conception, the discarding of unused embryos, a necessary result of PGD, is unacceptable under any circumstances.

A murkier ethical situation is found in the selection of a child's sex, which is easily performed by PGD. Currently, countries such as Great Britain have banned the selection of a child's sex for reasons other than preventing sex-linked diseases. Other countries allow the procedure for "family balancing", based on the desire of some parents to have at least one child of each sex. Still others, including the United States, have taken a scattershot approach to regulating these practices, essentially leaving it to the individual practicing physician to decide which practices are acceptable and which are not.

Even murkier are rare instances of disabled parents, such as those with deafness or dwarfism, who select embryos via PGD to ensure that they share their disability. These parents usually cite many positive aspects of their disabilities and associated culture as reasons for their choice, which they see as their moral right. To others, to purposely cause a disability in a child violates the basic medical principle of *Primum non nocere,* "first, do no harm." This procedure, although not illegal in most countries, demonstrates the complexity of ethical issues associated with choosing genetic traits in offspring.

Where could this process lead? Will this technology become more affordable and how should it be used? With the ability of technology to progress rapidly and unpredictably, a lack of definitive guidelines for the use of reproductive technologies before they arise might make it difficult for legislators to keep pace once they are in fact realized, assuming the process needs any government regulation at all. Other bioethicists argue that we should only deal with technologies that exist now, and not in some uncertain future. They argue that these types of procedures will always be expensive and rare, so the fears of eugenics and "master" races are unfounded and overstated. The debate continues.

43.7 Organogenesis and Vertebrate Formation

By the end of this section, you will be able to do the following:

- Describe the process of organogenesis
- Identify the anatomical axes formed in vertebrates

Gastrulation leads to the formation of the three germ layers that give rise, during further development, to the different organs in the animal body. This process is called **organogenesis**. Organogenesis is characterized by rapid and precise movements of the cells within the embryo.

Organogenesis

Organs form from the germ layers through the process of differentiation. During differentiation, the embryonic stem cells express specific sets of genes which will determine their ultimate cell type. For example, some cells in the ectoderm will express the genes specific to skin cells. As a result, these cells will differentiate into epidermal cells. The process of differentiation is regulated by cellular signaling cascades.

Scientists study organogenesis extensively in the lab in fruit flies (*Drosophila*) and the nematode *Caenorhabditis elegans*. *Drosophila* have segments along their bodies, and the patterning associated with the segment formation has allowed scientists to study which genes play important roles in organogenesis along the length of the embryo at different time points. The nematode *C.elegans* has roughly 1000 somatic cells and scientists have studied the fate of each of these cells during their development in the nematode life cycle. There is little variation in patterns of cell lineage between individuals, unlike in mammals where cell development from the embryo is dependent on cellular cues.

In vertebrates, one of the primary steps during organogenesis is the formation of the neural system. The ectoderm forms epithelial cells and tissues, and neuronal tissues. During the formation of the neural system, special signaling molecules called growth factors signal some cells at the edge of the ectoderm to become epidermis cells. The remaining cells in the center form the neural plate. If the signaling by growth factors were disrupted, then the entire ectoderm would differentiate into neural tissue.

The neural plate undergoes a series of cell movements where it rolls up and forms a tube called the **neural tube**, as illustrated in Figure 43.28. In further development, the neural tube will give rise to the brain and the spinal cord.

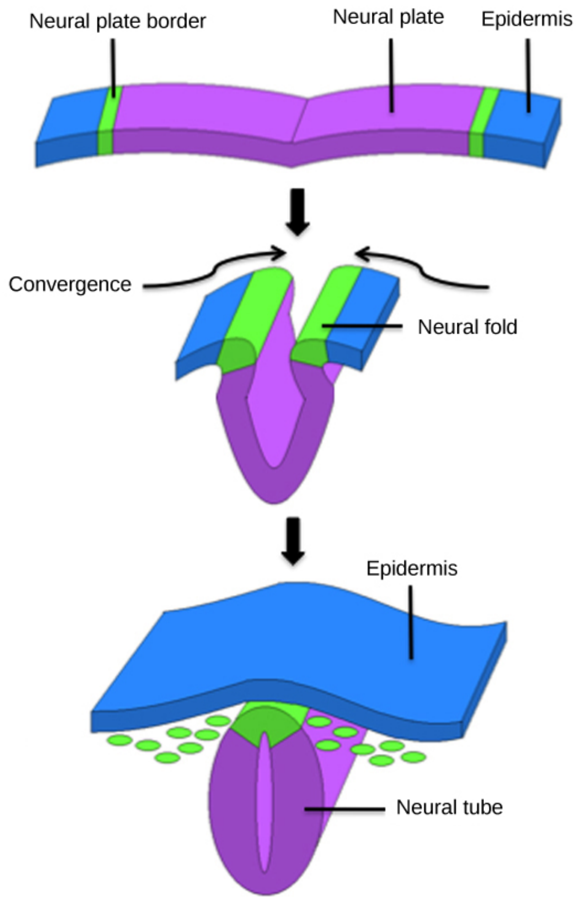

Figure 43.28 The central region of the ectoderm forms the neural tube, which gives rise to the brain and the spinal cord.

The mesoderm that lies on either side of the vertebrate neural tube will develop into the various connective tissues of the animal body. A spatial pattern of gene expression reorganizes the mesoderm into groups of cells called **somites** with spaces between them. The somites illustrated in Figure 43.29 will further develop into the cells that form the vertebrae and ribs, the dermis of the dorsal skin, the skeletal muscles of the back, and the skeletal muscles of the body wall and limbs. The mesoderm also forms a structure called the notochord, which is rod-shaped and forms the central axis of the animal body.

Figure 43.29 In this five-week old human embryo, somites are segments along the length of the body. (credit: modification of work by Ed Uthman)

Vertebrate Axis Formation

Even as the germ layers form, the ball of cells still retains its spherical shape. However, animal bodies have lateral-medial (left-right), dorsal-ventral (back-belly), and anterior-posterior (head-feet) axes, illustrated in Figure 43.30.

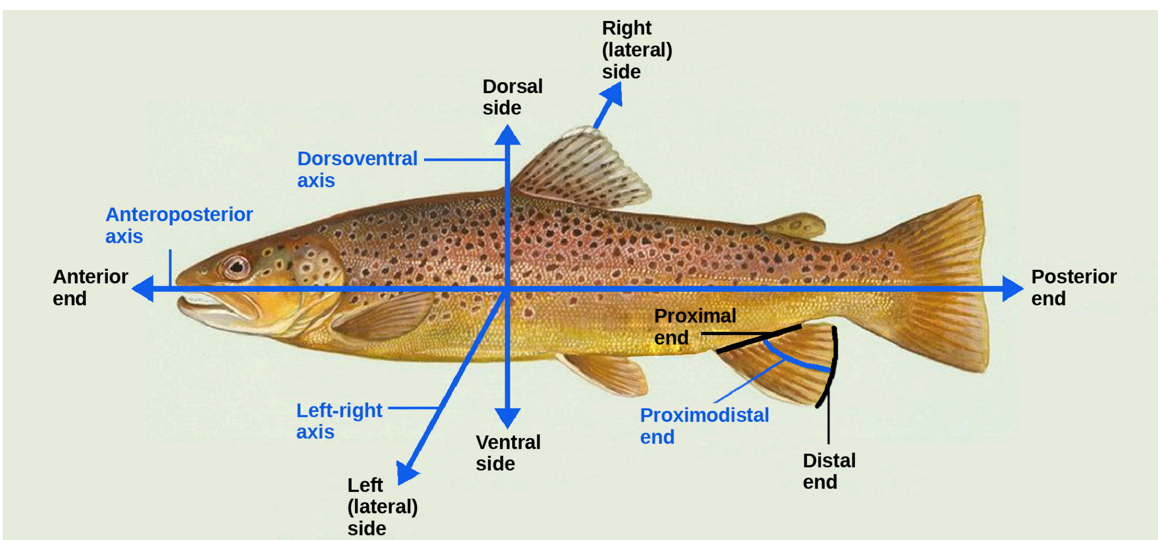

Figure 43.30 Animal bodies have three axes for symmetry. (credit: modification of work by NOAA)

How are these established? In one of the most seminal experiments ever to be carried out in developmental biology, Spemann and Mangold took dorsal cells from one embryo and transplanted them into the belly region of another embryo. They found that the transplanted embryo now had two notochords: one at the dorsal site from the original cells and another at the transplanted site. This suggested that the dorsal cells were genetically programmed to form the notochord and define the axis. Since then, researchers have identified many genes that are responsible for axis formation. Mutations in these genes leads to the loss of symmetry required for organism development.

Animal bodies have externally visible symmetry. However, the internal organs are not symmetric. For example, the heart is on the left side and the liver on the right. The formation of the central left-right axis is an important process during development. This internal asymmetry is established very early during development and involves many genes. Research is still ongoing to fully understand the developmental implications of these genes.

KEY TERMS

acrosomal reaction series of biochemical reactions that the sperm uses to break through the zona pellucida

asexual reproduction form of reproduction that produces offspring that are genetically identical to the parent

blastocyst structure formed when cells in the mammalian blastula separate into an inner and outer layer

budding form of asexual reproduction that results from the outgrowth of a part of a cell leading to a separation from the original animal into two individuals

bulbourethral gland secretion that cleanses the urethra prior to ejaculation

clitoris sensory structure in females; stimulated during sexual arousal

cloaca common body opening for the digestive, excretory, and reproductive systems found in non-mammals, such as birds

contraception (also, birth control) various means used to prevent pregnancy

estrogen reproductive hormone in females that assists in endometrial regrowth, ovulation, and calcium absorption

external fertilization fertilization of egg by sperm outside animal body, often during spawning

fission (also, binary fission) method by which multicellular organisms increase in size or asexual reproduction in which a unicellular organism splits into two separate organisms by mitosis

follicle stimulating hormone (FSH) reproductive hormone that causes sperm production in men and follicle development in women

fragmentation cutting or fragmenting of the original animal into parts and the growth of a separate animal from each part

gastrulation process in which the blastula folds over itself to form the three germ layers

gestation length of time for fetal development to birth

gonadotropin-releasing hormone (GnRH) hormone from the hypothalamus that causes the release of FSH and LH from the anterior pituitary

hermaphroditism state of having both male and female reproductive parts within the same individual

holoblastic complete cleavage; takes place in cells with a small amount of yolk

human beta chorionic gonadotropin (*β*-HCG) hormone produced by the chorion of the zygote that helps to maintain the corpus luteum and elevated levels of progesterone

infertility inability to conceive, carry, and deliver children

inhibin hormone made by Sertoli cells; provides negative feedback to hypothalamus in control of FSH and GnRH release

inner cell mass inner layer of cells in the blastocyst

internal fertilization fertilization of egg by sperm inside the body of the female

interstitial cell of Leydig cell in seminiferous tubules that makes testosterone

labia majora large folds of tissue covering the inguinal area

labia minora smaller folds of tissue within the labia majora

luteinizing hormone (LH) reproductive hormone in both men and women, causes testosterone production in men and ovulation and lactation in women

menopause loss of reproductive capacity in women due to decreased sensitivity of the ovaries to FSH and LH

menstrual cycle cycle of the degradation and regrowth of the endometrium

meroblastic partial cleavage; takes place in cells with a large amount of yolk

morning sickness condition in the mother during the first trimester; includes feelings of nausea

neural tube tube-like structure that forms from the ectoderm and gives rise to the brain and spinal cord

oogenesis process of producing haploid eggs

organogenesis process of organ formation

ovarian cycle cycle of preparation of egg for ovulation and the conversion of the follicle to the corpus luteum

oviduct (also, fallopian tube) muscular tube connecting the uterus with the ovary area

oviparity process by which fertilized eggs are laid outside the female's body and develop there, receiving nourishment from the yolk that is a part of the egg

ovoviparity process by which fertilized eggs are retained within the female; the embryo obtains its nourishment from the egg's yolk and the young are fully developed when they are hatched

ovulation release of the egg by the most mature follicle

parthenogenesis form of asexual reproduction where an egg develops into a complete individual without being fertilized

penis male reproductive structure for urine elimination and copulation

placenta organ that supports the diffusion of nutrients and waste between the mother's and fetus' blood

polyspermy condition in which one egg is fertilized by multiple sperm

progesterone reproductive hormone in women; assists in endometrial regrowth and inhibition of FSH and LH release

prostate gland structure that is a mixture of smooth muscle and glandular material and that contributes to semen

scrotum sac containing testes; exterior to the body

semen fluid mixture of sperm and supporting materials

seminal vesicle secretory accessory gland in males; contributes to semen

seminiferous tubule site of sperm production in testes

Sertoli cell cell in seminiferous tubules that assists developing sperm and makes inhibin

sexual reproduction mixing of genetic material from two individuals to produce genetically unique offspring

somite group of cells separated by small spaces that form from the mesoderm and give rise to connective tissue

spermatheca specialized sac that stores sperm for later use

spermatogenesis process of producing haploid sperm

testes pair of reproductive organs in males

testosterone reproductive hormone in men that assists in sperm production and promoting secondary sexual characteristics

trophoblast outer layer of cells in the blastocyst

uterus environment for developing embryo and fetus

vagina muscular tube for the passage of menstrual flow, copulation, and birth of offspring

viviparity process in which the young develop within the female, receiving nourishment from the mother's blood through a placenta

zona pellucida protective layer of glycoproteins on the mammalian egg

CHAPTER SUMMARY

43.1 Reproduction Methods

Reproduction may be asexual when one individual produces genetically identical offspring, or sexual when the genetic material from two individuals is combined to produce genetically diverse offspring. Asexual reproduction occurs through fission, budding, and fragmentation. Sexual reproduction may mean the joining of sperm and eggs within animals' bodies or it may mean the release of sperm and eggs into the environment. An individual may be one sex, or both; it may start out as one sex and switch during its life, or it may stay male or female.

43.2 Fertilization

Sexual reproduction starts with the combination of a sperm and an egg in a process called fertilization. This can occur either outside the bodies or inside the female. Both methods have advantages and disadvantages. Once fertilized, the eggs can develop inside the female or outside. If the egg develops outside the body, it usually has a protective covering over it. Animal anatomy evolved various ways to fertilize, hold, or expel the egg. The method of fertilization varies among animals. Some species release the egg and sperm into the environment, some species retain the egg and receive the sperm into the female body and then expel the developing embryo covered with shell, while still other species retain the developing offspring through the gestation period.

43.3 Human Reproductive Anatomy and Gametogenesis

As animals became more complex, specific organs and organ systems developed to support specific functions for the organism. The reproductive structures that evolved in land animals allow males and females to mate, fertilize internally, and support the growth and development of offspring. Processes developed to produce reproductive cells that had exactly half the number of chromosomes of each parent so that new combinations would have the appropriate amount of genetic material. Gametogenesis, the production of sperm (spermatogenesis) and eggs (oogenesis), takes place through the process of meiosis.

43.4 Hormonal Control of Human Reproduction

The male and female reproductive cycles are controlled by hormones released from the hypothalamus and anterior pituitary as well as hormones from reproductive tissues and organs. The hypothalamus monitors the need for the FSH and LH hormones made and released from the anterior pituitary. FSH and LH affect reproductive structures to cause the formation of sperm and the preparation of eggs for release and possible fertilization. In the male, FSH and LH stimulate Sertoli cells and interstitial cells of Leydig in the testes to facilitate sperm production. The Leydig cells produce testosterone, which also is responsible for the secondary sexual characteristics of males. In females, FSH and LH cause estrogen and progesterone to be produced. They regulate the female reproductive system which is divided into the ovarian cycle and the menstrual cycle. Menopause occurs when the ovaries lose their sensitivity to FSH and LH and the female reproductive cycles slow to a stop.

43.5 Human Pregnancy and Birth

Human pregnancy begins with fertilization of an egg and proceeds through the three trimesters of gestation. The labor process has three stages (contractions, delivery of the fetus, expulsion of the placenta), each propelled by hormones. The first trimester lays down the basic structures of the body, including the limb buds, heart, eyes, and the liver. The second trimester continues the development of all of the organs and systems. The third trimester exhibits the greatest growth of the fetus and culminates in labor and delivery. Prevention of a pregnancy can be accomplished through a variety of methods including barriers, hormones, or other means. Assisted reproductive technologies may help individuals who have infertility problems.

43.6 Fertilization and Early Embryonic Development

The early stages of embryonic development begin with fertilization. The process of fertilization is tightly controlled to ensure that only one sperm fuses with one egg. After fertilization, the zygote undergoes cleavage to form the blastula. The blastula, which in some species is a hollow ball of cells, undergoes a process called gastrulation, in which the three germ layers form. The ectoderm gives rise to the nervous system and the epidermal skin cells, the mesoderm gives rise to the muscle cells and connective tissue in the body, and the endoderm gives rise to columnar cells and internal organs.

43.7 Organogenesis and Vertebrate Formation

Organogenesis is the formation of organs from the germ layers. Each germ layer gives rise to specific tissue types. The first stage is the formation of the neural system in the ectoderm. The mesoderm gives rise to somites and the notochord. Formation of vertebrate axis is another important developmental stage.

VISUAL CONNECTION QUESTIONS

1. Figure 43.8 Which of the following statements about the male reproductive system is false?
   a. The vas deferens carries sperm from the testes to the penis.
   b. Sperm mature in seminiferous tubules in the testes.
   c. Both the prostate and the bulbourethral glands produce components of the semen.
   d. The prostate gland is located in the testes.

2. Figure 43.15 Which of the following statements about hormone regulation of the female reproductive cycle is false?
   a. LH and FSH are produced in the pituitary, and estradiol and progesterone are produced in the ovaries.
   b. Estradiol and progesterone secreted from the corpus luteum cause the endometrium to thicken.
   c. Both progesterone and estradiol are produced by the follicles.
   d. Secretion of GnRH by the hypothalamus is inhibited by low levels of estradiol but stimulated by high levels of estradiol.

3. Figure 43.17 Which of the following statements about the menstrual cycle is false?
   a. Progesterone levels rise during the luteal phase of the ovarian cycle and the secretory phase of the uterine cycle.
   b. Menstruation occurs just after LH and FSH levels peak.
   c. Menstruation occurs after progesterone levels drop.
   d. Estrogen levels rise before ovulation, while progesterone levels rise after.

REVIEW QUESTIONS

4. Which form of reproduction is thought to be best in a stable environment?
   a. asexual
   b. sexual
   c. budding
   d. parthenogenesis

5. Which form of reproduction can result from damage to the original animal?
   a. asexual
   b. fragmentation
   c. budding
   d. parthenogenesis

6. Which form of reproduction is useful to an animal with little mobility that reproduces sexually?
   a. fission
   b. budding
   c. parthenogenesis
   d. hermaphroditism

7. Genetically unique individuals are produced through ________.
   a. sexual reproduction
   b. parthenogenesis
   c. budding
   d. fragmentation

8. External fertilization occurs in which type of environment?
a. aquatic
b. forested
c. savanna
d. steppe

9. Which term applies to egg development within the female with nourishment derived from a yolk?
a. oviparity
b. viviparity
c. ovoviparity
d. ovovoparity

10. Which term applies to egg development outside the female with nourishment derived from a yolk?
a. oviparity
b. viviparity
c. ovoviparity
d. ovovoparity

11. Sperm are produced in the ________.
a. scrotum
b. seminal vesicles
c. seminiferous tubules
d. prostate gland

12. Most of the bulk of semen is made by the ________.
a. scrotum
b. seminal vesicles
c. seminiferous tubules
d. prostate gland

13. Which of the following cells in spermatogenesis is diploid?
a. primary spermatocyte
b. secondary spermatocyte
c. spermatid
d. sperm

14. Which female organ has the same embryonic origin as the penis?
a. clitoris
b. labia majora
c. greater vestibular glands
d. vagina

15. Which female organ has an endometrial lining that will support a developing baby?
a. labia minora
b. breast
c. ovaries
d. uterus

16. How many eggs are produced as a result of one meiotic series of cell divisions?
a. one
b. two
c. three
d. four

17. Which hormone causes Leydig cells to make testosterone?
a. FSH
b. LH
c. inhibin
d. estrogen

18. Which hormone causes FSH and LH to be released?
a. testosterone
b. estrogen
c. GnRH
d. progesterone

19. Which hormone signals ovulation?
a. FSH
b. LH
c. inhibin
d. estrogen

20. Which hormone causes the regrowth of the endometrial lining of the uterus?
a. testosterone
b. estrogen
c. GnRH
d. progesterone

21. Nutrient and waste requirements for the developing fetus are handled during the first few weeks by:
a. the placenta
b. diffusion through the endometrium
c. the chorion
d. the blastocyst

22. Progesterone is made during the third trimester by the:
a. placenta
b. endometrial lining
c. chorion
d. corpus luteum

23. Which contraceptive method is 100 percent effective at preventing pregnancy?
a. condom
b. oral hormonal methods
c. sterilization
d. abstinence

24. Which type of short term contraceptive method is generally more effective than others?
    a. barrier
    b. hormonal
    c. natural family planning
    d. withdrawal

25. Which hormone is primarily responsible for the contractions during labor?
    a. oxytocin
    b. estrogen
    c. β-HCG
    d. progesterone

26. Major organs begin to develop during which part of human gestation?
    a. fertilization
    b. first trimester
    c. second trimester
    d. third trimester

27. Which of the following is false?
    a. The endoderm, mesoderm, ectoderm are germ layers.
    b. The trophoblast is a germ layer.
    c. The inner cell mass is a source of embryonic stem cells.
    d. The blastula is often a hollow ball of cells.

28. During cleavage, the mass of cells:
    a. increases
    b. decreases
    c. doubles with every cell division
    d. does not change significantly

29. Which of the following gives rise to the skin cells?
    a. ectoderm
    b. endoderm
    c. mesoderm
    d. none of the above

30. The ribs form from the ________.
    a. notochord
    b. neural plate
    c. neural tube
    d. somites

CRITICAL THINKING QUESTIONS

31. Why is sexual reproduction useful if only half the animals can produce offspring and two separate cells must be combined to form a third?
32. What determines which sex will result in offspring of birds and mammals?
33. What are the advantages and disadvantages of external and internal forms of fertilization?
34. Why would paired external fertilization be preferable to group spawning?
35. Describe the phases of the human sexual response.
36. Compare spermatogenesis and oogenesis as to timing of the processes and the number and type of cells finally produced.
37. If male reproductive pathways are not cyclical, how are they controlled?
38. Describe the events in the ovarian cycle leading up to ovulation.
39. Describe the major developments during each trimester of human gestation.
40. Describe the stages of labor.
41. What do you think would happen if multiple sperm fused with one egg?
42. Why do mammalian eggs have a small concentration of yolk, while bird and reptile eggs have a large concentration of yolk?
43. Explain how the different germ layers give rise to different tissue types.
44. Explain the role of axis formation in development.