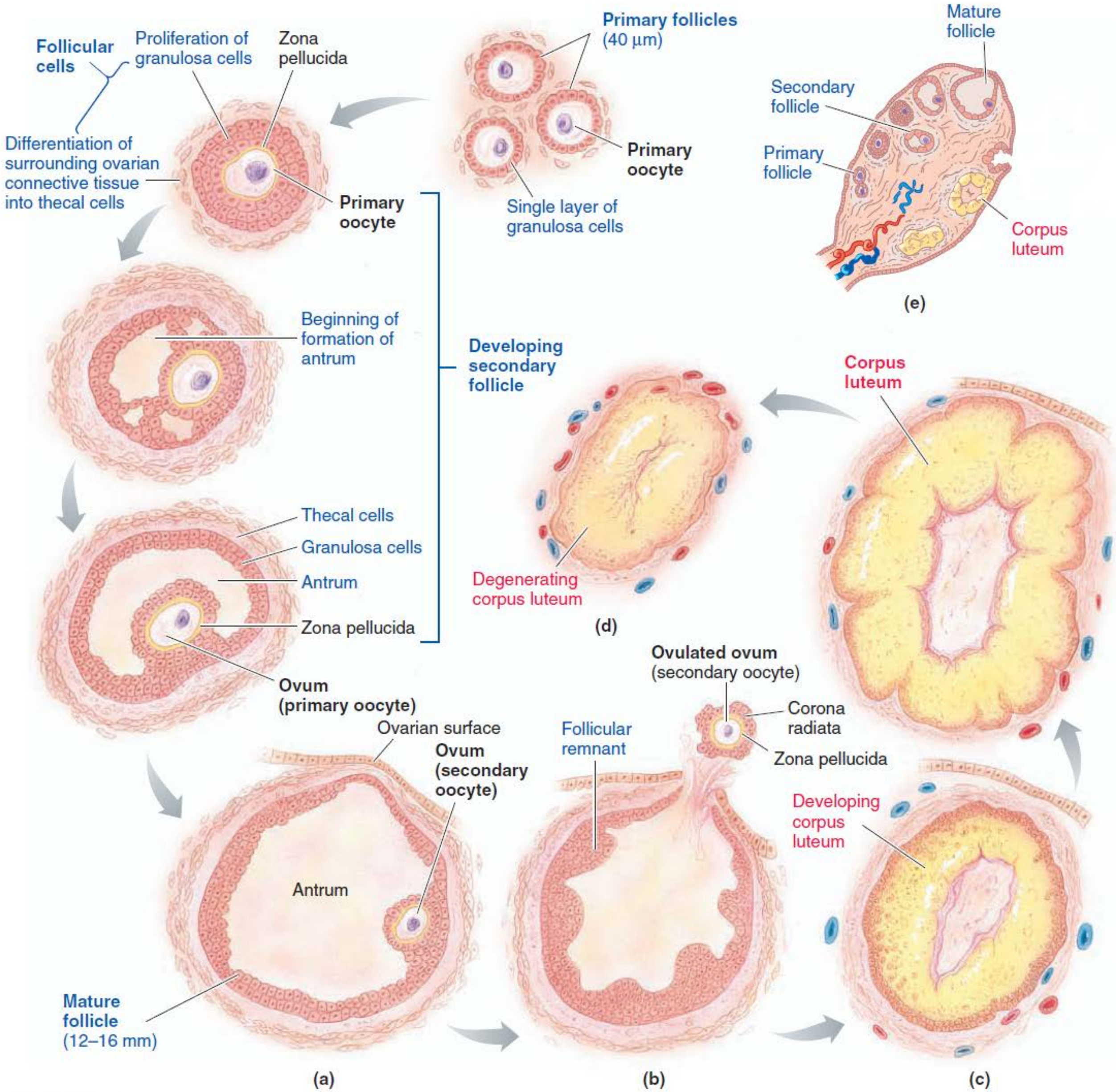


FIGURE 16-16 Development of the follicle, ovulation, and formation of the corpus luteum in a mammal. (a) Stages in follicular development from a primary follicle through a mature follicle. (b) Rupture of a mature follicle and release of an ovum (secondary oocyte) at ovulation. (c) Formation of a corpus luteum from the old follicular cells after ovulation. (d) Degeneration of the corpus luteum if the released ovum is not fertilized. (e) Ovary (actual size in a human female), showing development of a follicle, ovulation, and formation and degeneration of a corpus luteum.

The estrous cycle is regulated by complex hormonal interactions among the hypothalamus, anterior pituitary, and ovarian endocrine units

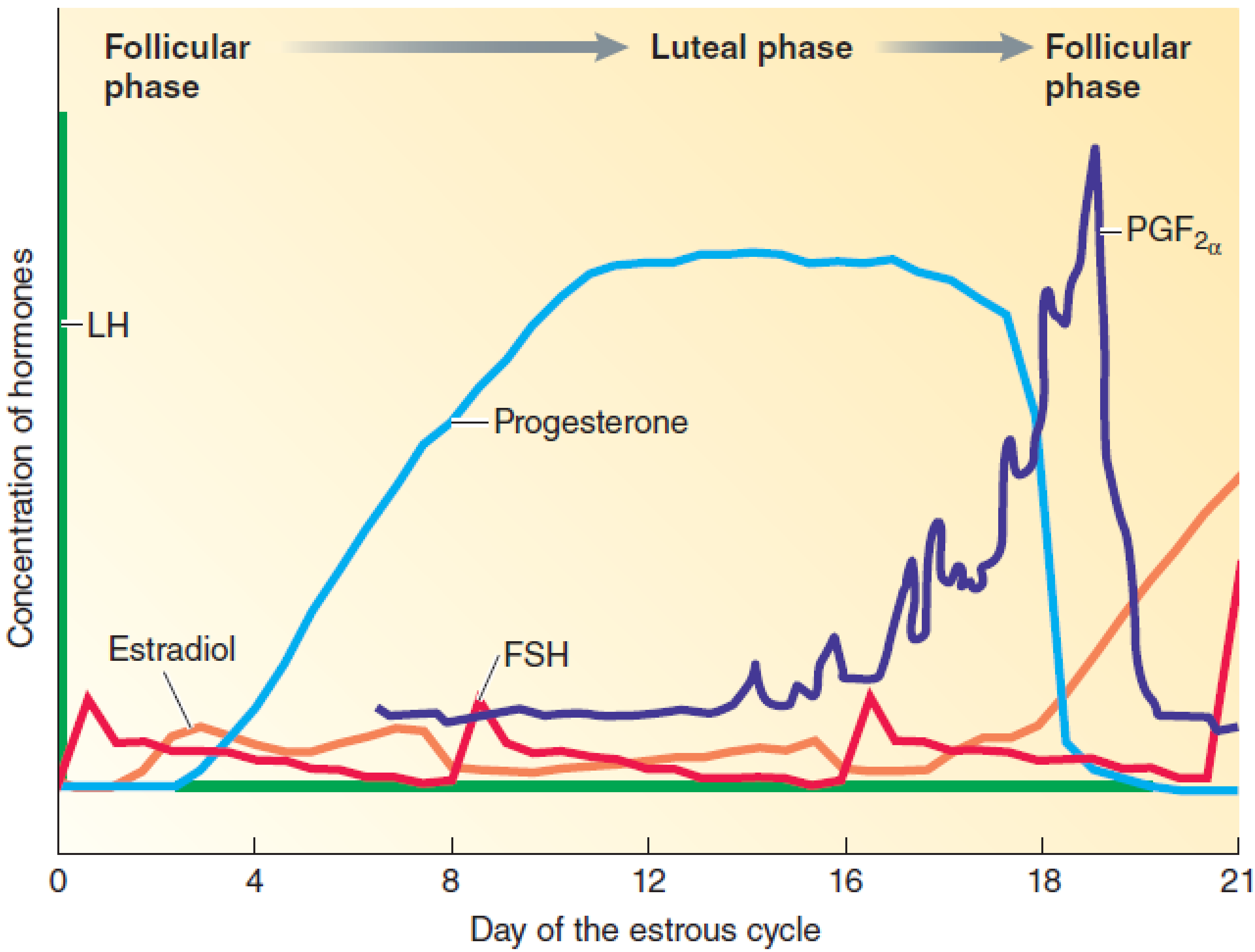
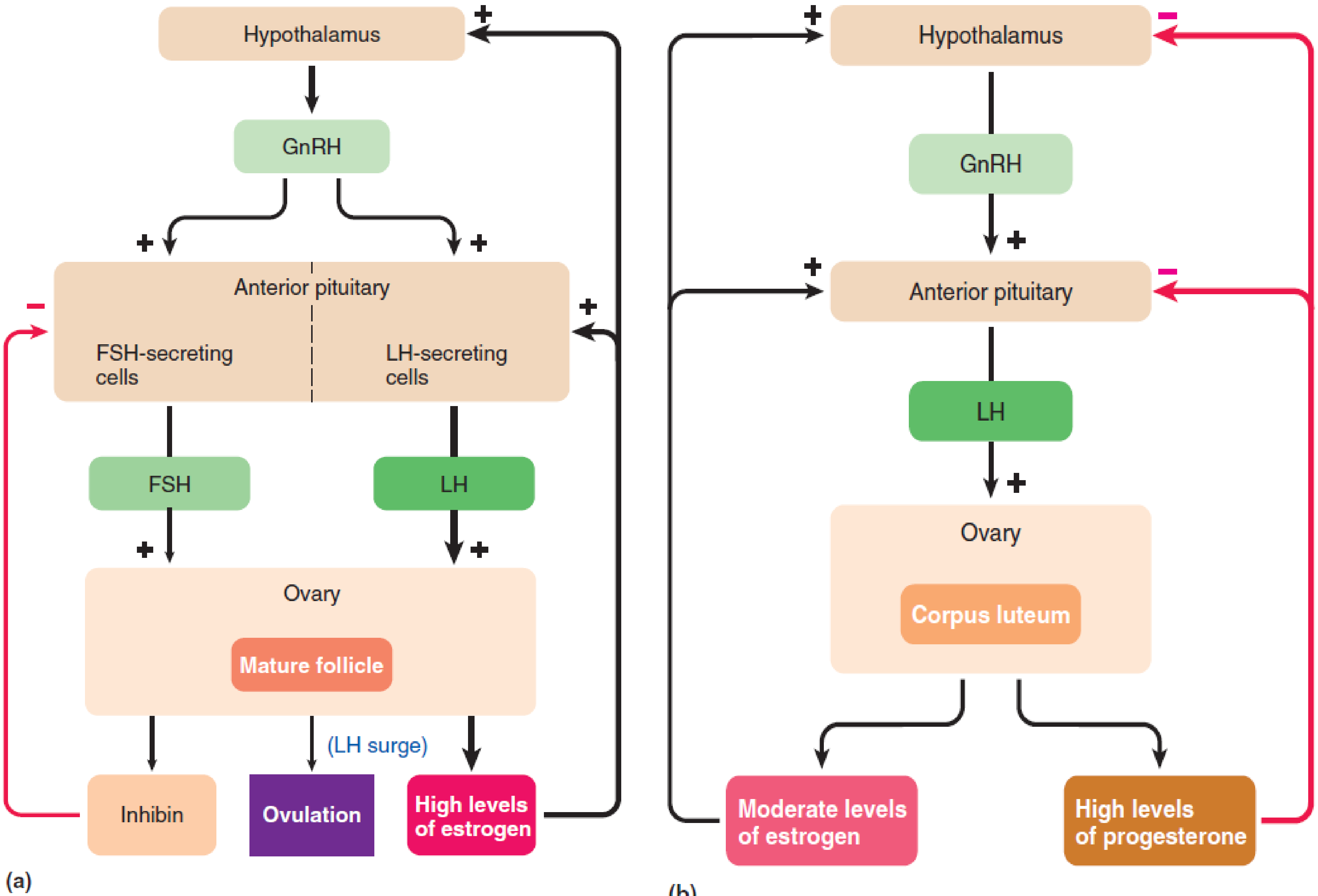
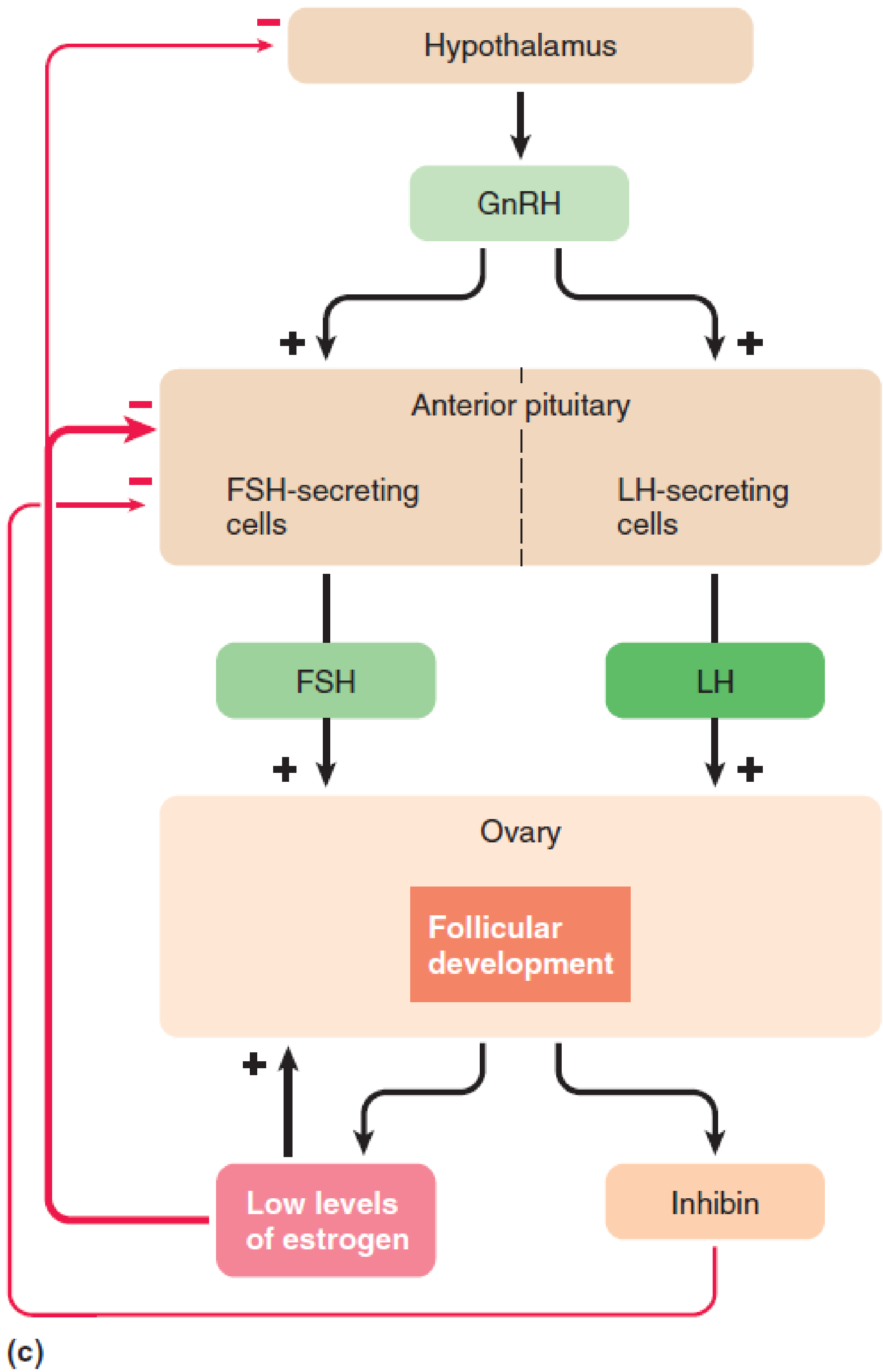


FIGURE 16-17 Correlation between h and the follicular and luteal phases of t estrous cycle. The cycle begins with a s 0) in mid-follicular phase, which initiate to the luteal phase. The upper grey arro luteal phase only.

Source: Courtesy Keith Inskeep, West Virginia University

FIGURE 16-18 Reproductive hormones in a female mammal. (a) Control of the LH surge at ovulation. (b) Feedback control during the luteal phase. (c) Feedback control of FSH and tonic LH secretion during the follicular phase.





16-18 **Reproductive hormones in a female mammal.**
rol of the LH surge at ovulation. (b) Feedback control during
al phase. (c) Feedback control of FSH and tonic LH secretion
ne follicular phase.

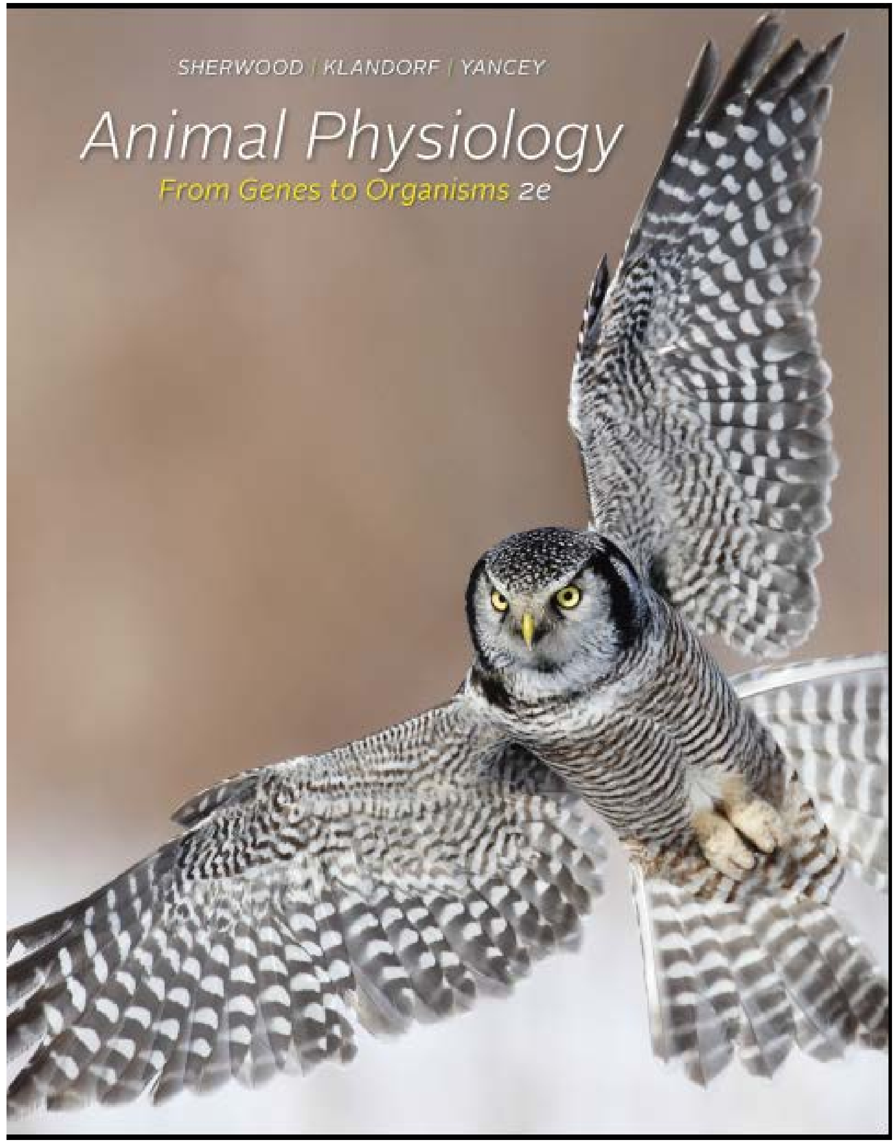
The uterine changes that occur during the estrous cycle reflect hormonal changes during the ovarian cycle

- The fluctuations in circulating levels of estrogens and progesterone that occur during the ovarian cycle induce profound cyclic changes in the uterus in the *uterine cycle.*
- In estrous mammals, the complete removal of the uterus, **hysterectomy,** after ovulation results in the persistence of the corpus luteum as if the female were pregnant. Because it reflects hormonal changes that occur during the ovarian cycle, the uterine cycle averages 17 to 24 days (in cattle), as does the ovarian cycle, although there is considerable variation from this mean even in normal animals.
- This variability is primarily a reflection of differing lengths of the follicular phase; the duration of the luteal phase is fairly constant within a species. However, across species the duration of the luteal phase varies considerably.

Fluctuating concentrations of estrogens and progesterone produce cyclic changes in cervical mucus

- Hormonally induced changes in the cervix occur during the ovarian cycle as well. Under the influence of estrogens during the follicular phase, the mucus secreted by the cervix becomes abundant, clear, and thin.
- This change, which is most pronounced when estrogens are at their peak and ovulation is approaching, facilitates passage of sperm through the cervical canal. After ovulation, under the influence of progesterone from the corpus luteum, the mucus becomes thick and sticky, essentially forming a plug across the cervical opening. This plug constitutes an important defense mechanism by preventing bacteria that might threaten a pregnancy (should conception have occurred) from entering the uterus from the vagina. Sperm cannot penetrate this thick mucus barrier.

Referensi: Chapter 18



Silahkan Lanjutkan dengan membaca..!

SEE YOU NEXT TIME!