chapter 20

Pregnancy, Growth, and Development

THE JOY AND SORROW OF MULTIPLE BIRTHS. A human uterus can best accommodate one fetus, and this is why most births are "singletons." About one in eighty pregnancies produces twins, and although these babies are often smaller and born earlier than singletons, most fare quite well. The picture isn't as bright as the number of fetuses increases. An Iowa couple became the parents of healthy septuplets in late 1997, and two of the children have lingering medical problems. A year later, a couple in Texas had octuplets, seven of whom survived. These families are two relative success stories.

After the McCaughey septuplets were born, Mario and Jane Simeone, of Tucson, Arizona, decided to tell the public that multiple pregnancies do not always have such happy endings. The Simeones learned this from their own tragedy. After six years of undergoing treatment for infertility, Jane delivered triplets on June 21, 1997, two girls and a boy, fifteen weeks premature. Within three weeks, both girls had died, and the boy, Mario Jr., remained hospitalized, gaining strength and weight. Although Mario Jr. came home by summer's end and has been healthy, his parents cannot forget his two sisters. One in ten "multiples" does not survive to see a first birthday. Those that do are more likely to have seizures, blindness, cerebral palsy, and mental retardation than singletons. Many multiple conceptions and pregnancies end before survival is possible.

Photo:
Multiples such as triplets and quadruplets are more likely to be born with health problems than "singletons."

4. Chemical barriers
   Spermicidal creams, foams, and jellies provide an unfavorable environment in the vagina for sperm survival.
5. Oral contraceptives
   Birth control pills contain synthetic estrogen-like and progesterone-like substances that disrupt a female's normal pattern of gonadotropin secretion and prevent ovulation and the normal buildup of the uterine lining.
6. Injectable contraception
   Intramuscular injection with medroxyprogesterone acetate every three months acts similarly to oral contraceptives to prevent pregnancy.
7. Contraceptive implants
   a. A contraceptive implant is a set of progesterone-containing capsules or rods inserted under a woman's skin.
   b. Progesterone released from the implant prevents ovulation.
8. Intrauterine devices (IUD)
   An IUD is a solid object inserted in the uterine cavity that prevents pregnancy by interfering with implantation of a blastocyst.
9. Surgical methods
   Vasectomies in males and tubal ligations in females are surgical sterilization procedures.

19.8 Sexually Transmitted Diseases (p. 520)

1. Sexually transmitted diseases (STDs) are passed during sexual contact and may go undetected for years.
2. The twenty recognized STDs share similar symptoms.

REVIEW EXERCISES

1. List the general functions of the male reproductive system. (p. 498)
2. Distinguish between the primary and accessory male reproductive organs. (p. 498)
3. Describe the structure of a testis. (p. 498)
4. Review the process of meiosis. (p. 500)
5. Describe the epididymis, and explain its function. (p. 500)
6. Trace the path of the vas deferens from the epididymis to the ejaculatory duct. (p. 501)
7. On a diagram, locate the seminal vesicles, prostate gland, and bulbourethral glands, and describe the composition of their secretions. (p. 501)
8. Describe the composition of semen. (p. 502)
9. Describe the structure of the penis. (p. 503)
10. Explain the mechanism that produces penile erection. (p. 504)
11. Distinguish between emission and ejaculation. (p. 505)
12. Explain the mechanism of ejaculation. (p. 505)
13. Explain the role of gonadotropin-releasing hormone (GnRH) in the control of male reproductive functions. (p. 505)
14. List several male secondary sex characteristics. (p. 506)
15. Explain the regulation of testosterone concentration. (p. 506)
16. List the general functions of the female reproductive system. (p. 507)
17. Describe the structure of an ovary. (p. 507)
18. Describe how a follicle matures. (p. 509)
19. On a diagram, locate the uterine tubes, and explain their function. (p. 510)
20. Describe the structure of the uterus. (p. 511)
21. On a diagram, locate the clitoris, and describe its structure. (p. 512)
22. Explain the role of gonadotropin-releasing hormone (GnRH) in regulating female reproductive functions. (p. 513)
23. List several female secondary sex characteristics. (p. 513)
24. Define *menstrual cycle*. (p. 513)
25. Summarize the major events in a menstrual cycle. (p. 513)
26. Describe the structure of a mammary gland. (p. 515)
27. Define *contraception*. (p. 516)
28. List several methods of contraception, and explain how each prevents pregnancy. (p. 516)
29. List several symptoms of sexually transmitted diseases. (p. 520)

CRITICAL THINKING

1. How are the human male and female reproductive tracts similar? How are the structures of the testis and ovary similar?
2. Why must the chromosome number be halved in sperm cells and oocytes?
3. Some men are unable to become fathers because their spermatids do not mature into sperm. Injection of their spermatids into their partner's secondary oocytes sometimes results in conception. A few men have fathered healthy babies this way. Why would this procedure work with spermatids, but not with primary spermatocytes?
4. *Contraception* literally means "against conception." According to this definition, is an intrauterine device a contraceptive? Why or why not?
5. Understanding the causes of infertility can be valuable in developing new birth control methods. Cite a type of contraceptive based on each of the following causes of infertility: (a) failure to ovulate due to a hormonal imbalance; (b) a large fibroid tumor that disturbs the uterine lining; (c) endometrial tissue blocking uterine tubes; (d) low sperm count (too few sperm per ejaculate).
6. How can a couple use "fertility awareness" methods to conceive a child or to prevent pregnancy?
7. Sometimes a sperm cell fertilizes a polar body rather than an oocyte. An embryo does not develop, and the fertilized polar body degenerates. Why is a polar body unable to support development of an embryo?
8. What changes, if any, would a male who has had one testis removed experience? A female who has had one ovary removed?
9. Does a tubal ligation cause a woman to enter menopause prematurely? Why or why not?

WEB CONNECTIONS

Visit the website for additional study questions and more information about this chapter at:

http://www.mhhe.com/shieress8

Chapter Objectives

After studying this chapter, you should be able to do the following:

20.1 Introduction

1. Distinguish between growth and development. (p. 528)
2. Distinguish between the prenatal and the postnatal periods. (p. 528)

20.2 Pregnancy

3. Define *pregnancy,* and describe the process of fertilization. (p. 528)

20.3 Prenatal Period

4. Describe the major events of cleavage. (p. 529)
5. Distinguish between an embryo and a fetus. (p. 530)
6. Describe the formation and function of the placenta. (p. 530)
7. Describe the hormonal changes in the maternal body during pregnancy. (p. 531)
8. Explain how the primary germ layers originate, and list the structures each layer produces. (p. 533)
9. Describe the major events of the embryonic stage of development. (p. 534)
10. Describe the major events of the fetal stage of development. (p. 537)
11. Trace the general path of blood through the fetal cardiovascular system. (p. 538)
12. Describe the birth process, and explain the role of hormones in this process. (p. 542)

20.4 Postnatal Period

13. Describe the major cardiovascular and physiological adjustments required of the newborn. (p. 545)

Aids to Understanding Words

allant- [sausage-shaped] *allant*ois: Tubelike structure extending from the yolk sac into the connecting stalk of the embryo.

chorio- [skin] *chorio*n: Outermost membrane surrounding the fetus and other fetal membranes.

cleav- [to divide] *cleav*age: Period of development characterized by division of the zygote into smaller and smaller cells.

lacun- [pool] *lacun*a: Space between the chorionic villi that fills with maternal blood.

morul- [mulberry] *morul*a: Embryonic structure consisting of a solid ball of about sixteen cells that resembles a mulberry.

nat- [to be born] pre*nat*al: Period of development before birth.

troph- [nurture] *troph*oblast: Cellular layer that surrounds the inner cell mass and helps nourish it.

umbil- [navel] *umbil*ical cord: Structure attached to the fetal naval (umbilicus) that connects the fetus to the placenta.

Key Terms

amnion (am´ne-on)
chorion (ko´re-on)
cleavage (klēv´ij)
embryo (em´bre-o)
fertilization (fer´´tĭ-lĭ-za´shun)
fetus (fe´tus)
gastrula (gas´troo-lah)
neonatal period (ne´´o-na´tal)
placenta (plah-sen´tah)
postnatal period (pōst-na´tal)
prenatal period (pre-na´tal)
primary germ layers (pri´mar-e jerm la´erz)
umbilical cord (um-bil´ĭ-kal kord)
zygote (zi´gōt)

20.1 Introduction

A sperm cell and an oocyte unite, forming a zygote, and the journey of prenatal development begins. Following thirty-eight weeks of cell division, growth, and specialization into distinctive tissues and organs, a new human being enters the world.

Before birth, an individual grows and develops. Growth is an increase in size. In humans and other many-celled organisms, growth entails an increase in cell numbers, followed by enlargement of the newly formed cells. Development, which includes growth, is the continuous process by which an individual changes from one life phase to another. These life phases include a **prenatal period** (pre-na´tal pe´re-od), which begins with fertilization and ends at birth, and a **postnatal** (pōst-na´tal) **period,** which begins at birth and ends at death.

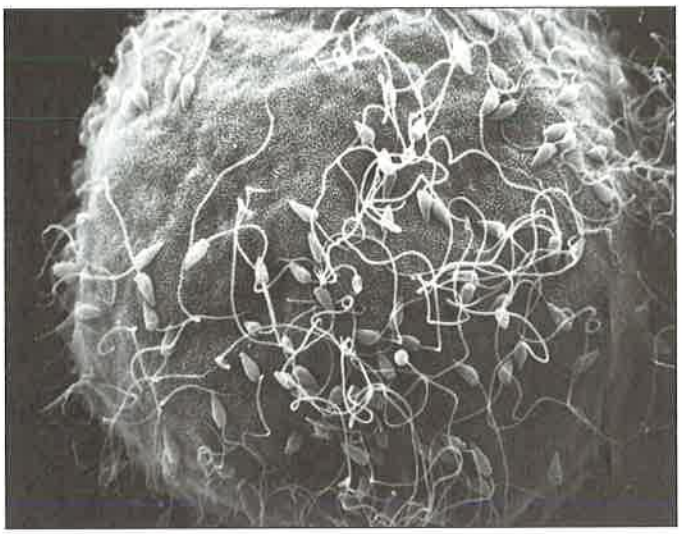


Figure 20.1
Scanning electron micrograph of sperm cells on the surface of an egg cell (1,100×). Only one sperm cell actually fertilizes the egg.

20.2 Pregnancy

Pregnancy (preg´nan-se) is the presence of a developing offspring in the uterus. It consists of three three-month periods called trimesters. Pregnancy results from the union of a secondary oocyte and a sperm cell, an event called **fertilization** (fer´´tĭ-lĭ-za´shun).

Transport of Sex Cells

Prior to fertilization, a female ovulates an egg cell (secondary oocyte), which enters a uterine tube. During sexual intercourse, the male deposits semen containing sperm cells in the vagina near the cervix. To reach the oocyte, the sperm cells must move upward through the uterus and uterine tube. Prostaglandins in the semen stimulate lashing of sperm tails and muscular contractions within the walls of the uterus and uterine tube, which help sperm cells move. Also, high concentrations of estrogens during the first part of the menstrual cycle stimulate the uterus and cervix to secrete a thin, watery fluid that promotes sperm transport and survival. Conversely, during the latter part of the cycle, when progesterone concentration is high, the female reproductive tract secretes a viscous fluid that hampers sperm transport and survival. These changes in the penetrability of the cervical mucus increase the chance that sperm will reach the oocyte when a woman is most fertile.

Sperm cells reach the upper portions of the uterine tube within an hour following sexual intercourse. Many sperm cells may reach the egg cell, but only one actually fertilizes it (fig. 20.1).

Fertilization

A sperm cell that reaches the oocyte invades the follicular cells that adhere to the oocyte's surface (corona radiata) and binds to the *zona pellucida* surrounding the oocyte cell membrane. The acrosome of the sperm cell releases enzymes (including hyaluronidase) that aid penetration by digesting proteins in the zona pellucida (fig. 20.2). However, at least several hundred sperm cells must be present to produce enough enzymes to enable one to penetrate. This is why males with very low sperm counts are said to be subfertile.

Union of the oocyte and sperm cell, rendering the structure a "fertilized egg," triggers lysosome-like vesicles just beneath the egg cell membrane to release enzymes that harden the zona pellucida. This reduces the chance that more than one sperm cell will penetrate.

Once a sperm cell enters the egg cell's cytoplasm, the nucleus in the sperm cell's head swells (fig. 20.3). The approaching nuclei from the two sex cells are called pronuclei, until they join. The egg cell then divides unequally to form a large cell, which becomes the fertilized egg, and a tiny second polar body, which is later expelled. Meiosis ends. Next, the nuclei of the egg cell and sperm cell unite. Their nuclear membranes fall apart, and their chromosomes mingle, completing fertilization.

Because the sperm cell and the egg cell each provides 23 chromosomes, the product of fertilization is a cell with 46 chromosomes—the usual number in a human body cell (somatic cell). This cell, called a **zygote** (zi´gōt), is the first cell of the future offspring.

Every human being once spent about half an hour as a single cell.

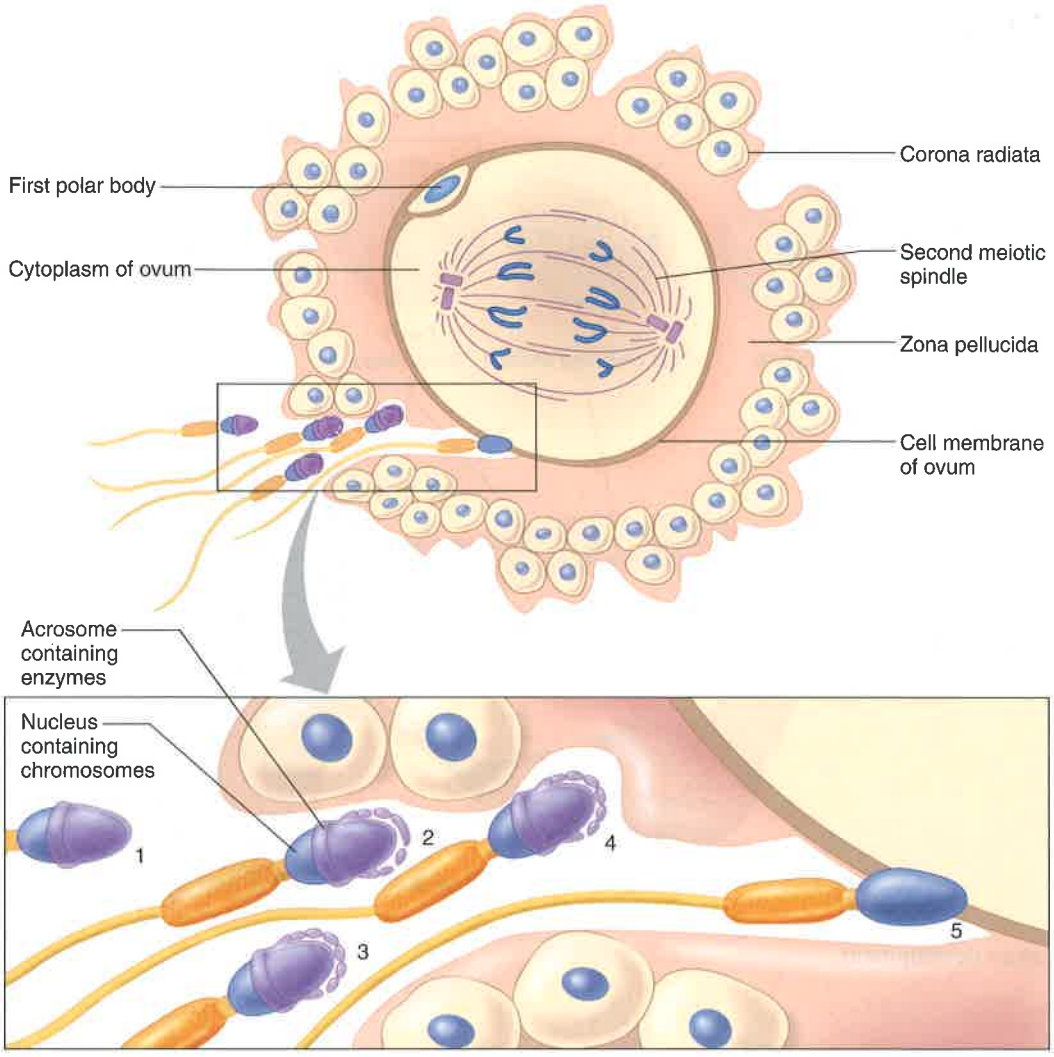


Figure 20.2
Steps in fertilization: (*1*) The sperm cell reaches the corona radiata surrounding egg cell. (*2*) The acrosome of the sperm cell releases a protein-digesting enzyme. (*3*, and *4*) The sperm cell penetrates the zona pellucida surrounding the egg cell. (*5*) The sperm cell's membrane fuses with the egg cell's membrane.

The approximate time of fertilization is fourteen days before the expected onset of the next menstrual period. The estimated time of birth is 266 days from fertilization. Most women give birth within ten to fifteen days of this calculated time.

CHECK YOUR RECALL

1. What factors aid the movements of the egg and sperm cells through the female reproductive tract?
2. Where in the female reproductive system does fertilization normally take place?
3. List the events of fertilization.

20.3 Prenatal Period

Early Embryonic Development

About 30 hours after forming, the zygote undergoes *mitosis,* giving rise to two new cells (blastomeres) (fig. 20.4*B*). These cells, in turn, divide into four cells, which divide into eight cells, and so forth. These divisions occur rapidly, with little time for growth. Thus, each division yields smaller cells. This phase of early rapid cell division is termed **cleavage** (klēv´ij) (see fig. 20.3).

During cleavage, the tiny mass of cells moves through the uterine tube to the uterine cavity. This trip takes about three days, and by then the structure consists of a solid ball of about sixteen cells. The ball is

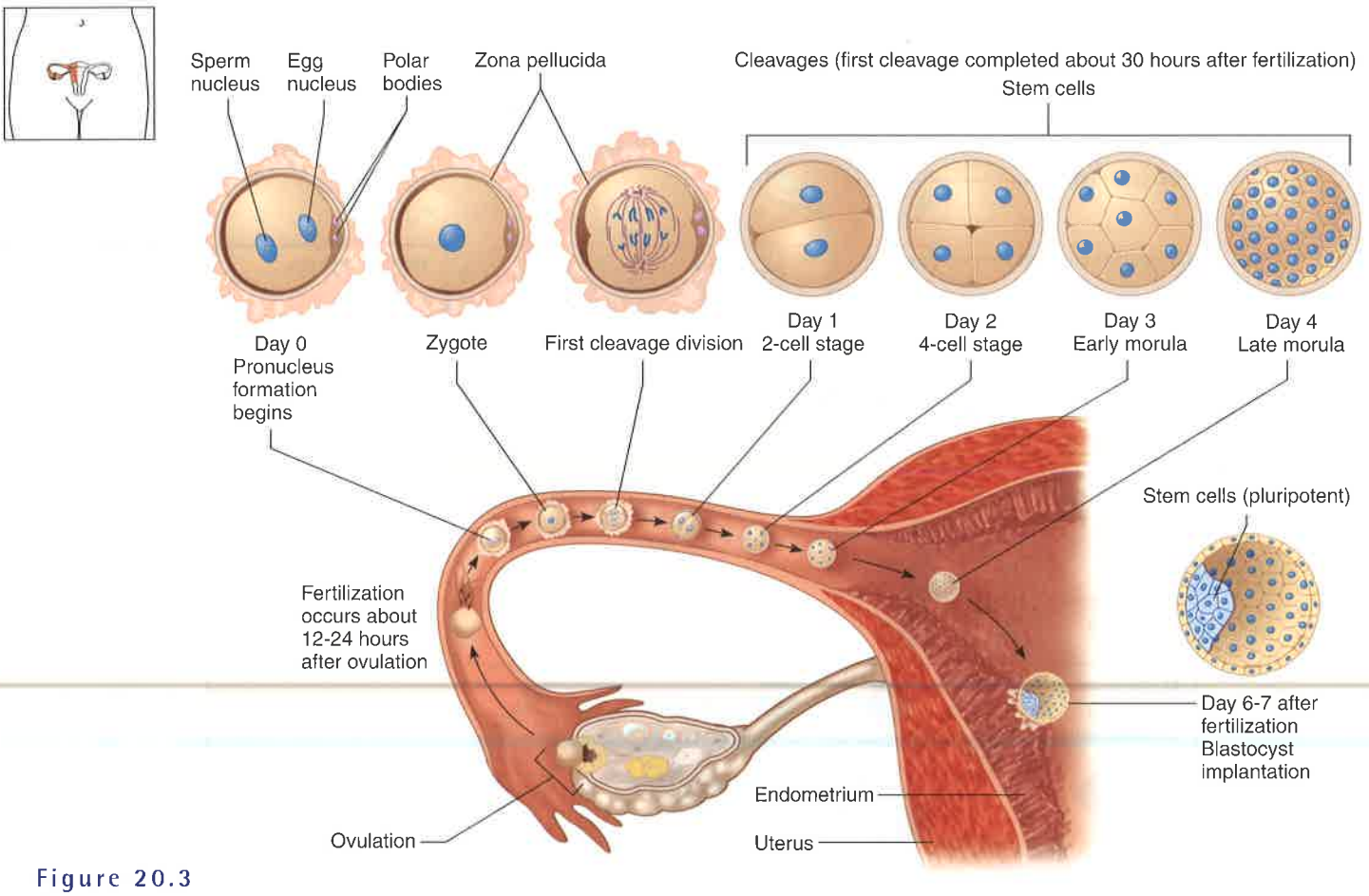


Figure 20.3
Stages of early human development.

called a *morula,* Latin for mulberry, which it resembles (fig. 20.4*C*).

The morula remains free within the uterine cavity for about three days. During this stage, the zona pellucida of the original egg cell degenerates. Then the morula hollows out, forming a *blastocyst,* which begins to attach to the endometrium. By the end of the first week of development, the blastocyst superficially implants in the endometrium (fig. 20.5). Up until this point, the cells that will become the developing offspring are pluripotent stem cells, which means that they can give rise to several specialized types of daughter cells, as well as yield additional stem cells.

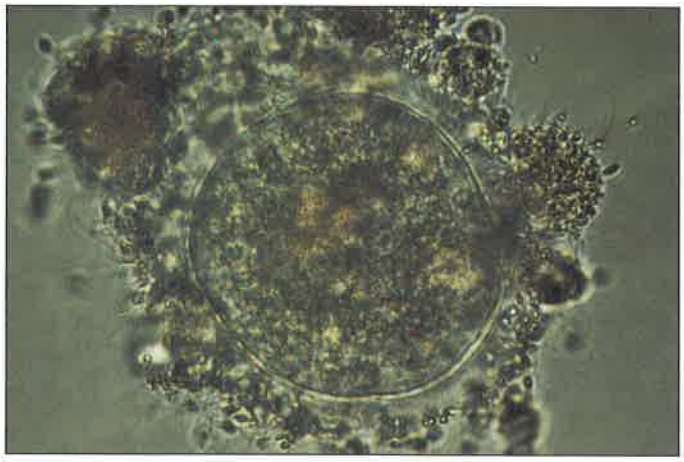
About the time of implantation, certain cells on the inner face of the blastocyst organize into a group (inner cell mass) that will give rise to the offspring. This marks the beginning of the **embryonic stage** of development. The offspring is termed an **embryo** (em´bre-o) until the end of the eighth week, when the basic structural form of the human body is recognizable. After the eighth week and until birth, the offspring is called a **fetus** (fe´tus). Rudiments of all organs are present by the end of embryonic development. These organs and other structures enlarge and specialize during fetal development.

Eventually, the cells surrounding the embryo, with cells of the endometrium, form a complex vascular structure called the **placenta** (plah-sen´tah). This organ attaches the embryo to the uterine wall and exchanges nutrients, gases, and wastes between maternal blood and the embryo's blood. The placenta also secretes hormones.

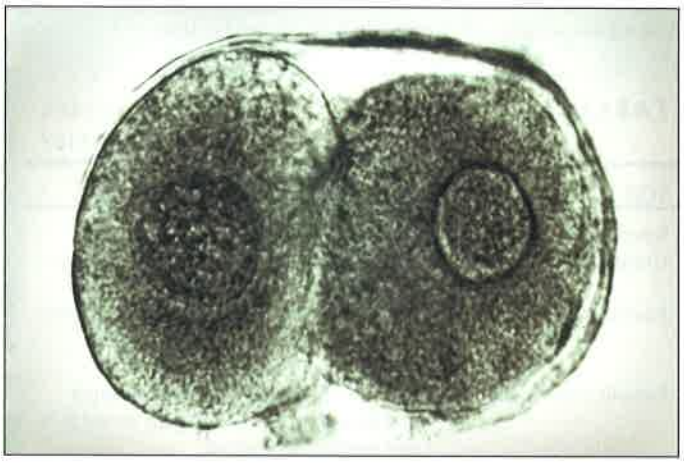
CHECK YOUR RECALL

1. What is cleavage?
2. What is implantation?
3. How do an embryo and a fetus differ?

Sometimes two ovarian follicles release egg cells simultaneously, and if both are fertilized, the resulting zygotes develop into fraternal (dizygotic) twins. Such twins are no more alike genetically than siblings. Twins may also develop from a single fertilized egg (monozygotic twins). This may happen if two inner cell masses form within a blastocyst and each produces an embryo. Monozygotic twins usually share a single placenta and are genetically identical. Thus, they are always the same sex and are very similar in appearance.



A



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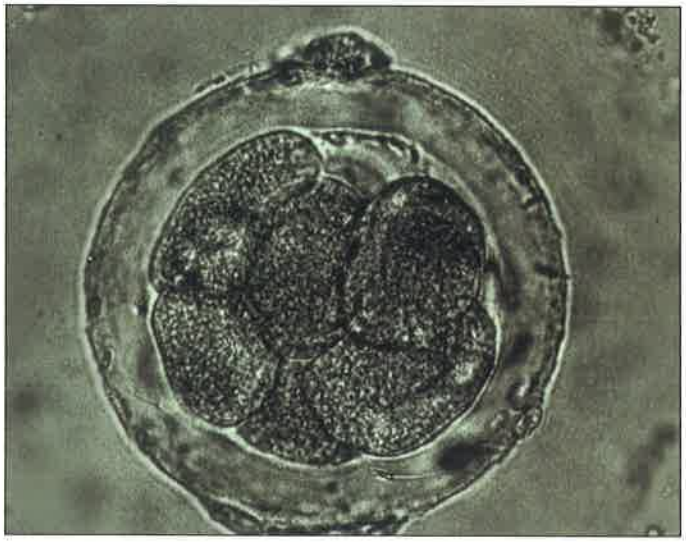
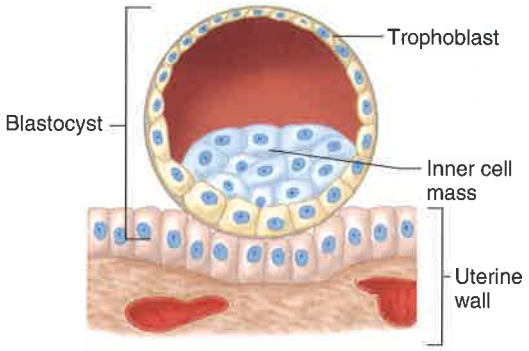
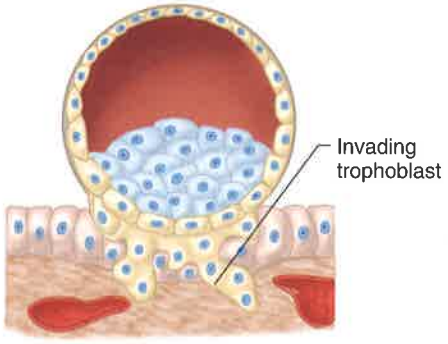


C

Figure 20.4
Light micrographs of (*A*) a human egg surrounded by follicular cells and sperm cells (250×), (*B*) the two-cell stage (600×), and (*C*) a morula (500×).



A



B

Figure 20.5
About the sixth day of development, the blastocyst (*A*) contacts the uterine wall and (*B*) begins to implant. The trophoblast, which will help form the placenta, secretes hCG, a hormone that maintains the pregnancy.

Hormonal Changes During Pregnancy

During a typical menstrual cycle, the corpus luteum degenerates about two weeks after ovulation. Consequently, concentrations of estrogens and progesterone decline rapidly, the uterine lining breaks down, and the endometrium sloughs away as menstrual flow. If this occurs following implantation, the embryo is lost (spontaneously aborted).

The hormone **human chorionic gonadotropin (hCG)** normally prevents spontaneous abortion. Cells from the outer blastocyst form a layer of embryonic cells called the trophoblast, which surrounds the developing embryo and later helps form the placenta (fig. 20.5). The trophoblast secretes hCG. This hormone, similar in function to luteinizing hormone (LH), maintains the corpus luteum, which continues secreting estrogens and progesterone, stimulating the uterine wall to grow and develop. At the same time, hCG inhibits the anterior pituitary's release of follicle-stimulating hormone (FSH) and LH, halting the normal menstrual cycle.

Topic of Interest FEMALE INFERTILITY

Infertility is the inability to conceive after a year of trying. In 90% of cases, infertility has a physical cause, and 60% of the time, the abnormality is in the female's reproductive system.

A common cause of female infertility is insufficient secretion (hyposecretion) of gonadotropic hormones by the anterior pituitary, resulting in absence of ovulation (anovulation). Testing the urine for *pregnanediol,* a product of progesterone metabolism, detects an anovulatory cycle. Because progesterone concentration normally rises after ovulation, no increase in pregnanediol in the urine during the latter part of the menstrual cycle suggests lack of ovulation.

Fertility specialists can treat anovulation due to hyposecretion of gonadotropic hormones by administering human chorionic gonadotropin (hCG) obtained from human placentas. Another ovulation-stimulating biochemical, human menopausal gonadotropin (hMG), contains luteinizing hormone (LH) and follicle-stimulating hormone (FSH) and is obtained from the urine of postmenopausal women. However, either hCG or hMG may overstimulate the ovaries and cause many follicles to release secondary oocytes simultaneously, which may result in multiple births if several are fertilized.

Another cause of female infertility is *endometriosis,* in which small pieces of the inner uterine lining (endometrium) move up through the uterine tubes during menstruation and implant in the abdominal cavity. Here, the tissue changes in a similar way to the uterine lining during the menstrual cycle. The abnormally located tissue breaks down at the end of the cycle but cannot be expelled. Instead, it remains in the abdominal cavity, irritating the lining (peritoneum) and causing considerable pain. This tissue also stimulates formation of fibrous tissue (fibrosis), which may encase the ovary, preventing ovulation or obstructing the uterine tubes.

Sexually transmitted diseases (STDs), such as gonorrhea, cause some women to become infertile. These infections can inflame and obstruct the uterine tubes or stimulate production of viscous mucus that plugs the cervix and prevents sperm entry.

Women become infertile if their ovaries must be removed, such as to treat cancer. In an experimental procedure, healthy ovarian tissue can be implanted in her upper arm, and healthy oocytes removed later. The oocytes can be fertilized *in vitro* (see Topic of Interest on page 535).

Finding the right treatment for a particular patient requires determining the infertility's cause. Table 20A describes diagnostic tests for female infertility.

TABLE 20A TESTS TO ASSESS FEMALE INFERTILITY

TEST	WHAT IT CHECKS
Hormone levels	Whether ovulation occurs
Ultrasound	Placement and appearance of reproductive organs and structures
Postcoital test	Cervix examined soon after unprotected intercourse to see if mucus is thin enough to allow sperm through
Endometrial biopsy	Small piece of uterine lining sampled and viewed under microscope to see if it can support an embryo
Hysterosalpingogram	Dye injected into uterine tube and followed with scanner shows if tube is clear or blocked
Laparoscopy	Small, lit optical device inserted near navel to detect scar tissue blocking tubes, which ultrasound may miss

Secretion of hCG continues at a high level for about two months, then declines by the end of four months. Detecting this hormone in urine or blood is the basis of pregnancy tests. The corpus luteum persists throughout pregnancy, but its function as a hormone source becomes less important after the first three months (first trimester), when the placenta secretes sufficient estrogens and progesterone (fig. 20.6).

Placental estrogens and *placental progesterone* maintain the uterine wall during the second and third trimesters of pregnancy. The placenta also secretes a hormone called **placental lactogen** that, with placental estrogens and progesterone, stimulates breast development and prepares the mammary glands for milk secretion. Placental progesterone and a polypeptide hormone called *relaxin* from the corpus luteum inhibit

Very early in pregnancy, while vast hormonal changes sweep a woman's body and the embryo rapidly increases in size and complexity, the woman may not yet realize what is happening. Early signs of pregnancy resemble those of approaching menstruation, such as bloating and irritable mood. As the pregnancy continues, the woman's blood volume increases by one-third, and her bones may weaken if she does not receive adequate dietary calcium. Muscle spasms may occur in response to rapid weight gain. In the later months, the fetus pushing against the woman's internal organs can produce heartburn, shortness of breath, and frequent urination. Fetal movements become noticeable by the fourth or fifth month, first as slight flutterings, then as jabs, kicks, and squirming movements.

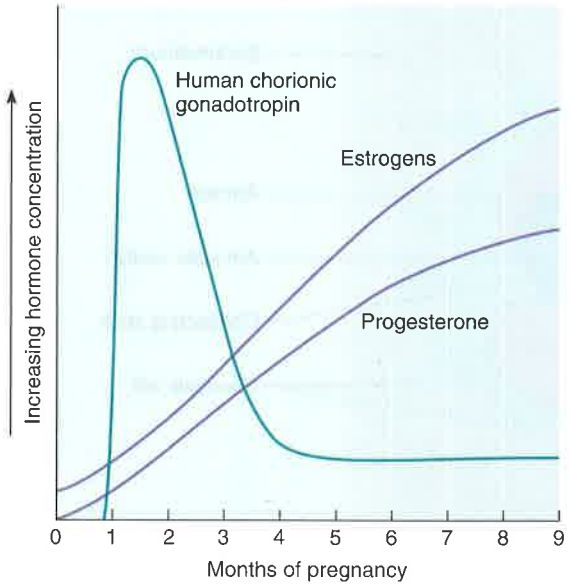


Figure 20.6
Relative concentrations of three hormones in maternal blood during pregnancy.

TABLE 20.1 HORMONAL CHANGES DURING PREGNANCY

1. Following implantation, cells of the embryo begin to secrete human chorionic gonadotropin.
2. Human chorionic gonadotropin maintains the corpus luteum, which continues to secrete estrogens and progesterone.
3. The developing placenta secretes large quantities of estrogens and progesterone.
4. Placental estrogens and progesterone:
   a. stimulate the uterine lining to continue development.
   b. maintain the uterine lining.
   c. inhibit the anterior pituitary's secretion of follicle-stimulating hormone (FSH) and luteinizing hormone (LH).
   d. stimulate development of mammary glands.
   e. inhibit uterine contractions (progesterone).
   f. enlarge the reproductive organs (estrogens).
5. Relaxin from the corpus luteum also inhibits uterine contractions and relaxes the pelvic ligaments.
6. The placenta secretes placental lactogen that stimulates breast development.
7. Aldosterone from the adrenal cortex promotes renal reabsorption of sodium.
8. Parathyroid hormone from the parathyroid glands helps maintain a high concentration of maternal blood calcium.

the smooth muscles in the myometrium, suppressing uterine contractions until the birth process begins.

The high concentration of placental estrogens during pregnancy enlarges the vagina and external reproductive organs. Also, relaxin relaxes the ligaments joining the symphysis pubis and sacroiliac joints during the last week of pregnancy, allowing greater movement at these joints and aiding the passage of the fetus through the birth canal.

Other hormonal changes of pregnancy include increased adrenal secretion of aldosterone, which promotes renal reabsorption of sodium and leads to fluid retention. The parathyroid glands secrete parathyroid hormone, which helps maintain a high concentration of maternal blood calcium (see chapter 11, p. 291). Table 20.1 summarizes the hormonal changes of pregnancy.

CHECK YOUR RECALL

1. Which hormone normally prevents spontaneous abortion?
2. What is the source of the hormones that sustain the uterine wall during pregnancy?
3. What other hormonal changes occur during pregnancy?

Embryonic Stage

The embryonic stage extends until the eighth week of prenatal development. During this time, the placenta forms, the main internal organs develop, and the major external body structures appear.

Early in the embryonic stage, the cells of the inner cell mass organize into a flattened **embryonic disc** with two distinct layers—an outer *ectoderm* and an inner *endoderm*. A short time later, the ectoderm and endoderm fold, and a third layer of cells, the *mesoderm,* forms between them. All organs form from these three cell layers, called the **primary germ layers** (pri´mar-e jerm la´erz) (fig. 20.7). A *connecting stalk* attaches the embryonic disc to the developing placenta. The two-week embryo, with its three primary germ layers, is called a **gastrula** (gas´troo-lah). Table 20.2 summarizes the stages of early embryonic development.

Ectodermal cells give rise to the nervous system, portions of special sensory organs, the epidermis, hair,

TABLE 20.2 STAGES AND EVENTS OF EARLY HUMAN PRENATAL DEVELOPMENT

STAGE	TIME PERIOD	PRINCIPAL EVENTS
Fertilized ovum	12–24 hours following ovulation	Oocyte fertilized; zygote has 23 pairs of chromosomes and is genetically distinct
Cleavage	30 hours to third day	Mitosis increases cell number
Morula	Third to fourth day	Solid ball of cells
Blastocyst	Fifth day through second week	Hollowed ball forms trophoblast (outside) and inner cell mass, which implants and flattens to form embryonic disc
Gastrula	End of second week	Primary germ layers form

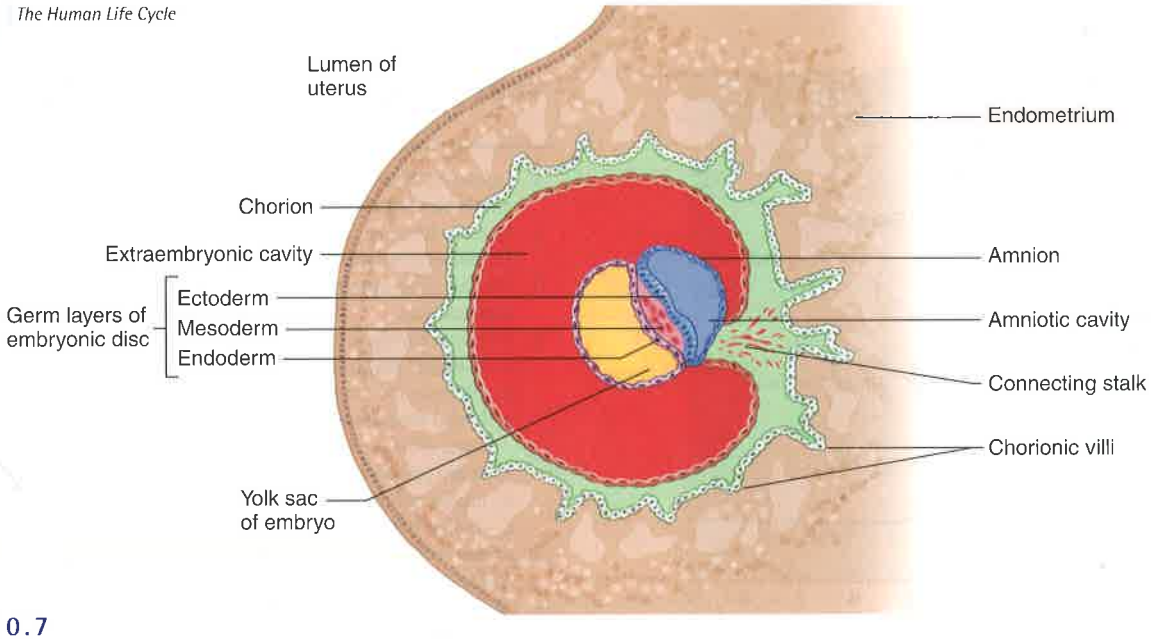


Figure 20.7
Early in the embryonic stage of development, the three primary germ layers form.

nails, glands of the skin, and linings of the mouth and anal canal. Mesodermal cells form all types of muscle tissue, bone tissue, bone marrow, blood, blood vessels, lymphatic vessels, connective tissues, internal reproductive organs, kidneys, and the epithelial linings of the body cavities. Endodermal cells produce the epithelial linings of the digestive tract, respiratory tract, urinary bladder, and urethra.

As the embryo implants in the uterus, proteolytic enzymes from the trophoblast break down endometrial tissue, providing nutrients for the developing embryo. A second layer of cells begins to line the trophoblast, and together these two layers form a structure called the **chorion** (ko´re-on). Soon, slender projections grow out from the trophoblast, including the new cell layer, eroding their way into the surrounding endometrium by continuing to secrete proteolytic enzymes. These projections become increasingly complex and form the highly branched **chorionic villi,** which are well established by the end of the fourth week.

As the chorionic villi develop, embryonic blood vessels appear within them and are continuous with those passing through the connecting stalk to the body of the embryo. At the same time, irregular spaces called **lacunae** form around and between the villi. These spaces fill with maternal blood that escapes from eroded endometrial blood vessels.

During the fourth week of development, the flat embryonic disc is transformed into a cylindrical structure. The head and jaws develop, the heart beats and forces blood through the blood vessels, and tiny buds, which will give rise to the upper and lower limbs, form (fig. 20.8).

During the fifth through the seventh weeks, as figure 20.8 shows, the head grows rapidly and becomes rounded and erect. The face, with developing eyes, nose, and mouth, becomes more humanlike. The upper and lower limbs elongate, and fingers and toes appear

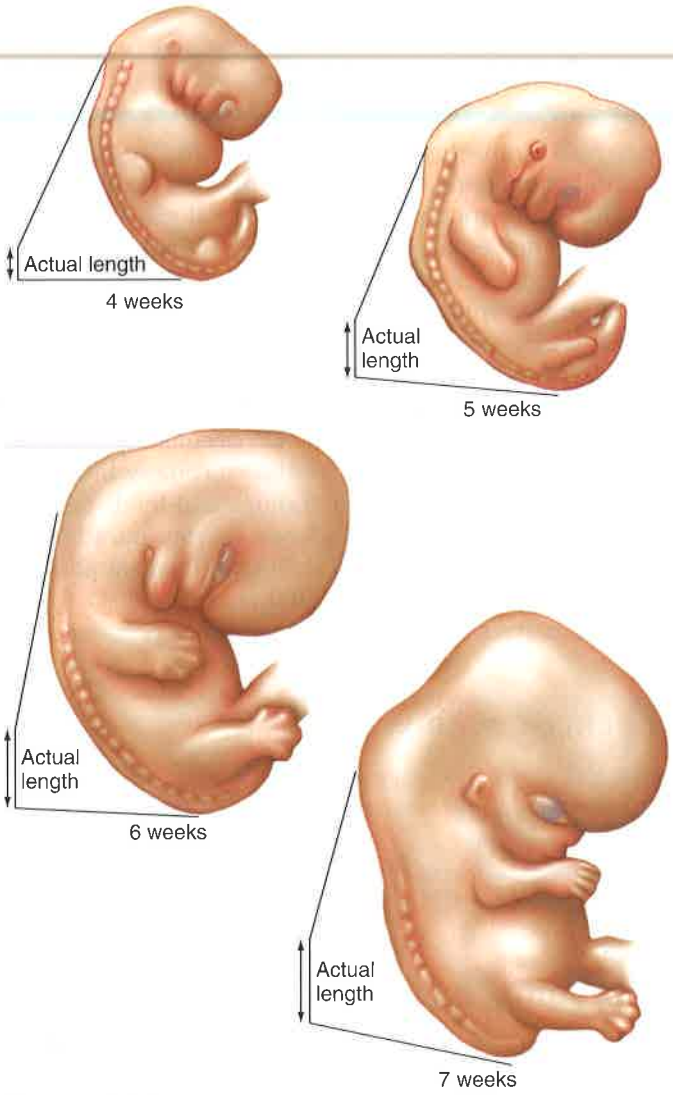


Figure 20.8
In the fifth through the seventh weeks of development, the embryonic body and face develop a humanlike appearance.

Topic of Interest ASSISTED REPRODUCTIVE TECHNOLOGIES

Michele and Ray L'Esperance wanted children badly, but Michele's uterine tubes had been removed due to scarring. A procedure called *in vitro fertilization (IVF)* enabled the couple to have children.

First, Michele received human menopausal gonadotropin to stimulate development of ovarian follicles. When an ultrasound scan showed that the follicles had grown to a certain diameter, she received human chorionic gonadotropin (which acts like LH) to induce ovulation. Then, Michele's physician used an optical instrument called a laparoscope to examine the interior of her abdomen and take the largest oocytes from an ovary. The oocytes were incubated at 37°C in a medium buffered at pH 7.4. When the oocytes matured, they were mixed in a laboratory dish with Ray's sperm cells, which had been washed to remove inhibitory factors. Secretions from Michele's reproductive tract were added to activate the sperm.

Next, fertilized egg cells were selected and incubated in a special medium for about 60 hours. At this stage, five of the eight- to sixteen-cell balls of cells were transferred through Michele's cervix and into her uterus to increase the chances that one or two would complete development. (Today, fewer fertilized eggs are transferred because of medical problems associated with multiple births, as the chapter opener describes.) The L'Esperances beat the odds—they had healthy quintuplets (fig. 20A)!

Success rates for IVF vary from clinic to clinic, ranging from 0 to 40%, with the average about 17%. Pregnancy via IVF is expensive, costing thousands of dollars. Table 20B describes other assisted reproductive technologies.

Figure 20A
In vitro fertilization worked for Michele and Ray L'Esperance. Five fertilized ova implanted in Michele's uterus are now Erica, Alexandria, Veronica, Danielle, and Raymond. But many couples are disappointed with the high failure rate of the technology.

TABLE 20B ASSISTED REPRODUCTIVE TECHNOLOGIES

TECHNOLOGY	PROCEDURE	CONDITION IT TREATS
Artificial insemination	Donated sperm cells or pooled specimens are placed near a woman's cervix.	Male infertility—lack of sperm cells or low sperm count
Surrogate mother	An oocyte fertilized in vitro is implanted in a woman other than the one who donated the oocyte. The surrogate, or "gestational mother," gives the newborn to the "genetic mother" and her partner, the sperm donor.	Female infertility—lack of a uterus
Gamete intrafallopian transfer (GIFT)	Oocytes are removed from a woman's ovary, then placed along with donated sperm cells into a uterine tube.	Female infertility—bypasses blocked uterine tube
Zygote intrafallopian transfer (ZIFT)	An oocyte fertilized in vitro is placed in a uterine tube. It travels to the uterus on its own.	Female infertility—bypasses blocked uterine tube
Embryo adoption	A woman is artificially inseminated with sperm cells from a man whose partner cannot ovulate healthy oocytes. If the woman conceives, the morula is flushed from her uterus and implanted in the uterus of the sperm donor's partner.	Female infertility—a woman has nonfunctional ovaries, but a healthy uterus

(fig. 20.9). By the end of the seventh week, all the main internal organs are present, and as these structures enlarge, the body takes on a humanlike appearance.

Until about the end of the eighth week, the chorionic villi cover the entire surface of the former trophoblast. However, as the embryo and the chorion surrounding it enlarge, only those villi that remain in contact with the endometrium endure. The others degenerate, and the portions of the chorion to which they were attached become smooth. Thus, the region of the chorion still in contact with the uterine wall is restricted to a disc-shaped area that becomes the placenta.

A thin **placental membrane** separates embryonic blood within the capillary of a chorionic villus from

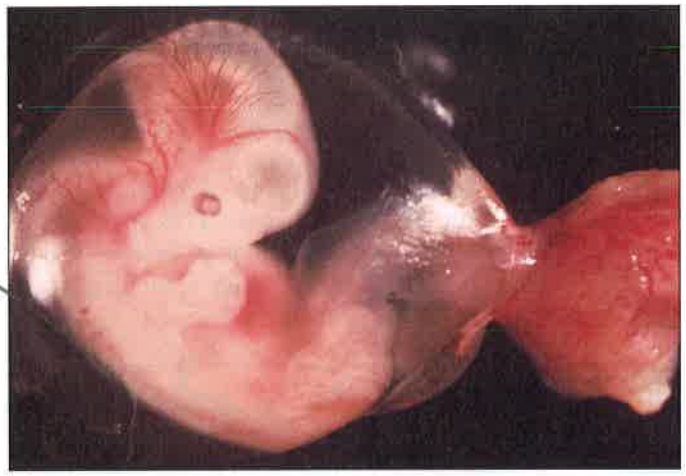


Figure 20.9
Human embryo after about six weeks of development (6.5×).

maternal blood in a lacuna. Across this membrane, which is composed of the epithelium of the chorionic villus and the epithelial wall of the capillary inside the villus, maternal and embryonic blood exchange substances (fig. 20.10). Oxygen and nutrients diffuse from the maternal blood into the embryo's blood, and carbon dioxide and other wastes diffuse from the embryo's blood into the maternal blood. Various substances also cross the placental membrane by active transport and pinocytosis.

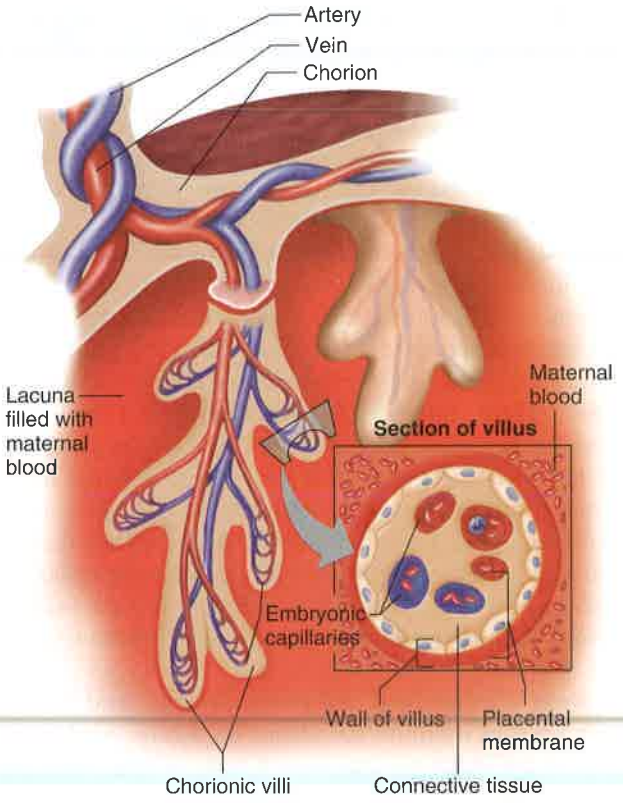


Figure 20.10
As illustrated in the section of villus (lower part of figure), the placental membrane consists of the epithelial wall of an embryonic capillary and the epithelial wall of a chorionic villus.

If a pregnant woman takes an addictive substance, her newborn may suffer from withdrawal symptoms when amounts of the chemical it is accustomed to receiving suddenly plummet. Newborn addiction occurs with certain drugs of abuse, such as heroin, and with some prescription drugs used to treat anxiety. It also occurs with very large doses of vitamin C. Although vitamin C is not addictive, if a fetus is accustomed to megadoses, the sudden drop in vitamin C level after birth may bring on symptoms of deficiency.

CHECK YOUR RECALL

1. Describe the major events of the embryonic stage of development.
2. Which tissues and structures develop from ectoderm? From mesoderm? From endoderm?
3. How do embryonic and maternal blood exchange substances?
4. Describe how the placenta forms.

The embryonic portion of the placenta is the chorion and its villi; the maternal portion is the area of the uterine wall where the villi attach (fig. 20.11). When fully formed, the placenta is a reddish-brown disc about 20 centimeters long and 2.5 centimeters thick, and weighing about 0.5 kilogram.

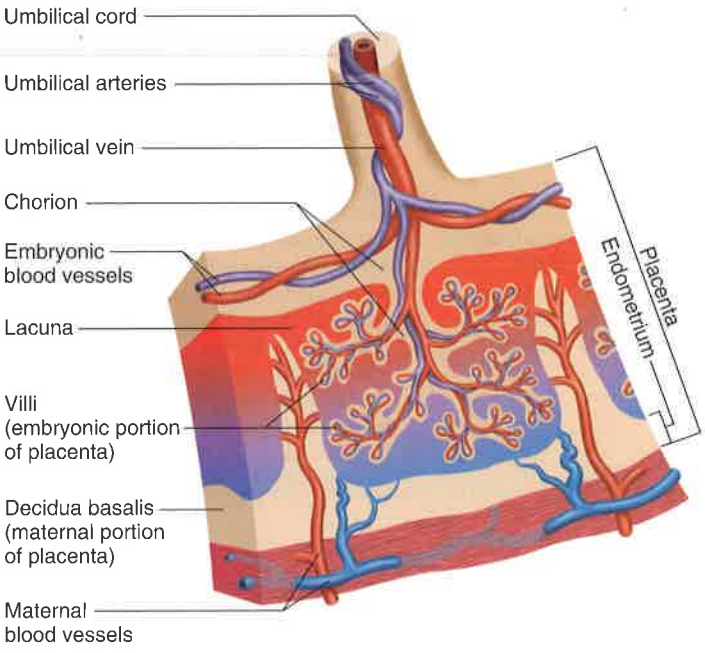


Figure 20.11
The placenta consists of an embryonic portion and a maternal portion.

While the placenta forms, another membrane, called the **amnion** (am´ne-on), develops around the embryo during the second week. Its margin attaches around the edge of the embryonic disc, and **amniotic fluid** fills the space between the amnion and the embryonic disc.

As the embryo becomes more cylindrical, the amnion margins fold, enclosing the embryo in the amnion and amniotic fluid. The amnion envelops the tissues on the underside of the embryo, by which the embryo attaches to the chorion and the developing placenta. In this manner, the **umbilical cord** (um-bil´ĭ-kal kord) forms (fig. 20.12).

The umbilical cord contains three blood vessels—two *umbilical arteries* and one *umbilical vein*—that transport blood between the embryo and the placenta (see fig. 20.11). The umbilical cord suspends the embryo in the *amniotic cavity*. The amniotic fluid allows the embryo to grow freely without compression from surrounding tissues and also protects the embryo from jarring movements of the woman's body.

Two other embryonic membranes form during development—the yolk sac and the allantois (fig. 20.12). The **yolk sac** forms during the second week and attaches to the underside of the embryonic disc. It forms blood cells in the early stages of development and gives rise to the cells that later become sex cells.

The **allantois** (ah-lan´to-is) forms during the third week as a tube extending from the early yolk sac into the connecting stalk of the embryo. It, too, forms blood cells and gives rise to the umbilical arteries and vein.

By the beginning of the eighth week, the embryo is usually 30 millimeters long and weighs less than 5 grams. It is recognizable as human (fig. 20.13).

CHECK YOUR RECALL

1. What is the function of amniotic fluid?
2. Which blood vessels are in the umbilical cord?
3. What is the significance of the yolk sac?

Fetal Stage

The **fetal stage** begins at the end of the eighth week of development and lasts until birth. During this period, growth is rapid, and body proportions change considerably. At the beginning of the fetal stage, the head is disproportionately large, and the lower limbs are short. Gradually, the proportions become more like those of a child.

During the third month, growth in body length accelerates, but head growth slows. The upper limbs

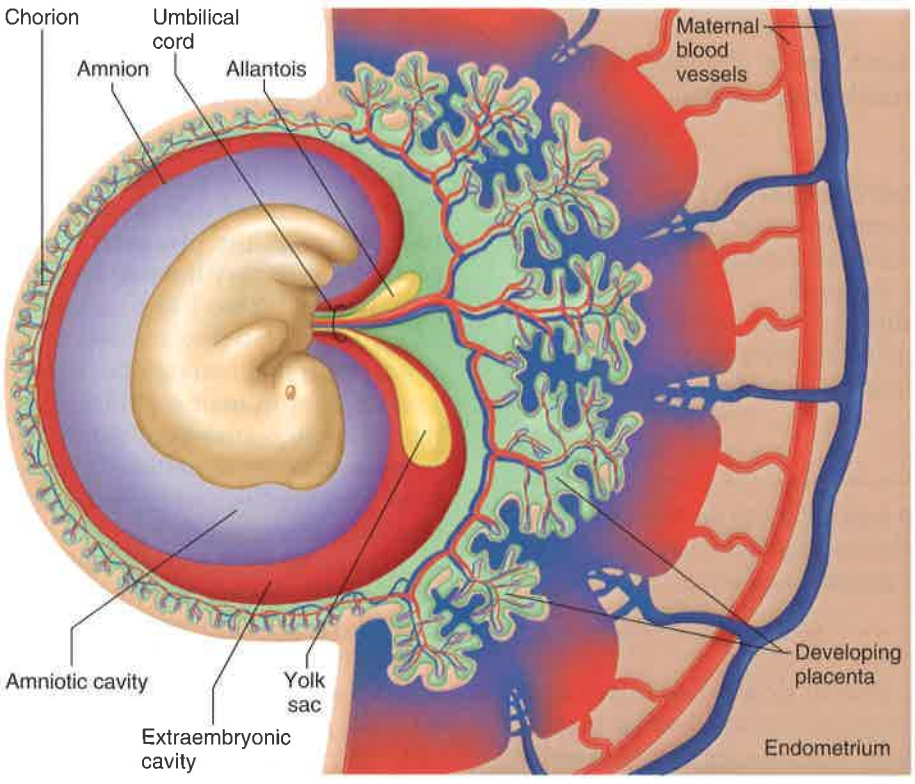


Figure 20.12
As the amnion develops, it surrounds the embryo, and the umbilical cord begins to form from structures in the connecting stalk.

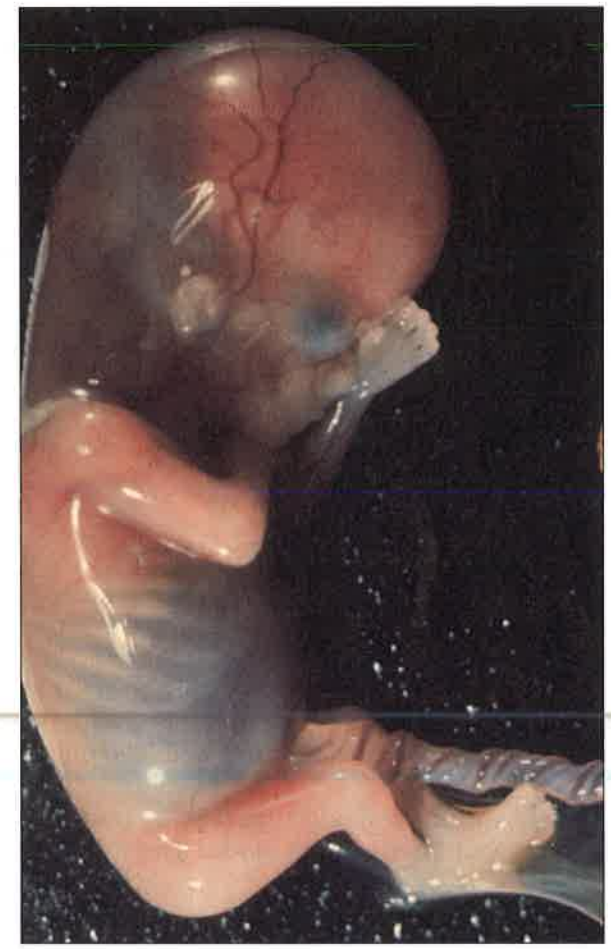


Figure 20.13
By the beginning of the eighth week of development, the embryonic body is recognizable as human (6×).

reach the length they will maintain throughout development, and ossification centers appear in most bones. By the twelfth week, the external reproductive organs are distinguishable as male or female.

In the fourth month, the body grows rapidly and reaches a length of up to 20 centimeters. The lower limbs lengthen considerably, and the skeleton continues to ossify.

A four-month-old fetus will startle and turn away if a bright light is flashed on the pregnant woman's belly. Fetuses also react to sudden loud noises.

In the fifth month, growth slows. The lower limbs reach their final relative proportions. Skeletal muscles contract, and the pregnant woman may feel fetal movements. Hair appears on the head. Fine, downy hair and a cheesy mixture of dead epidermal cells and sebum from the sebaceous glands cover the skin.

During the sixth month, the fetus gains substantial weight. Eyebrows and eyelashes appear. The skin is quite wrinkled and translucent, and blood vessels in the skin give the fetus a reddish appearance.

In the seventh month, fat is deposited in subcutaneous tissues, making the skin smoother. The eyelids, which fused during the third month, reopen. At the end of this month, the fetus is about 40 centimeters long.

In the final trimester, fetal brain cells rapidly form networks, as organs specialize and grow. A layer of fat is laid down beneath the skin. In the male, the testes descend from regions near the developing kidneys, through the inguinal canal, and into the scrotum. The digestive and respiratory systems mature last, which is why premature infants often have difficulty digesting milk and breathing.

At the end of the ninth month (on average, 266 days), the fetus is *full-term*. It is about 50 centimeters long and weighs 2.7–3.6 kilograms. The skin has lost its downy hair, but sebum and dead epidermal cells still coat it. Hair usually covers the scalp. The fingers and toes have well-developed nails. The skull bones are largely ossified. As figure 20.14 shows, the fetus is usually positioned upside down, with its head toward the cervix.

CHECK YOUR RECALL

1. What major changes occur during the fetal stage of development?
2. Describe a full-term fetus.

Fetal Blood and Circulation

Throughout fetal development, the maternal blood supplies oxygen and nutrients and carries away wastes. These substances diffuse between maternal and fetal blood through the placental membrane, and umbilical blood vessels carry them to and from the fetal body.

The fetal blood and cardiovascular system must adapt to intrauterine existence. The concentration of oxygen-carrying hemoglobin in fetal blood is about 50% greater than in maternal blood, and fetal hemoglobin has a greater attraction for oxygen than does adult hemoglobin. At a particular oxygen partial pressure, fetal hemoglobin can carry 20–30% more oxygen than can adult hemoglobin.

Figure 20.15 shows the path of blood in the fetal cardiovascular system. The umbilical vein transports blood rich in oxygen and nutrients from the placenta to the fetus. This vein enters the body and extends along the anterior abdominal wall to the liver. About half the blood it carries passes into the liver, and the rest enters a vessel called the **ductus venosus,** which bypasses the liver.

The ductus venosus extends a short distance and joins the inferior vena cava. There, oxygenated blood from the placenta mixes with deoxygenated blood from

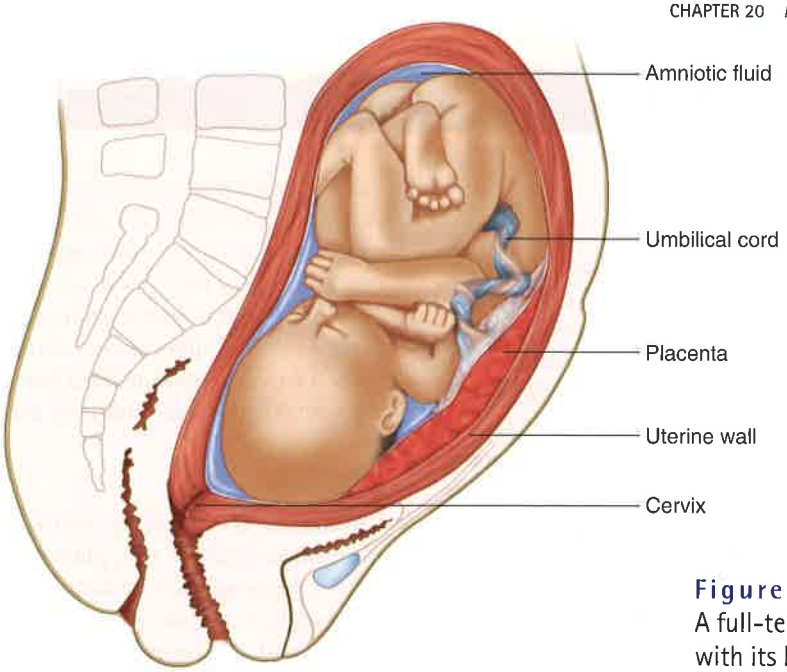


Figure 20.14
A full-term fetus is usually positioned with its head near the cervix.

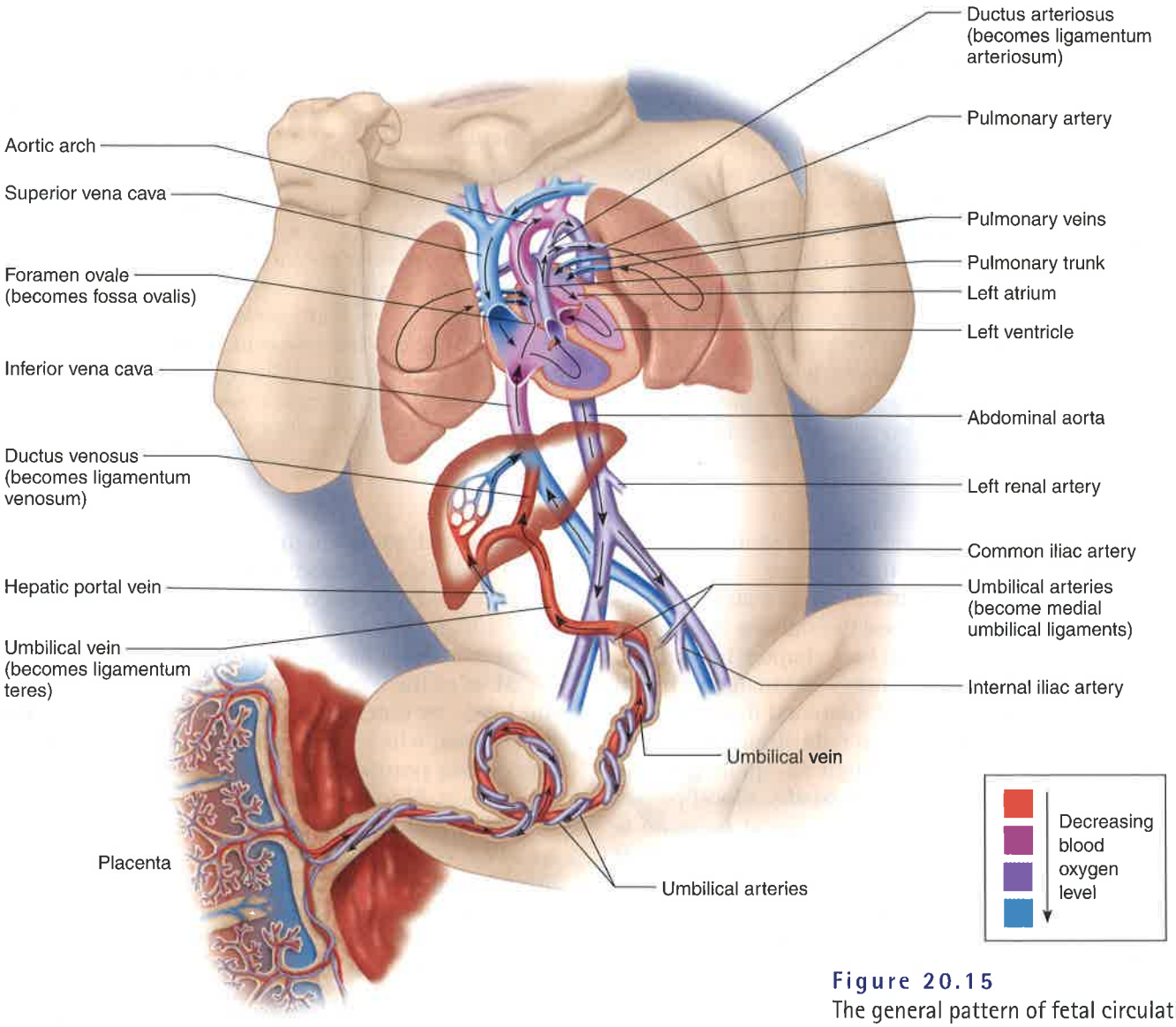


Figure 20.15
The general pattern of fetal circulation.

Topic of Interest SOME CAUSES OF BIRTH DEFECTS

Thalidomide

The idea that the placenta always protects the embryo and fetus from harmful substances was tragically disproven between 1957 and 1961, when 10,000 children in Europe were born with flippers in place of limbs. Doctors soon determined that the teratogen (an agent that causes a birth defect) was the mild tranquilizer *thalidomide,* which all of the mothers of deformed infants had taken early in pregnancy, the time when limbs form. The United States was spared a thalidomide disaster because an astute government physician noted the drug's adverse effects on experimental monkeys and halted testing.

Rubella

At about the same time as the thalidomide crisis, another teratogen, a virus, was sweeping the United States. In the early 1960s, a *rubella* (German measles) epidemic caused 20,000 birth defects and 30,000 stillbirths. Successful vaccination programs have since greatly lowered the incidence of "congenital rubella syndrome" in many countries.

Alcohol

A pregnant woman who has as few as one or two alcoholic drinks a day, or perhaps a large amount at a crucial time in prenatal development, risks *fetal alcohol syndrome (FAS)* in her unborn child. Animal studies show that even small amounts of alcohol can alter fetal brain chemistry. Thus, it is best to avoid drinking alcohol entirely when pregnant or when trying to become pregnant.

A child with FAS has a small head, misshapen eyes, and a flat face and nose (fig. 20B). He or she grows slowly before and after birth. Intellect is impaired, ranging from minor learning disabilities to mental retardation. Teens and young adults with FAS are short and have small heads. Many remain at an early grade-school level of development, and they often lack social and communication skills.

In the United States today, FAS is the third most common cause of mental retardation in newborns. One to three of every 1,000 infants has the syndrome, and more than 40,000 of these children are born each year.

Cigarettes

Chemicals in cigarette smoke stress a fetus. Carbon monoxide crosses the placenta and plugs sites on the fetus's hemoglobin molecules that bind oxygen. Other chemicals in smoke prevent nutrients from reaching the fetus. Studies comparing the placentas of smokers and nonsmokers show that smoke-exposed placentas lack important growth factors. The result of these assaults is poor growth before and after birth. Cigarette smoking during pregnancy is linked to spontaneous abortion, stillbirth, prematurity, and low birth weight.

Nutrients

Certain nutrients in large amounts, particularly vitamins, act in the body as drugs. The acne medication *isotretinoin* (Accutane) is a derivative of vitamin A that causes spontaneous abortions and defects of the heart, nervous system, and face. A vitamin A-based drug used to treat psoriasis, as well as excesses of vitamin A itself, also cause birth defects because some forms of the vitamin are stored in body fat for up to three years after ingestion.

Malnutrition in a pregnant woman threatens the fetus. Obstetric records of pregnant women before, during, and

the lower parts of the fetal body. This mixture continues through the vena cava to the right atrium.

In an adult heart, blood from the right atrium enters the right ventricle and is pumped through the pulmonary trunk and arteries to the lungs (see chapter 13, p. 333). The fetal lungs, however, are nonfunctional, and blood largely bypasses them. Much of the blood from the inferior vena cava that enters the fetal right atrium is shunted directly into the left atrium through an opening in the atrial septum called the **foramen ovale.** Blood passes through the foramen ovale because blood pressure is somewhat greater in the right atrium than in the left atrium. Furthermore, a small valve on the left side of the atrial septum overlies the foramen ovale and helps prevent blood from moving in the reverse direction.

The rest of the fetal blood entering the right atrium, including a large proportion of the deoxygenated blood entering from the superior vena cava, passes into the right ventricle and out through the pulmonary trunk. Only a small volume of blood enters the pulmonary circuit because the lungs are collapsed, and their blood vessels have a high resistance to blood flow. However, enough blood does reach lung tissues to sustain them.

Most of the blood in the pulmonary trunk bypasses the lungs by entering a fetal vessel called the **ductus arteriosus,** which connects the pulmonary trunk to the descending portion of the aortic arch. As a result of this connection, blood with a relatively low oxygen concentration, which is returning to the heart through the superior vena cava, bypasses the lungs. At the same time, it is prevented from entering the portion of the aorta that branches to the heart and brain.

The more highly oxygenated blood that enters the left atrium through the foramen ovale mixes with a small amount of deoxygenated blood returning from the pulmonary veins. This mixture moves into the left ventricle

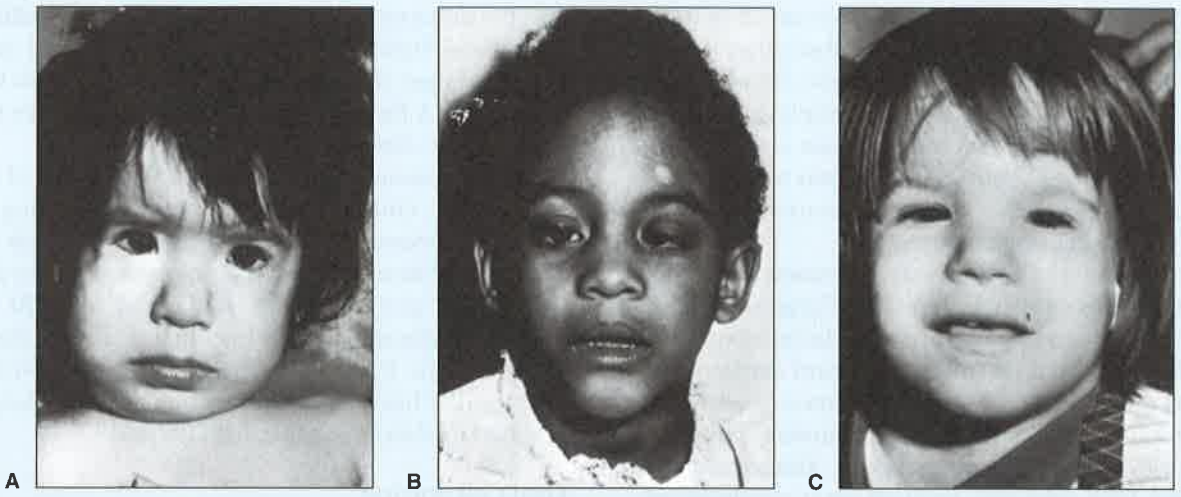


Figure 20B

Fetal alcohol syndrome. Some children whose mothers drank alcohol during pregnancy have characteristic flat faces that are strikingly similar in children of different races. Women who drink excessively while pregnant have a 30–45% chance of having a child affected to some degree by prenatal exposure to alcohol. However, only 6% of exposed offspring have full-blown fetal alcohol syndrome.

after World War II link inadequate nutrition early in pregnancy to an increase in spontaneous abortions. The aborted fetuses had very little brain tissue. More recent studies reveal that malnutrition or starvation before birth causes shifts in metabolism to make the most of calories from food. This protective action, however, sets the stage for developing obesity and associated disorders, such as type II diabetes and cardiovascular disease, in adulthood. Poor nutrition later in pregnancy affects placenta development. The infant has a low birth weight and is at high risk for short stature, tooth decay, delayed sexual development, learning disabilities, and possibly mental retardation.

Occupational Hazards

The workplace can be a source of teratogens. Women who work with textile dyes, lead, certain photographic chemicals, semiconductor materials, mercury, and cadmium have increased rates of spontaneous abortion and delivering children with birth defects. The male's role in environmentally caused birth defects is not well understood. However, men whose jobs expose them to sustained heat, such as smelter workers, glass manufacturers, and bakers, may produce sperm that can fertilize an oocyte but possibly lead to spontaneous abortion or a birth defect. A virus or a toxic chemical carried in semen may also cause a birth defect.

and is pumped into the aorta. Some of it reaches the myocardium through the coronary arteries, and some reaches the brain tissues through the carotid arteries.

Blood carried by the descending aorta is partially oxygenated and partially deoxygenated. Some of it is carried into the branches of the aorta that lead to the lower regions of the body. The rest passes into the umbilical arteries, which branch from the internal iliac arteries and lead to the placenta. There, the blood is reoxygenated (fig. 20.15).

Table 20.3 summarizes the major features of fetal circulation. At birth, the fetal cardiovascular system

TABLE 20.3 FETAL CARDIOVASCULAR ADAPTATIONS

ADAPTATION	FUNCTION
Fetal blood	Has greater oxygen-carrying capacity than blood in an adult
Umbilical vein	Carries oxygenated blood from placenta to fetus
Ductus venosus	Conducts about half the blood from umbilical vein directly to inferior vena cava, bypassing liver
Foramen ovale	Conveys much blood entering right atrium from inferior vena cava, through atrial septum, and into left atrium, bypassing lungs
Ductus arteriosus	Conducts some blood from pulmonary trunk to aorta, bypassing lungs
Umbilical arteries	Carry blood from internal iliac arteries to placenta

Genetics Connection FETAL CHROMOSOME CHECKS

The chromosomes in a cell's nucleus provide clues to the individual's health. A chromosome number other than 46 signals a serious medical condition, as do chromosomes that have missing or extra material. Sampling fetal cells and preparing charts of the chromosomes can help prenatally diagnose these conditions. Certain tests can also be applied to sampled cells to detect disorders caused by abnormal or missing single genes.

Ultrasound, in which sound waves bounced off a fetus are converted into an image, can detect large-scale structural anomalies that are part of certain chromosomal syndromes. Also, blood tests (maternal serum marker tests) performed on a pregnant woman at fifteen weeks measure hormones (alpha fetoprotein, human chorionic gonadotropin, and a form of estrogen). Abnormal levels indicate that fetal cells may have an extra chromosome. Doctors follow up questionable ultrasound or blood test results with one of the following procedures that examines fetal chromosomes (fig. 20C).

Chorionic Villus Sampling

Chorionic villus sampling (CVS) examines the chromosomes in chorionic villus cells, which are genetically identical to fetal cells because they are derived from the same fertilized egg. The test carries a risk of causing miscarriage. Thus, only women who have previously had a child with a detectable chromosome abnormality usually have the test. CVS is performed at or after the tenth week of gestation.

Amniocentesis

Amniocentesis is performed after the fourteenth week of gestation. A physician uses ultrasound to guide a needle into the amniotic sac and withdraws about 5 milliliters of fluid. Fetal fibroblasts in the fluid are cultured and their chromosomes checked. It takes about a week to grow these cells. A faster technique uses DNA probes to highlight specific chromosomes.

Amniocentesis carries about a 0.5% chance of causing miscarriage. Only women whose risk of having a fetus with a chromosomal anomaly equals or exceeds the risk of the procedure are offered amniocentesis. This includes women of any age who have had a child with a detectable chromosomal abnormality and women over age thirty-five. (Older women are more likely to produce oocytes that have extra or missing chromosomes, which can lead to abnormal fetuses if fertilized.)

Fetal Cell Sorting

A new way to check fetal chromosomes is fetal cell sorting, which separates rare fetal cells from a pregnant woman's bloodstream. A device called a fluorescence-activated cell sorter can pull out the fetal cells. The technique is safer than CVS or amniocentesis because the fetus and its membranes are not touched.

Fetal cell sorting traces its roots to 1957, when an autopsy on a pregnant woman revealed cells from a very early embryo lodged in a blood vessel in her lung. Researchers were able to tell that the cells were from an embryo only because the cells had Y chromosomes, which female cells lack. Since then, researchers have found that fetal cells enter the maternal circulation in up to 70% of all pregnancies, and may remain for decades in the woman's body, sometimes triggering an immune attack years later. Fetal cell sorting is still experimental.

must adjust when the placenta ceases to function and the newborn begins to breathe.

The umbilical cord usually contains two arteries and one vein. A small percentage of newborns have only one umbilical artery. Since this condition is often associated with other cardiovascular disorders, the vessels within the severed cord are routinely counted following birth.

CHECK YOUR RECALL

1. Which umbilical vessel carries oxygen-rich blood to the fetus?
2. What is the function of the ductus venosus?
3. How does fetal circulation allow blood to bypass the lungs?

Birth Process

Pregnancy usually continues for thirty-eight weeks from conception, which is forty weeks from the woman's last menstrual period. Pregnancy ends with the *birth process*. A period of rapid changes and intense physical demands on the pregnant woman begins hours or days before the birth.

A declining progesterone concentration plays a major role in initiating birth. During pregnancy, progesterone suppresses uterine contractions. As the placenta ages, the progesterone concentration within the uterus declines, which stimulates synthesis of a prostaglandin that promotes uterine contractions. At the same time, the cervix begins to thin and then open. Changes in the cervix may begin a week or two before other signs of labor occur.

Another stimulant of the birth process is stretching of the uterine and vaginal tissues late in pregnancy.

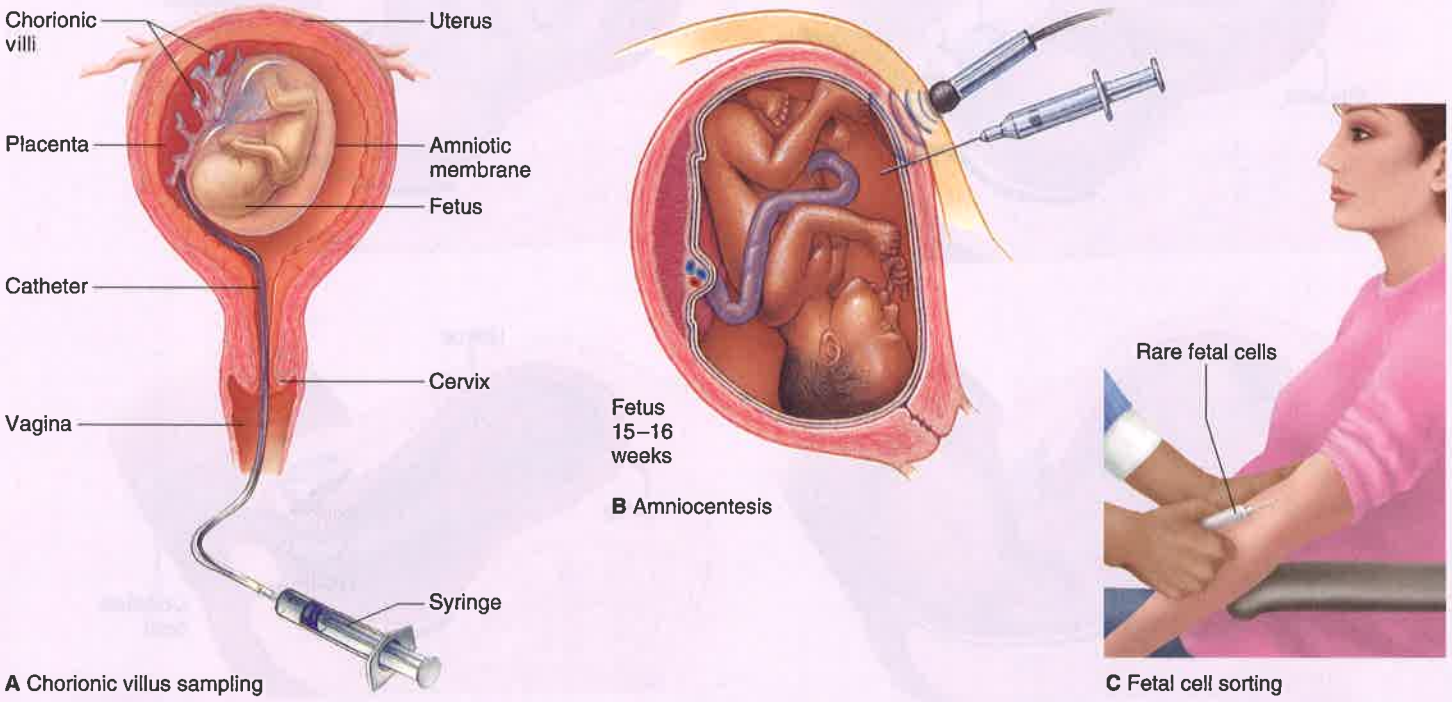


Figure 20C

Three ways to check a fetus's chromosomes. (A) Chorionic villus sampling (CVS) removes cells of the chorionic villi, whose chromosomes match those of the fetus because they all descend from the fertilized ovum. CVS is usually performed earlier than amniocentesis. (B) In amniocentesis, a needle is inserted into the uterus to collect a sample of amniotic fluid, which contains fetal cells. The cells are grown in the laboratory and then dropped onto a microscope slide to spread the chromosomes. The chromosomes are then stained and arranged into a chromosome chart (karyotype). Amniocentesis is performed after the fifteenth week of gestation. (C) Fetal cell sorting separates fetal cells in the woman's circulation. A genetic counselor interprets the results of these tests for patients.

This initiates nerve impulses to the hypothalamus, which in turn signals the posterior pituitary gland to release the hormone **oxytocin** (see chapter 11, p. 288). Oxytocin stimulates powerful uterine contractions. Combined with the greater excitability of the myometrium due to the decline in progesterone secretion, oxytocin aids labor in its later stages.

During labor, rhythmic muscular contractions begin at the top of the uterus and extend down its length. Since the fetus is usually positioned head downward, labor contractions force the head against the cervix (fig. 20.16). This action stretches the cervix, which elicits a reflex that stimulates still stronger labor contractions. Thus, a *positive feedback system* operates, in which uterine contractions produce more intense uterine contractions. At the same time, continuing cervix dilation reflexly stimulates the posterior pituitary to increase oxytocin release. As labor continues, positive feedback stimulates abdominal wall muscles to contract, which also helps force the fetus through the cervix and vagina to the outside.

An infant passing through the birth canal can tear the delicate tissues between the vulva and anus (perineum). To avoid a ragged tear, a physician makes an *episiotomy,* a clean cut in the perineal tissues.

Following birth of the fetus, the placenta separates from the uterine wall, and uterine contractions expel it through the birth canal. Bleeding accompanies the expelled placenta, termed the *afterbirth,* because the separation damages vascular tissues. However, oxytocin stimulates continued uterine contraction, which compresses the bleeding vessels and minimizes blood loss.

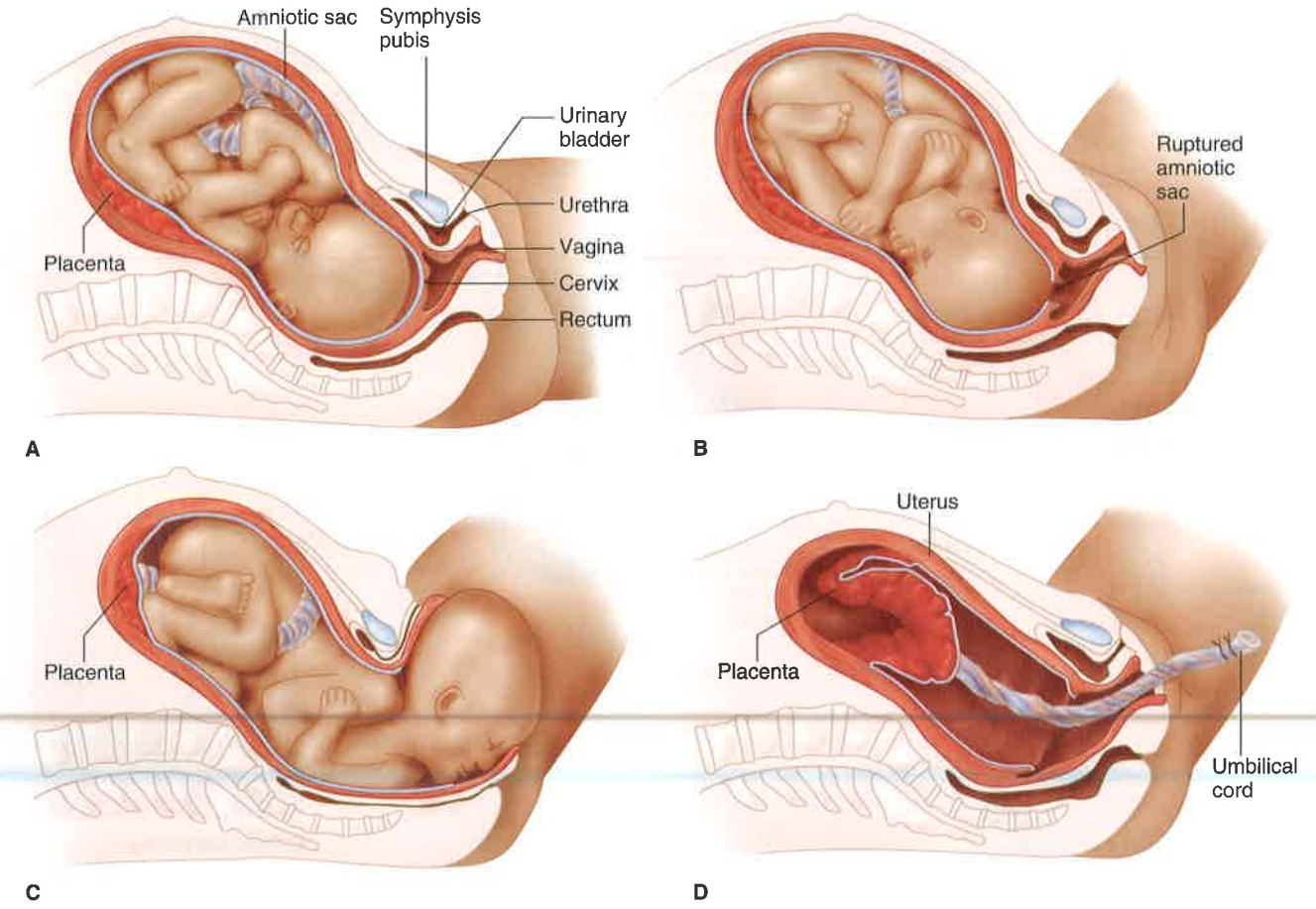


Figure 20.16
Stages in birth. (*A*) Fetal position before labor, (*B*) dilation of the cervix, (*C*) expulsion of the fetus, (*D*) expulsion of the placenta.

Breast-feeding also contributes to returning the uterus to its original, prepregnancy size, as the suckling of the newborn stimulates the release of oxytocin from the posterior pituitary.

CHECK YOUR RECALL

1. Describe the role of progesterone in initiating labor.
2. Explain how dilation of the cervix affects labor.

20.4 Postnatal Period

Following birth, both mother and newborn experience physiological and structural changes.

Milk Production and Secretion

During pregnancy, placental estrogens and progesterone stimulate further development of the mammary glands. Estrogens cause the ductile systems to grow and branch and deposit abundant fat around them. Progesterone stimulates development of the alveolar glands at the ends of the ducts. Placental lactogen also promotes these changes.

Hormonal activity doubles breast size during pregnancy, and the mammary glands become capable of secreting milk. However, milk is not secreted because placental progesterone inhibits milk production, and placental lactogen blocks the action of *prolactin* (see chapter 11, p. 287).

Following childbirth and the expulsion of the placenta, maternal blood concentrations of placental hormones decline rapidly. In two or three days, prolactin, which is no longer inhibited, stimulates the mammary glands to secrete milk. Meanwhile, the glands secrete a thin, watery fluid called *colostrum*. Colostrum is rich in proteins, but its carbohydrate and fat concentrations are lower than those of milk. Colostrum contains antibodies from the mother's immune system that protect the newborn from certain infections.

Milk ejection requires contraction of specialized *myoepithelial cells* surrounding the alveolar glands (fig. 20.17). Suckling or mechanical stimulation of the nipple or areola elicits the reflex action that controls this process. Impulses from sensory receptors within the breasts go to the hypothalamus, which signals the poste-

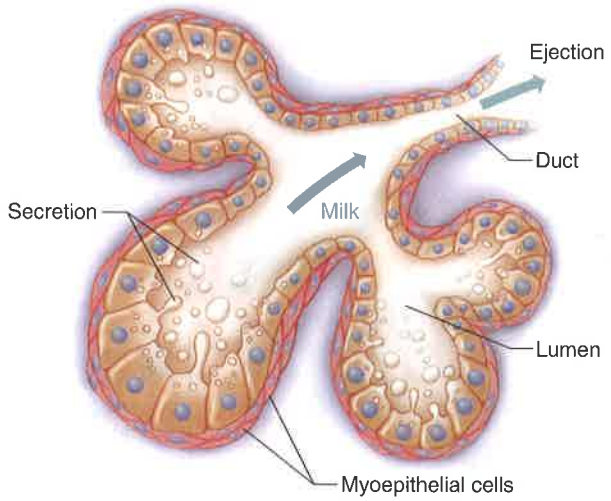


Figure 20.17
Myoepithelial cells eject milk from an alveolar gland.

rior pituitary gland to release oxytocin. Oxytocin travels in the bloodstream to the breasts and stimulates myoepithelial cells to contract. As a result, milk is ejected into a suckling infant's mouth in about 30 seconds.

As long as milk is removed from the breasts, release of prolactin and oxytocin continues, and the mammary glands produce milk. If milk is not removed regularly, the hypothalamus inhibits prolactin secretion, and within about one week, the mammary glands stop producing milk.

Human milk is the best possible food for human babies. The milk of other animals contains different concentrations of nutrients than human milk.

CHECK YOUR RECALL

1. How does pregnancy affect the mammary glands?
2. What stimulates the mammary glands to produce milk?
3. What causes milk to flow into the ductile system of a mammary gland?

Neonatal Period

The **neonatal** (ne´´o-na´tal) **period** begins abruptly at birth and extends to the end of the first four weeks. At birth, the newborn must make quick physiological adjustments to become self-reliant. It must respire, obtain and digest nutrients, excrete wastes, and regulate body temperature.

The largest newborn of recent times was a 24-pound 4-ounce baby boy born in Turkey.

A newborn's most immediate requirement is to obtain oxygen and excrete carbon dioxide. The first breath must be particularly forceful because the newborn's lungs are collapsed, and its small airways offer considerable resistance to air movement. Also, surface tension tends to hold the moist membranes of the lungs together. However, the lungs of a full-term fetus continuously secrete *surfactant* (see chapter 16, p. 443), which reduces surface tension. After the first powerful breath begins to expand the lungs, breathing eases.

Premature infants' survival chances increase directly with age and weight. Survival is more likely if the lungs are sufficiently developed with the thin respiratory membranes necessary for rapid exchange of oxygen and carbon dioxide, and if the lungs produce enough surfactant to reduce alveolar surface tension. A fetus of less than twenty-four weeks or weighing less than 600 grams at birth seldom survives, even with intensive medical care. *Neonatology* is the medical field that deals with premature and ill newborns.

The newborn has a high metabolic rate, and its immature liver may be unable to supply enough glucose to support its metabolic requirements. Consequently, the newborn typically utilizes stored fat for energy.

A newborn's kidneys are usually unable to produce concentrated urine, so they excrete a dilute fluid. For this reason, the newborn may become dehydrated and develop a water and electrolyte imbalance. Also, some of the newborn's homeostatic control mechanisms may not function adequately. For example, the temperature-regulating system may be unable to maintain a constant body temperature.

When the placenta ceases to function and breathing begins, the newborn's cardiovascular system also changes. Following birth, the umbilical vessels constrict. The umbilical arteries close first, and if the umbilical cord is not clamped or severed for a minute or so, blood continues to flow from the placenta to the newborn through the umbilical vein, adding to the newborn's blood volume. Similarly, the ductus venosus constricts shortly after birth and appears in the adult as a fibrous cord (ligamentum venosum) superficially embedded in the wall of the liver.

The foramen ovale closes as a result of blood pressure changes in the right and left atria as fetal vessels constrict. As blood ceases to flow from the umbilical vein into the inferior vena cava, the blood pressure in the right atrium falls. Also, as the lungs expand with the first breathing movements, resistance to blood flow through the pulmonary circuit decreases, more blood enters the left atrium through the pulmonary veins, and the blood pressure in the left atrium increases.

As the blood pressure in the left atrium rises and that in the right atrium falls, the valve on the left side of the atrial septum closes the foramen ovale. In most individuals, this valve gradually fuses with the tissues along the

margin of the foramen. In an adult, a depression called the *fossa ovalis* marks the site of the previous opening.

The ductus arteriosus, like the other fetal vessels, constricts after birth. After the ductus arteriosus closes, blood can no longer bypass the lungs by moving from the pulmonary trunk directly into the aorta. In an adult, a cord called the *ligamentum arteriosum* represents the ductus arteriosus.

In *patent ductus arteriosus (PDA)*, the ductus arteriosus fails to close completely. This condition is common in newborns whose mothers were infected with rubella virus (German measles) during the first three months of pregnancy.

After birth, the metabolic rate and oxygen consumption in neonatal tissues increase, in large part to maintain body temperature. If the ductus arteriosus remains open, the neonate's blood oxygen concentration may be too low to adequately supply tissues, including the myocardium. If PDA is not corrected surgically, the heart may fail, even though the myocardium is normal.

Changes in the newborn's cardiovascular system are gradual. Constriction of the ductus arteriosus may be functionally complete within 15 minutes, but the permanent closure of the foramen ovale may take up to a year.

Recall that fetal hemoglobin is slightly different and has a greater affinity for oxygen than the adult type. Fetal hemoglobin production falls after birth, and by the time an infant is four months old, most of the circulating hemoglobin is the adult type. Figure 20.18 illustrates cardiovascular changes in the newborn.

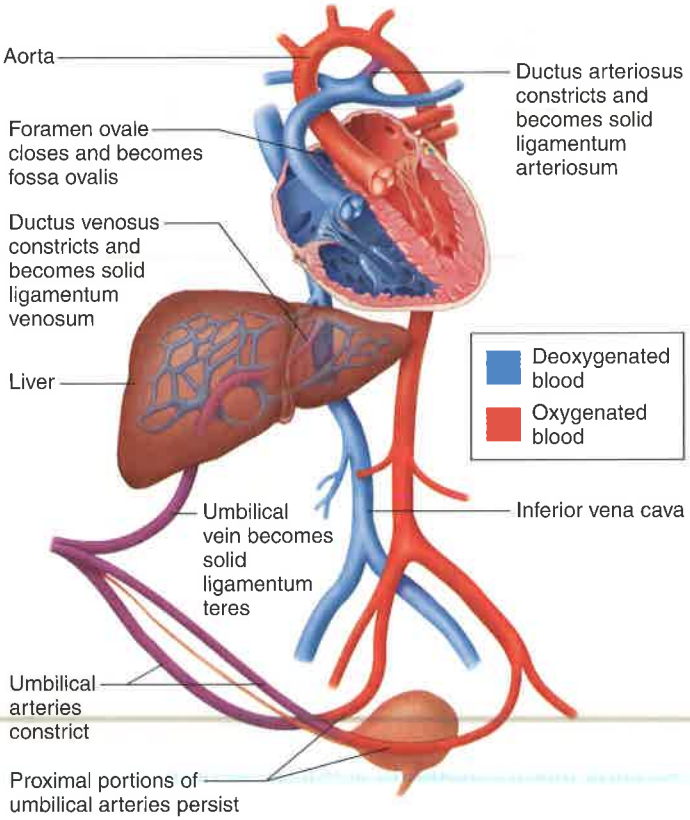


Figure 20.18
Major changes in the newborn's cardiovascular system.

CHECK YOUR RECALL

1. Why must a newborn's first breath be particularly forced?
2. What does a newborn use for energy during its first few days of life?
3. How do the kidneys of a newborn differ from those of an adult?
4. What changes occur in the newborn's cardiovascular system?

Table 20.4 summarizes the major events during the neonatal period as well as those of the later stages of human development. Table 20.5 outlines aging-related changes.

Clinical Terms Related to Pregnancy, Growth, and Development

abruptio placentae (ab-rup´she-o plah-cen´tā) Premature separation of the placenta from the uterine wall.

dizygotic twins (di´´zi-got´ik twinz) Twins resulting from two sperm cells fertilizing two egg cells.

hydatidiform mole (hi´´dah-tid´ī-form mōl) Abnormal pregnancy resulting from a pathologic ovum; a mass of cysts.

hydramnios (hi-dram´ne-os) Excess amniotic fluid.

intrauterine transfusion (in´´trah-u´ter-in trans-fu´zhun) Transfusion administered by injecting blood into the fetal peritoneal cavity before birth.

lochia (lo´ke-ah) Vaginal discharge following childbirth.

meconium (mĕ-ko´ne-um) Anal discharge from the digestive tract of a full-term fetus or a newborn.

monozygotic twins (mon´´o-zi-got´ik twinz) Twins resulting from one sperm cell fertilizing one egg cell, which then splits.

perinatology (per´´ī-na-tol´o-je) Branch of medicine concerned with the fetus after twenty-five weeks of development and with the newborn for the first four weeks after birth.

postpartum (pōst-par´tum) Occurring after birth.

teratology (ter´´ah-tol´o-je) Study of substances that cause abnormal development and congenital malformations.

trimester (tri-mes´ter) Each third of the total period of pregnancy.

ultrasonography (ul´´trah-son-og´rah-fe) Technique used to visualize the size and position of fetal structures from patterns of deflected ultrasonic waves.

TABLE 20.4 STAGES IN POSTNATAL DEVELOPMENT

STAGE	TIME PERIOD	MAJOR EVENTS
Neonatal period	Birth to end of fourth week	Newborn begins to respire, eat, digest nutrients, excrete wastes, regulate body temperature, and make cardiovascular adjustments
Infancy	End of fourth week to one year	Growth rate is high; teeth begin to erupt; muscular and nervous systems mature so that coordinated activities are possible; communication begins
Childhood	One year to puberty	Growth rate is high; deciduous teeth erupt and are replaced by permanent teeth; high degree of muscular control is achieved; bladder and bowel controls are established; intellectual abilities mature
Adolescence	Puberty to adulthood	Person becomes reproductively functional and emotionally more mature; growth spurts occur in skeletal and muscular systems; high levels of motor skills are developed; intellectual abilities increase
Adulthood	Adolescence to old age	Person remains relatively unchanged anatomically and physiologically; degenerative changes begin to occur
Senescence	Old age to death	Degenerative changes continue; body becomes less and less able to cope with demands; death usually results from mechanical disturbances in the cardiovascular system or from disease processes that affect vital organs

TABLE 20.5 AGING-RELATED CHANGES

ORGAN SYSTEM	AGING-RELATED CHANGES
Integumentary system	Degenerative loss of collagenous and elastic fibers in dermis; decreased production of pigment in hair follicles; reduced activity of sweat and sebaceous glands
	Skin thins, wrinkles, and dries out; hair turns gray and then white
Skeletal system	Degenerative loss of bone matrix
	Bones become thinner, less dense, and more likely to fracture; stature may shorten due to compression of intervertebral discs and vertebrae
Muscular system	Loss of skeletal muscle fibers; degenerative changes in neuromuscular junctions
	Loss of muscular strength
Nervous system	Degenerative changes in neurons; loss of dendrites and synaptic connections; accumulation of lipofuscin in neurons; decreases in sensation
	Decreasing efficiency in processing and recalling information; decreasing ability to communicate; diminished sense of smell and taste; loss of elasticity of lenses and consequent loss of ability to accommodate for close vision
Endocrine system	Reduced hormonal secretions
	Decreased metabolic rate; reduced ability to cope with stress; reduced ability to maintain homeostasis
Cardiovascular system	Degenerative changes in cardiac muscle; decrease in lumen diameters of arteries and arterioles
	Decreased cardiac output; increased resistance to blood flow; increased blood pressure
Lymphatic system	Decrease in efficiency of immune system
	Increased incidence of infections and neoplastic diseases; increased incidence of autoimmune diseases
Digestive system	Decreased motility in gastrointestinal tract; reduced secretion of digestive juices
	Reduced efficiency of digestion
Respiratory system	Degenerative loss of elastic fibers in lungs; fewer alveoli
	Reduced vital capacity; increase in dead air space; reduced ability to clear airways by coughing
Urinary system	Degnerative changes in kidneys; fewer functional nephrons
	Reductions in filtration rate, tubular secretion, and reabsorption
Reproductive systems	
Male	Reduced secretion of sex hormones; enlargement of prostate gland; decrease in sexual energy
Female	Degenerative changes in ovaries; decrease in secretion of sex hormones; menopause; regression of secondary sex characteristics

Clinical Connection

Preeclampsia, also called "toxemia of pregnancy," is a complication that produces dangerously high blood pressure in a pregnant woman. Evidence suggests that preeclampsia may be passed on through the male. For many years, obstetricians routinely asked their patients if their mothers had preeclampsia, because it has a tendency to occur in women whose mothers were affected. However, in 1998 a study of 1.7 million pregnancies in Norway revealed that if a man's first wife had preeclampsia, his second wife had double the average risk of developing the condition too. Another study in 2001 on 298 men and 237 women in Utah found that women whose mothers-in-law had experienced preeclampsia when pregnant with the women's husbands faced approximately twice the risk of developing the condition themselves. Somehow, a gene from the male must affect the placenta in a way that elevates the pregnant woman's blood pressure.

SUMMARY OUTLINE

20.1 Introduction (p. 528)

Growth is an increase in size. Development is the process of changing from one life phase to another.

20.2 Pregnancy (p. 528)

Pregnancy is the presence of a developing offspring in the uterus.

1. Transport of sex cells
   a. A male deposits semen in the vagina during sexual intercourse.
   b. A sperm cell lashes its tail to move, and is aided by muscular contractions in the female reproductive tract.
2. Fertilization
   a. An enzyme helps a sperm cell penetrate the zona pellucida.
   b. When a sperm cell penetrates an egg cell membrane, changes in the membrane and the zona pellucida prevent entry of additional sperm cells.
   c. Fusion of the nuclei of a sperm cell and an egg cell completes fertilization.
   d. The product of fertilization is a zygote with 46 chromosomes.

20.3 Prenatal Period (p. 529)

1. Early embryonic development
   a. Cells undergo mitosis, giving rise to smaller and smaller cells during cleavage.
   b. The developing offspring moves down the uterine tube to the uterus, where it implants in the endometrium.
   c. The offspring is called an embryo through the eighth week of development. Thereafter, it is a fetus.
   d. Eventually, embryonic and maternal cells form a placenta.
2. Hormonal changes during pregnancy
   a. Embryonic cells produce human chorionic gonadotropin (hCG), which maintains the corpus luteum.
   b. Placental tissue produces high concentrations of estrogens and progesterone.
      (1) Estrogens and progesterone maintain the uterine wall and inhibit secretion of follicle-stimulating hormone (FSH) and luteinizing hormone (LH).
      (2) Progesterone and relaxin inhibit contraction of uterine muscles.
      (3) Estrogens cause enlargement of the vagina.
      (4) Relaxin helps relax the ligaments of the pelvic joints.
   c. Placental lactogen stimulates development of the breasts and mammary glands.
   d. During pregnancy, increased aldosterone secretion promotes retention of sodium and body fluid. Increased secretion of parathyroid hormone helps maintain a high concentration of maternal blood calcium.
3. Embryonic stage
   a. The embryonic stage extends from the beginning of the second week through the eighth week of development.
   b. During this stage, the placenta and main internal and external body structures develop.
   c. The cells of the inner cell mass organize into primary germ layers.
   d. The embryonic disc becomes cylindrical and attaches to the developing placenta.
   e. The placental membrane consists of the epithelium of the chorionic villi and the epithelium of the capillaries inside the villi.
      (1) Oxygen and nutrients diffuse from maternal blood across the placental membrane and into fetal blood.
      (2) Carbon dioxide and other wastes diffuse from fetal blood across the placental membrane and into maternal blood.
   f. A fluid-filled amnion develops around the embryo.
   g. The umbilical cord forms as the amnion envelops the tissues attached to the underside of the embryo.
   h. The yolk sac forms on the underside of the embryonic disc.
   i. The allantois extends from the yolk sac into the connecting stalk.
   j. By the beginning of the eighth week, the embryo is recognizable as human.
4. Fetal stage
   a. The fetal stage extends from the end of the eighth week of development until birth.
   b. Existing structures grow and mature. Only a few new parts appear.
   c. The fetus is full-term at the end of thirty-eight weeks.
5. Fetal blood and circulation
   a. Umbilical vessels carry blood between the placenta and the fetus.
   b. Fetal blood carries a greater concentration of oxygen than does maternal blood.
   c. Blood enters the fetus through the umbilical vein and partially bypasses the liver through the ductus venosus.
   d. Blood enters the right atrium and partially bypasses the lungs through the foramen ovale.
   e. Blood entering the pulmonary trunk partially bypasses the lungs through the ductus arteriosus.
   f. Blood enters the umbilical arteries from the internal iliac arteries.
6. Birth process
   a. During pregnancy, placental progesterone inhibits uterine contractions.
   b. A variety of factors promote birth.
      (1) A decreasing progesterone concentration and the release of a prostaglandin initiate the birth process.
      (2) The posterior pituitary gland releases oxytocin.
      (3) Oxytocin stimulates uterine muscles to contract, and labor begins.
   c. Following birth, placental tissues are expelled.

20.4 Postnatal Period (p. 544)

1. Milk production and secretion
   a. Following childbirth, concentrations of placental hormones decline, the action of prolactin is no longer blocked, and the mammary glands begin to secrete milk.
   b. A reflex response to mechanical stimulation of the nipple stimulates the posterior pituitary to release oxytocin, which causes the alveolar ducts to eject milk.
2. Neonatal period
   a. The neonatal period extends from birth to the end of the first four weeks.
   b. The newborn must begin to respire, obtain nutrients, excrete wastes, and regulate body temperature.
   c. The first breath must be powerful to expand the lungs.
   d. The liver is immature and unable to supply sufficient glucose, so the newborn depends primarily on stored fat for energy.
   e. A newborn's immature kidneys cannot concentrate urine well.
   f. A newborn's homeostatic mechanisms may function imperfectly, and body temperature may be unstable.
   g. The cardiovascular system changes when placental circulation ceases.
      (1) Umbilical vessels constrict.
      (2) The ductus venosus constricts.
      (3) A valve closes the foramen ovale as blood pressure in the right atrium falls and pressure in the left atrium rises.
      (4) The ductus arteriosus constricts.

REVIEW EXERCISES

1. Define *growth* and *development.* (p. 528)
2. Define *pregnancy.* (p. 528)
3. Describe how sperm cells move within the female reproductive tract. (p. 528)
4. Describe the process of fertilization. (p. 528)
5. Describe the process of cleavage. (p. 529)
6. Describe the process of implantation. (p. 530)
7. Define *embryo.* (p. 530)
8. Define *fetus.* (p. 530)
9. Describe the formation of the placenta, and explain its functions. (p. 530)
10. Explain the major hormonal changes in the maternal body during pregnancy. (p. 531)
11. Explain how the primary germ layers form. (p. 533)
12. List the major body parts derived from ectoderm, mesoderm, and endoderm. (p. 533)
13. Define *placental membrane.* (p. 535)
14. Distinguish between the chorion and the amnion. (p. 537)
15. Explain the function of amniotic fluid. (p. 537)
16. Describe the formation of the umbilical cord. (p. 537)
17. Explain how the yolk sac and allantois form. (p. 537)
18. List the major changes in the fetal stage of development. (p. 537)
19. Describe a full-term fetus. (p. 538)
20. Compare the properties of fetal hemoglobin with those of adult hemoglobin. (p. 538)
21. Trace the pathway of blood from the placenta to the fetus and back to the placenta. (p. 538)
22. Discuss the events that occur during the birth process. (p. 542)
23. Explain the roles of prolactin and oxytocin in milk production and secretion. (p. 544)
24. Explain why a newborn's first breath must be particularly forceful. (p. 545)
25. Explain why newborns tend to develop water and electrolyte imbalances. (p. 545)
26. Describe the changes in the newborn's cardiovascular system. (p. 545)

CRITICAL THINKING

1. Why can twins resulting from a single fertilized egg exchange blood or receive organ transplants from each other without rejection, while twins resulting from two fertilized eggs sometimes cannot?
2. What symptoms may appear if a newborn's ductus arteriosus fails to close?
3. What kinds of studies and information are required to determine whether a man's exposure to a potential teratogen can cause birth defects years later? How would such analysis differ if a woman were exposed?
4. In Aldous Huxley's book *Brave New World,* egg cells are fertilized *in vitro* and develop assembly-line style. To render some of the embryos less intelligent, lab workers give them alcohol. What medical condition does this scenario invoke?
5. What technology would enable a fetus born in the fourth month to survive in a laboratory setting? (This is not yet possible.)
6. Toxins usually cause more severe medical problems if exposure is during the first eight weeks of pregnancy rather than during the later weeks. Why?
7. Milk from a cow has a higher percentage of protein and a lower percentage of fat than does human milk. Why do you think this is so?

WEB CONNECTIONS

Visit the website for additional study questions and more information about this chapter at:

http://www.mhhe.com/shieress8

Appendix

AIDS TO UNDERSTANDING WORDS

acetabul-, vinegar cup: *acetabul*um
adip-, fat: *adip*ose tissue
agglutin-, to glue together: *agglutin*ation
aliment-, food: *aliment*ary canal
allant-, sausage-shaped: *allant*ois
alveol-, small cavity: *alveol*us
an-, without: *an*aerobic respiration
ana-, up: *ana*bolic
andr-, man: *andr*ogens
append-, to hang something: *append*icular
ax-, axis: *ax*ial skeleton
bil-, bile: *bil*irubin
-blast, budding: osteo*blast*
brady-, slow: *brady*cardia
bronch-, windpipe: *bronch*us
calat-, something inserted: inter*calat*ed disc
calyc-, small cup: *calyc*es
cardi-, heart: peri*cardi*um
carp-, wrist: *carp*als
cata-, down: *cata*bolic
chondr-, cartilage: *chondr*ocyte
chorio-, skin: *chorio*n
choroid, skinlike: *choroid* plexus
chym-, juice: *chym*e
-clast, broken: osteo*clast*
cleav-, to divide: *cleav*age
cochlea, snail: *cochlea*
condyl-, knob: *condyl*e
corac-, beaklike: *corac*oid process
cort-, covering: *cort*ex
cribr-, sievelike: *cribr*iform plate
cric-, ring: *cric*oid cartilage
crin-, to secrete: endo*crin*e
crist-, ridge: *crist*a galli
cut-, skin: sub*cut*aneous
cyt-, cell: *cyt*oplasm
de-, undoing: *de*amination
decidu-, falling off: *decidu*ous
dendr-, tree: *dendr*ite
derm-, skin: *derm*is
detrus-, to force away: *detrus*or muscle
di-, two: *di*saccharide
diastol-, dilation: *diastol*e
diuret-, to pass urine: *diuret*ic
dors-, back: *dors*al
ejacul-, to shoot forth: *ejacul*ation
embol-, stopper: *embol*us
endo-, within: *endo*plasmic reticulum
epi-, upon: *epi*thelial tissue
erg-, work: syn*erg*ist
erythr-, red: *erythr*ocyte
exo-, outside: *exo*crine gland
extra-, outside: *extra*cellular
fimb-, fringe: *fimb*riae
follic-, small bag: hair *follic*le
fov-, pit: *fov*ea
funi-, small cord or fiber: *funi*culus
gangli-, a swelling: *gangli*on
gastr-, stomach: *gastr*ic gland
-gen, to be produced: aller*gen*
-genesis, origin: spermato*genesis*
germ-, to bud or sprout: *germ*inal
glen-, joint socket: *glen*oid cavity
-glia, glue: neuro*glia*
glom-, little ball: *glom*erulus
glyc-, sweet: *glyc*ogen
-gram, something written: electrocardio*gram*
hema-, blood: *hema*toma
hemo-, blood: *hemo*globin
hepat-, liver: *hepat*ic duct
homeo-, same: *homeo*stasis
humor-, fluid: *humor*al
hyper-, above: *hyper*tonic
hypo-, below: *hypo*tonic
im-, (or in-), not: *im*balance
immun-, free: *immun*ity
inflamm-, to set on fire: *inflamm*ation
inter-, between: *inter*phase
intra-, inside: *intra*membranous
iris, rainbow: *iris*
iso-, equal: *iso*tonic
kerat-, horn: *kerat*in
labi-, lip: *labi*a
labyrinth, maze: *labyrinth*
lacri-, tears: *lacri*mal gland
lacun-, pool: *lacun*a
laten-, hidden: *laten*t
-lemm, rind or peel: neuri*lemm*a
leuko-, white: *leuko*cyte
lingu-, tongue: *lingu*al tonsil
lip-, fat: *lip*ids
-logy, study of: physio*logy*
-lyte, dissolvable: electro*lyte*
macro-, large: *macro*phage
macula, spot: *macula* lutea
meat-, passage: auditory *meat*us
melan-, black: *melan*in
mening-, membrane: *mening*es
mens-, month: *mens*trual cycle
meta-, change: *meta*bolism
mict-, to pass urine: *mict*urition
mit-, thread: *mit*osis
mono-, one: *mono*saccharide
mons-, mountain: *mons* pubis
morul-, mulberry: *morul*a
moto-, moving: *moto*r
mut-, change: *mut*ation
myo-, muscle: *myo*fibril
nat-, to be born: pre*nat*al
nephr-, kidney: *nephr*on
neutr-, neither one nor the other: *neutr*al
nod-, knot: *nod*ule
nutri-, nourish: *nutri*ent
odont-, tooth: *odont*oid process
olfact-, to smell: *olfact*ory
-osis, abnormal increase in production: leukocyto*sis*
oss-, bone: *oss*eous tissue
papill-, nipple: *papill*ary muscle
para-, beside: *para*thyroid glands
pariet-, wall: *pariet*al membrane
patho-, disease: *patho*gen
pelv-, basin: *pelv*ic cavity
peri-, around: *peri*cardial membrane
phag-, to eat: *phag*ocytosis
pino-, to drink: *pino*cytosis
pleur-, rib: *pleur*al membrane
plex-, interweaving: choroid *plex*us
poie-, to make: hemoto*poie*sis
poly-, many: *poly*unsaturated
pseudo-, false: *pseudo*stratified epithelium
puber-, adult: *puber*ty
pylor-, gatekeeper: *pylor*ic sphincter
sacchar-, sugar: mono*sacchar*ide
sarco-, flesh: *sarco*plasm
scler-, hard: *scler*a
seb-, grease: *seb*aceous gland
sens-, feeling: *sens*ory neuron
-som, body: ribo*some*
squam-, scale: *squam*ous epithelium
stasis-, standing still: homeo*stasis*
strat-, layer: *strat*ified
syn-, together: *syn*thesis
systol-, contraction: *systol*e
tachy-, rapid: *tachy*cardia
tetan-, stiff: *tetan*ic
thromb-, clot: *thromb*ocyte
toc-, birth: oxy*toc*in
-tomy, cutting: ana*tomy*
trigon-, triangle: *trigon*e
troph-, well fed: muscular hyper*troph*y
-tropic, influencing: adrenocortico*tropic*
tympan-, drum: *tympan*ic membrane
umbil-, navel: *umbil*ical cord
ventr-, belly or stomach: *ventr*icle
vill-, hair: *vill*i
vitre-, glass: *vitre*ous humor
zym-, ferment: en*zym*e