Chapter 46

Animal Reproduction

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

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Overview: Pairing Up for Sexual Reproduction

- Each earthworm produces sperm and eggs; in a few weeks, new worms will hatch from fertilized eggs
- Animal reproduction takes many forms
- Aspects of animal form and function can be viewed broadly as adaptations contributing to reproductive success

Fig. 46-1

Concept 46.1: Both asexual and sexual reproduction occur in the animal kingdom

- **Sexual reproduction** is the creation of an offspring by fusion of a male gamete (**sperm**) and female gamete (**egg**) to form a **zygote**
- **Asexual reproduction** is creation of offspring without the fusion of egg and sperm

Mechanisms of Asexual Reproduction

- Many invertebrates reproduce asexually by **fission**, separation of a parent into two or more individuals of about the same size

PLAY Video: Hydra Budding

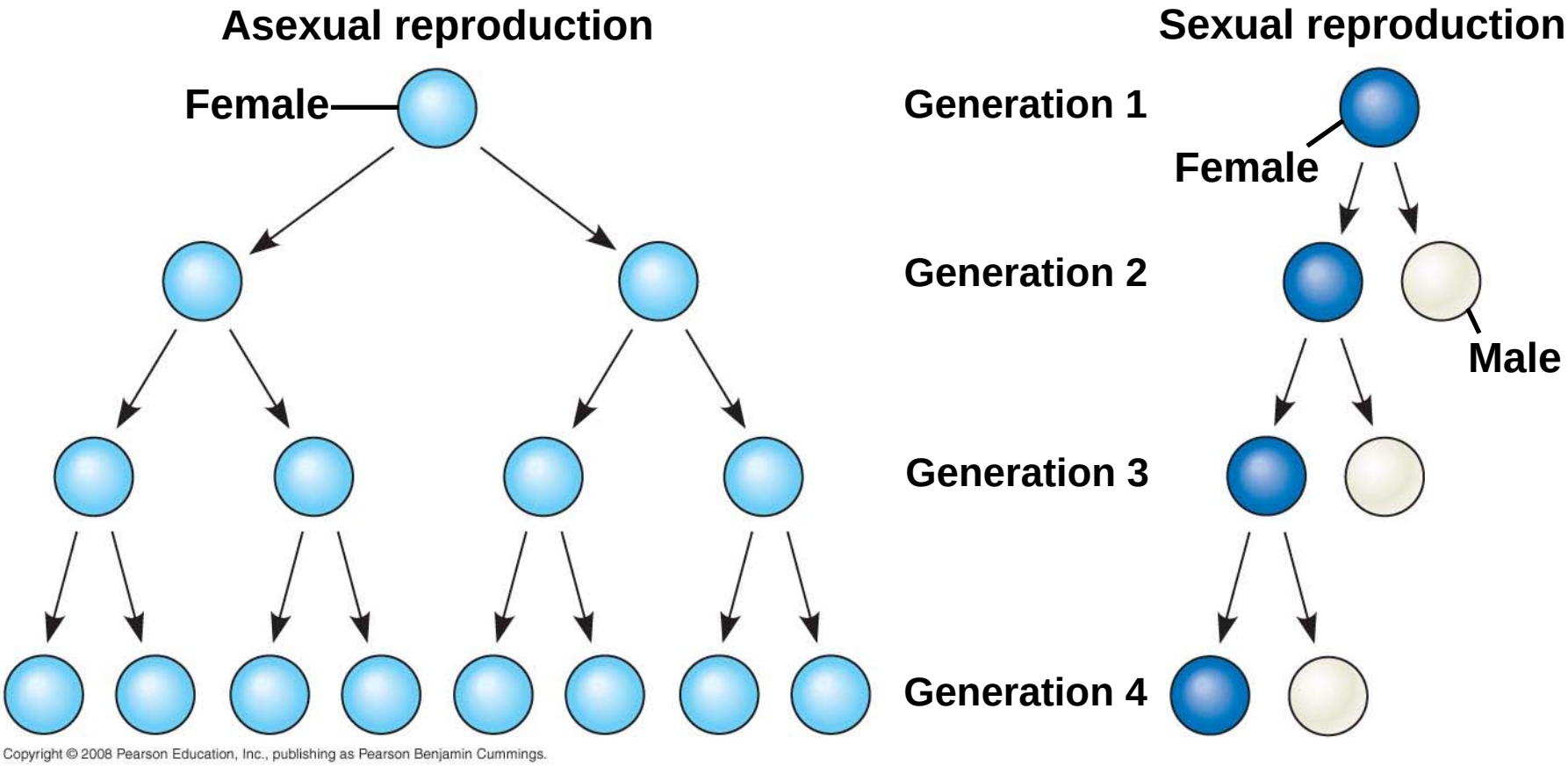
Fig. 46-2

- In **budding**, new individuals arise from outgrowths of existing ones
- *Fragmentation* is breaking of the body into pieces, some or all of which develop into adults
- Fragmentation must be accompanied by *regeneration*, regrowth of lost body parts
- **Parthenogenesis** is the development of a new individual from an unfertilized egg

Sexual Reproduction: An Evolutionary Enigma

- Sexual females have half as many daughters as asexual females; this is the “twofold cost” of sexual reproduction
- Despite this, almost all eukaryotic species reproduce sexually

Fig. 46-3



- Sexual reproduction results in genetic recombination, which provides potential advantages:
  - An increase in variation in offspring, providing an increase in the reproductive success of parents in changing environments
  - An increase in the rate of adaptation
  - A shuffling of genes and the elimination of harmful genes from a population

Reproductive Cycles and Patterns

- **Ovulation** is the release of mature eggs at the midpoint of a female cycle
- Most animals exhibit reproductive cycles related to changing seasons
- Reproductive cycles are controlled by hormones and environmental cues
- Animals may reproduce asexually or sexually, or they may alternate these methods

- Several genera of fishes, amphibians, and lizards reproduce only by a complex form of parthenogenesis that involves the doubling of chromosomes after meiosis
- Asexual whiptail lizards are descended from a sexual species, and females still exhibit mating behaviors

Fig. 46-4

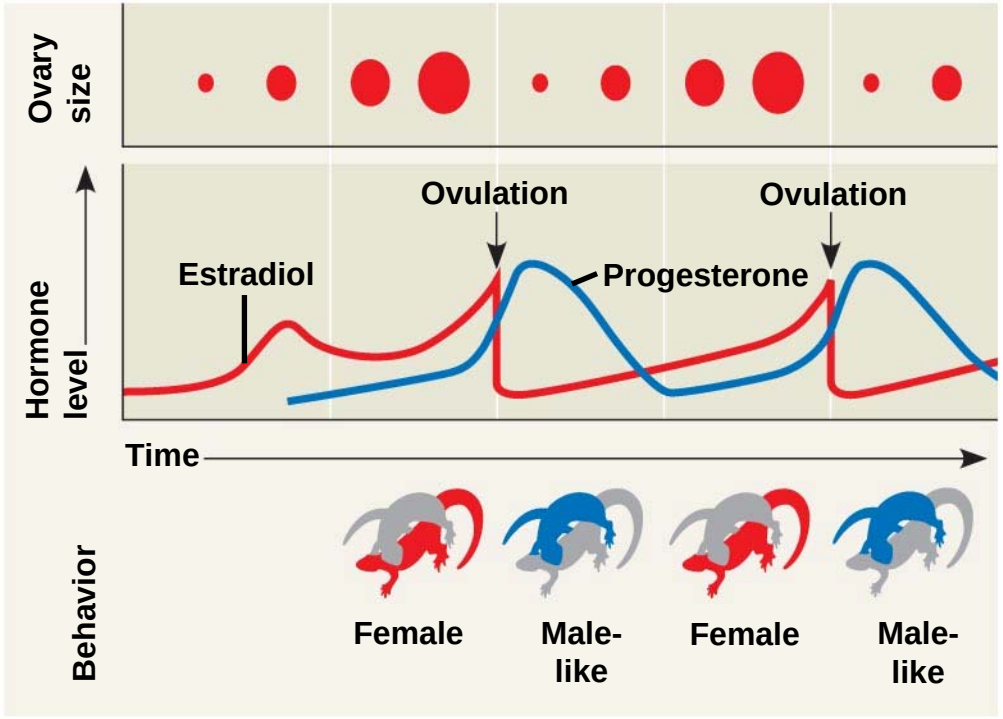
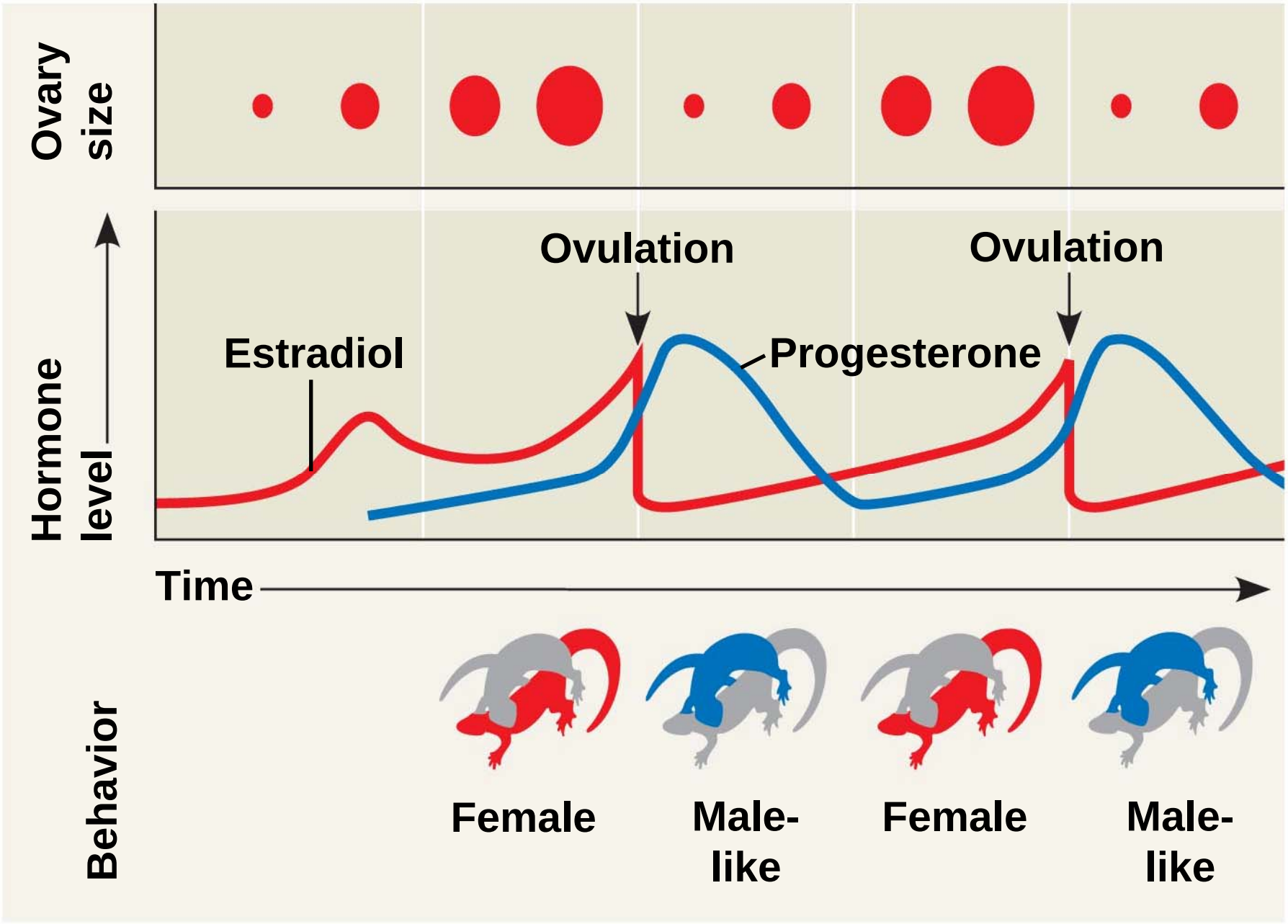


Fig. 46-4a

Fig. 46-4b



- Sexual reproduction is a special problem for organisms that seldom encounter a mate
- One solution is **hermaphroditism**, in which each individual has male and female reproductive systems
- Some hermaphrodites can self-fertilize

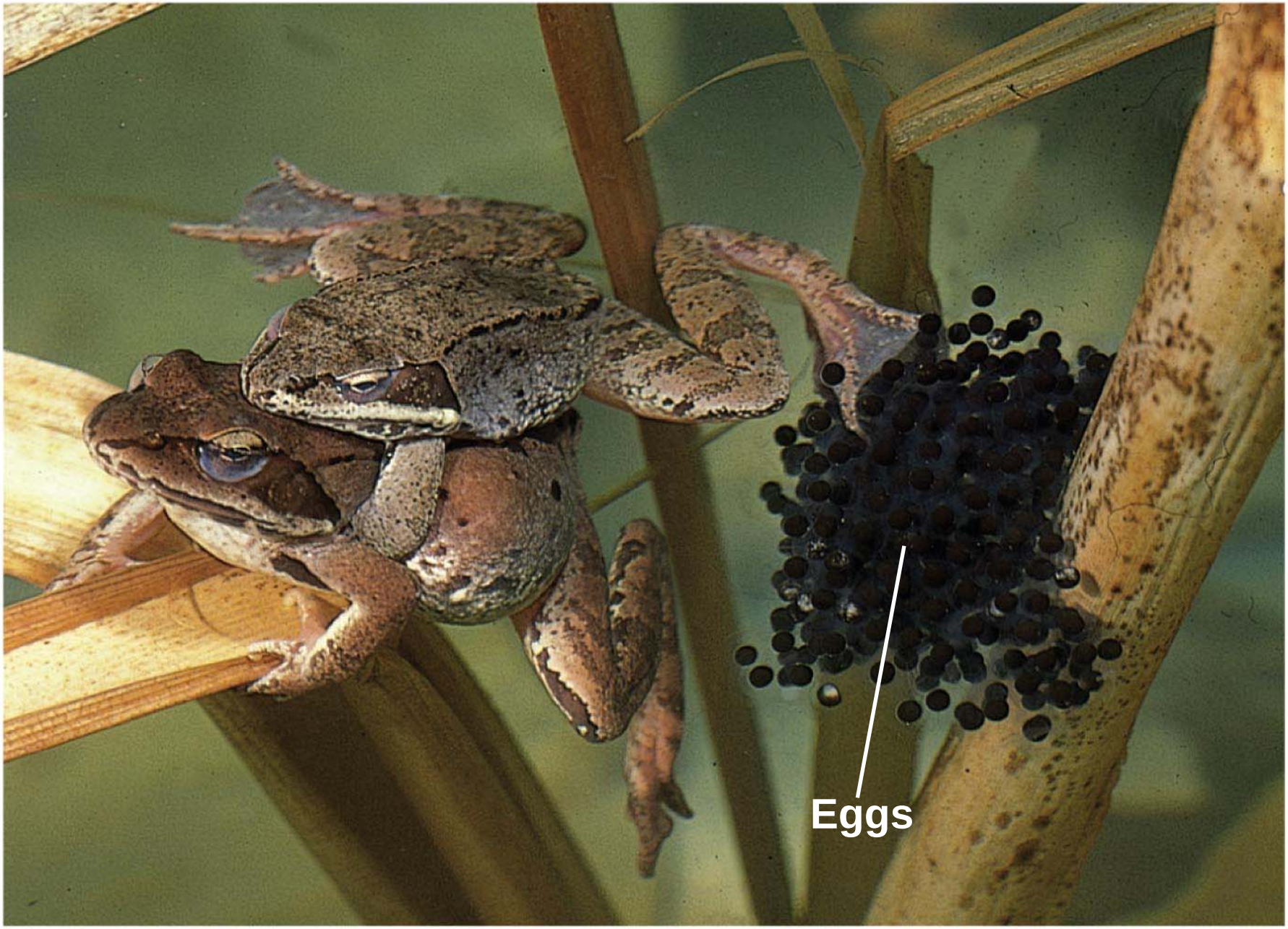
- Individuals of some species undergo sex reversals
- Some species exhibit male to female reversal (for example, certain oysters), while others exhibit female to male reversal (for example, a coral reef fish)

Concept 46.2: Fertilization depends on mechanisms that bring together sperm and eggs of the same species

- The mechanisms of **fertilization**, the union of egg and sperm, play an important part in sexual reproduction
- In **external fertilization**, eggs shed by the female are fertilized by sperm in the external environment

PLAY Video: Hydra Releasing Sperm

Fig. 46-5



- In **internal fertilization**, sperm are deposited in or near the female reproductive tract, and fertilization occurs within the tract
- Internal fertilization requires behavioral interactions and compatible copulatory organs
- All fertilization requires critical timing, often mediated by environmental cues, pheromones, and/or courtship behavior

Ensuring the Survival of Offspring

- All species produce more offspring than the environment can handle, and the proportion that survives is quite small
- Species with external fertilization produce more gametes than species with internal fertilization

- Species with internal fertilization provide greater protection of the embryos and more parental care
- The embryos of some terrestrial animals develop in amniote eggs with protective layers
- Some other animals retain the embryo, which develops inside the female
- In many animals, parental care helps ensure survival of offspring

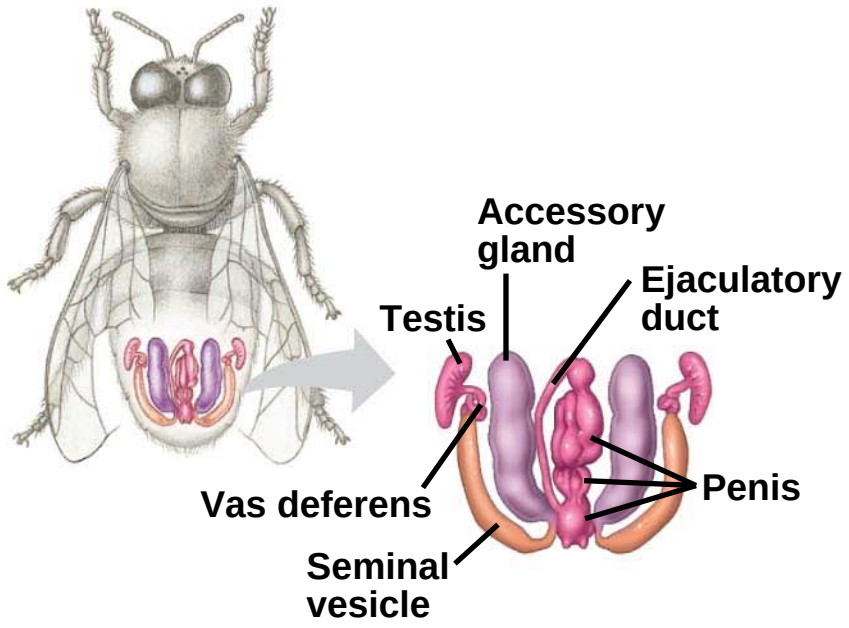
Fig. 46-6

Gamete Production and Delivery

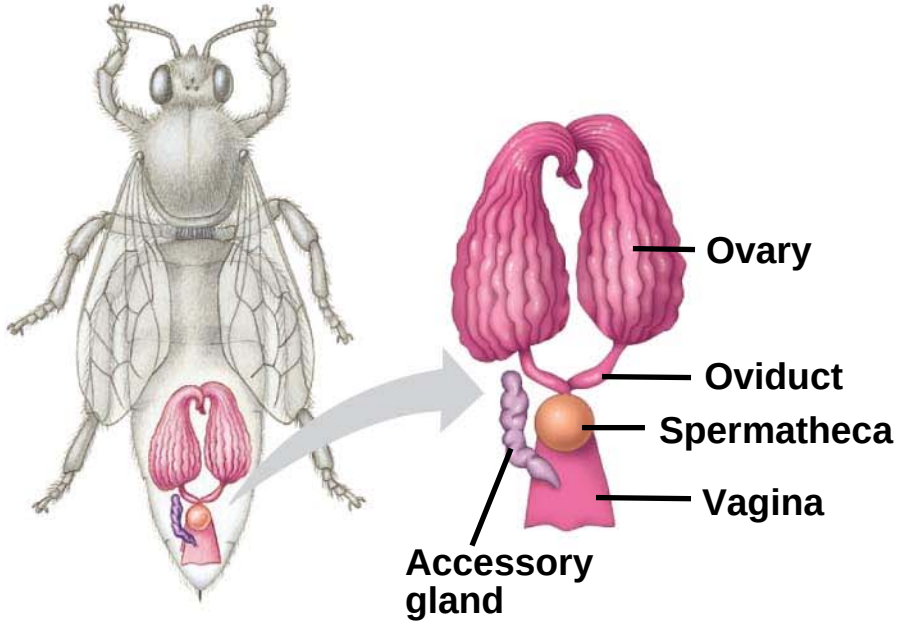
- To reproduce sexually, animals must have systems that produce gametes
- In most species individuals have **gonads**, organs that produce gametes
- Some simple systems do not have gonads, but gametes form from undifferentiated tissue
- The most complex systems contain many sets of accessory tubes and glands that carry, nourish, and protect gametes and developing embryos

- Most insects have separate sexes with complex reproductive systems
- In many insects, the female has a **spermatheca** in which sperm is stored during copulation

Fig. 46-7



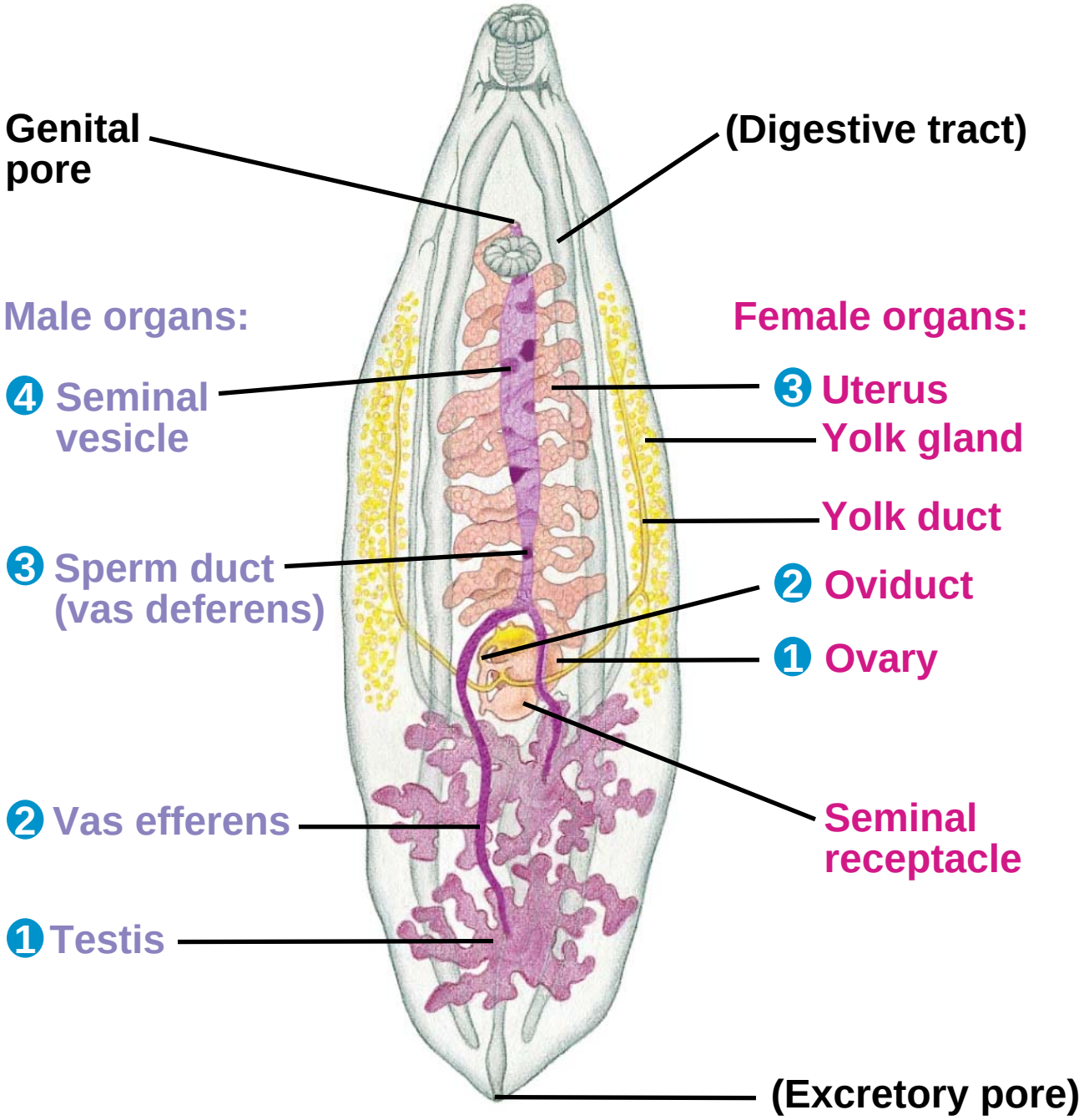
(a) Male honeybee (drone)



(b) Female honeybee (queen)

- Even animals with simple body plans can have complex reproductive systems, for example parasitic flatworms

Fig. 46-8

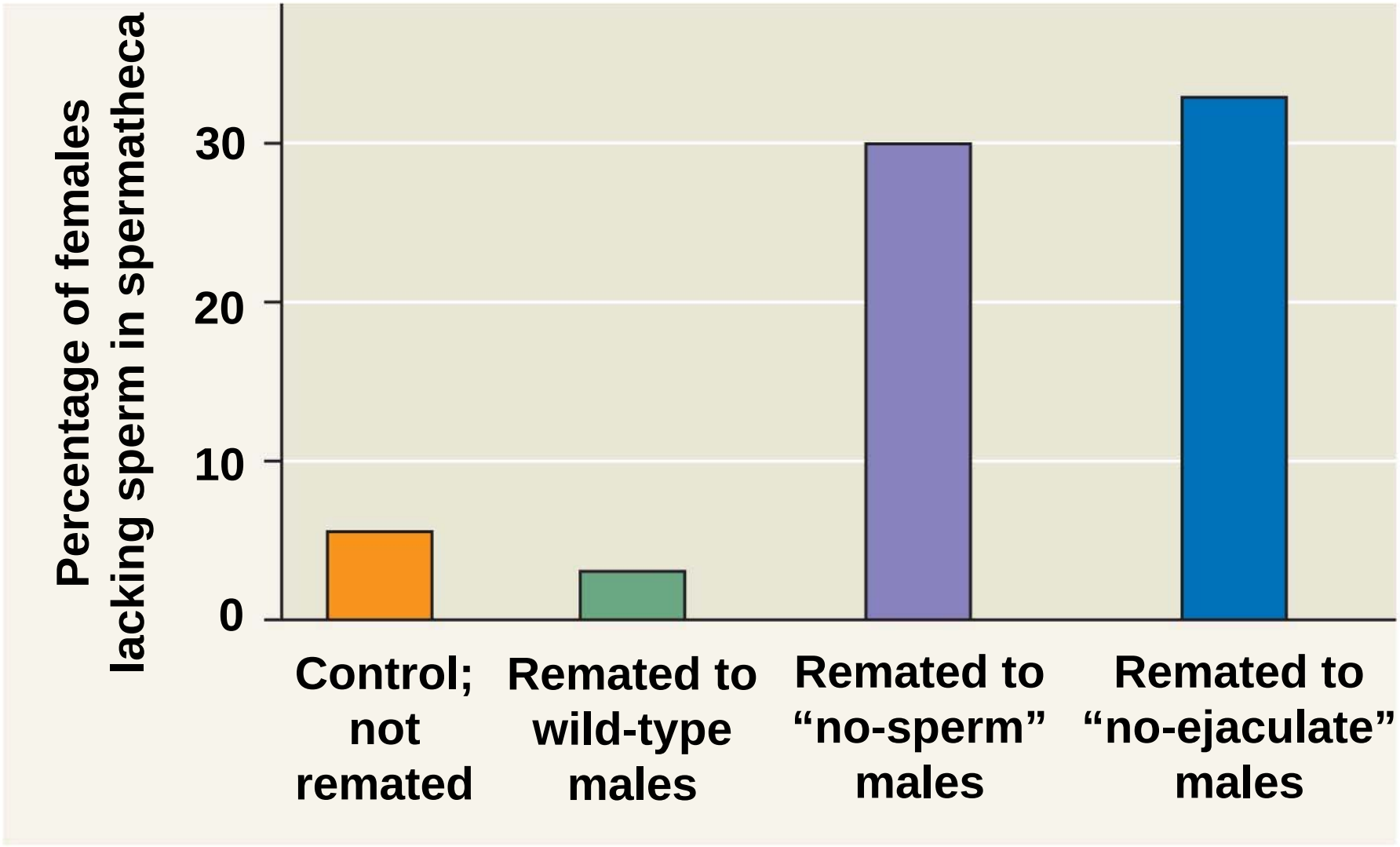


- A **cloaca** is a common opening between the external environment and the digestive, excretory, and reproductive systems
- A cloaca is common in nonmammalian vertebrates; mammals usually have a separate opening to the digestive tract

- Monogamy is relatively rare among animals
- Males and/or females of some species have evolved mechanisms to decrease the chance of their mate mating with another individual

Fig. 46-9

RESULTS



Concept 46.3: Reproductive organs produce and transport gametes

- The following section focuses on the human reproductive system

Female Reproductive Anatomy

- The female external reproductive structures include the clitoris and two sets of labia
- The internal organs are a pair of gonads and a system of ducts and chambers that carry gametes and house the embryo and fetus

PLAY Animation: Female Reproductive Anatomy

Fig. 46-10

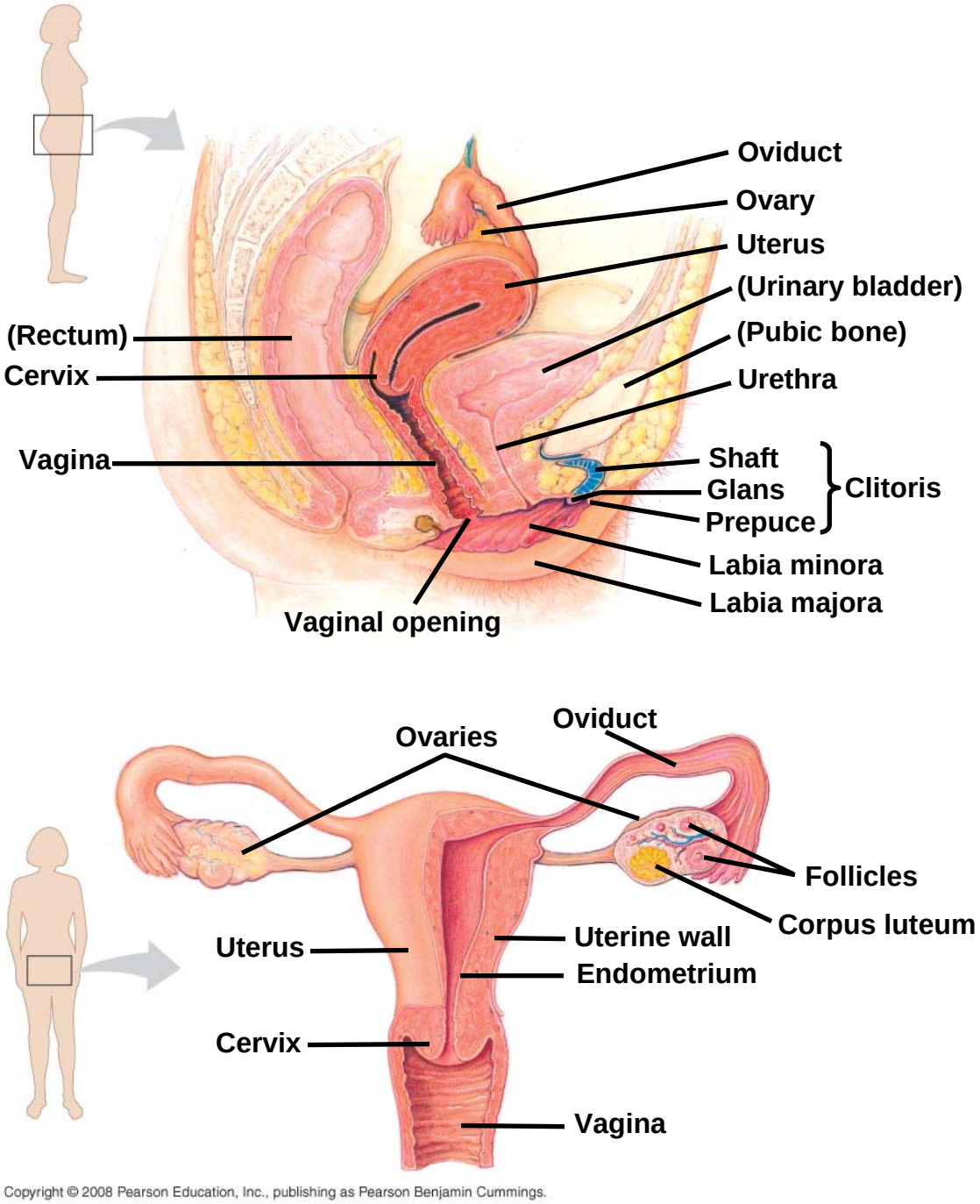


Fig. 46-10a

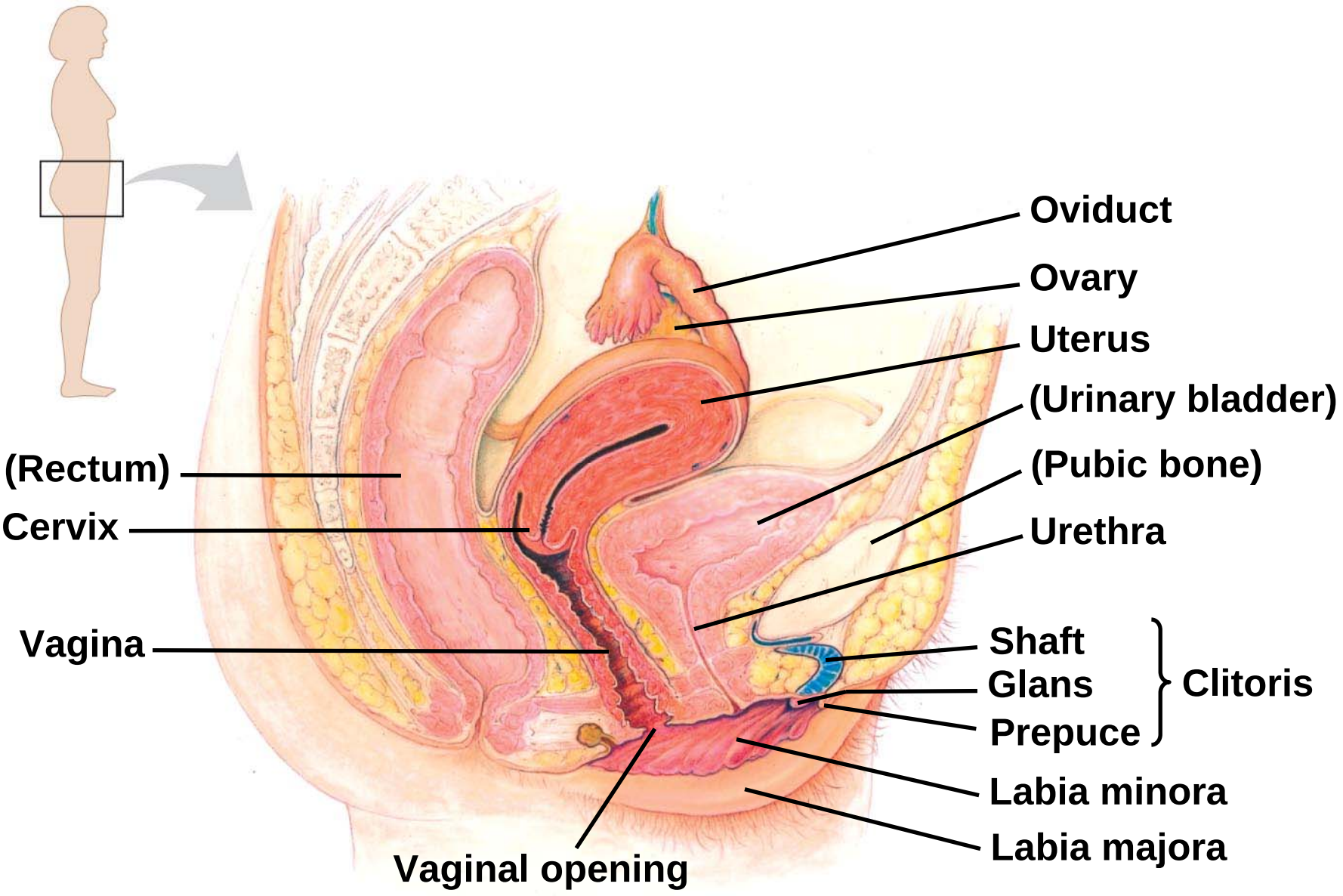
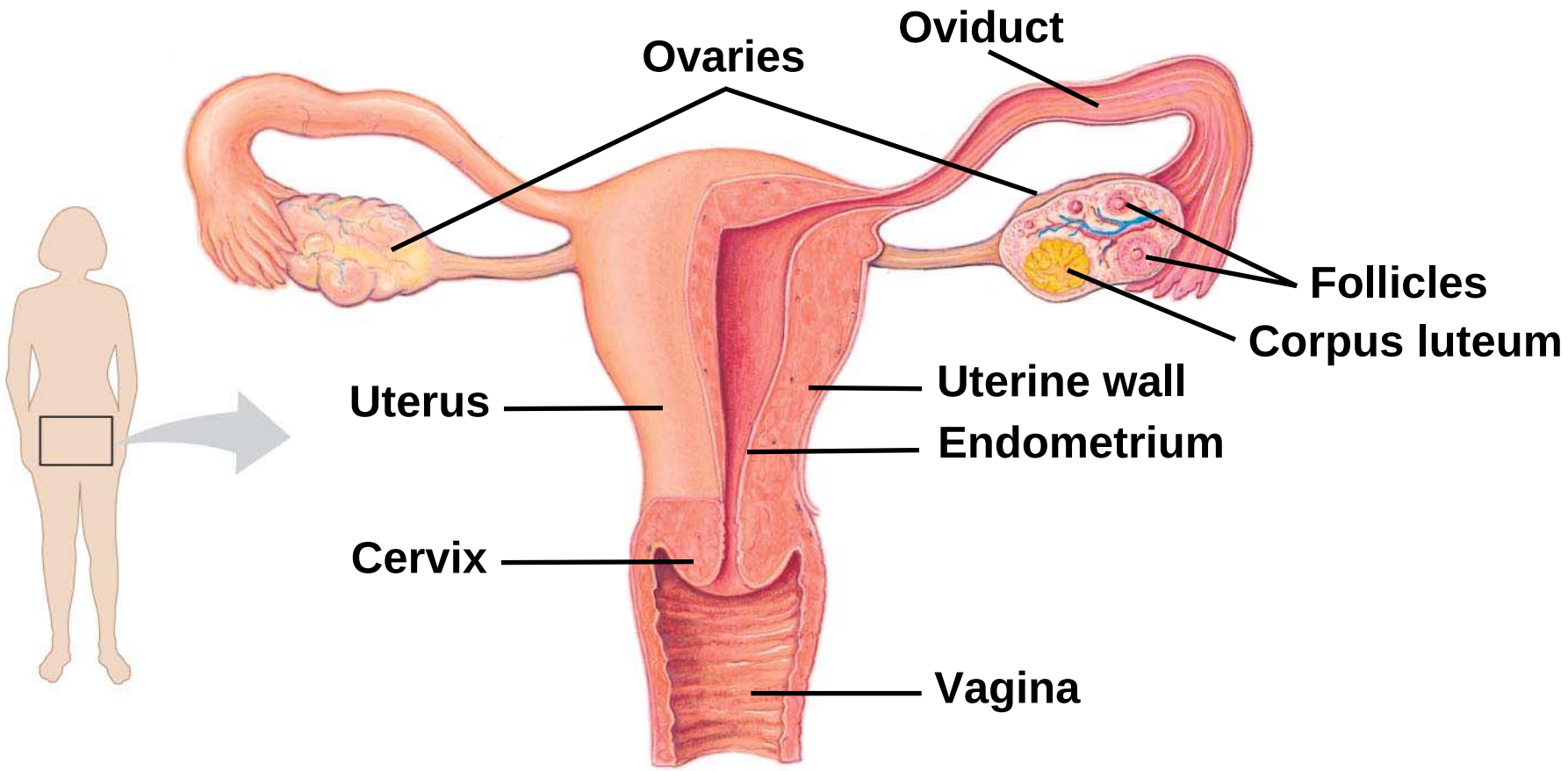


Fig. 46-10b



Ovaries

- The female gonads, the ovaries, lie in the abdominal cavity
- Each ovary contains many **follicles**, which consist of a partially developed egg, called an **oocyte**, surrounded by support cells
- Once a month, an oocyte develops into an ovum (egg) by the process of **oogenesis**

- Ovulation expels an egg cell from the follicle
- The remaining follicular tissue grows within the ovary, forming a mass called the **corpus luteum**
- The corpus luteum secretes hormones that help to maintain pregnancy
- If the egg is not fertilized, the corpus luteum degenerates

Oviducts and Uterus

- The egg cell travels from the ovary to the uterus via an **oviduct**, or fallopian tube
- Cilia in the oviduct convey the egg to the **uterus**, also called the womb
- The uterus lining, the **endometrium**, has many blood vessels
- The uterus narrows at the **cervix**, then opens into the vagina

Vagina and Vulva

- The **vagina** is a thin-walled chamber that is the repository for sperm during copulation and serves as the birth canal
- The vagina opens to the outside at the **vulva**, which consists of the **labia majora**, **labia minora**, **hymen**, and **clitoris**

- The clitoris has a head called a **glans** covered by the **prepuce**
- The vagina, labia minora, and clitoris are rich with blood vessels; the clitoris also has many nerve endings

Mammary Glands

- The **mammary glands** are not part of the reproductive system but are important to mammalian reproduction
- Within the glands, small sacs of epithelial tissue secrete milk

Male Reproductive Anatomy

- The male's external reproductive organs are the scrotum and penis
- Internal organs are the gonads, which produce sperm and hormones, and accessory glands

PLAY Animation: Male Reproductive Anatomy

Fig. 46-11

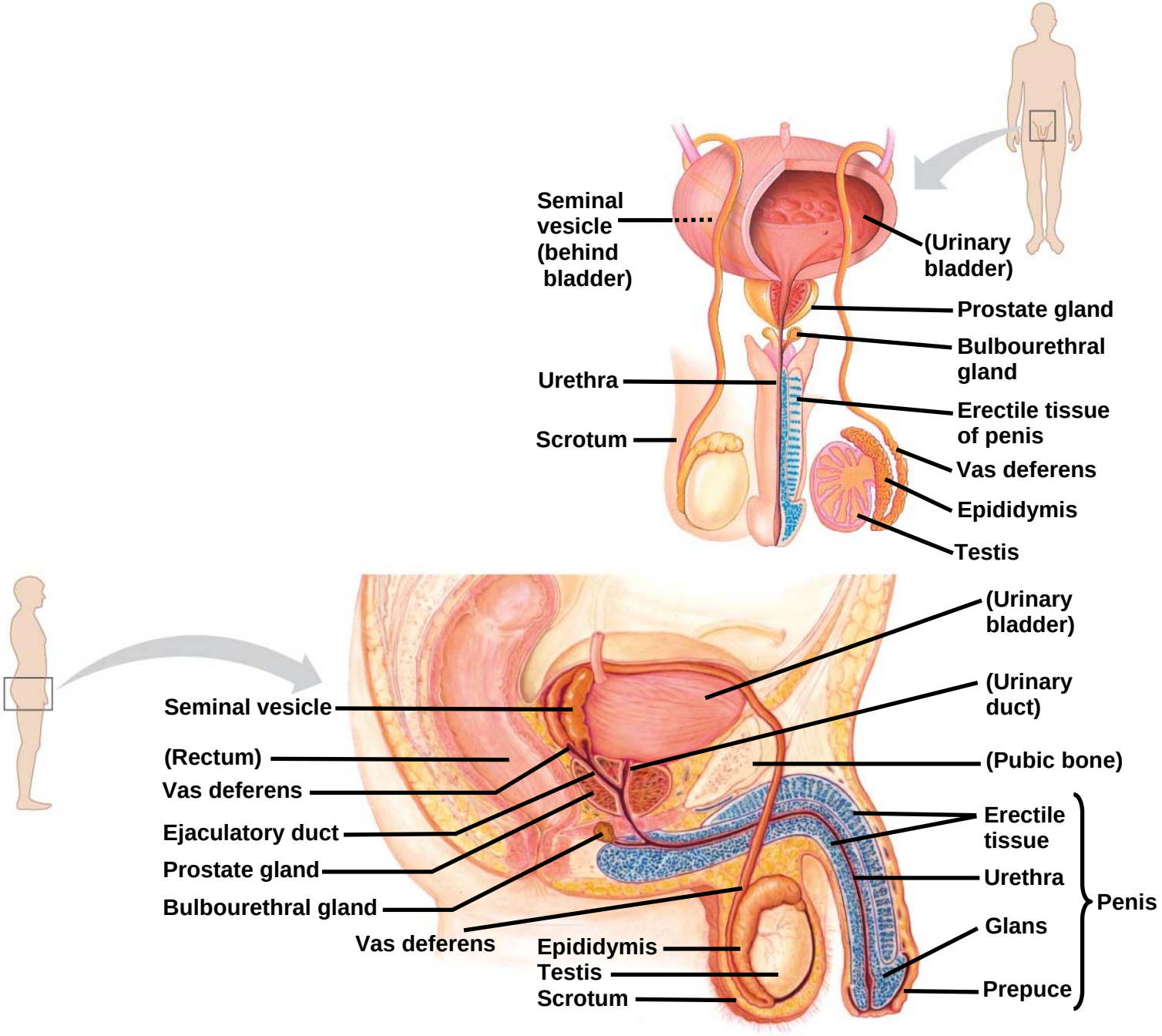


Fig. 46-11a

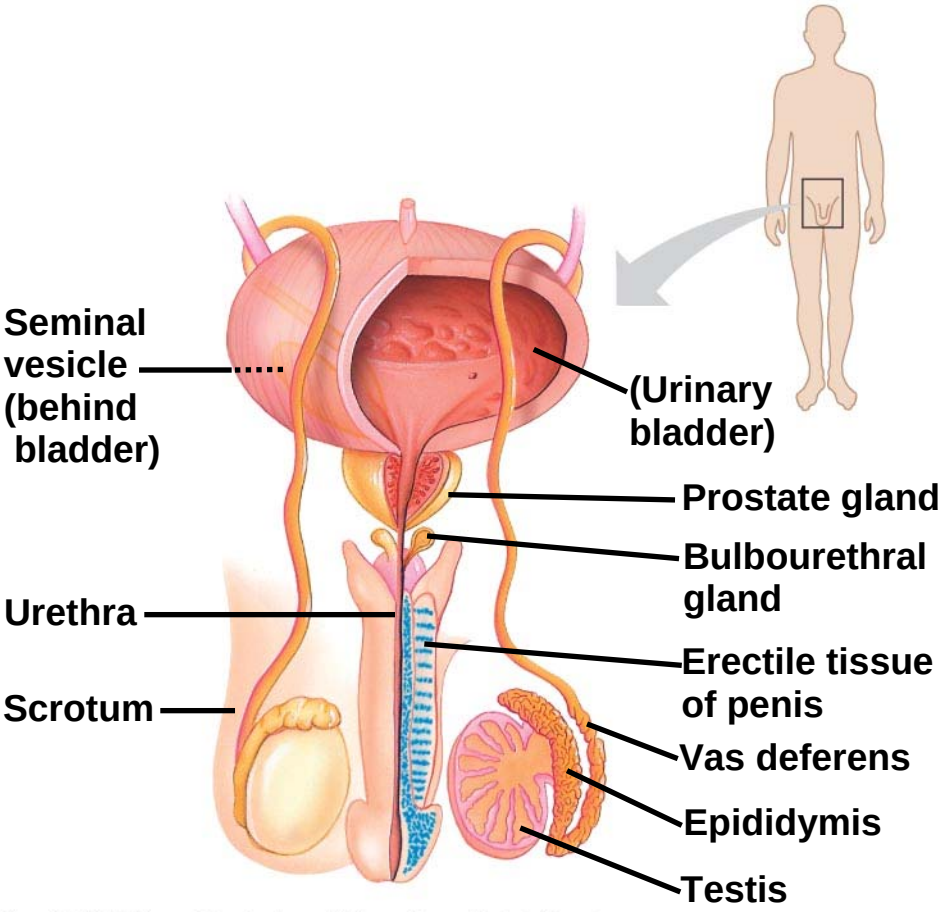
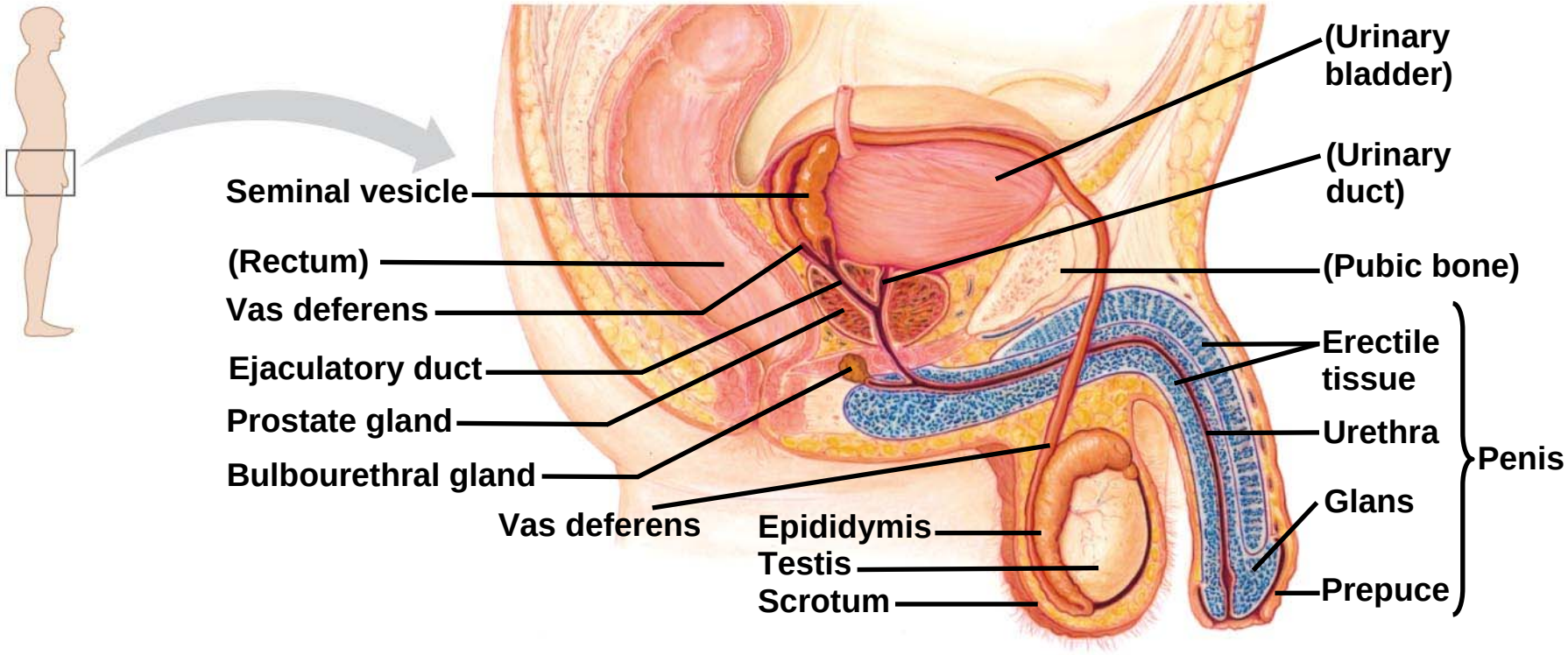


Fig. 46-11b



Testes

- The male gonads, or **testes**, consist of highly coiled tubes surrounded by connective tissue
- Sperm form in these **seminiferous tubules**
- **Leydig cells** produce hormones and are scattered between the tubules
- Production of normal sperm cannot occur at the body temperatures of most mammals

- The testes of many mammals are held outside the abdominal cavity in the **scrotum**, where the temperature is lower than in the abdominal cavity

Ducts

- From the seminiferous tubules of a testis, sperm pass into the coiled tubules of the **epididymis**
- During **ejaculation**, sperm are propelled through the muscular **vas deferens** and the **ejaculatory duct**, and then exit the penis through the **urethra**

Accessory Glands

- **Semen** is composed of sperm plus secretions from three sets of accessory glands
- The two **seminal vesicles** contribute about 60% of the total volume of semen
- The **prostate gland** secretes its products directly into the urethra through several small ducts
- The *bulbourethral glands* secrete a clear mucus before ejaculation that neutralizes acidic urine remaining in the urethra

Penis

- The human **penis** is composed of three cylinders of spongy erectile tissue
- During sexual arousal, the erectile tissue fills with blood from the arteries, causing an erection
- The head of the penis has a thinner skin covering than the shaft, and is more sensitive to stimulation

Human Sexual Response

- Two reactions predominate in both sexes:
  - **Vasocongestion**, the filling of tissue with blood
  - **Myotonia**, increased muscle tension
- The sexual response cycle has four phases: excitement, plateau, orgasm, and resolution
- Excitement prepares the penis and vagina for **coitus** (sexual intercourse)

- Direct stimulation of genitalia maintains the plateau phase and prepares the vagina for receipt of sperm
- **Orgasm** is characterized by rhythmic contractions of reproductive structures
  - In males, semen is first released into the urethra and then ejaculated from the urethra
  - In females, the uterus and outer vagina contract

- During the resolution phase, organs return to their normal state and muscles relax

Concept 46.4: The timing and pattern of meiosis in mammals differ for males and females

- **Gametogenesis**, the production of gametes by meiosis, differs in females and males
- Sperm are small and motile and are produced throughout the life of a sexually mature male
- **Spermatogenesis** is production of mature sperm

Fig. 46-12a

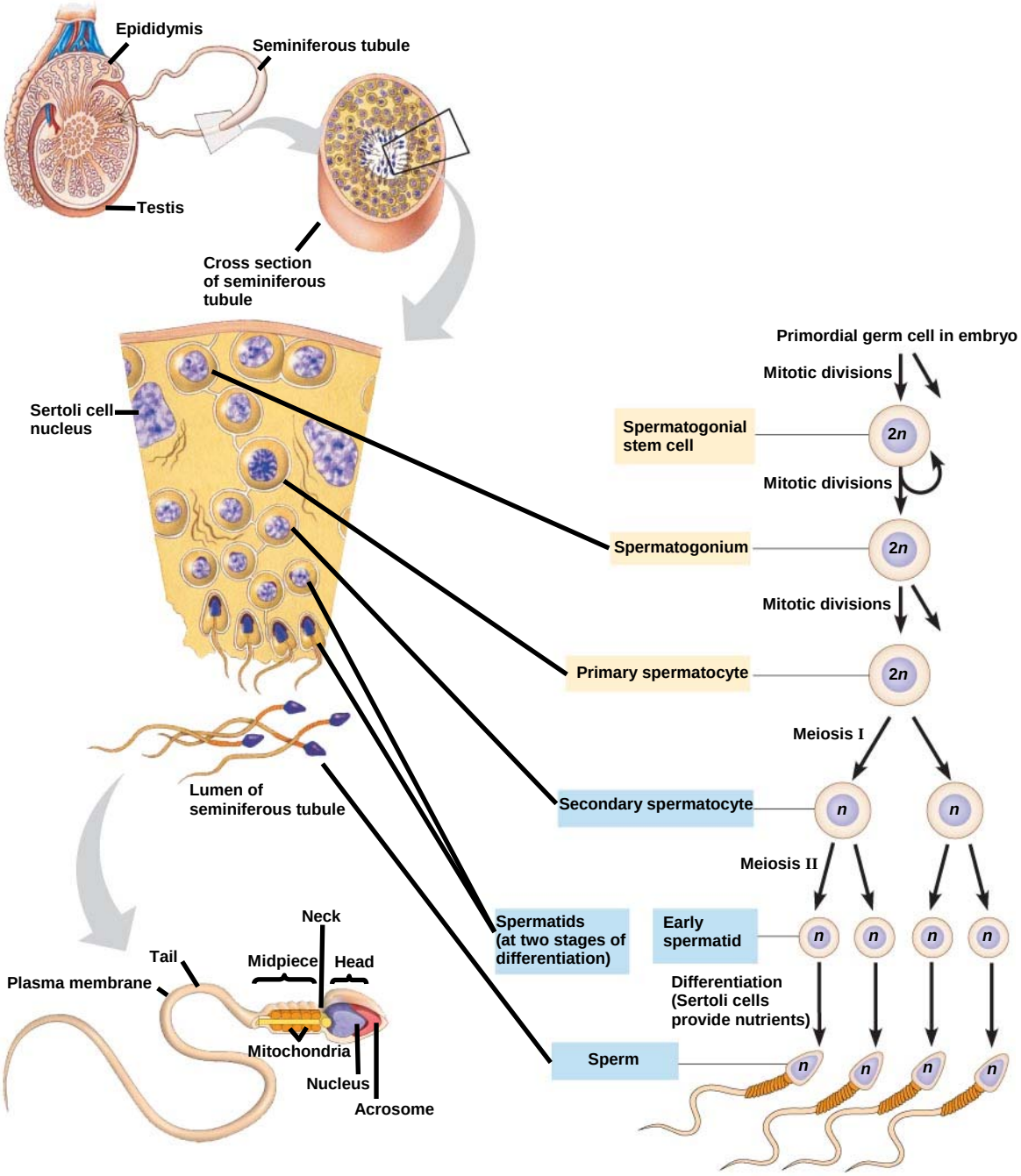


Fig. 46-12b

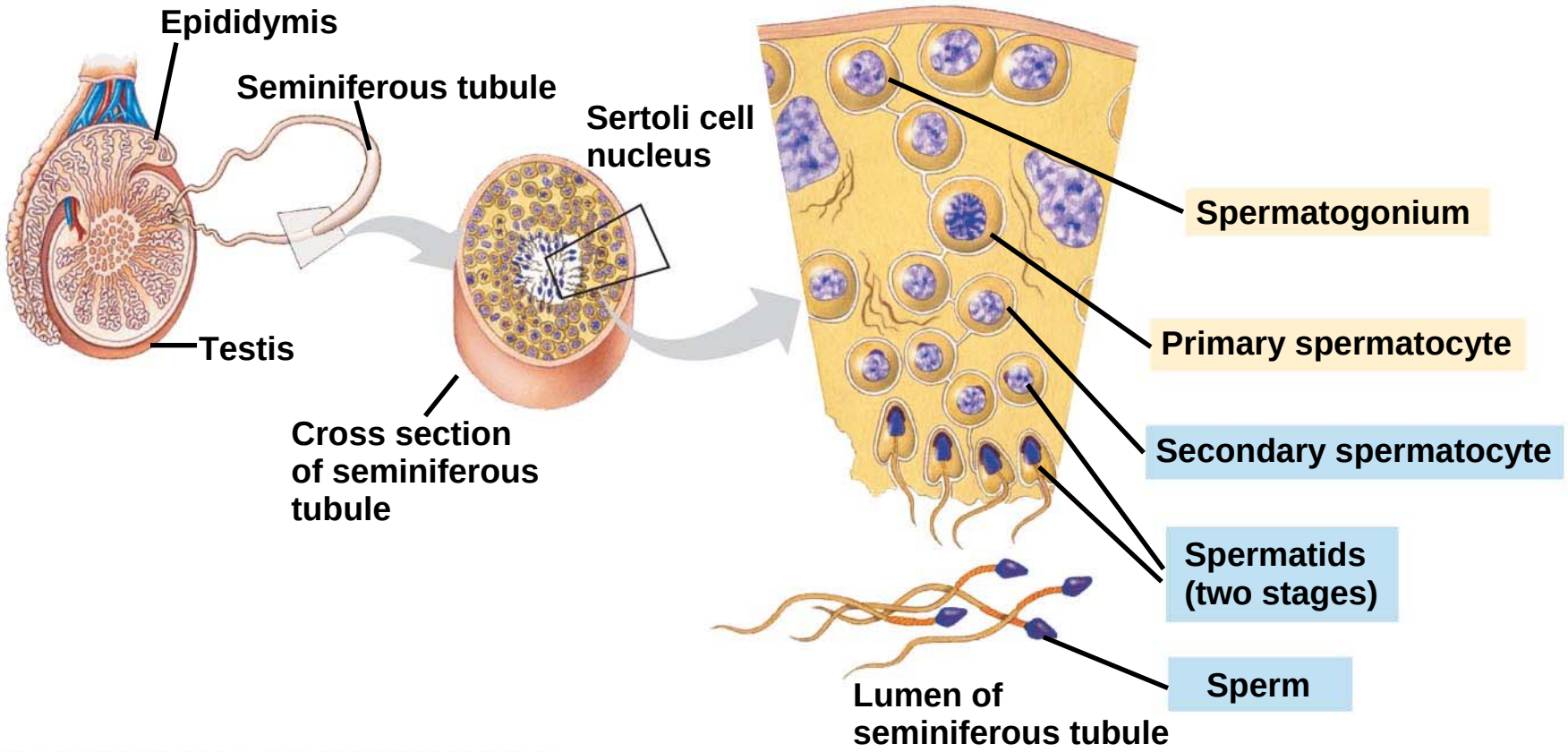


Fig. 46-12c

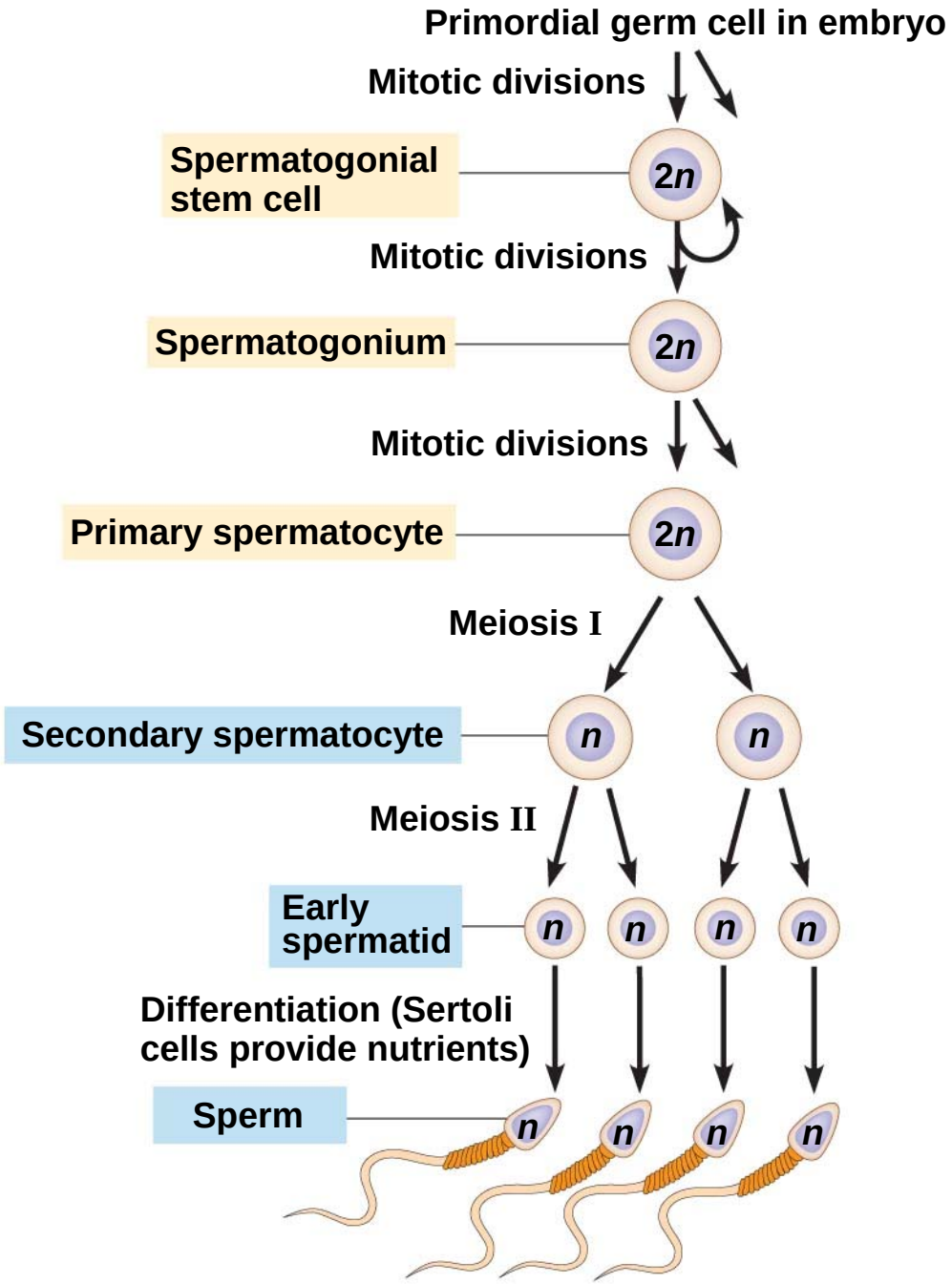
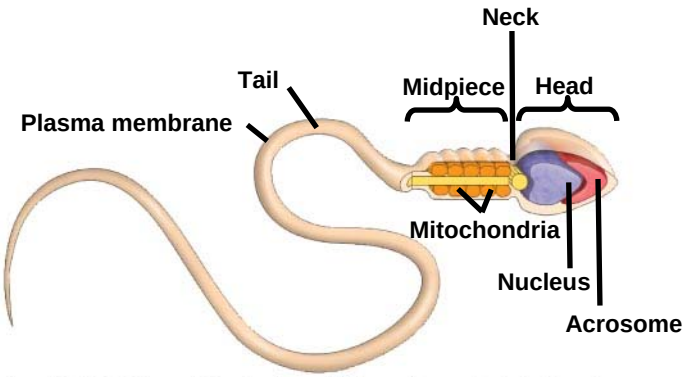


Fig. 46-12d



- Eggs contain stored nutrients and are much larger
- **Oogenesis** is development of mature oocytes (eggs) and can take many years

Fig. 46-12e

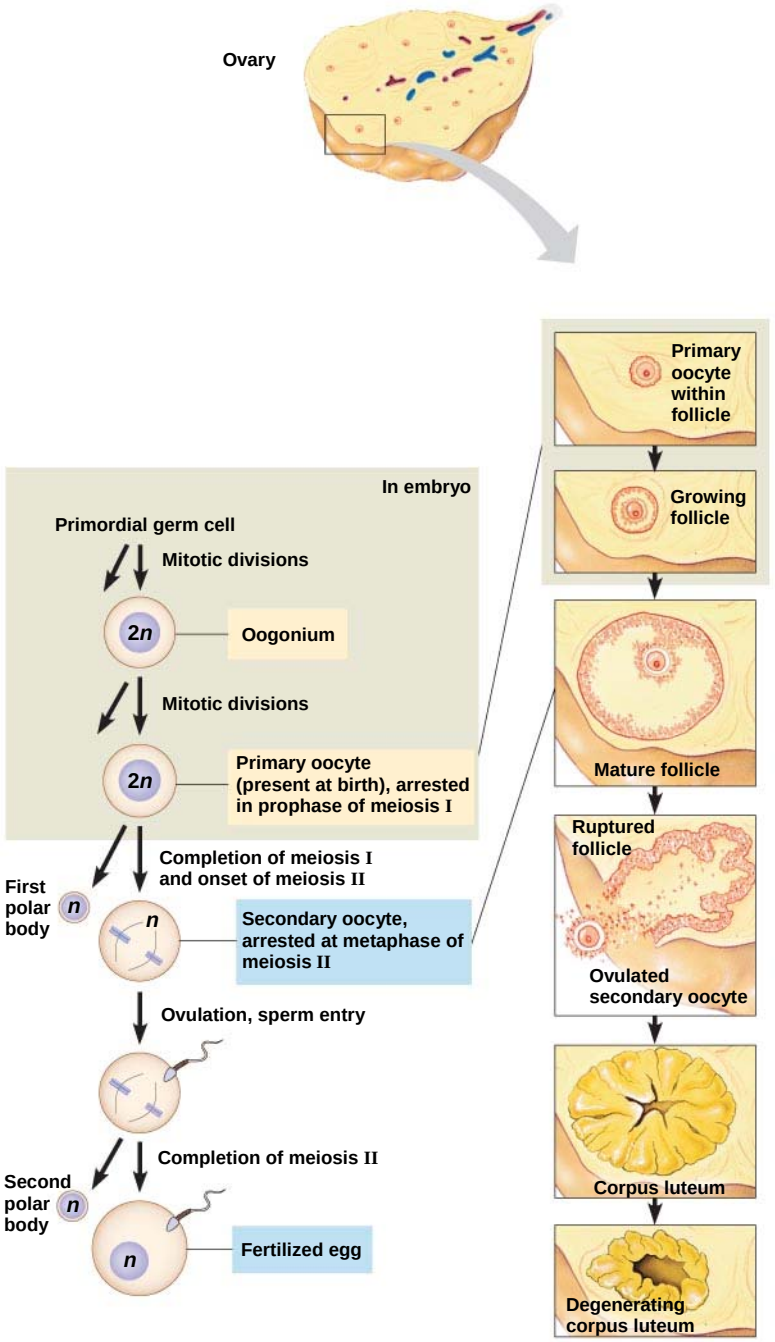


Fig. 46-12f

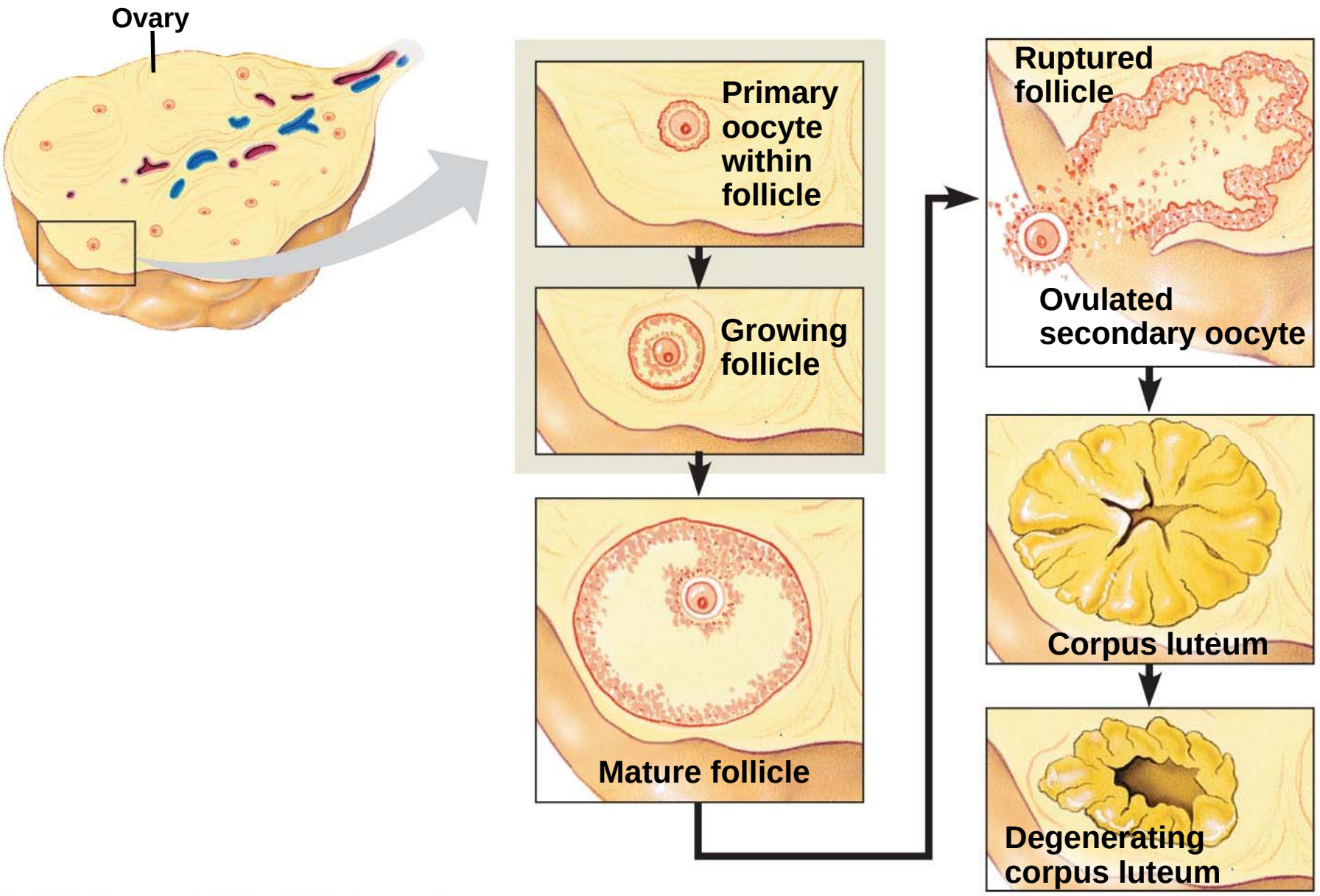
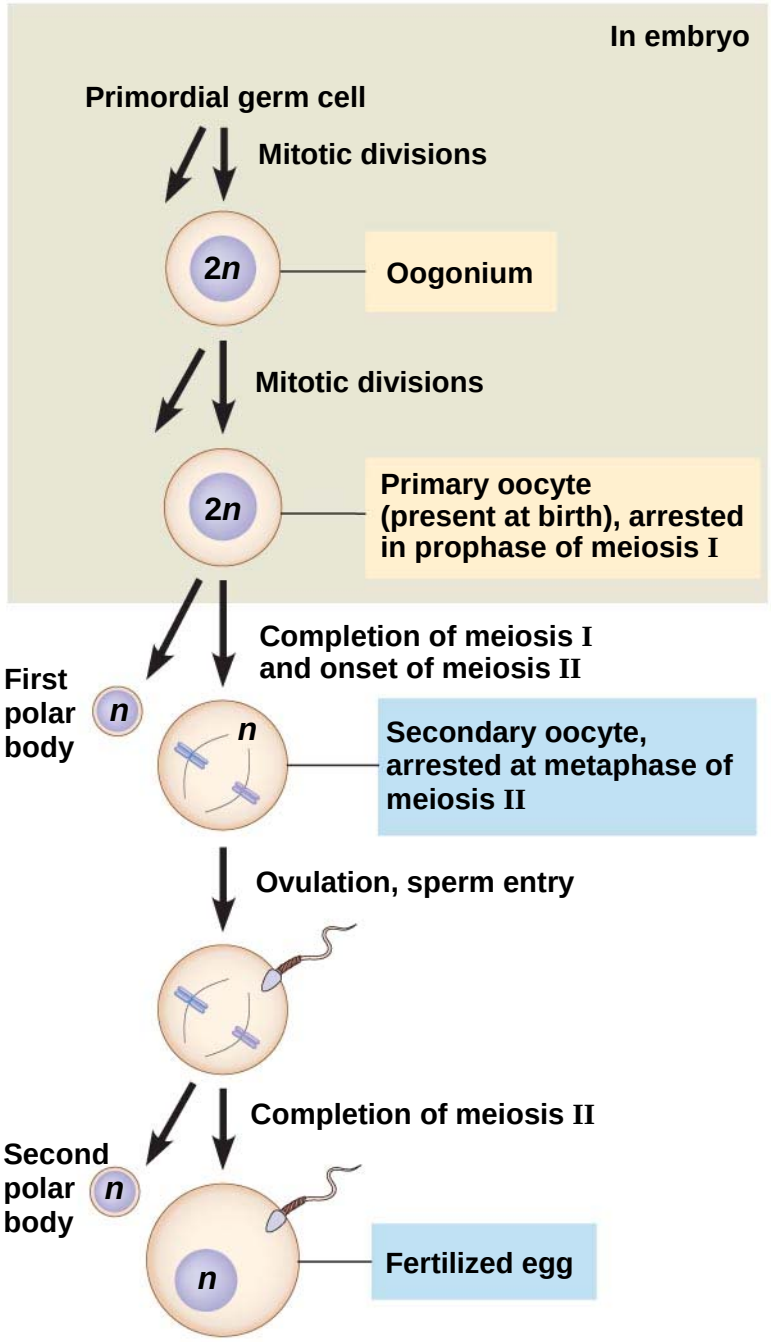


Fig. 46-12g



- Spermatogenesis differs from oogenesis:
  - In oogenesis, one egg forms from each cycle of meiosis; in spermatogenesis four sperm form from each cycle of meiosis
  - Oogenesis ceases later in life in females; spermatogenesis continues throughout the adult life of males
  - Oogenesis has long interruptions; spermatogenesis produces sperm from precursor cells in a continuous sequence

Concept 46.5: The interplay of tropic and sex hormones regulates mammalian reproduction

- Human reproduction is coordinated by hormones from the hypothalamus, anterior pituitary, and gonads
- Gonadotropin-releasing hormone (GnRH) is secreted by the hypothalamus and directs the release of FSH and LH from the anterior pituitary
- FSH and LH regulate processes in the gonads and the production of sex hormones

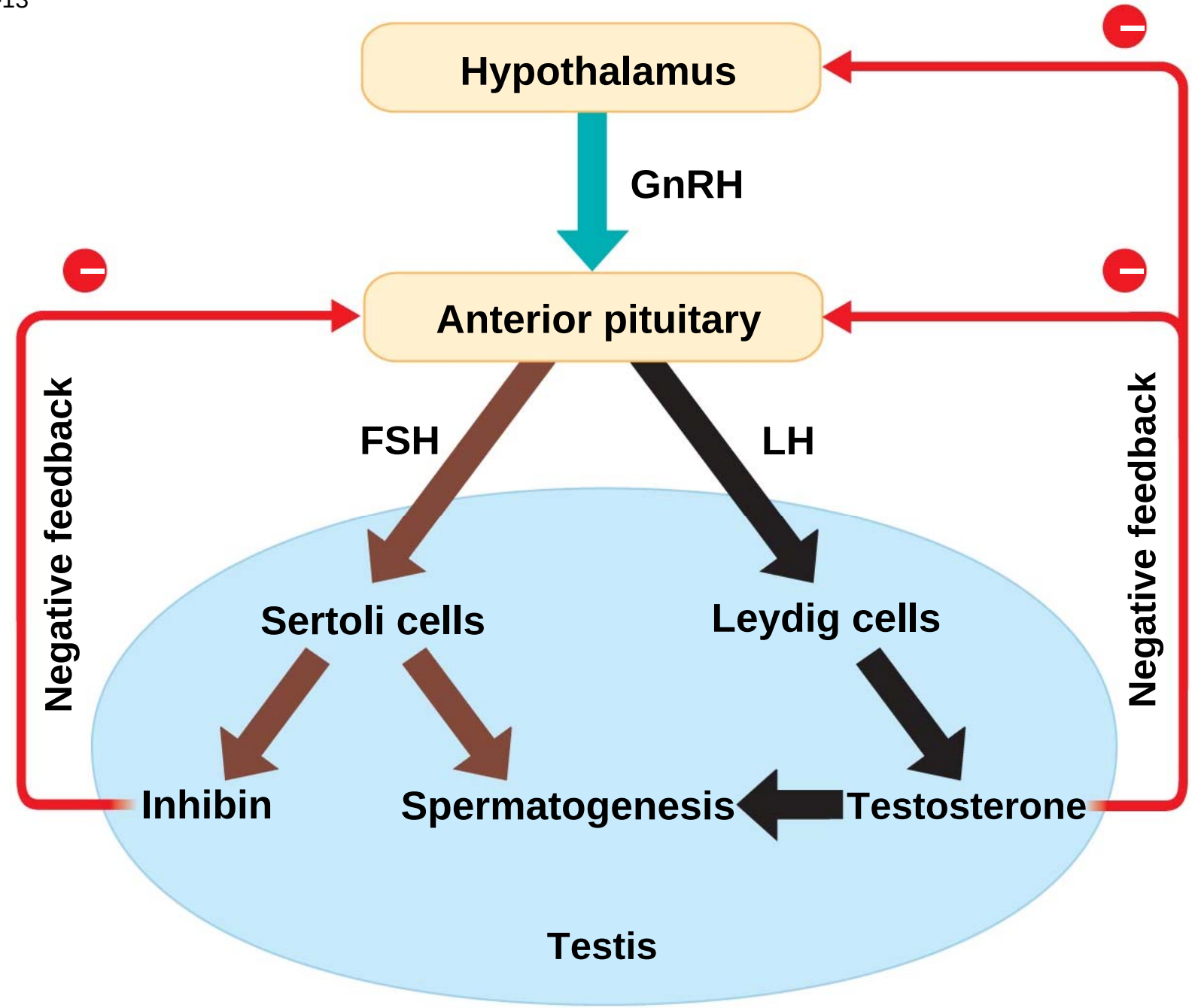
- The sex hormones are androgens, estrogens, and progesterone
- Sex hormones regulate:
  - The development of primary sex characteristics during embryogenesis
  - The development of secondary sex characteristics at puberty
  - Sexual behavior and sex drive

Hormonal Control of the Male Reproductive System

- FSH promotes the activity of Sertoli cells, which nourish developing sperm and are located within the seminiferous tubules
- LH regulates Leydig cells, which secrete testosterone and other androgen hormones, which in turn promote spermatogenesis

PLAY Animation: Male Hormones

Fig. 46-13



- Testosterone regulates the production of GnRH, FSH, and LH through negative feedback mechanisms
- Sertoli cells secrete the hormone **inhibin**, which reduces FSH secretion from the anterior pituitary

The Reproductive Cycles of Females

- In females, the secretion of hormones and the reproductive events they regulate are cyclic
- Prior to ovulation, the endometrium thickens with blood vessels in preparation for embryo implantation
- If an embryo does not implant in the endometrium, the endometrium is shed in a process called **menstruation**

- Hormones closely link the two cycles of female reproduction:
  - Changes in the uterus define the **menstrual cycle** (also called the **uterine cycle**)
  - Changes in the ovaries define the **ovarian cycle**

Fig. 46-14

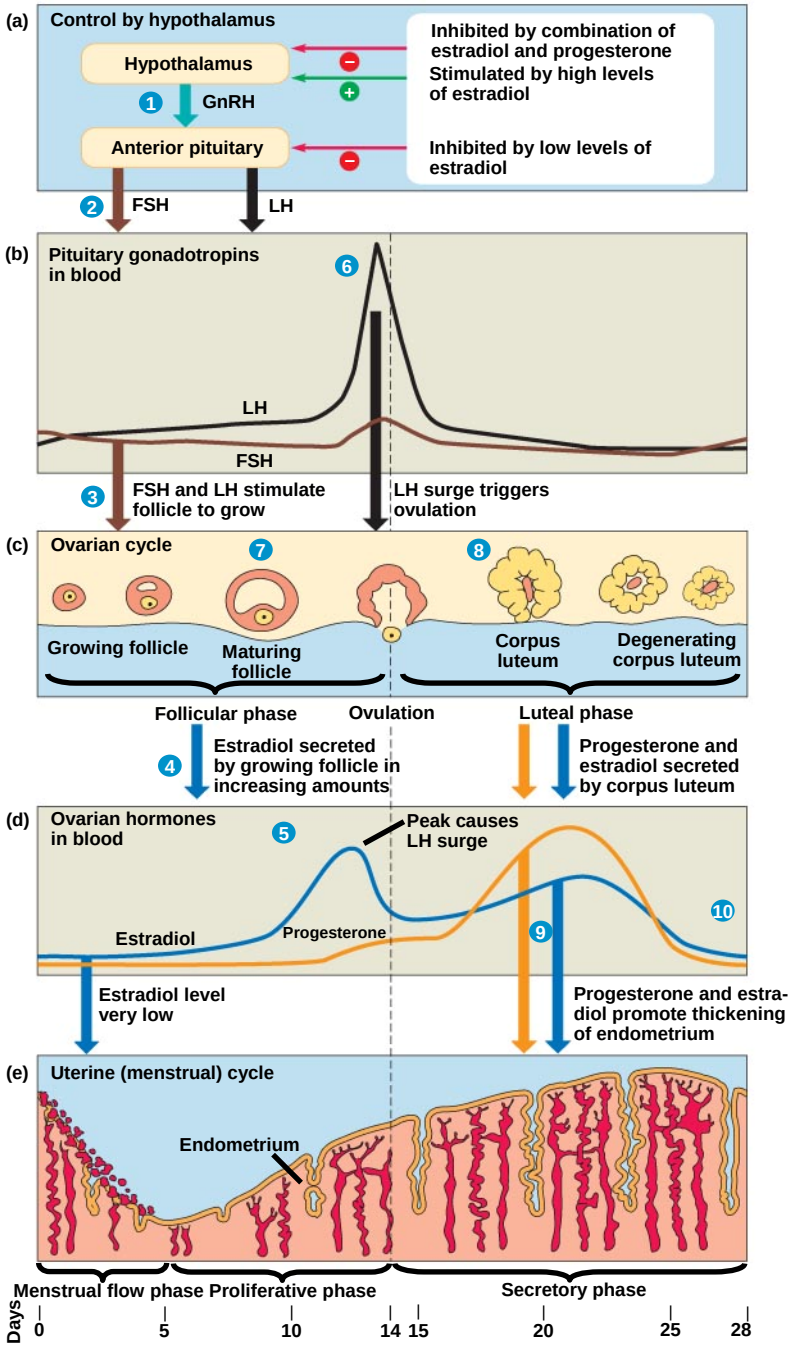


Fig. 46-14a

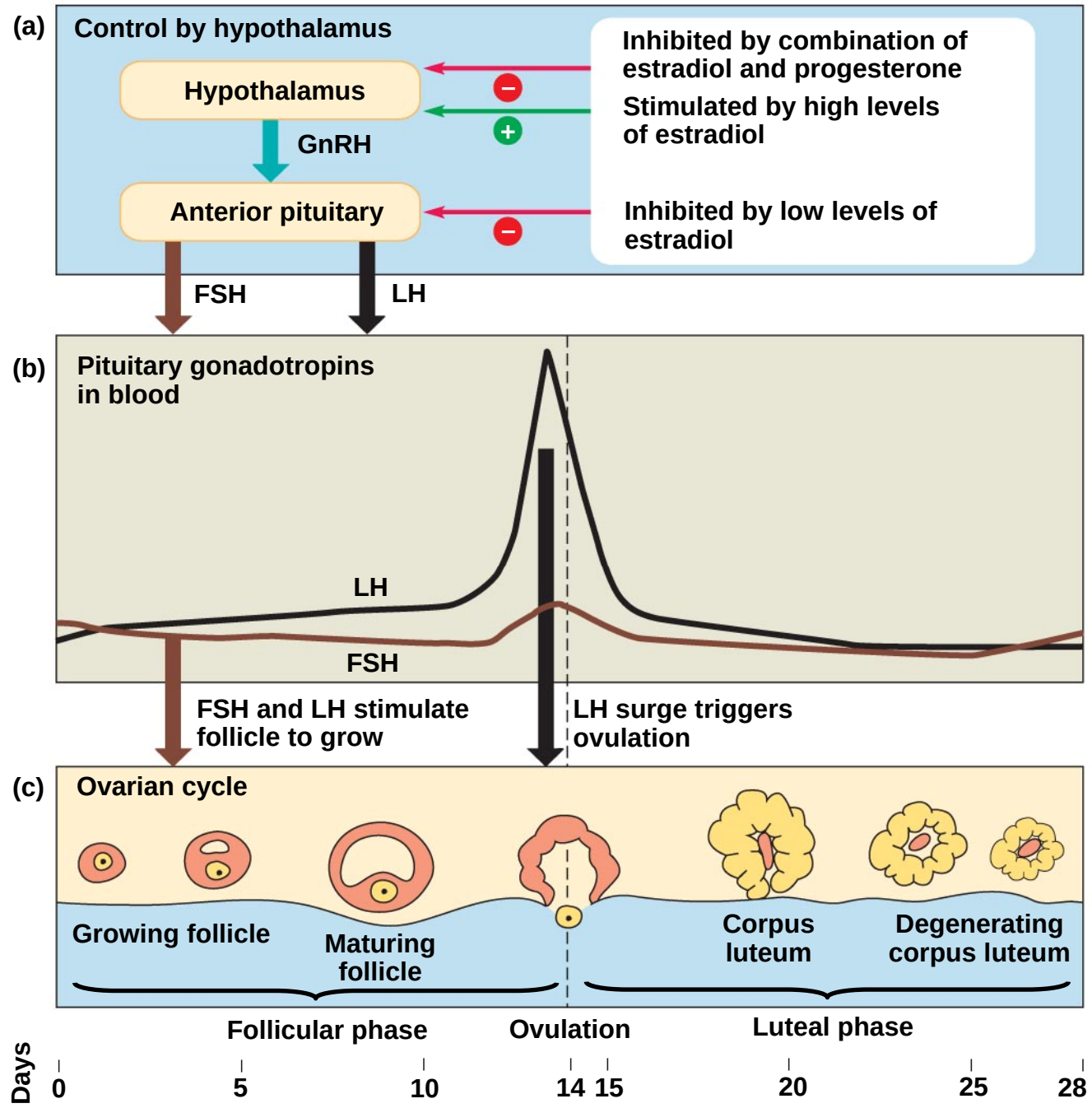
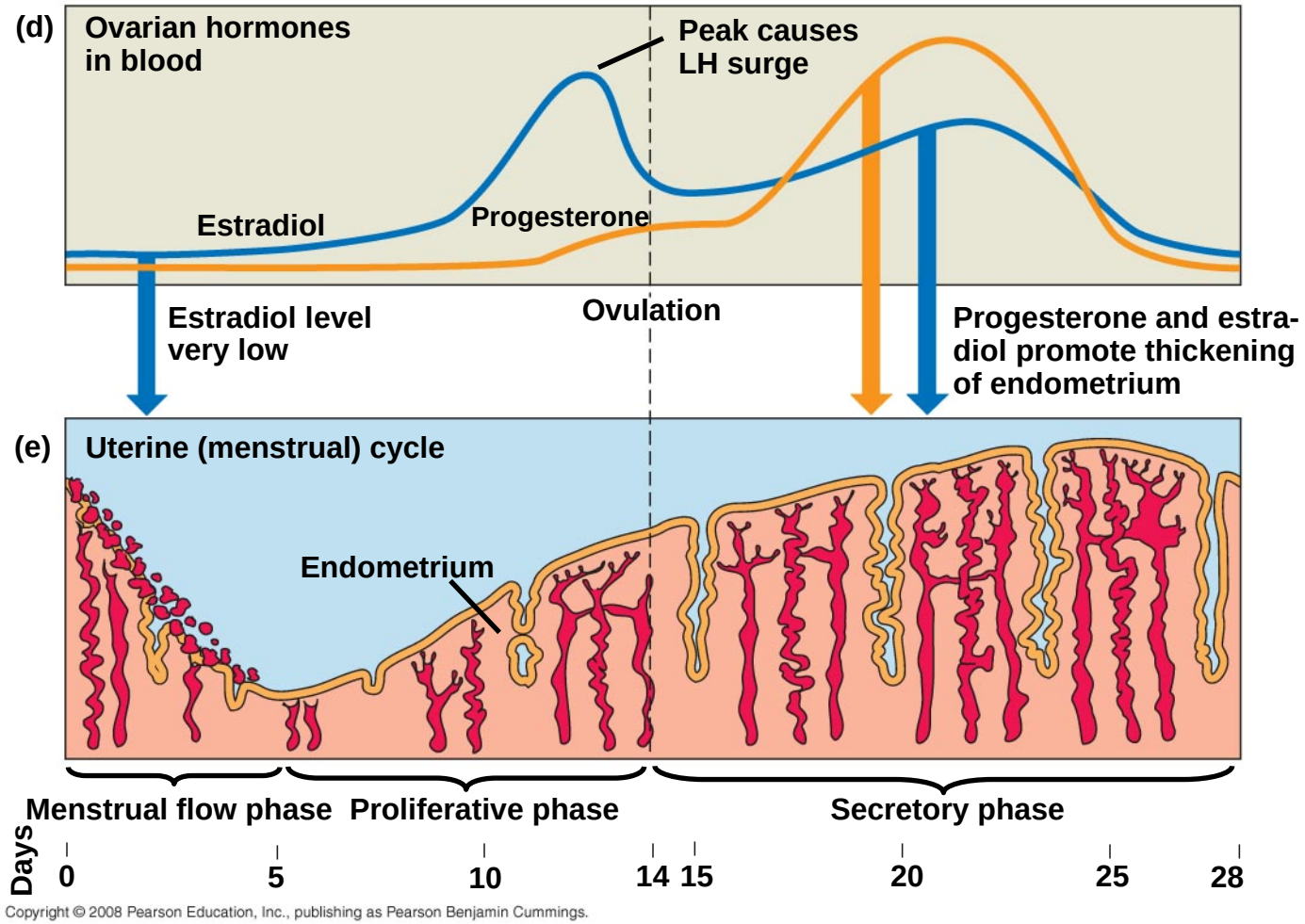


Fig. 46-14b



The Ovarian Cycle

- The sequential release of GnRH then FSH and LH stimulates follicle growth
- Follicle growth and an increase in the hormone estradiol characterize the **follicular phase** of the ovarian cycle
- The follicular phase ends at ovulation, and the secondary oocyte is released

PLAY Animation: Ovulation

- Following ovulation, the follicular tissue left behind transforms into the corpus luteum; this is the **luteal phase**
- The corpus luteum disintegrates, and ovarian steroid hormones decrease

PLAY Animation: Post Ovulation

The Uterine (Menstrual) Cycle

- Hormones coordinate the uterine cycle with the ovarian cycle
  - Thickening of the endometrium during the **proliferative phase** coordinates with the follicular phase
  - Secretion of nutrients during the **secretory phase** coordinates with the luteal phase
  - Shedding of the endometrium during the **menstrual flow phase** coordinates with the growth of new ovarian follicles

- A new cycle begins if no embryo implants in the endometrium
- Cells of the uterine lining can sometimes migrate to an abnormal, or **ectopic**, location
- Swelling of these cells in response to hormone stimulation results in a disorder called **endometriosis**

Menopause

- After about 500 cycles, human females undergo **menopause**, the cessation of ovulation and menstruation
- Menopause is very unusual among animals
- Menopause might have evolved to allow a mother to provide better care for her children and grandchildren

Menstrual Versus Estrous Cycles

- Menstrual cycles are characteristic of humans and some other primates:
  - The endometrium is shed from the uterus in a bleeding called menstruation
  - Sexual receptivity is not limited to a timeframe

- **Estrous cycles** are characteristic of most mammals:
  - The endometrium is reabsorbed by the uterus
  - Sexual receptivity is limited to a “heat” period
  - The length and frequency of estrus cycles varies from species to species

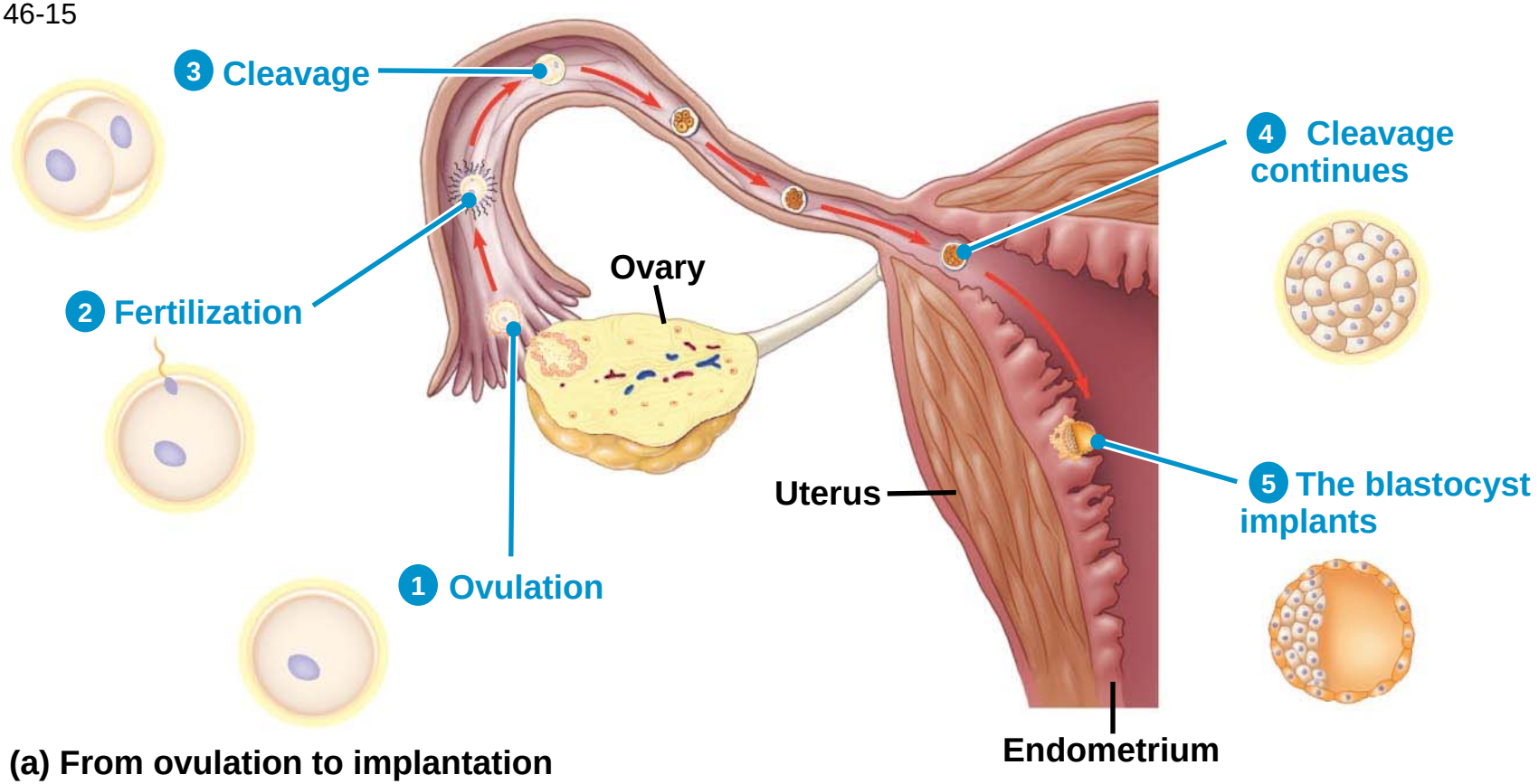
Concept 46.6: In placental mammals, an embryo develops fully within the mother's uterus

- An egg develops into an embryo in a series of predictable events

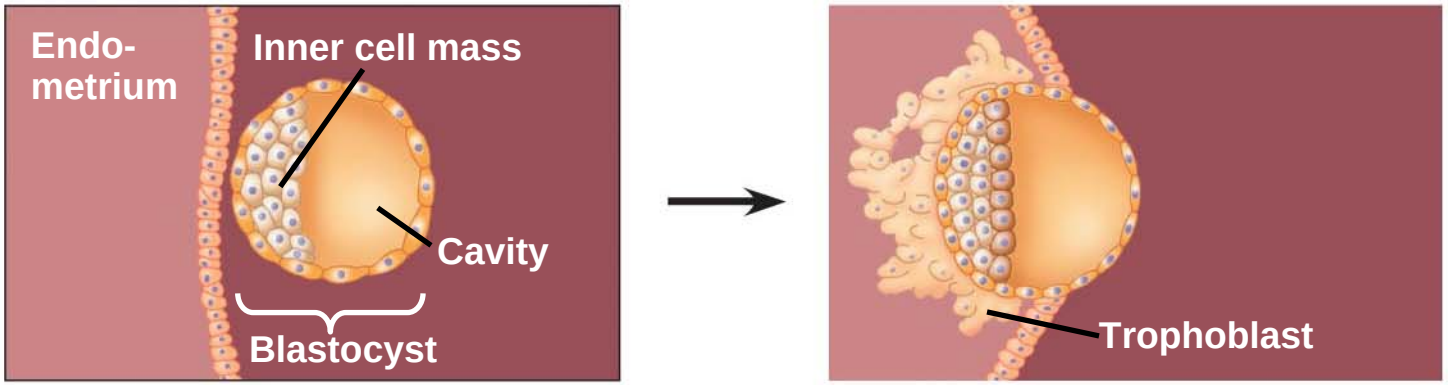
Conception, Embryonic Development, and Birth

- **Conception**, fertilization of an egg by a sperm, occurs in the oviduct
- The resulting zygote begins to divide by mitosis in a process called **cleavage**
- Division of cells gives rise to a **blastocyst**, a ball of cells with a cavity

Fig. 46-15



(a) From ovulation to implantation



(b) Implantation of blastocyst

- After blastocyst formation, the embryo implants into the endometrium
- The embryo releases **human chorionic gonadotropin (hCG),** which prevents menstruation
- **Pregnancy**, or **gestation**, is the condition of carrying one or more embryos in the uterus
- Duration of pregnancy in other species correlates with body size and maturity of the young at birth

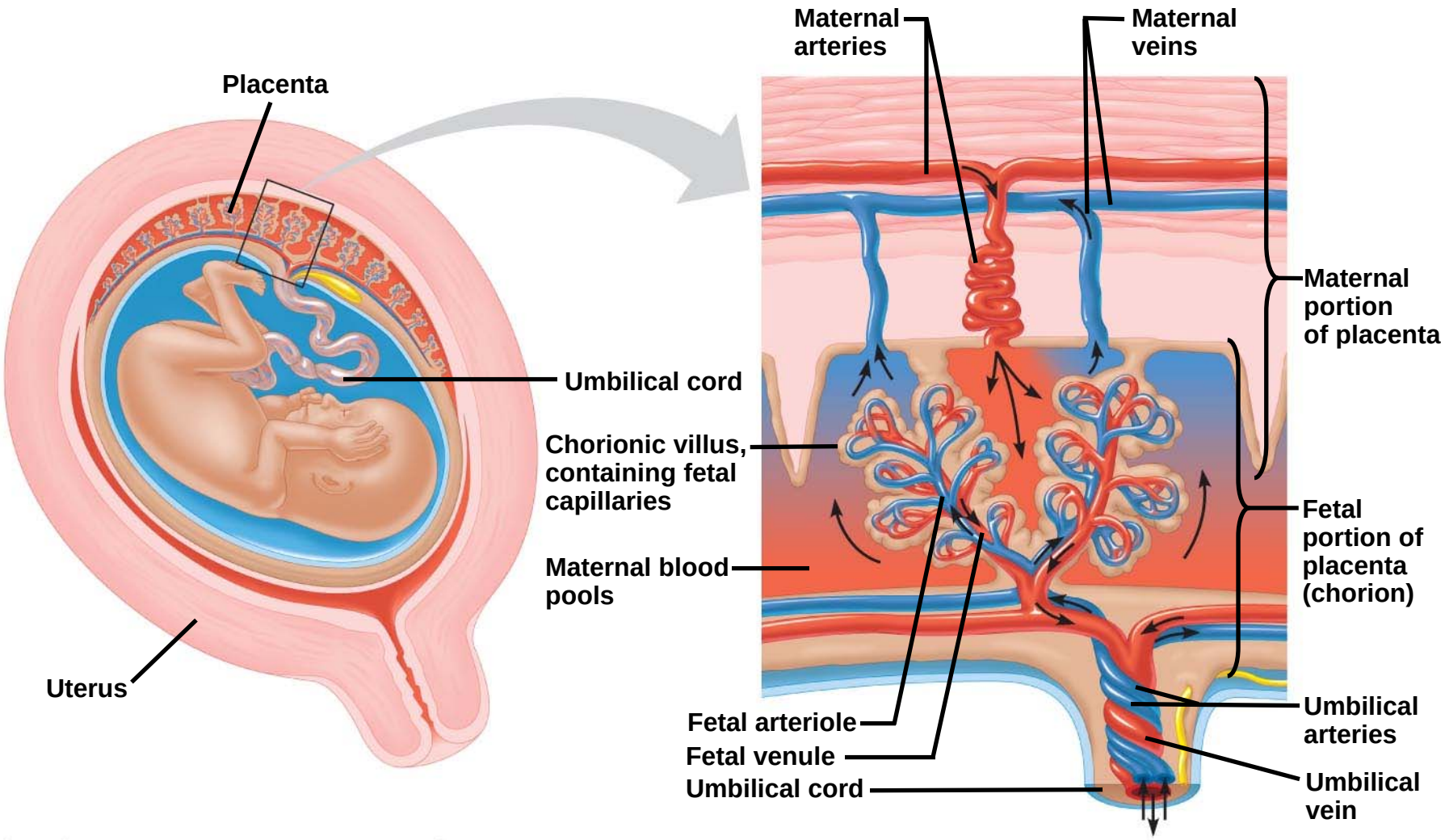
- Pregnancies can terminate spontaneously due to chromosomal or developmental abnormalities
- An ectopic pregnancy occurs when a fertilized egg begins to develop in the fallopian tube

First Trimester

- Human gestation can be divided into three **trimesters** of about three months each
- The first trimester is the time of most radical change for both the mother and the embryo
- During implantation, the endometrium grows over the blastocyst

- During its first 2 to 4 weeks, the embryo obtains nutrients directly from the endometrium
- Meanwhile, the outer layer of the blastocyst, called the **trophoblast**, mingles with the endometrium and eventually forms the **placenta**
- Blood from the embryo travels to the placenta through arteries of the umbilical cord and returns via the umbilical vein

Fig. 46-16



- Splitting of the embryo during the first month of development results in genetically identical twins
- Release and fertilization of two eggs results in fraternal and genetically distinct twins

- The first trimester is the main period of **organogenesis**, development of the body organs
- All the major structures are present by 8 weeks, and the embryo is called a **fetus**

- Changes occur in the mother
  - Growth of the placenta
  - Cessation of ovulation and the menstrual cycle
  - Breast enlargement
  - Nausea is also very common

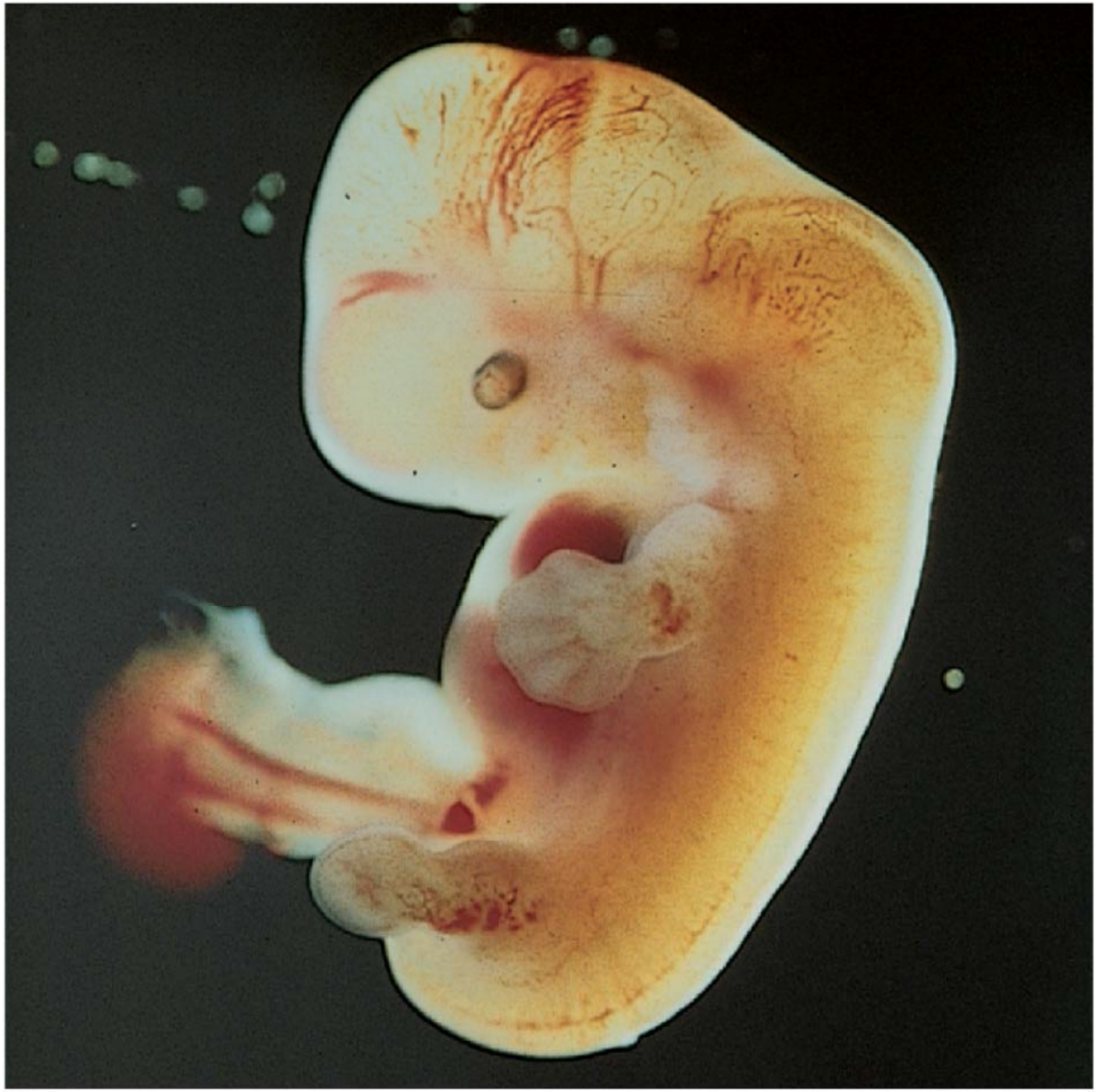
Fig. 46-17

(a) 5 weeks

(b) 14 weeks

(c) 20 weeks

Fig. 46-17a

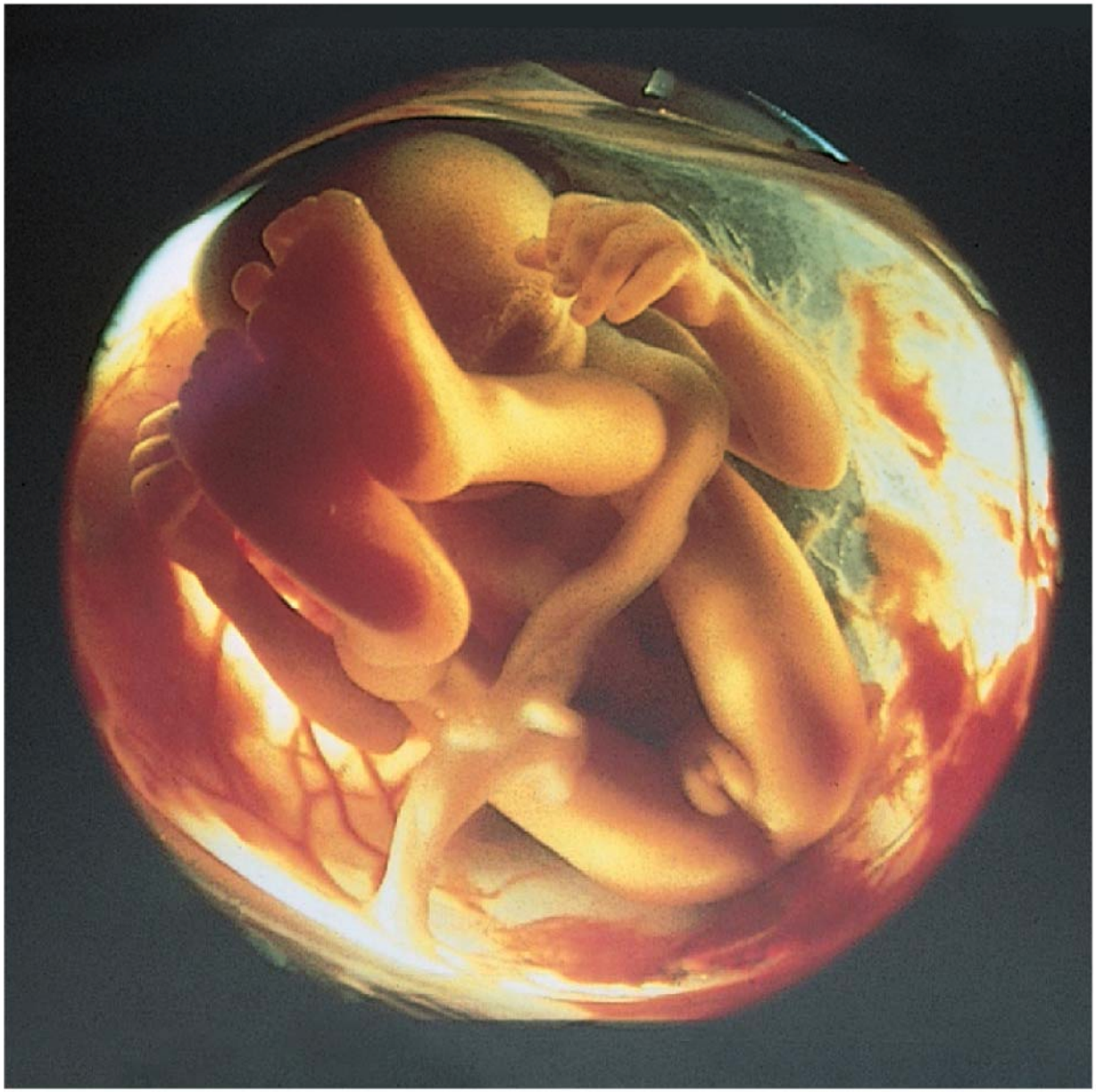


(a) 5 weeks

Fig. 46-17b

(b) 14 weeks

Fig. 46-17c



(c) 20 weeks

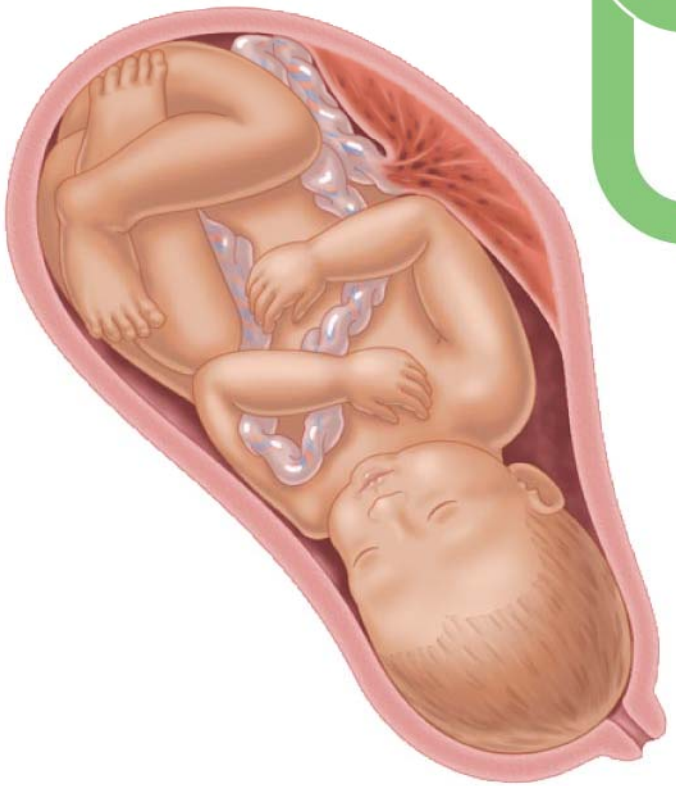
Second Trimester

- During the second trimester
  - The fetus grows and is very active
  - The mother may feel fetal movements
  - The uterus grows enough for the pregnancy to become obvious

Third Trimester

- During the third trimester, the fetus grows and fills the space within the embryonic membranes
- A complex interplay of local regulators and hormones induces and regulates **labor**, the process by which childbirth occurs

Fig. 46-18



Estradiol

from ovaries

Induces oxytocin receptors on uterus

Oxytocin

from fetus and mother's posterior pituitary

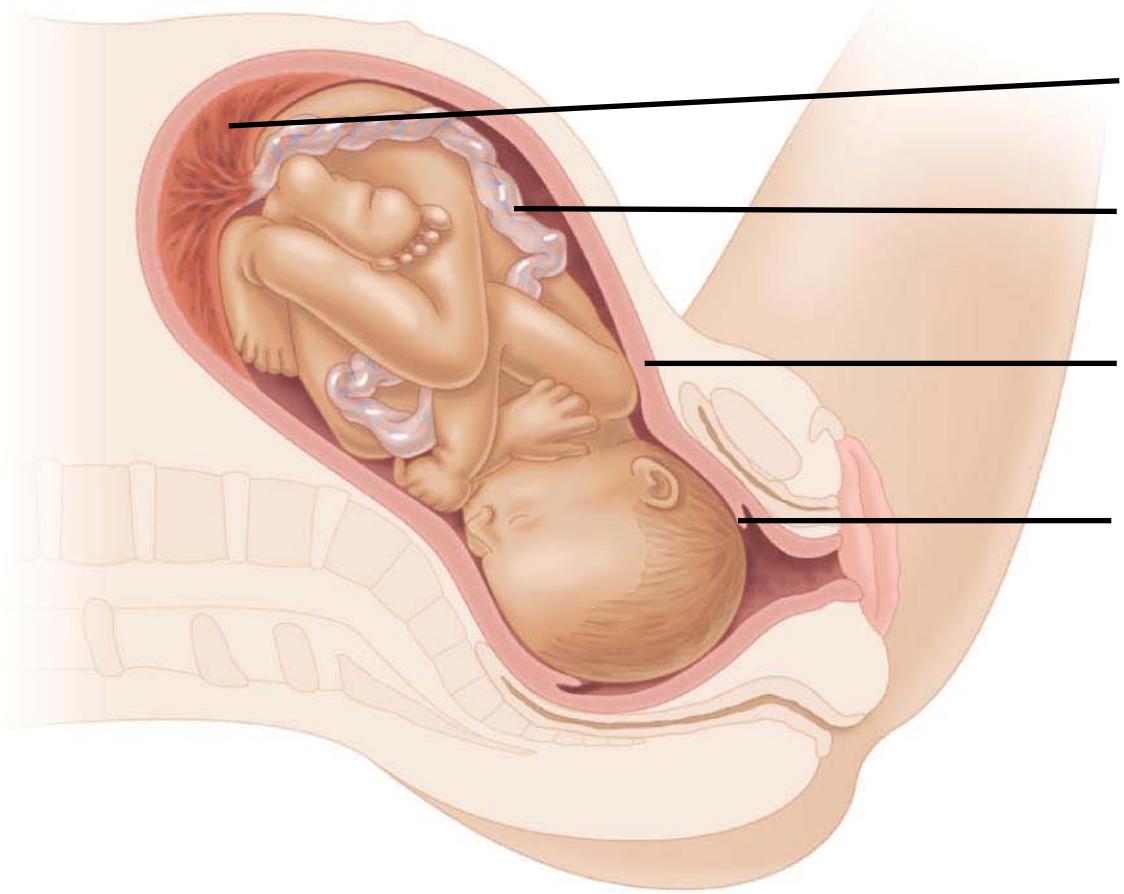
Stimulates uterus to contract

Stimulates placenta to make Prostaglandins

Stimulate more contractions of uterus

Positive feedback

Fig. 46-19-1



Placenta

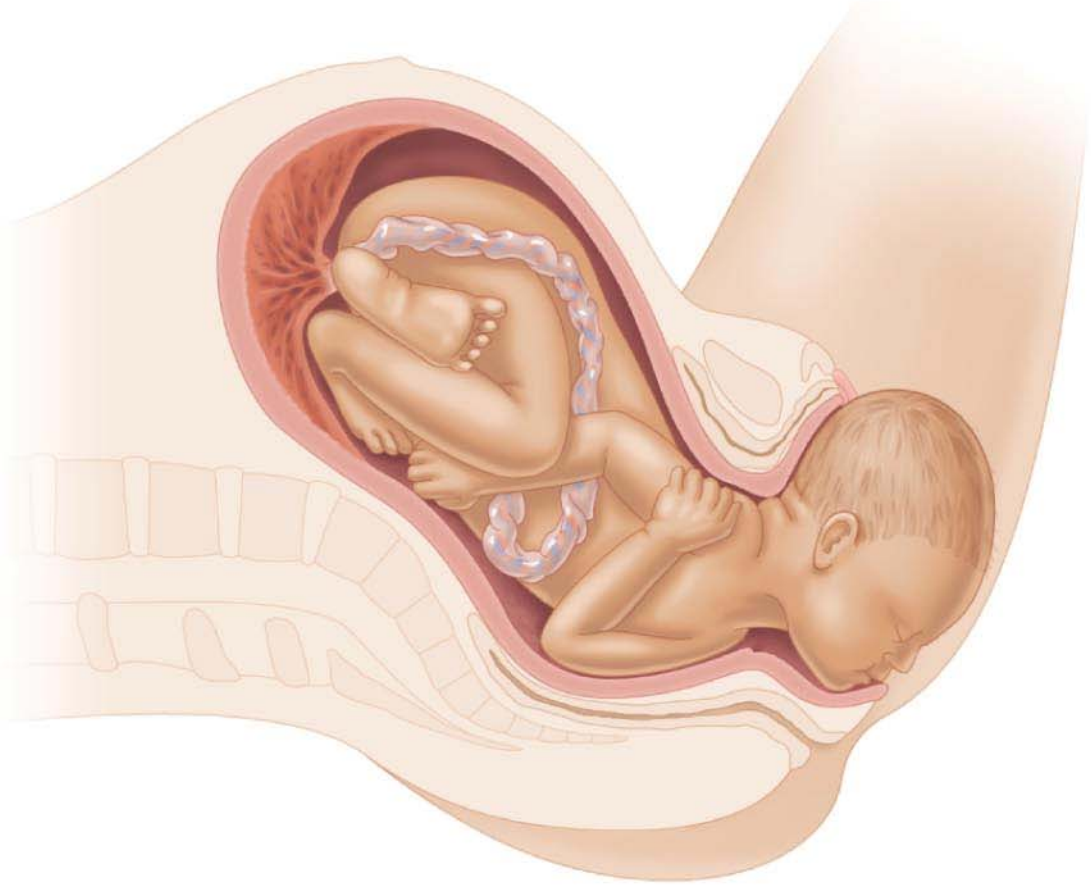
Umbilical cord

Uterus

Cervix

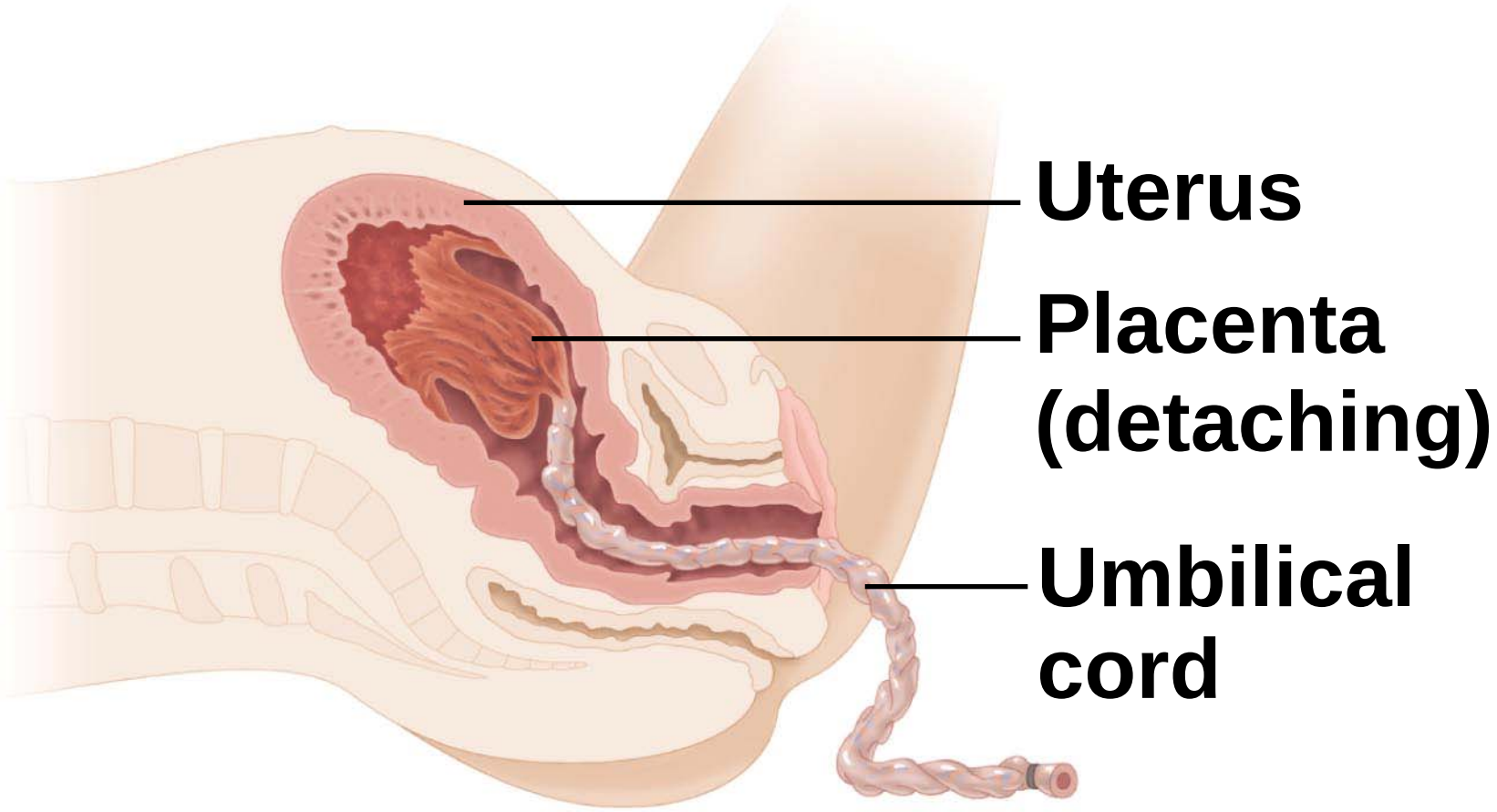
1 Dilation of the cervix

Fig. 46-19-2



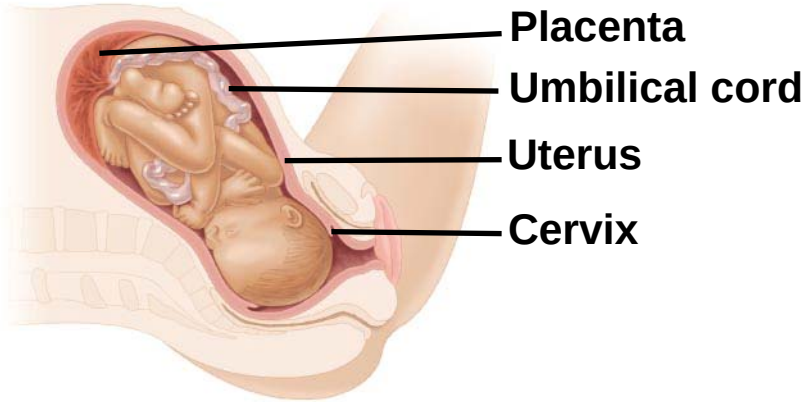
❷ Expulsion: delivery of the infant

Fig. 46-19-3



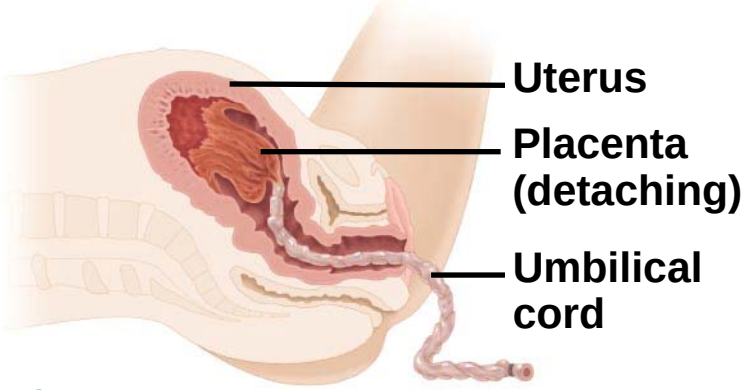
❸ Delivery of the placenta

Fig. 46-19-4



1 Dilation of the cervix

2 Expulsion: delivery of the infant



3 Delivery of the placenta

- Birth, or parturition, is brought about by a series of strong, rhythmic uterine contractions
- First the baby is delivered, and then the placenta
- **Lactation**, the production of milk, is unique to mammals

Maternal Immune Tolerance of the Embryo and Fetus

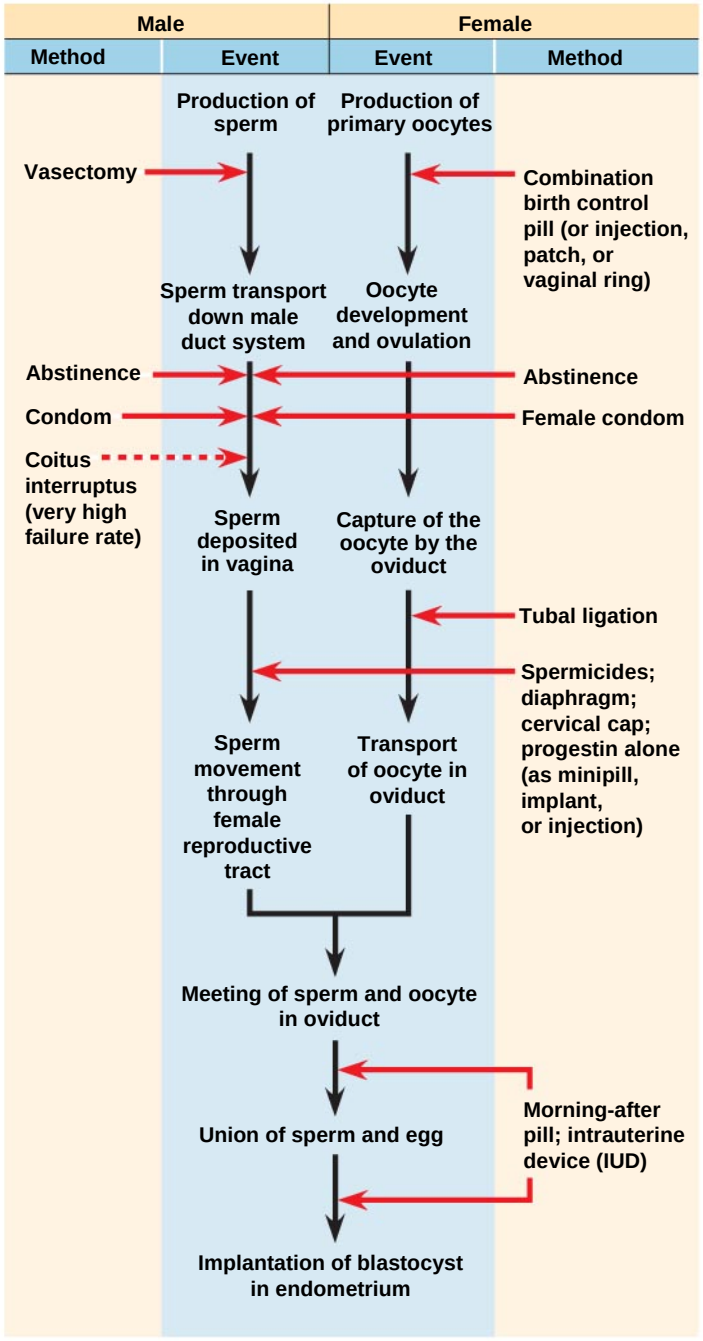
- A woman's acceptance of her "foreign" offspring is not fully understood
- It may be due to suppression of the immune response in her uterus

Contraception and Abortion

- **Contraception**, the deliberate prevention of pregnancy, can be achieved in a number of ways
- Contraceptive methods fall into three categories:
  - Preventing release of eggs and sperm
  - Keeping sperm and egg apart
  - Preventing implantation of an embryo

- A health-care provider should be consulted for complete information on the choice and risks of contraception methods

Fig. 46-20



- The **rhythm method**, or **natural family planning**, is to refrain from intercourse when conception is most likely; it has a pregnancy rate of 10–20%
- Coitus interruptus, the withdrawal of the penis before ejaculation, is unreliable
- **Barrier methods** block fertilization with a pregnancy rate of less than 10%
  - A **condom** fits over the penis
  - A **diaphragm** is inserted into the vagina before intercourse

- Intrauterine devices are inserted into the uterus and interfere with fertilization and implantation; the pregnancy rate is less than 1%
- Female **birth control pills** are hormonal contraceptives with a pregnancy rate of less than 1%

- Sterilization is permanent and prevents the release of gametes
  - **Tubal ligation** ties off the oviducts
  - **Vasectomy** ties off the vas deferens
- **Abortion** is the termination of a pregnancy
- Spontaneous abortion, or miscarriage, occurs in up to one-third of all pregnancies
- The drug RU486 results in an abortion within the first 7 weeks of a pregnancy

Modern Reproductive Technologies

- Recent advances are addressing reproductive problems

Detecting Disorders During Pregnancy

- Amniocentesis and chorionic villus sampling are invasive techniques in which amniotic fluid or fetal cells are obtained for genetic analysis
- Noninvasive procedures usually use ultrasound imaging to detect fetal condition
- Genetic testing of the fetus poses ethical questions and can present parents with difficult decisions

Treating Infertility

- Modern technology can provide infertile couples with **assisted reproductive technologies**
- ***In vitro* fertilization (IVF)** mixes eggs with sperm in culture dishes and returns the embryo to the uterus at the 8 cell stage
- Sperm are injected directly into an egg in a type of IVF called **intracytoplasmic sperm injection (ICSI)**

PLAY Video: Ultrasound of Human Fetus 1

PLAY Video: Ultrasound of Human Fetus 2

Fig. 46-UN1

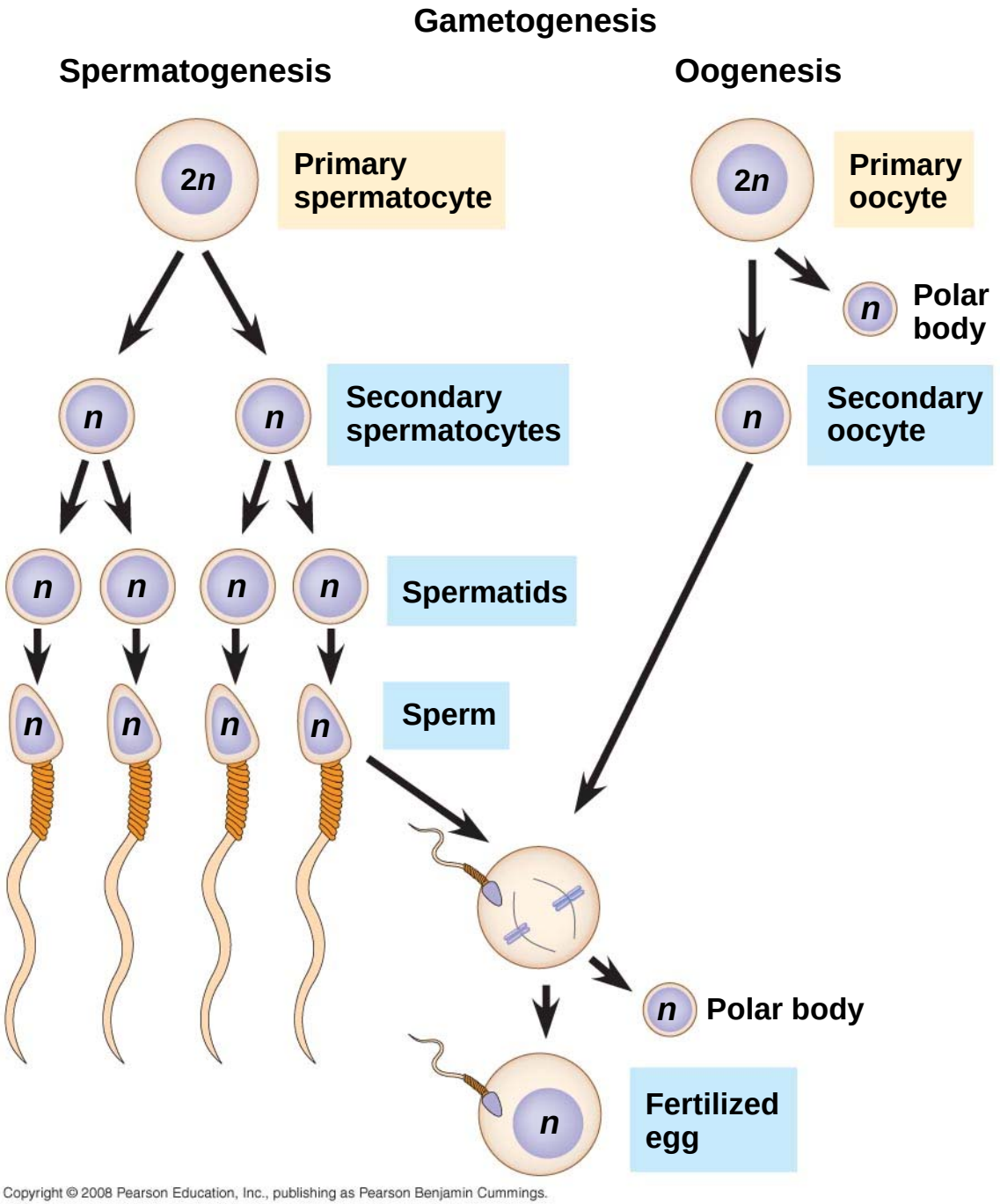
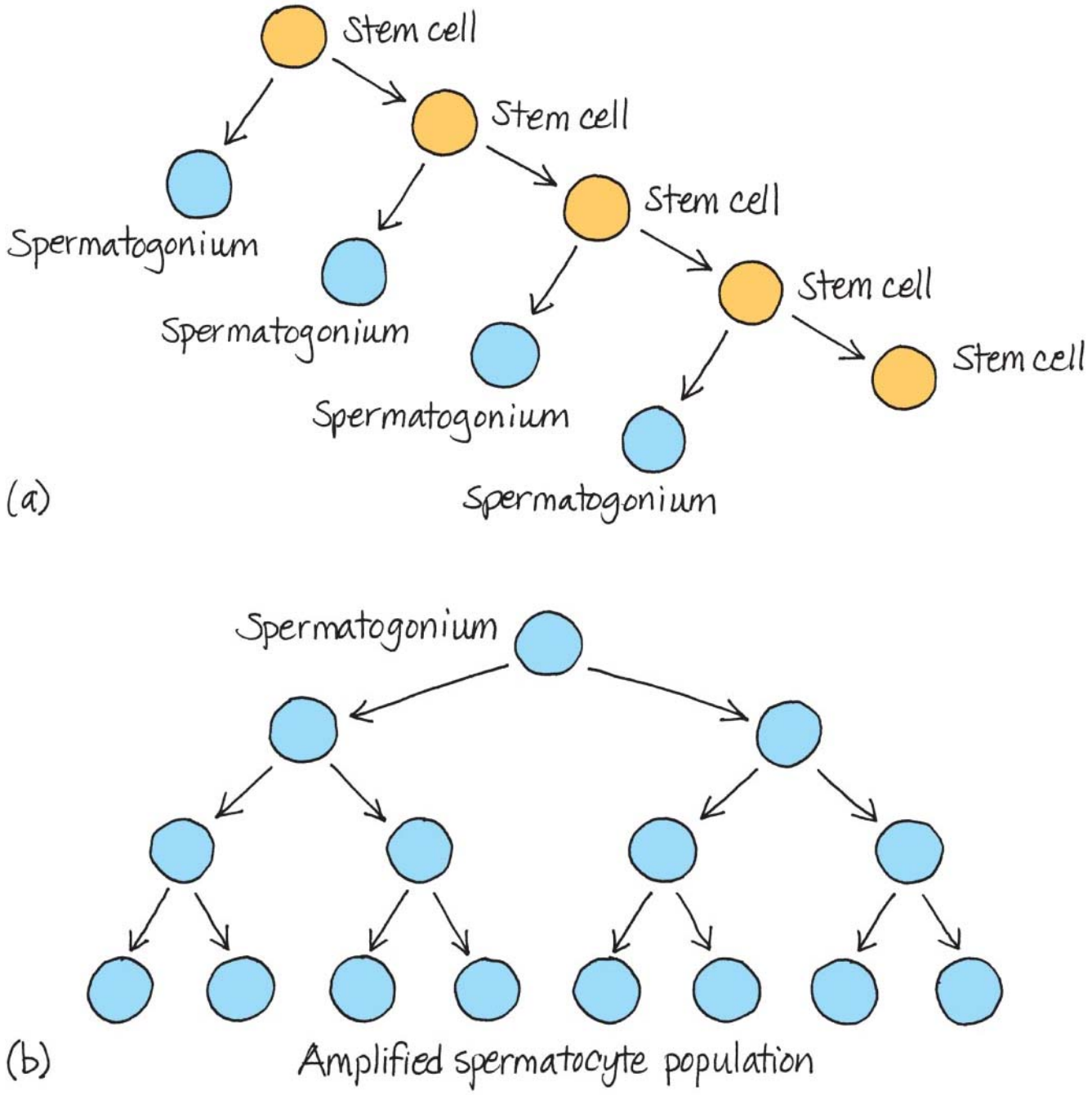


Fig. 46-UN2



You should now be able to:

1. Distinguish between asexual and sexual reproduction
2. Explain how hermaphroditism may be advantageous to animals that have difficulty encountering a member of the opposite sex
3. Describe various ways in which animals may protect developing embryos
4. Using diagrams, identify and state the function of each component of the male and female reproductive systems

5. Describe oogenesis and spermatogenesis; describe three major differences between them

6. Explain how the uterine and ovarian cycles are synchronized and describe the functions of the hormones involved

7. List the various methods of contraception, how each works, and how effective each is

8. Describe techniques that allow us to learn about the health and genetics of a fetus