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.

How can each of these earthworms be both male and female?

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 . One parent *clones* offspring.
- Many invertebrates reproduce asexually by ***fission*** = *separation of a parent into two or more individuals of about the same size*.

Asexual reproduction of a sea anemone

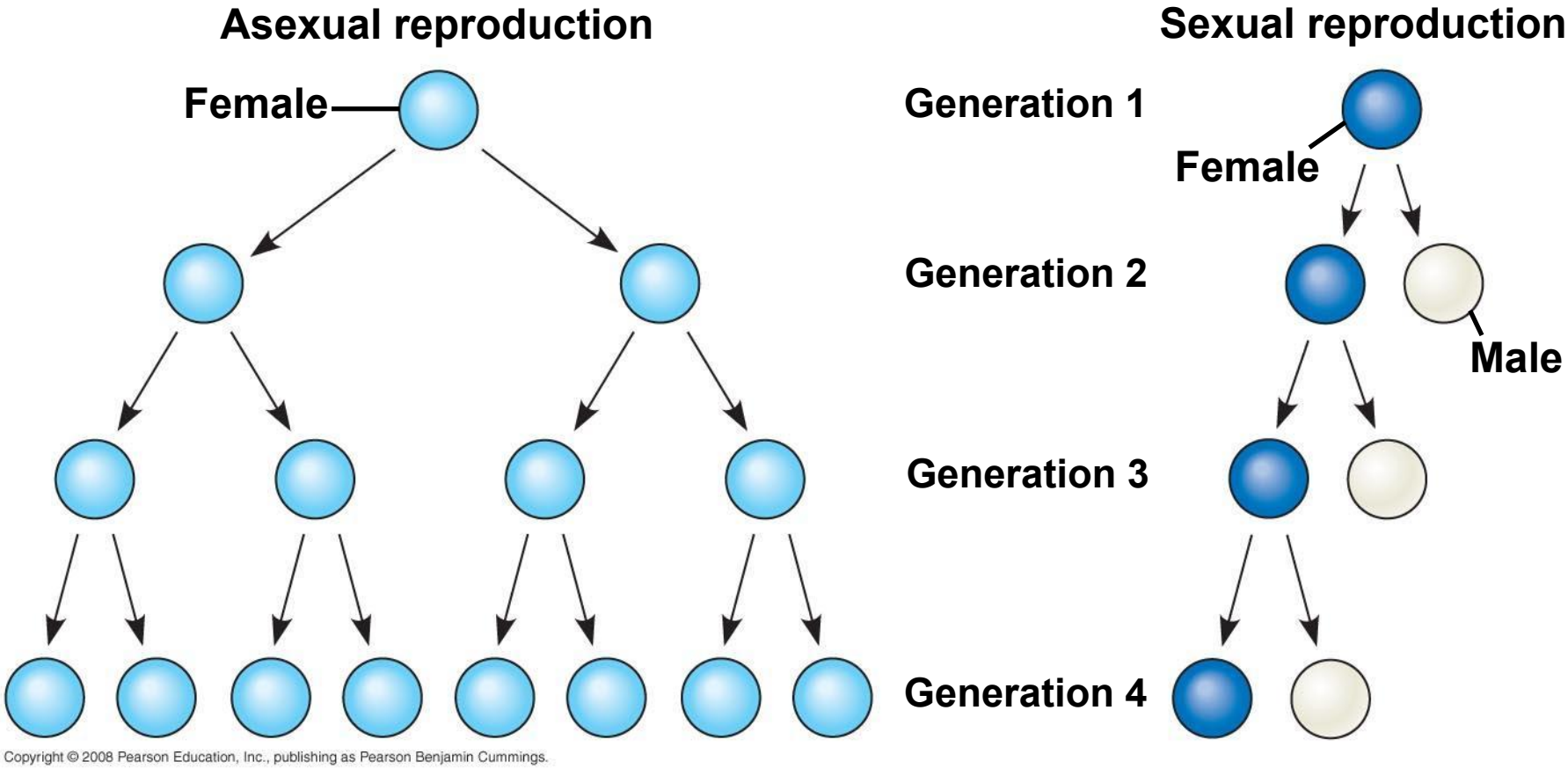
Asexual Reproduction

- ***Budding*** = new individuals arise from outgrowths of existing ones.
- ***Fragmentation*** = 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.

The “reproductive handicap” of sex: Sexual females have half as many daughters as asexual females.



Sexual reproduction - Variety

- 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.

- Sexual reproduction is a special problem for organisms that seldom encounter a mate.
- One solution is **hermaphroditism** = *each individual has BOTH 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).

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.

External fertilization

- 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.

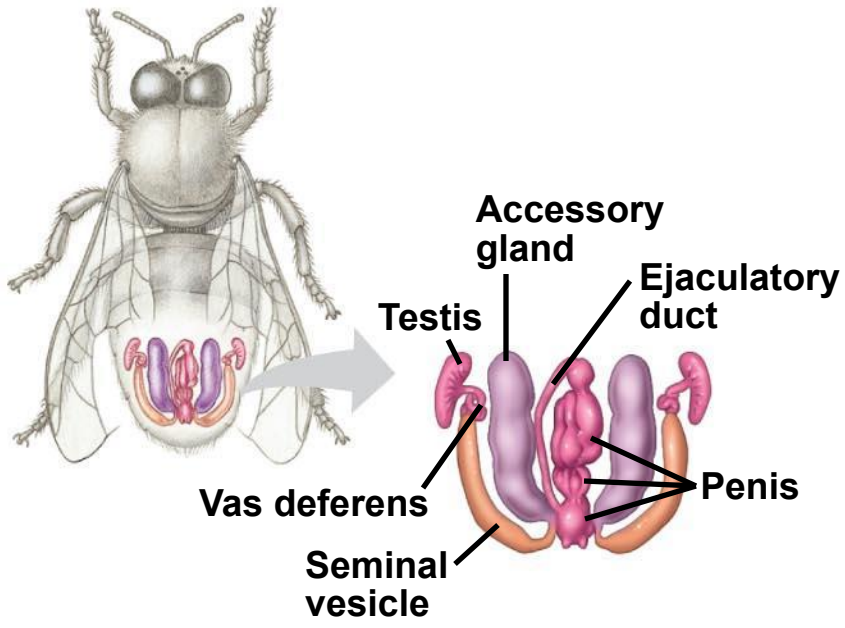
Parental care in an invertebrate

Animal Gamete Production and Delivery

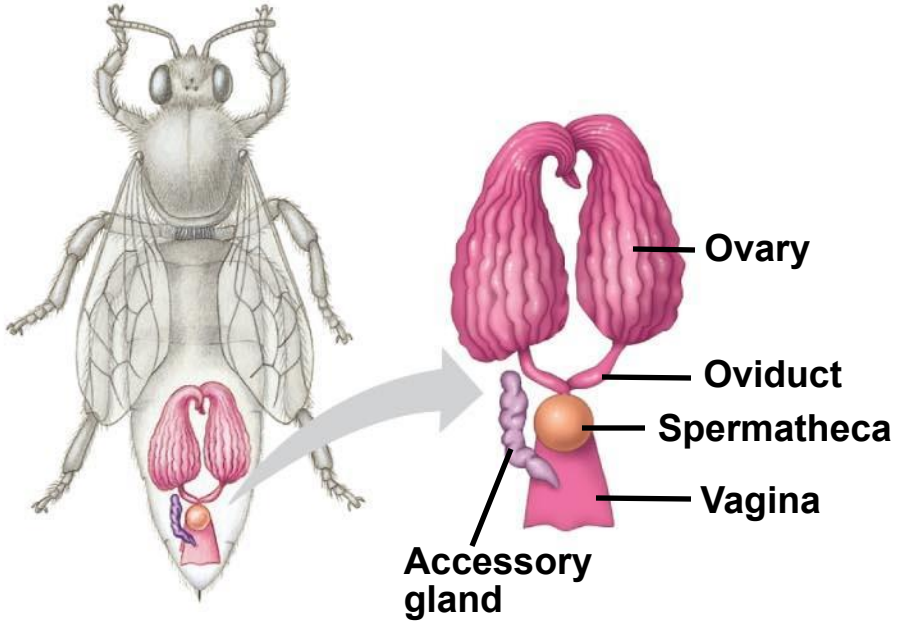
- To reproduce sexually, animals must have systems that produce gametes.
- In most species individuals have **gonads** = sex organs that produce gametes.
- Some simple systems do not have gonads, but gametes form from undifferentiated tissue.
- The most complex systems contain many sets of accessory 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.

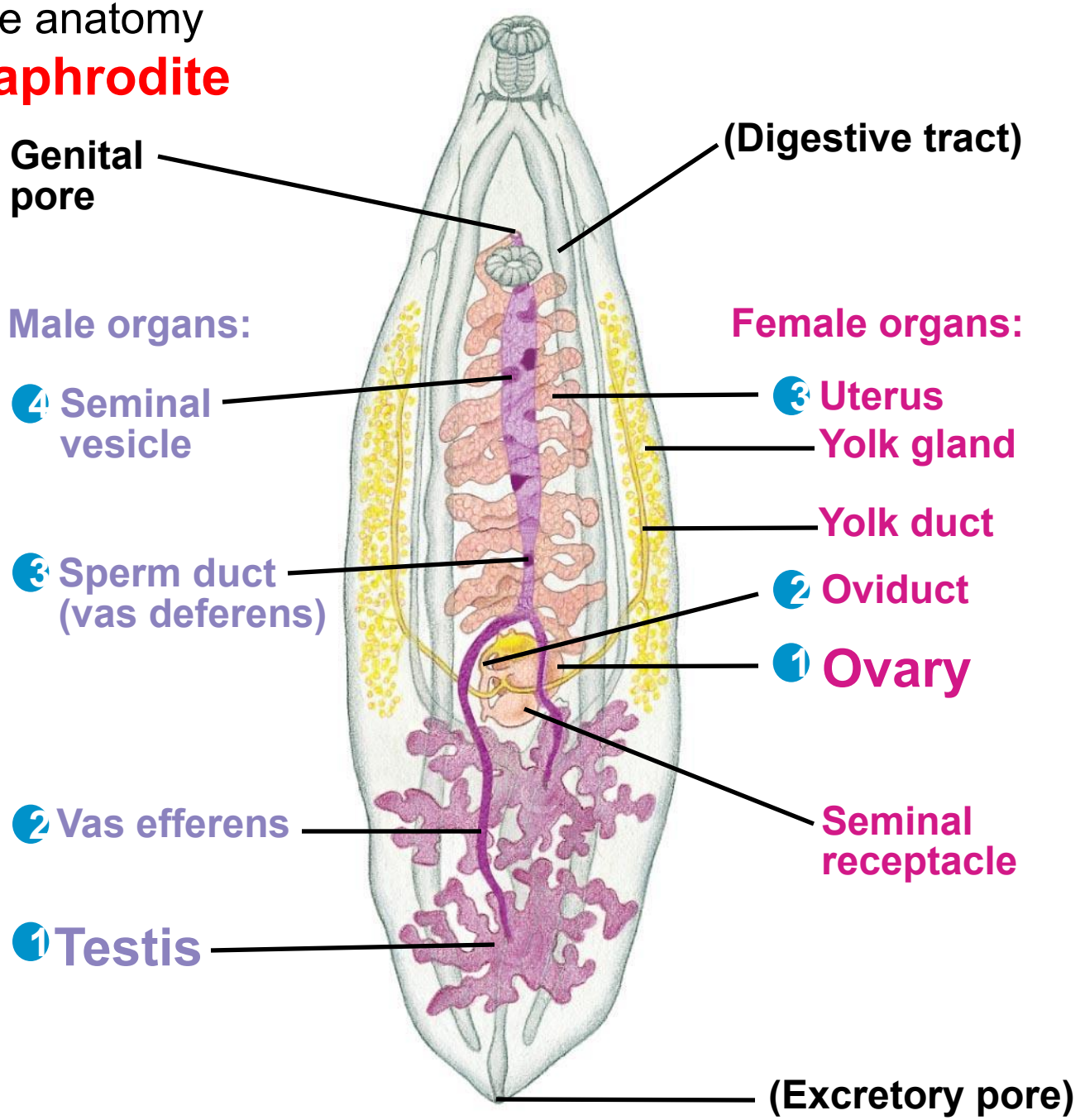


(a) Male honeybee (drone)



(b) Female honeybee (queen)

Reproductive anatomy of a **hermaphrodite**



- 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.

Reproductive organs produce and transport gametes

- The following section focuses on the human reproductive system.

Ovaries = Female Gonads

- The female gonads, the ovaries, lie in the abdominal cavity.
- Each ovary contains many **follicles**, which are egg chambers consisting 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.

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.

Testes = Male Gonads

- The **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. So the testes 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, mature 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.**

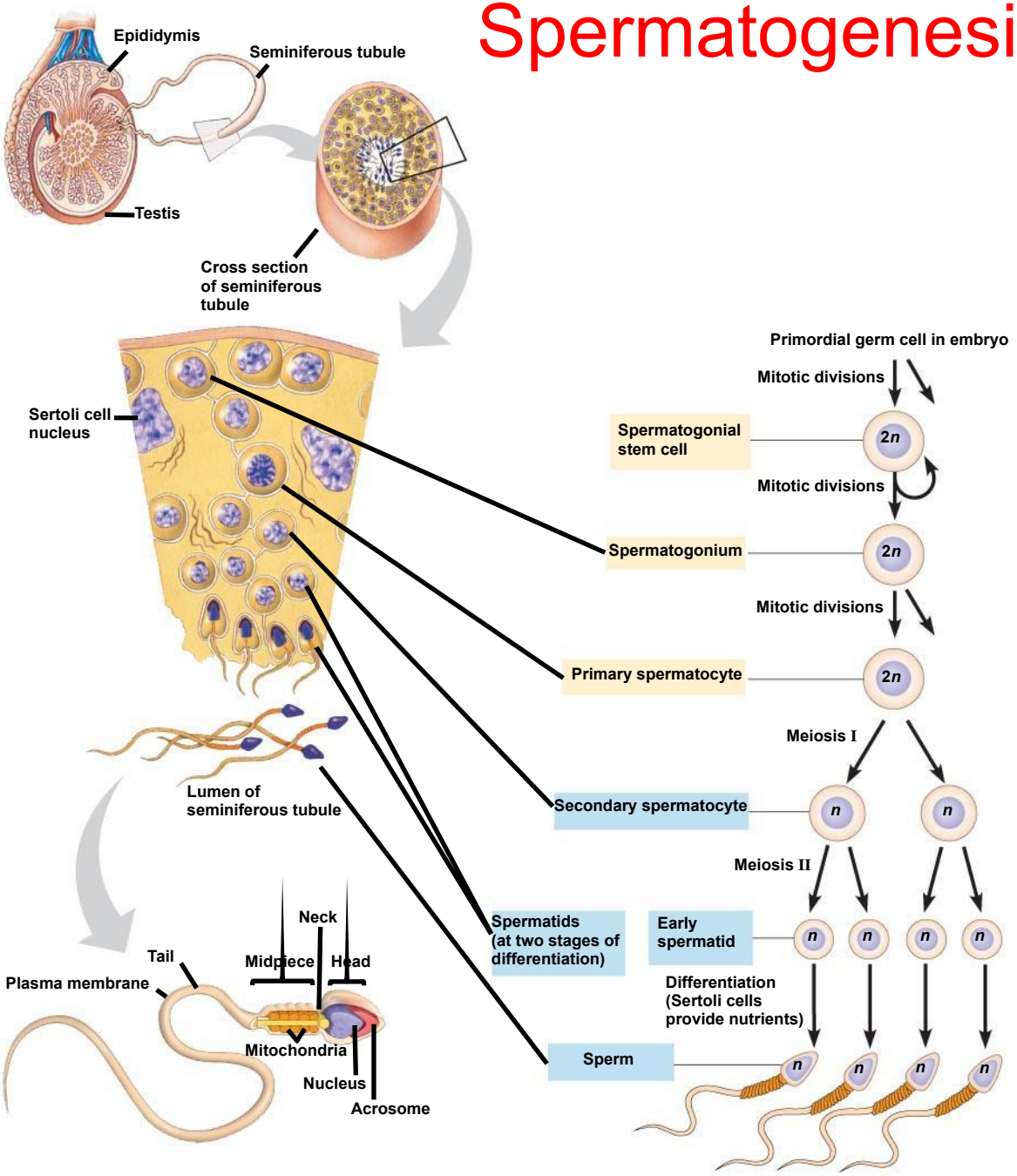
Accessory Glands

- **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.

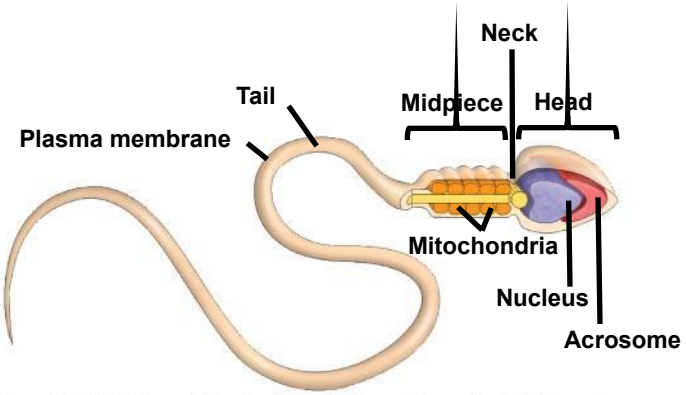
The timing and pattern of meiosis in mammals differ for males and females

- **Gametogenesis** = the production of gametes by meiosis. This 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.

Spermatogenesis

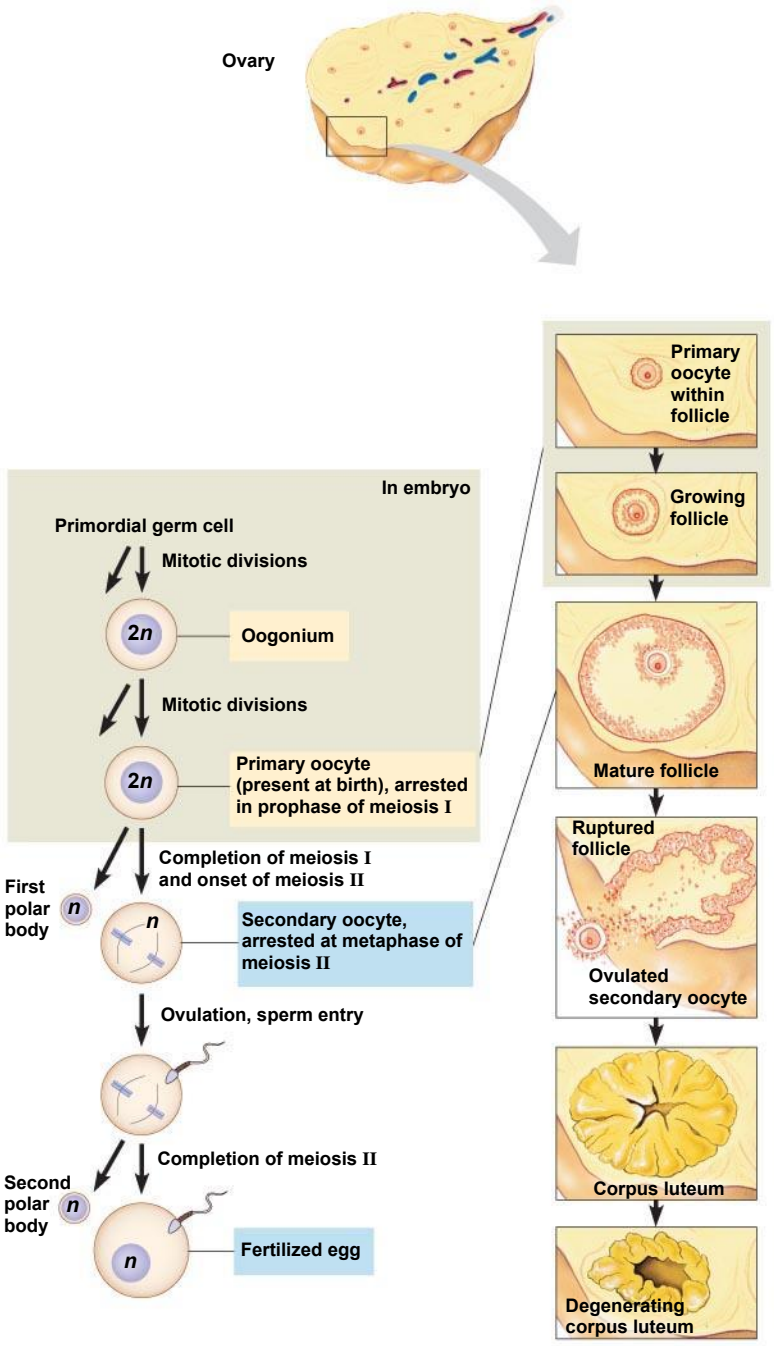


Mature sperm



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

Oogenesis



Spermatogenesis vs. Oogenesis

- 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.

The interplay of tropic and sex hormones regulates mammalian reproduction

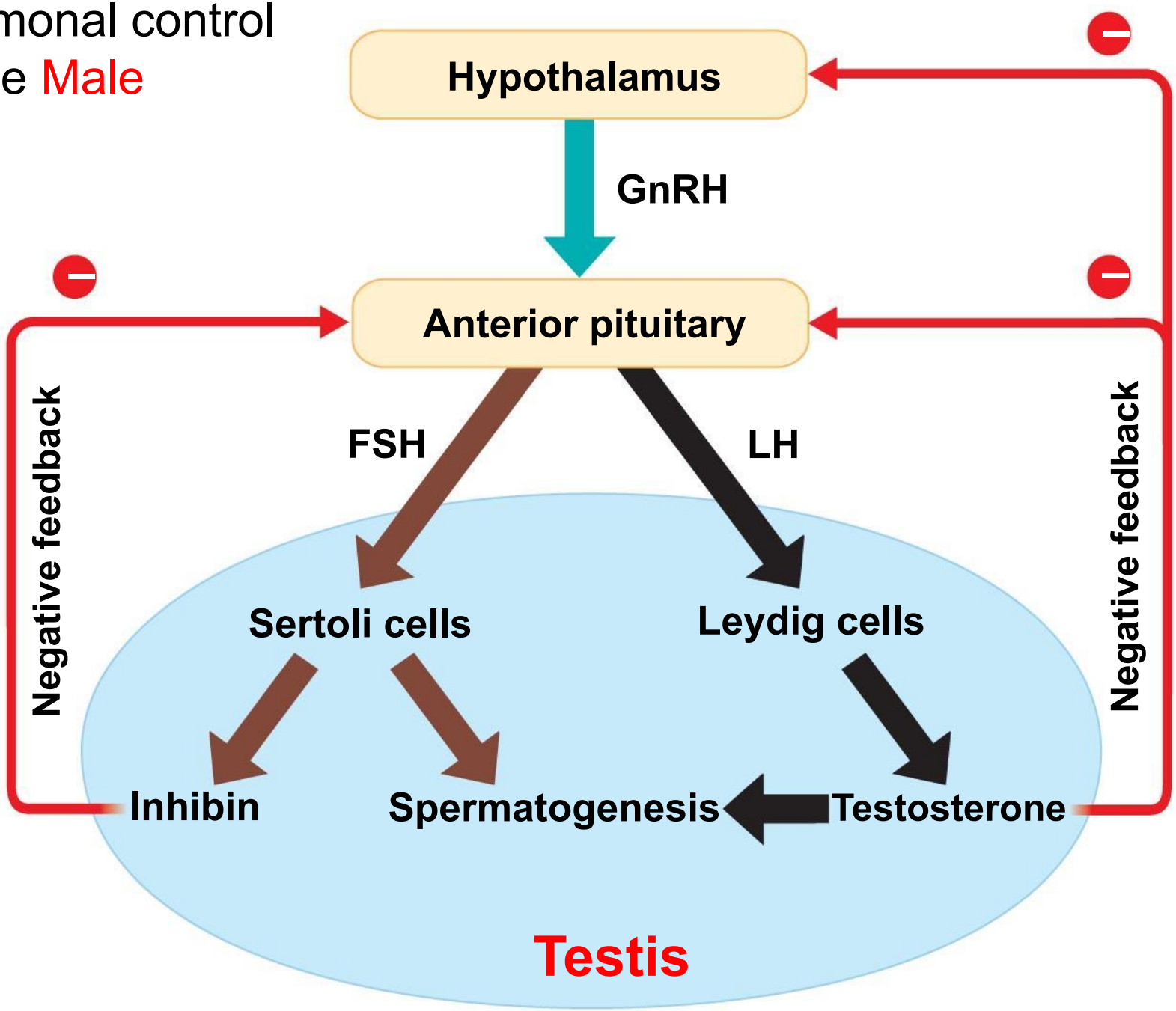
- *Human reproduction is coordinated by hormones from the hypothalamus, anterior pituitary, and gonads*.
- Gonadotropin-releasing hormone (GnRH) is secreted by the hypothalamus and directs the release of FSH and LH from the anterior pituitary.
- FSH and LH regulate processes in the gonads and the production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

Hormonal control in the Male



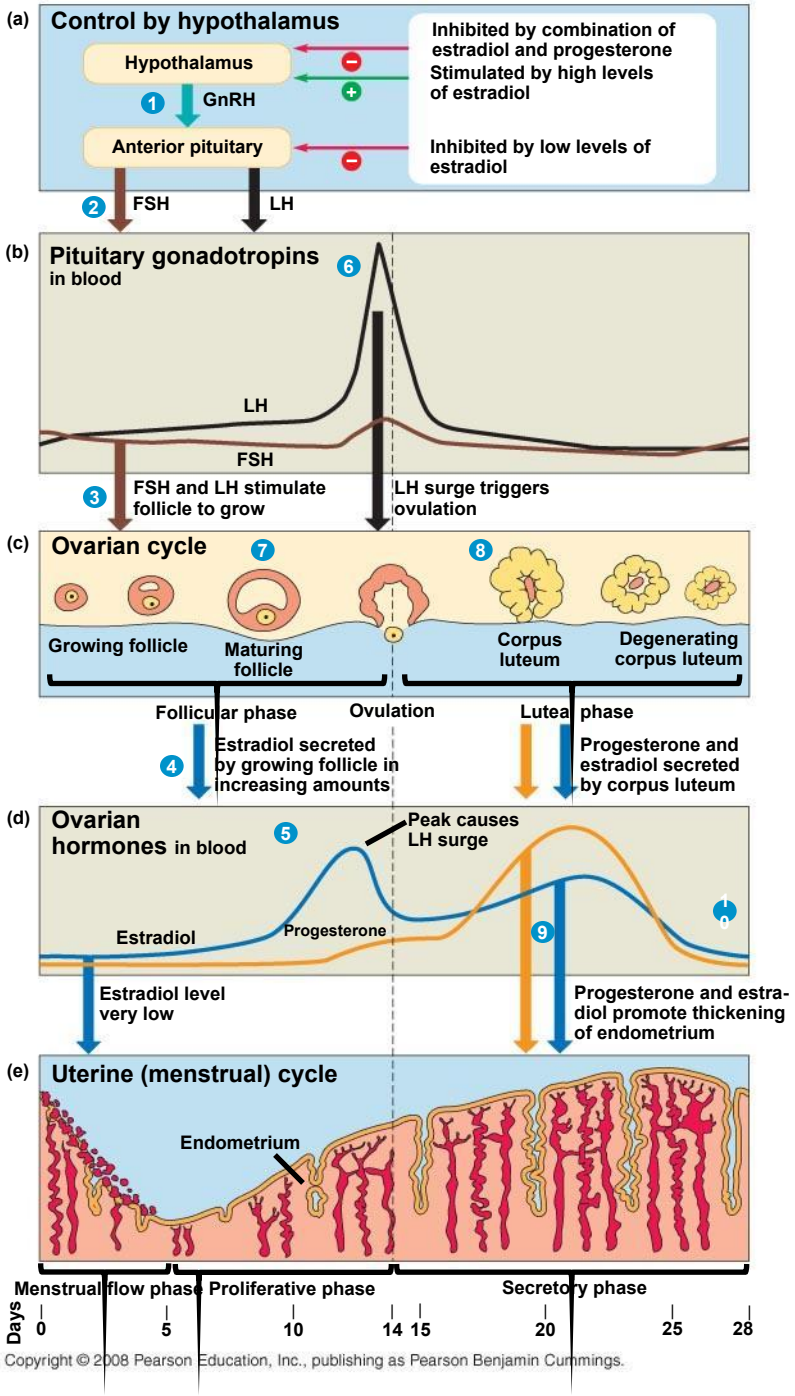
- Testosterone regulates the production of GnRH, FSH, and LH through negative feedback mechanisms.
- Sertoli cells secrete the hormone **inhibin**, which reduces FSH secretion from the anterior pituitary.

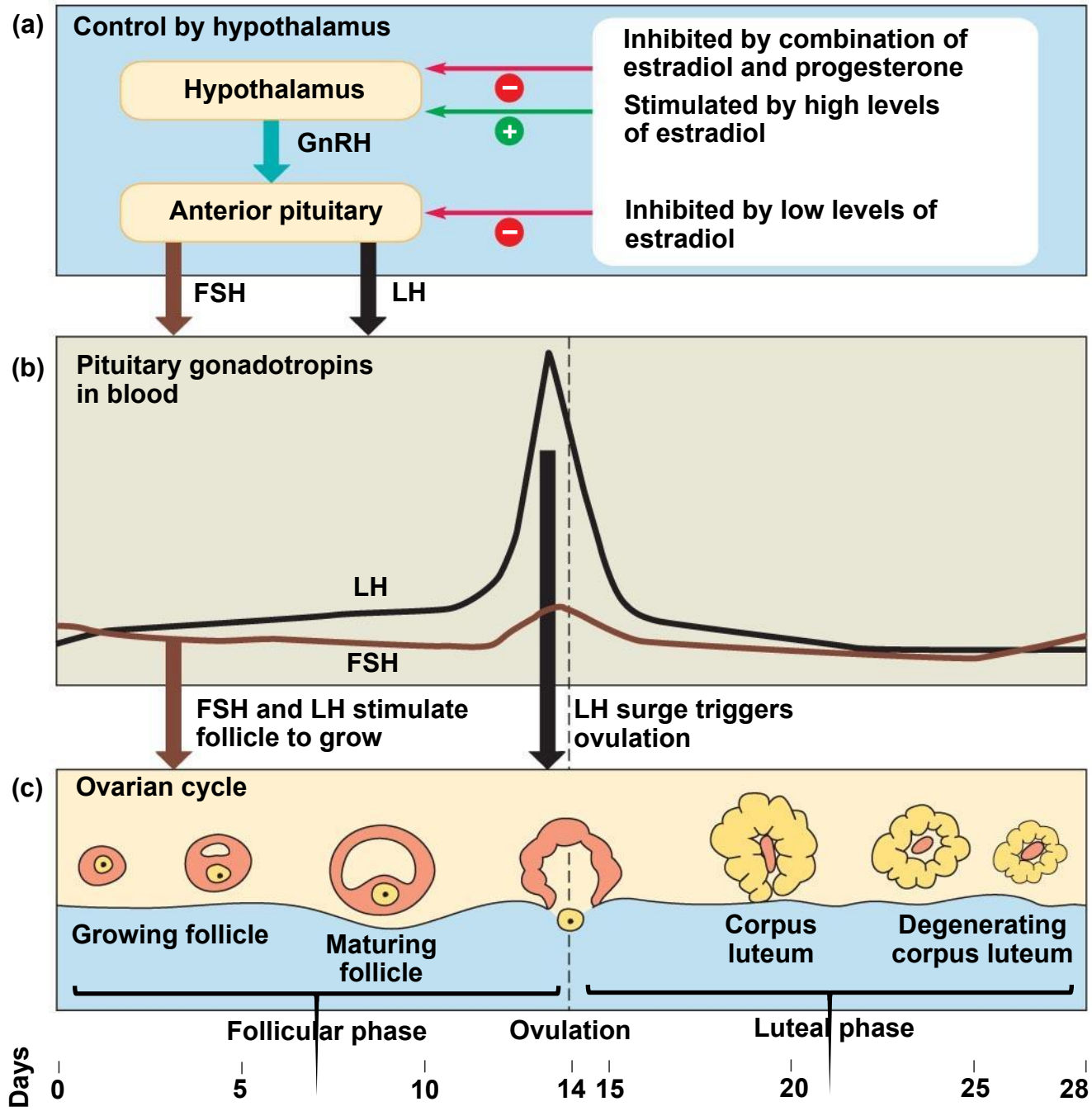
The Reproductive Cycles of Females

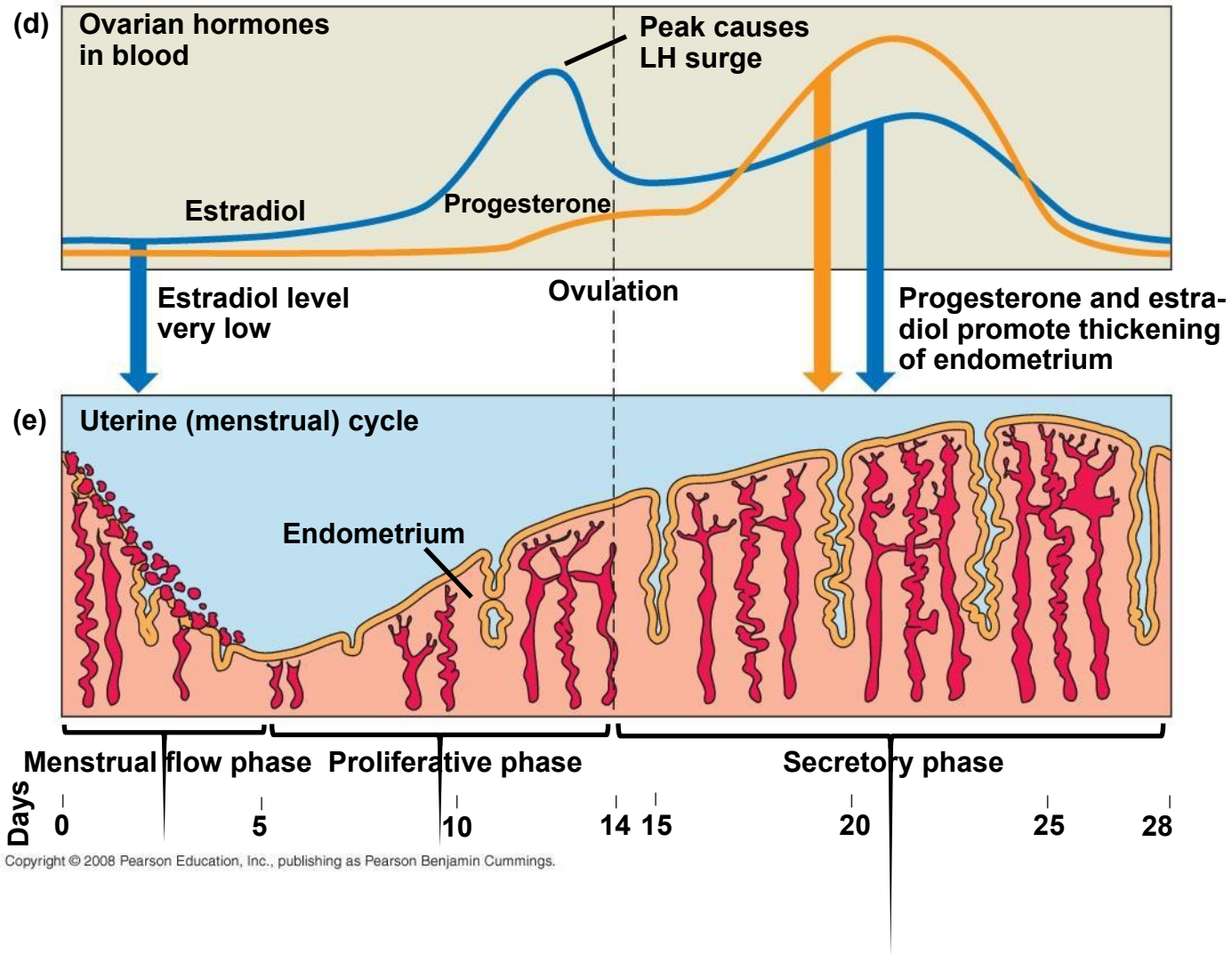
- In females, the secretion of hormones and the reproductive events they regulate are cyclic.
- Prior to ovulation, the endometrium = uterine lining, thickens with blood vessels in preparation for embryo implantation.
- If an embryo does not implant in the endometrium, the endometrium is shed in a process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

- Hormones closely link the two cycles of female reproduction:
  - Changes in the uterus / uterine lining with blood vessels define the **menstrual cycle** (also called the **uterine cycle**).
  - Changes in the ovaries / follicle / egg chamber define the **ovarian cycle**.

The reproductive cycle of the human female







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.

- 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 .

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 vs 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.

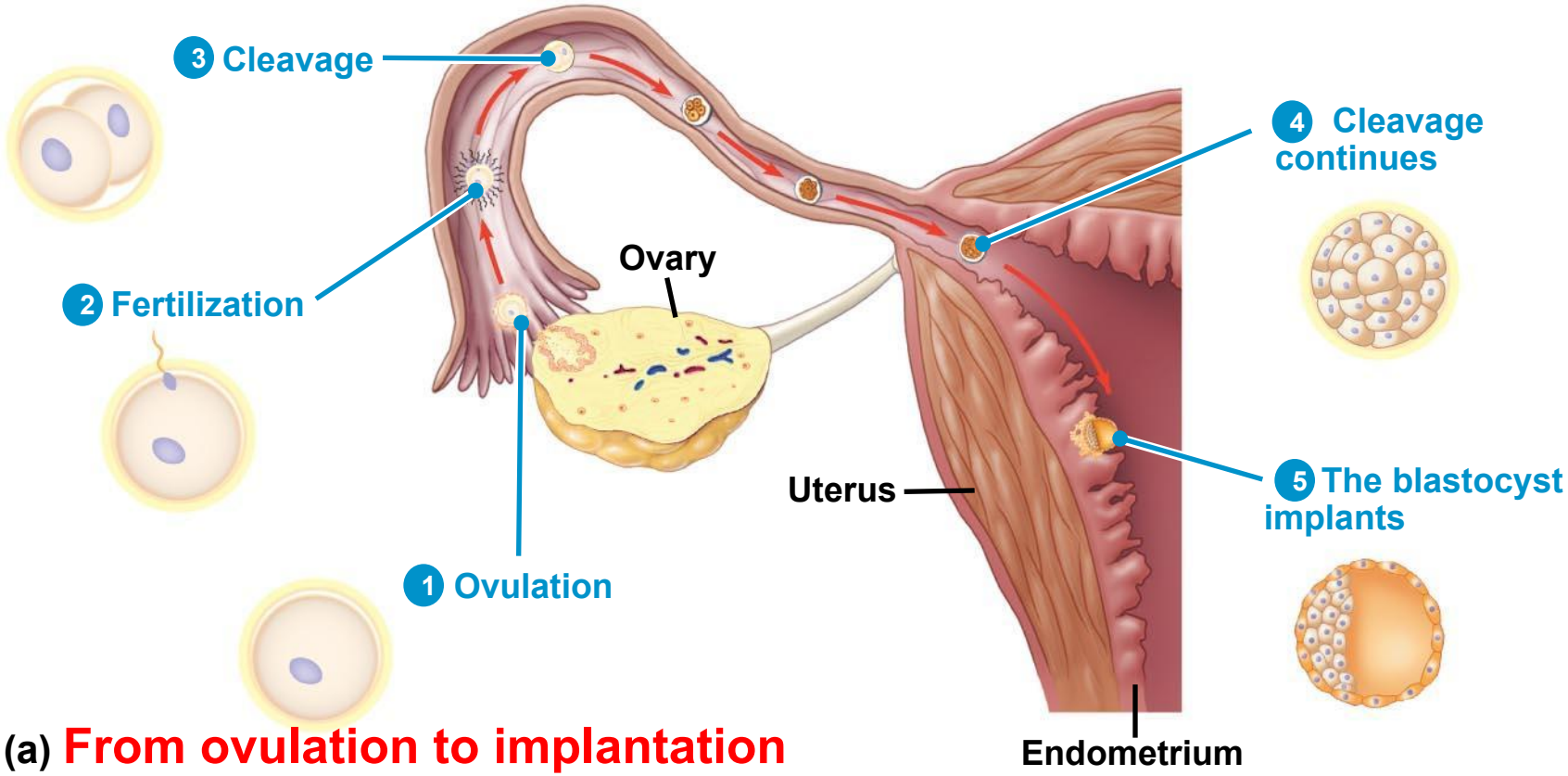
- **Estrous cycles** are characteristic of most mammals:
  - The endometrium is reabsorbed by the uterus
  - Sexual receptivity is limited to a “heat” period
  - The length and frequency of estrus cycles varies from species to species.

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

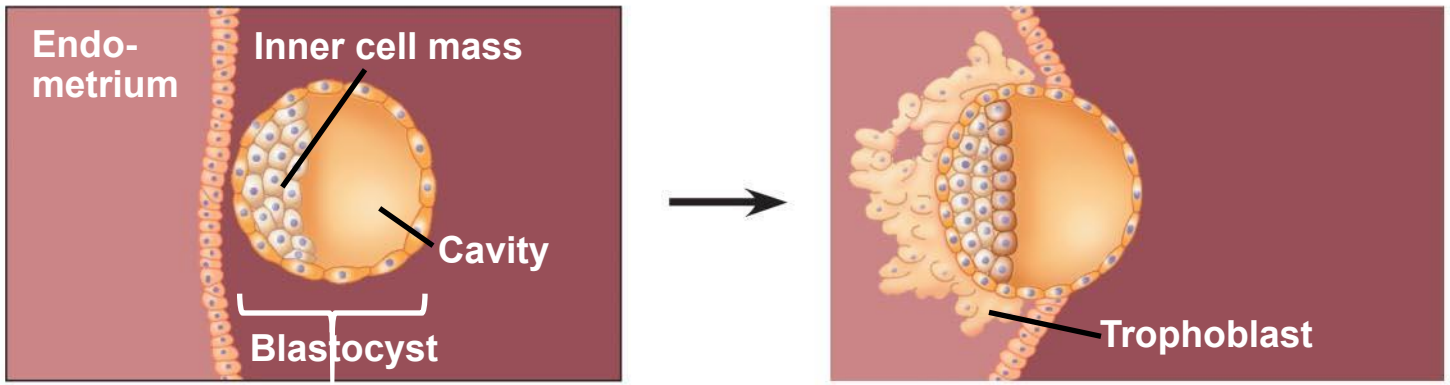
- An egg develops into an embryo in a series of predictable events.

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.



(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.

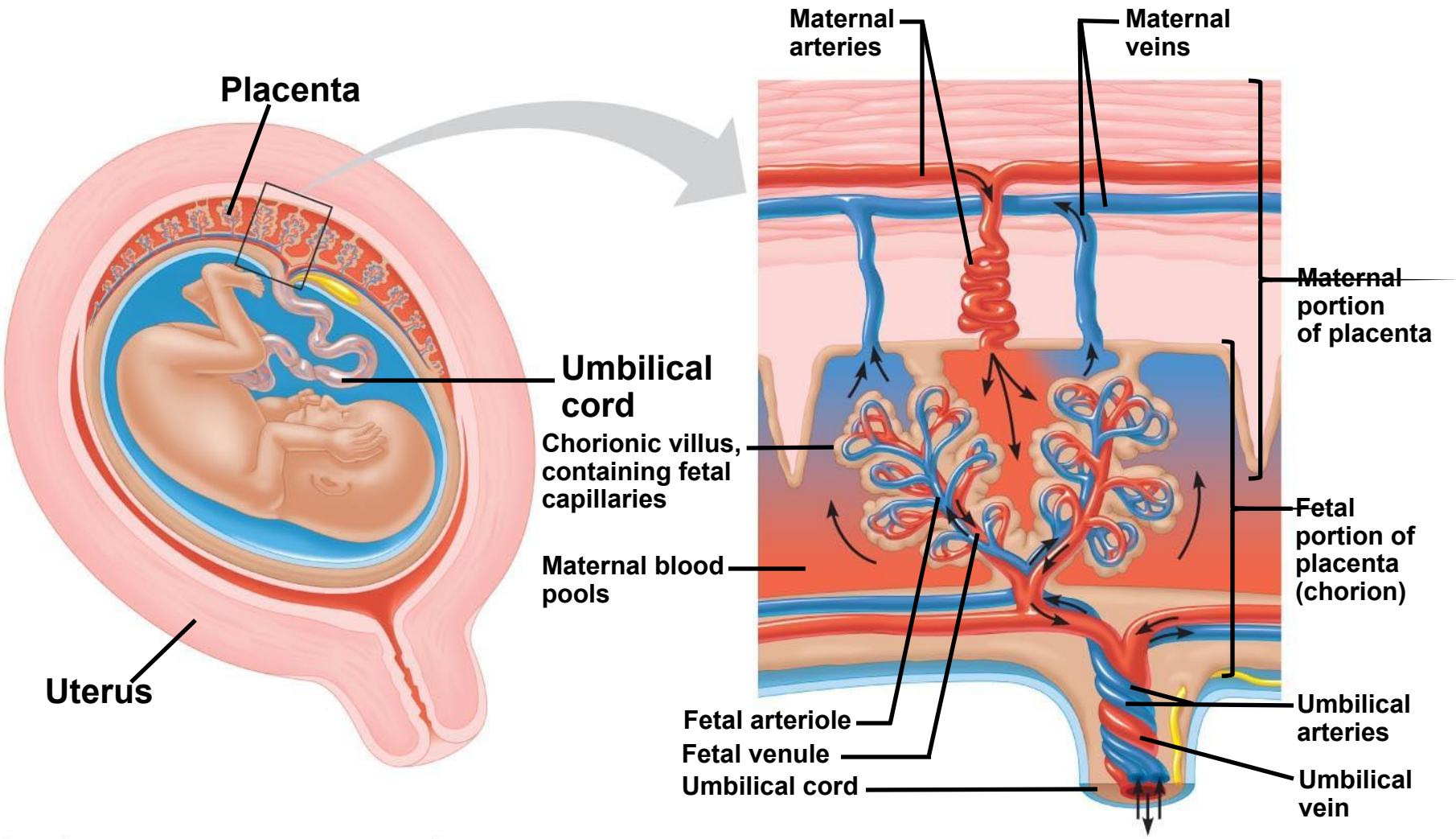
- Pregnancies can terminate spontaneously due to chromosomal or developmental abnormalities.
- An ectopic pregnancy occurs when a fertilized egg begins to develop in the fallopian tube.

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.

Placental circulation



- 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.

Human fetal development

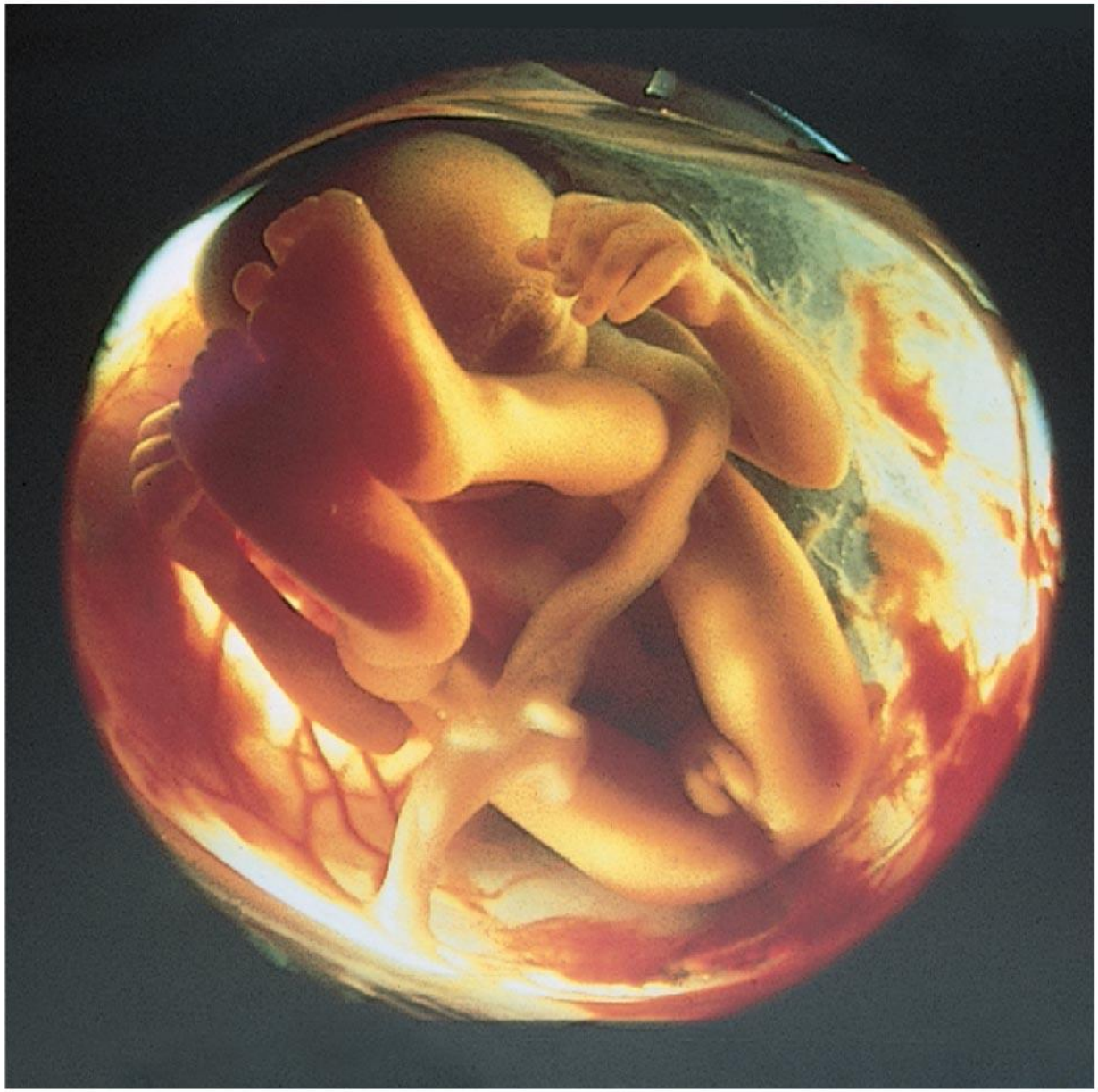
(a) 5 weeks

(b) 14 weeks

(c) 20 weeks

(a) 5 weeks

(b) 14 weeks



(c) 20 weeks

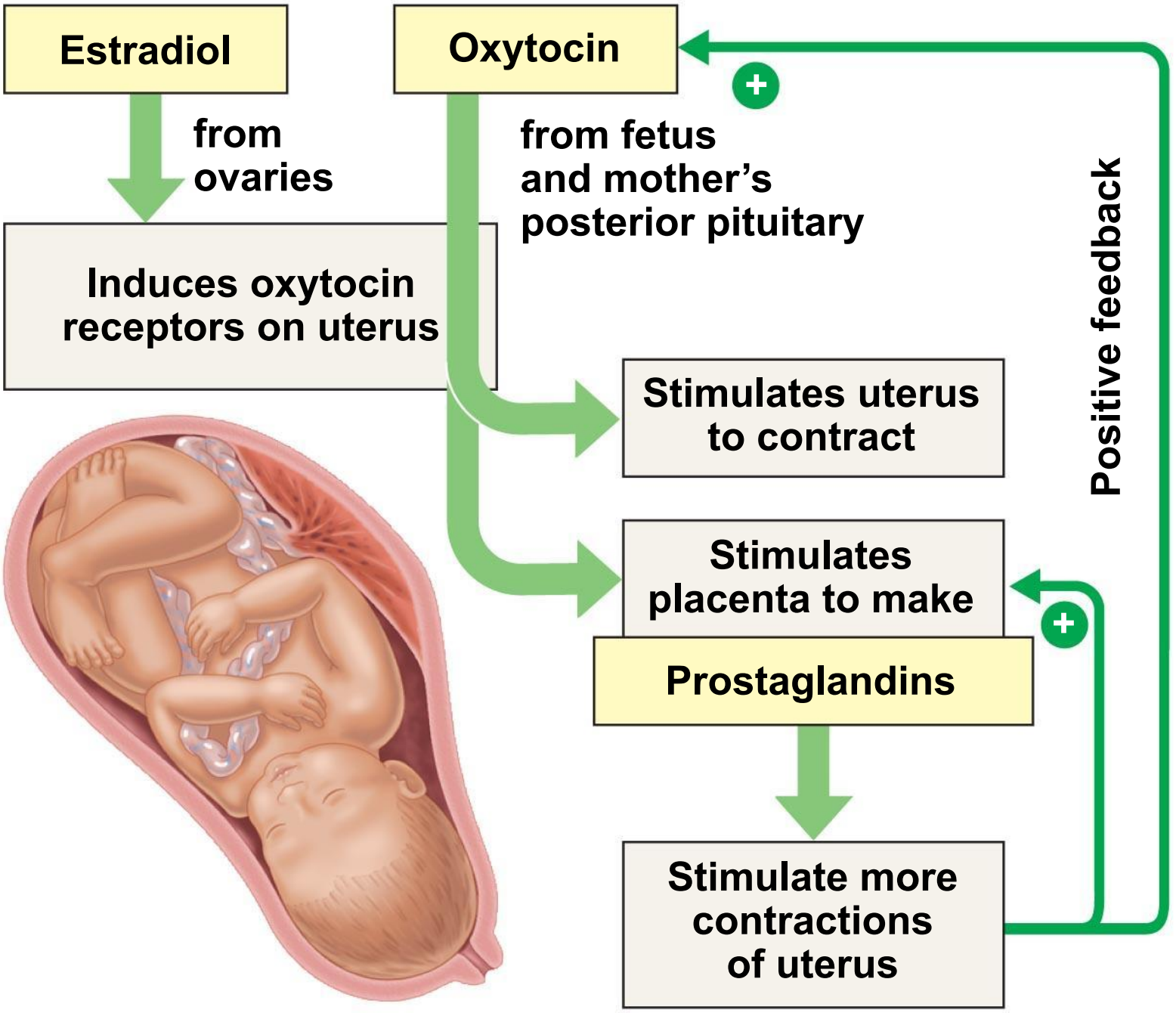
Second Trimester

- 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.

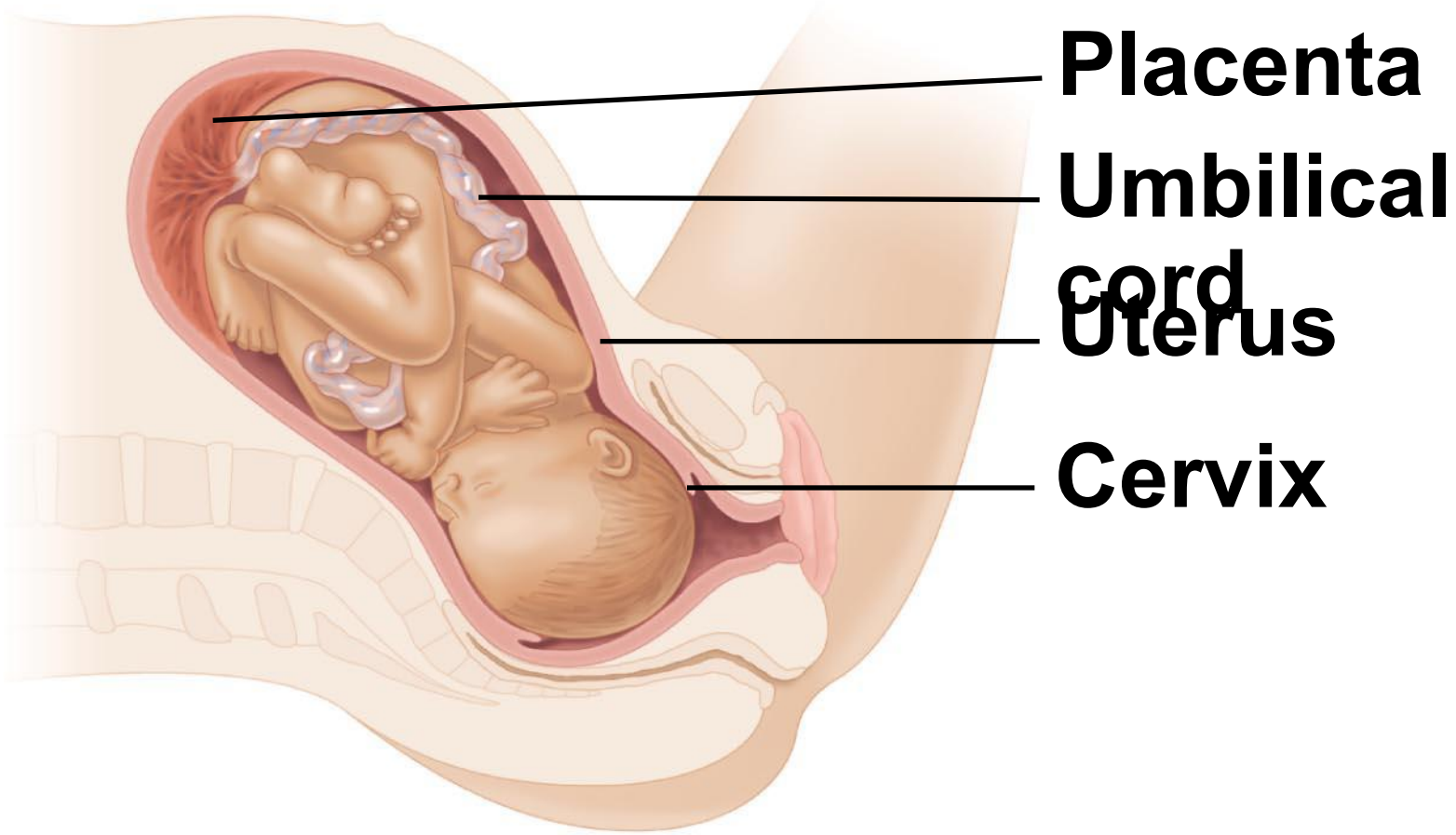
Third Trimester

- 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.

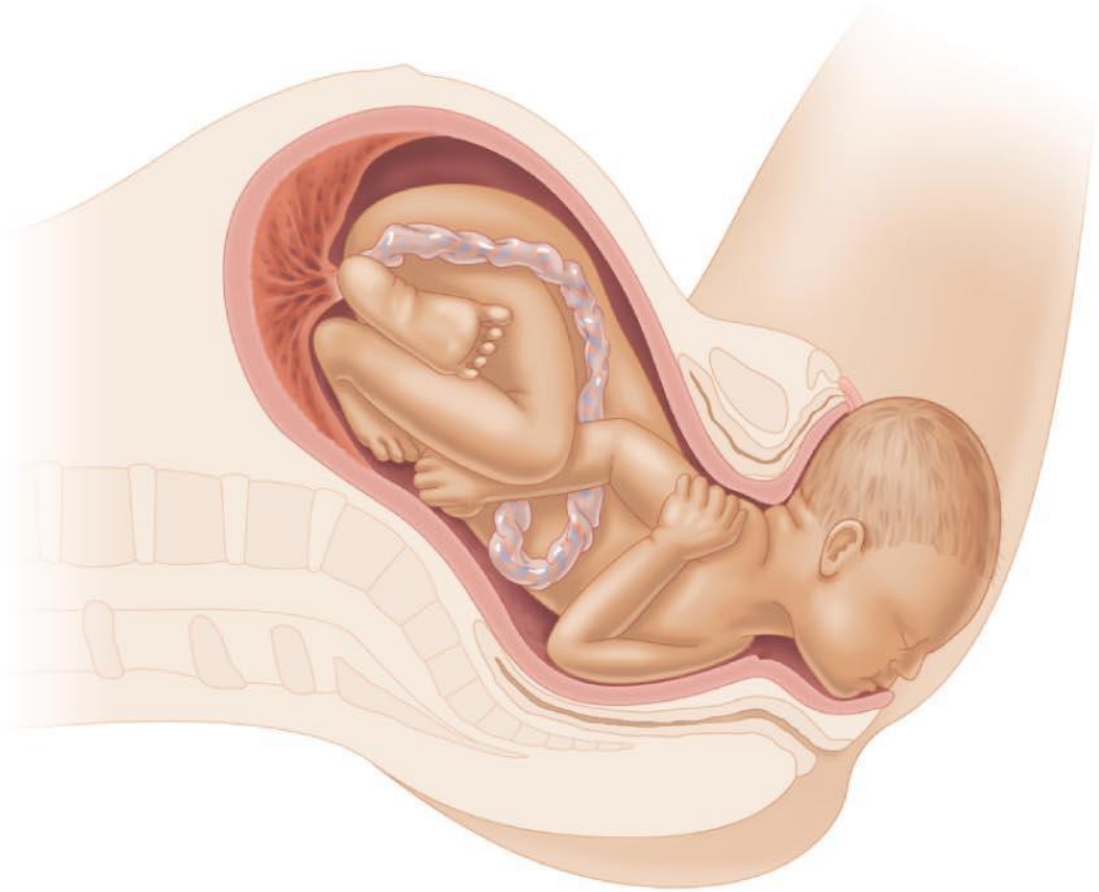
Labor



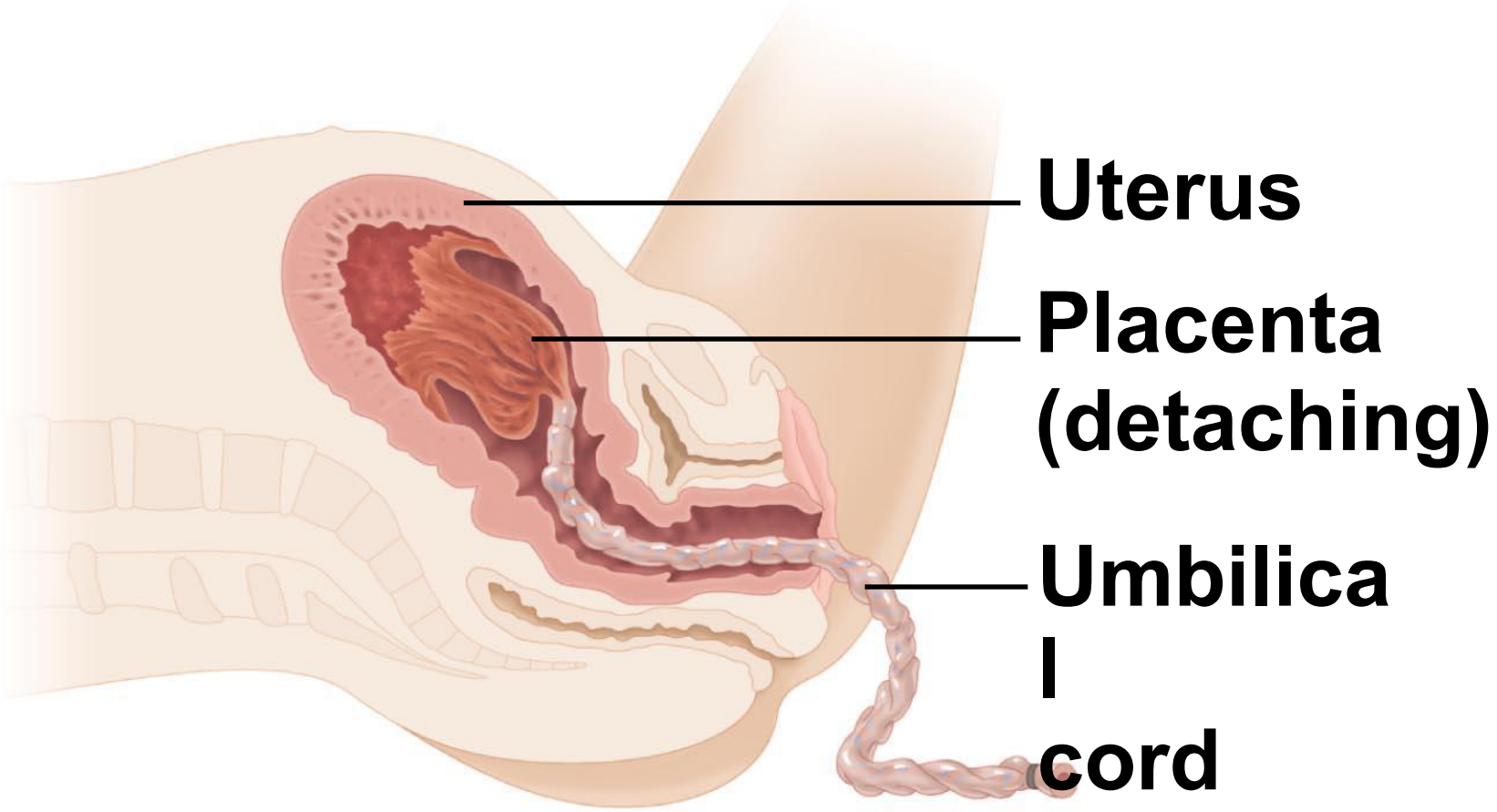
The three stages of labor



1 Dilation of the cervix

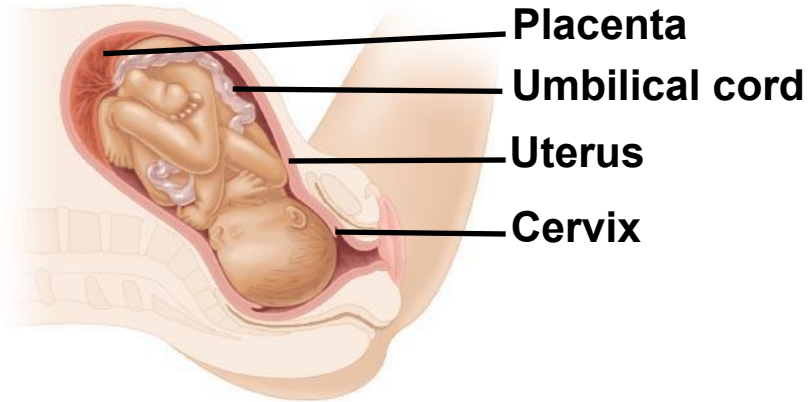


❷ Expulsion: delivery of the infant



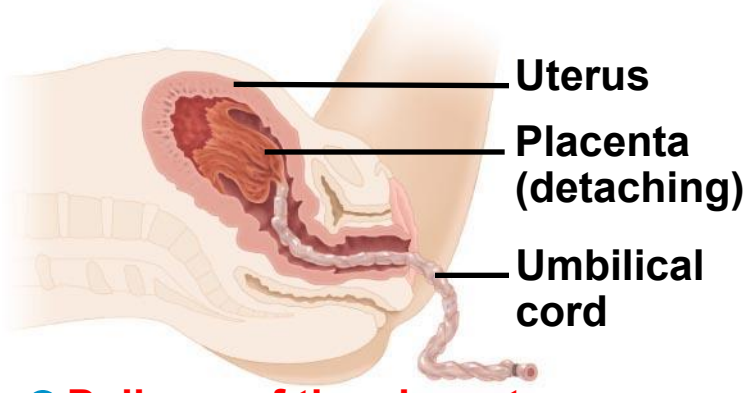
❸ Delivery of the placenta

The three stages of labor



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. This 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.

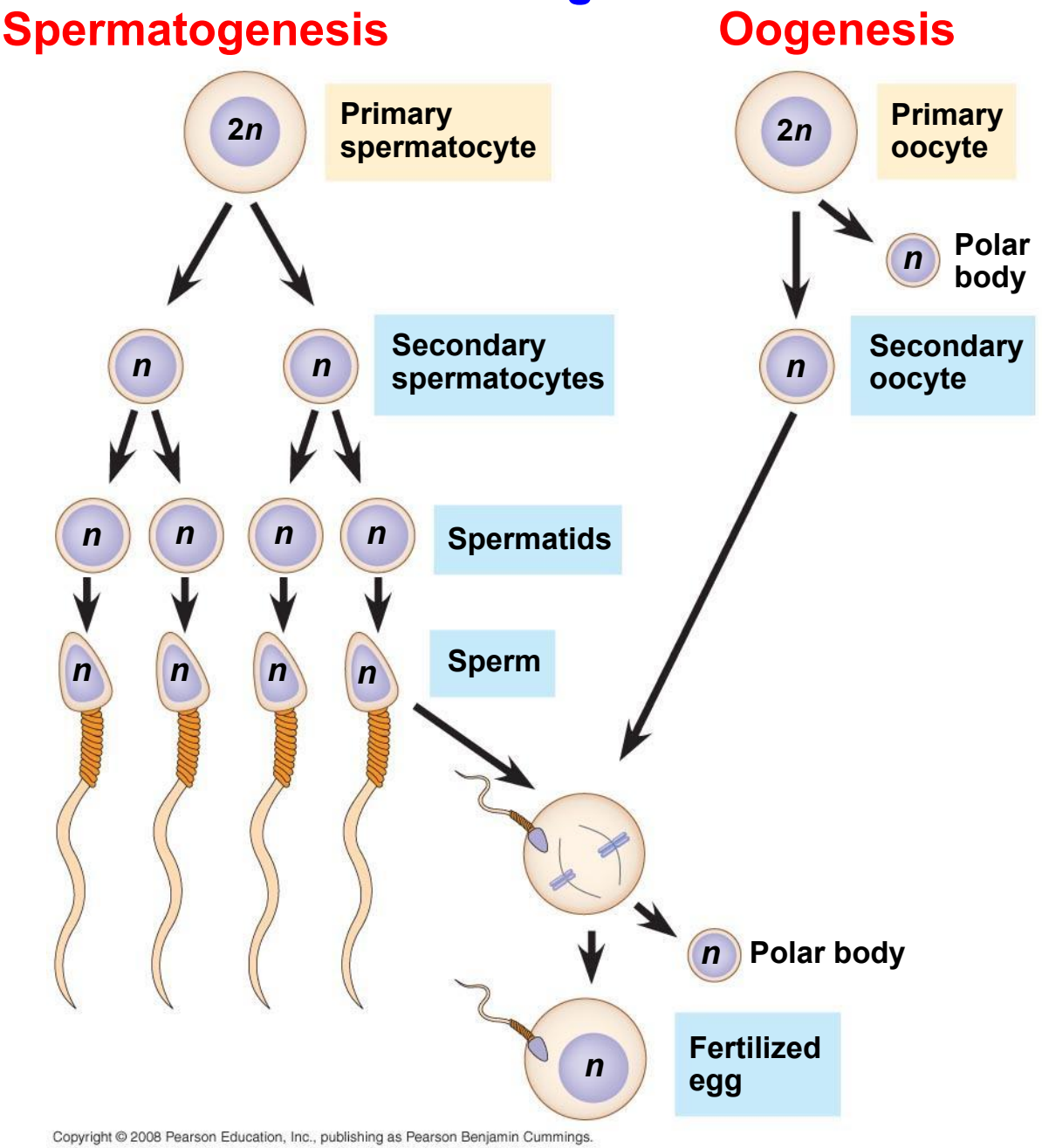
Detecting Disorders During Pregnancy

- 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).**

Gametogenesis



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