Fetal Development

chapter 3

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Objectives

1. Define key terms listed.
2. Define *chromosome* and state the number in each human body cell.
3. Compare a gene and a chromosome.
4. Explain how the sex of an individual is determined.
5. Describe human fertilization and implantation.
6. Discuss fetal development.
7. Explain the development and function of the placenta.
8. Review the functions of amniotic fluid and the umbilical cord.
9. Diagram fetal circulation to circulation after birth.
10. Discuss multifetal pregnancy, and compare two types of twins.

Key Terms

age of viability (p. 37)
amnion (ĂM-nē-ŏn, p. 32)
blastocyst (BLĂS-tō-sĭst, p. 31)
chorion (KŌ-rē-ŏn, p. 32)
chorionic villi (KŌ-rē-ŏn-ĭk VĬL-ī, p. 33)
chromosomes (KRŌ-mō-sōmz, p. 29)
conception (p. 31)
decidua (də-sidū-ə, p. 31)
deoxyribonucleic acid (DNA) (dē-ŎK-sē-rī-bō-nū-KLĀ-ĭk, p. 29)
dizygotic (p. 37)
ductus arteriosus (DŬK-tŭs ăhr-TĒR-ē-Ō-sŭs, p. 35)
ductus venosus (vĕn-Ō-sŭs, p. 35)
embryonic period (ĕm-brē-ŎN-ĭk, p. 32)
fertilization (p. 30)
foramen ovale (fŏră-mĕn ō-VĂL, p. 35)
gametes (GĂM-ētz, p. 30)
gametogenesis (găm-ĕ-tō-JĔN-ĕ-sĭs, p. 30)
genes (jēnz, p. 29)
hydramnios (hī-DRĂM-nē-ŏs, p. 33)
implantation (p. 31)
meiosis (mī-Ō-sĭs, p. 30)
mitosis (mī-TŌ-sĭs, p. 30)
monozygotic (p. 37)
morula (MŌR-ū-lă, p. 31)
multifetal pregnancy (p. 37)
oligohydramnios (ol-ĭgō-hī-DRĂM-nē-ŏs, p. 33)
placenta (plăSĔN-tă, p. 33)
teratogenic agents (p. 31)
trophoblasts (TRŌF-ō-blăsts, p. 31)
Wharton's jelly (p. 35)
zygote (ZĪ-gōt, p. 31)

GENETICS

At birth, the human body consists of many millions of cells, but life begins with a single cell. The first cell of a new human being is formed by the fusion of a sperm from the male and an ovum from the female. Genetic codes are programmed into the new individual's cells by **deoxyribonucleic acid (DNA)**.

DNA is viewed as spiral-shaped strands found in the nucleus of all human cells. Figure 3-1 shows the relationships of the cell, nucleus, chromosome, genes, and DNA. DNA is the master protein that controls the development and functioning of all cells.

Genes are programmed to use DNA through specific codes of instructions from four molecules: adenine (A), thymine (T), cytosine (C), and guanine (G). A single mistake in a code or variation in the genetic sequence means a cell may make the wrong amount or type of protein, which can disrupt the cell's function and lead to changes that may have serious effects on the developing organism. These mistakes can lead to mutations or disease. Defects within the cell's DNA code are the root of many inherited disorders. The master blueprint for a person's characteristics is determined by genes in chromosomes, which are located within the nucleus of each body cell.

CHROMOSOMES

Chromosomes are threadlike, spiral structures found within the nucleus of each cell. Chromosomes are made up of long chains or building blocks of DNA that

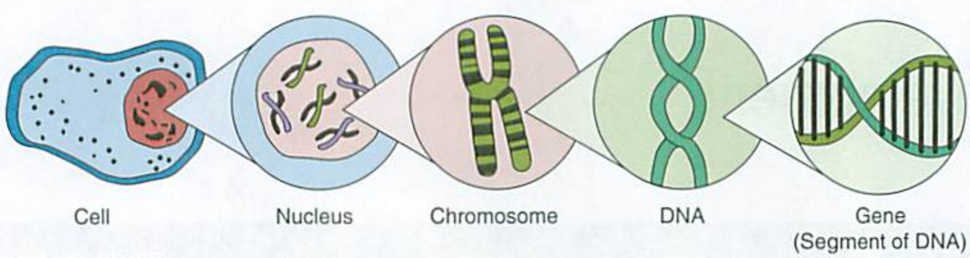


FIGURE 3-1 Inside the cell: cell, nucleus, chromosome, DNA, and gene.

control heredity. Chromosomes occur in pairs; one member of the pair is supplied by the mother and the other by the father. Each cell in the human body contains 46 chromosomes, or 22 arranged pairs, known as *autosomes* (body chromosomes), and one pair of **gametes**, or "sex cells," which determine the sex of the fetus. Each chromosome is composed of genes, which are defined as segments of DNA that control heredity. A gene can be described as a single bead, and a chromosome is like a string of beads.

CELL DIVISION AND GAMETOGENESIS

The division of a cell begins in its nucleus, which contains the gene-bearing chromosomes. The two types of cell division are mitosis and meiosis.

Mitosis is a continuous process by which the body grows and develops and dead body cells are replaced. In this type of cell division, each daughter cell contains the same number of chromosomes as the parent cell. The 46 chromosomes in a body cell are called the **diploid** number of chromosomes. The process of mitosis in the sperm is called **spermatogenesis,** and in the ovum is called **oogenesis** (the development of an oocyte into an ovum).

Meiosis is a different type of cell division in which the reproductive cells undergo two sequential divisions. During meiosis, the number of chromosomes in each cell is reduced to half, or 23 chromosomes, each with one sex chromosome only. This is called the **haploid** number of chromosomes. This process is completed in the sperm before it travels toward the fallopian tube and in the ovum after ovulation if fertilized. At the moment of **fertilization** (when the sperm and ovum unite), the new cell contains 23 chromosomes from the sperm and 23 chromosomes from the ovum, thus returning to the diploid number of chromosomes (46); traits are therefore inherited from both the mother and the father. The formation of gametes by this type of cell division is called **gametogenesis**.

As soon as fertilization occurs, a chemical change in the membrane around the fertilized ovum prevents penetration by another sperm.

GENES

Each gene (a segment of the DNA chain) is coded for inheritance. The coded information carried by the DNA in the gene is responsible for individual traits, such as eye and hair color, facial features, and body shape. Genes carry instructions for **dominant** and **recessive** traits. Dominant traits usually overpower recessive traits and are passed on to the offspring. If only one parent carries a dominant trait, 50% of the offspring will have that dominant trait. If *each* parent carries a recessive trait, there is a chance that one of the offspring will display that trait (Figure 3-2).

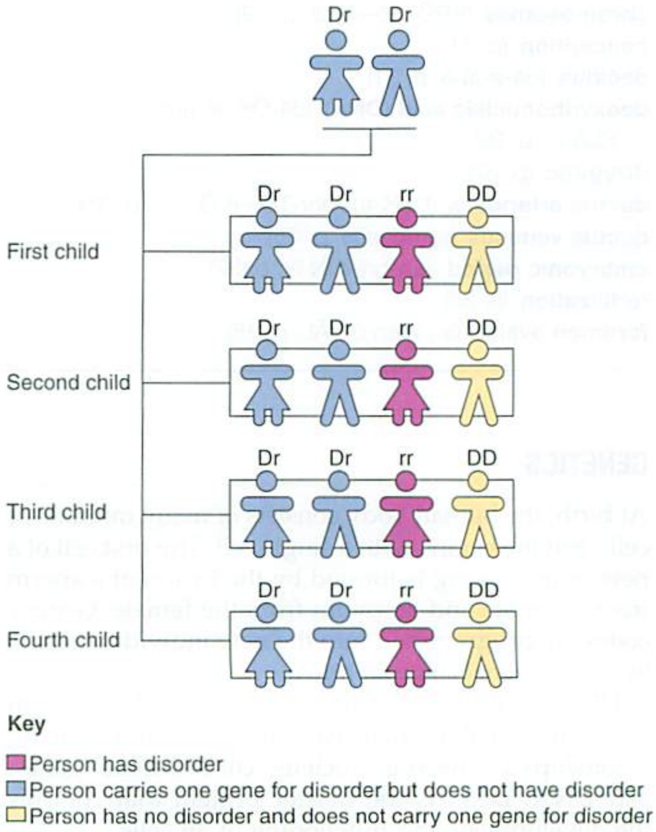


FIGURE 3-2 This figure shows how a disorder carried as a recessive trait can be passed on to offspring when each parent is a carrier of that recessive trait. (D) represents a dominant gene, and (r) represents a recessive gene.

SEX DETERMINATION

The sex of an individual is determined at the time of fertilization. It depends on the type of spermatozoon that penetrates the ovum (egg). The spermatozoon (sperm cell) has an X or Y chromosome, whereas the female ovum always contains the X chromosome. When the spermatozoon with an X factor unites with the ovum, a female (XX) will result. When an ovum is fertilized with a spermatozoon that contains the Y factor, a male (XY) will result. Because the father may contribute either a Y- or X-bearing sperm, it is the male sperm that is responsible for determining the sex of the embryo (Figure 3-3).

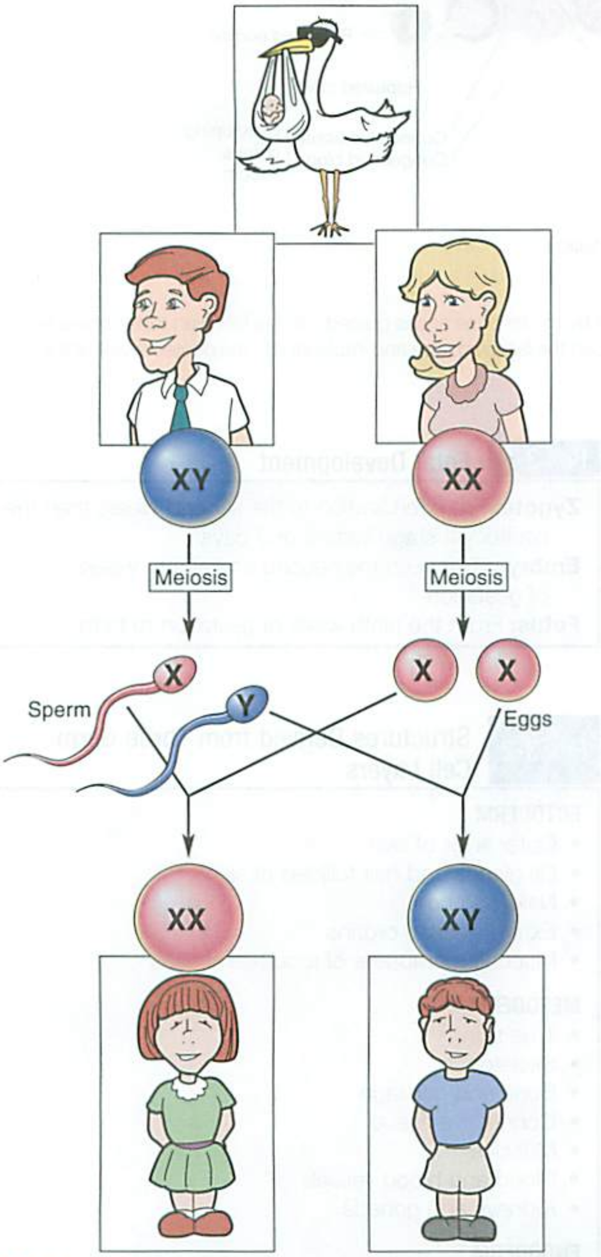


FIGURE 3-3 Sex determination at the time of conception. If an X chromosome from the man unites with an X chromosome from the woman, the child will be female (XX). If a Y chromosome from the man unites with an X chromosome from the woman, the child will be male (XY).

BEGINNING OF EMBRYONIC DEVELOPMENT

FERTILIZATION

Conception is the union of the egg and sperm, also known as *fertilization*. Fertilization normally takes place in the outer third of the uterine (fallopian) tube. Approximately 300 million spermatozoa are deposited into the vagina at ejaculation. Most of the sperm remain in the vagina and within the cervical mucus in the endometrium. After a single sperm enters the ovum, a membrane forms that prevents the entry of more sperm. The ovum can be fertilized for approximately 6 to 24 hours after its release from the ovary, whereas sperm are viable for up to 5 days after ejaculation and their entrance into the female genital tract. At fertilization, the nucleus of the sperm and the nucleus of the ovum unite to form a **zygote**.

? Did You Know?

Life Expectancy of Ovum and Sperm

Although the ovum lives and can be fertilized for 6 to 24 hours after ovulation, the sperm can live for up to 5 days after ejaculation.

IMPLANTATION

The zygote begins a rapid series of cell divisions while traveling down the fallopian tube toward the uterus. Within approximately 3 days, cell division results in a solid mass of 16 cells, called a **morula**. The morula cells continue to multiply as the morula floats free in the uterine cavity for another 3 or 4 days. Large cells tend to mass at the periphery of the morula ball, leaving a fluid space surrounding an inner cell mass. At this stage, the formed structure is termed a **blastocyst**. The cells in the outer ring are known as **trophoblasts**. At this time, the blastocyst contains various components: (1) a fluid-filled cavity; (2) the trophoblast (outer wall), which later will become the **placenta;** and (3) an inner cell mass, which will form the **embryo.** The trophoblast cells secrete enzymes that permit them to invade the thickened uterine lining, or endometrium (**decidua**). During **implantation** (the cell mass typically takes root in the upper segment of the uterus), trophoblastic cells provide nutrition for the embryo from nutrients carried in the maternal blood. The trophoblastic layer (which later forms the chorion) of blastocyst cells begin to mature rapidly (Figure 3-4). As early as the twelfth day, miniature villi, or rootlike projections, reach out from the layer of cells into the uterine endometrium. These projections **(chorionic villi)** extend from the chorion into the endometrium.

During the stages of development that immediately follow implantation, **teratogenic agents** such as drugs, viruses, or radiation may exert profound and

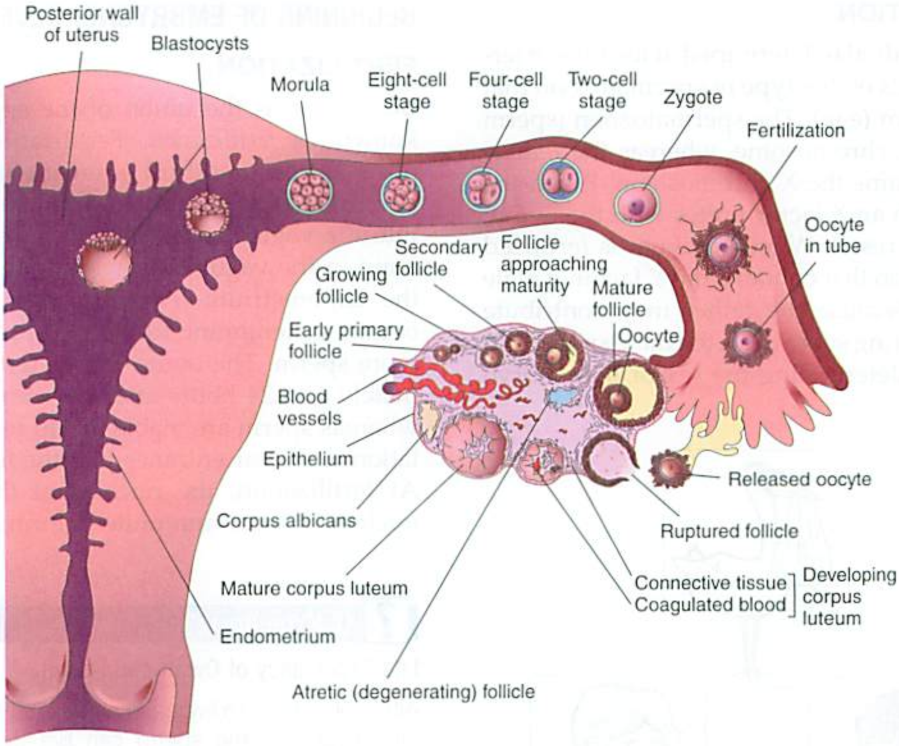


FIGURE 3-4 **Ovulation and fertilization.** Ovulation occurs; the egg is caught by the fimbriae and is guided into the fallopian tube, where fertilization occurs. The zygote continues to multiply (but not grow in size) as it passes through the fallopian tube and implants into the posterior wall of the uterus at approximately 7 days.

damaging effects on the developing embryo. The **embryonic period** of development is from the second to the eighth week after conception, when most of the basic organ structures are formed. From the eighth week until birth, this developing human being is called a **fetus** (Box 3-1).

EMBRYONIC CELL DIFFERENTIATION

During the second and third weeks after conception, three cell layers form: the **ectoderm, mesoderm,** and **endoderm.** These cell layers become all of the tissues and organs of the embryo. Each germ layer has specific characteristics (Box 3-2). The differentiated cells stay attached by a body stalk, which later forms the umbilical cord by day 14. Small spaces soon form the **amniotic cavity.** This hollow space will eventually surround the developing embryo and fetus like a protective, transparent sac.

FETAL MEMBRANES AND AMNIOTIC FLUID

The two membranes, called the *chorion* and the *amnion*, begin to form at the time of implantation. The **amnion**, the inner membrane, protects the developing embryo. It forms a cavity in which the embryo or fetus floats, suspended in amniotic fluid. The amnion expands to accommodate the growing fetus. The **chorion** is the

Box 3-1 Fetal Development

Zygote: From fertilization to the second week; then the blastocyst stage lasts 2 or 3 days

Embryo: Between the second and eighth weeks of gestation

Fetus: From the ninth week of gestation to birth

Box 3-2 Structures Derived from Three Germ Cell Layers

ECTODERM
- Outer layer of skin
- Oil glands and hair follicles of skin
- Nails and hair
- External sense organs
- Mucous membrane of mouth and anus

MESODERM
- True skin
- Skeleton
- Bone and cartilage
- Connective tissue
- Muscles
- Blood and blood vessels
- Kidneys and gonads

ENDODERM
- Lining of trachea, pharynx, and bronchi
- Lining of digestive tract
- Lining of bladder and urethra

outer membrane that encloses the growing amnion. As the fetus grows, the amnion expands until the chorion and the amnion fuse together to become the amniotic sac, or "bag of waters." The amniotic sac contains a clear, slightly straw-colored liquid, called the **amniotic fluid**. This fluid consists of 98% water and contains traces of protein, glucose, fetal lanugo (hair), fetal urine, and vernix caseosa (a cheesy material that covers the fetal skin). Examination of the amniotic fluid for diagnostic purposes (amniocentesis) is discussed in Chapter 5. Most amniotic fluid appears to be derived from the maternal blood. Later, the fetus also adds to the fluid by excreting urine into it. Some amniotic fluid is swallowed by the fetus and is subsequently absorbed by its gastrointestinal tract. The amount of amniotic fluid present at term varies from 800 to 1000 mL. The presence of more than 2 L is called **hydramnios** (excessive fluid). An excess of amniotic fluid is associated with malformations of the fetal central nervous system and the gastrointestinal tract. An amount of amniotic fluid that is less than 300 mL is **oligohydramnios**, and it is associated with renal abnormalities. The functions of the amniotic fluid are listed in Box 3-3.

PLACENTA

The **placenta** is a remarkable fetomaternal organ that consists of both fetal and maternal sections. This organ permits the exchange of materials carried in the bloodstream between the mother and the embryo or fetus (Figure 3-5).

The placenta formation begins at the outer layer of the blastocyst, called the *trophoblastic cells*. These cells proliferate and develop the **chorionic villi** (projections that become the major site of exchange between maternal and fetal circulation). These villi penetrate the decidua (lining of the uterus). The maternal vessels dilate around the villi and form sinuses that become the intervillous spaces. The chorionic villi float freely in a pool of maternal blood and divide repeatedly to form complex treelike structures in which each villus becomes a branch. Some villi attach themselves to the endometrial maternal tissue, anchoring the zygote (fertilized egg) to the endometrium (lining of the uterus). The placental villi can be likened to the roots of plants submerged in a bowl of water in that they absorb nourishment from the water that surrounds them. The maternal blood circulates slowly, enabling it to be transferred across the membrane of the villi, absorbing nutrients and oxygen and excreting waste. Minimum uteroplacental circulation begins early, approximately 17 days after conception. As gestation continues, the intervillous spaces grow larger and become separated by a series of partitions or segments. In the mature placenta, there are as many as 30 separate segments, called **cotyledons.** Approximately 100 maternal arterioles supply the mature placenta to provide enough blood for gas and nutrient exchange. The rate of uteroplacental blood flow increases from 50 mL/min at 10 weeks to 500 to 600 mL/min at term. The maternal and fetal circulatory systems are separate, with an occasional break in one of the smaller chorionic villi, allowing some mixing of fetal and maternal blood products.

Box 3-3 Functions of Amniotic Fluid

- Allows the embryo or fetus to move about freely
- Prevents the amnion from adhering to the embryo or fetus
- Cushions the embryo or fetus against injury from external sources
- Maintains a constant temperature surrounding the embryo or fetus
- Provides fluid homeostasis for the embryo or fetus
- Prevents umbilical cord compression

PLACENTAL FUNCTIONS

The placental functions include protection, nutrition, respiration, excretion, and hormone production.

Placental Transfer

Placental transport or transfer involves movement of gases, nutrients, waste materials, drugs, and other substances across the placenta from maternal to fetal circulation or from fetal to maternal circulation. Transfer can be modified by maternal nutritional status, exercise, and disease. Transfer can be increased by maternal hyperglycemia and decreased by reduced uteroplacental blood flow.

Immunologic Functions

Immunologic functions of the placenta include protection of the fetus from pathogens and prevention from rejection by the mother. The placenta allows most viruses, some bacteria, pollutants, and most drugs to cross the placental membrane. In general, blood cells are too large to cross unless there is a placental leak (break), which would allow them to enter fetal circulation, or the reverse (fetal cells entering maternal circulation). Because of this, prenatal $Rh_o(D)$ immune globulin (RhoGAM) is given to Rh-negative women at 28 weeks' gestation to prevent Rh isoimmunization (see Chapter 13). Some substances (e.g., drugs and pollutants) that circulate in the maternal bloodstream can be teratogenic and can harm the fetus. Because some prescribed drugs for medical conditions may be harmful to the fetus, the woman should consult her health care provider before taking them.

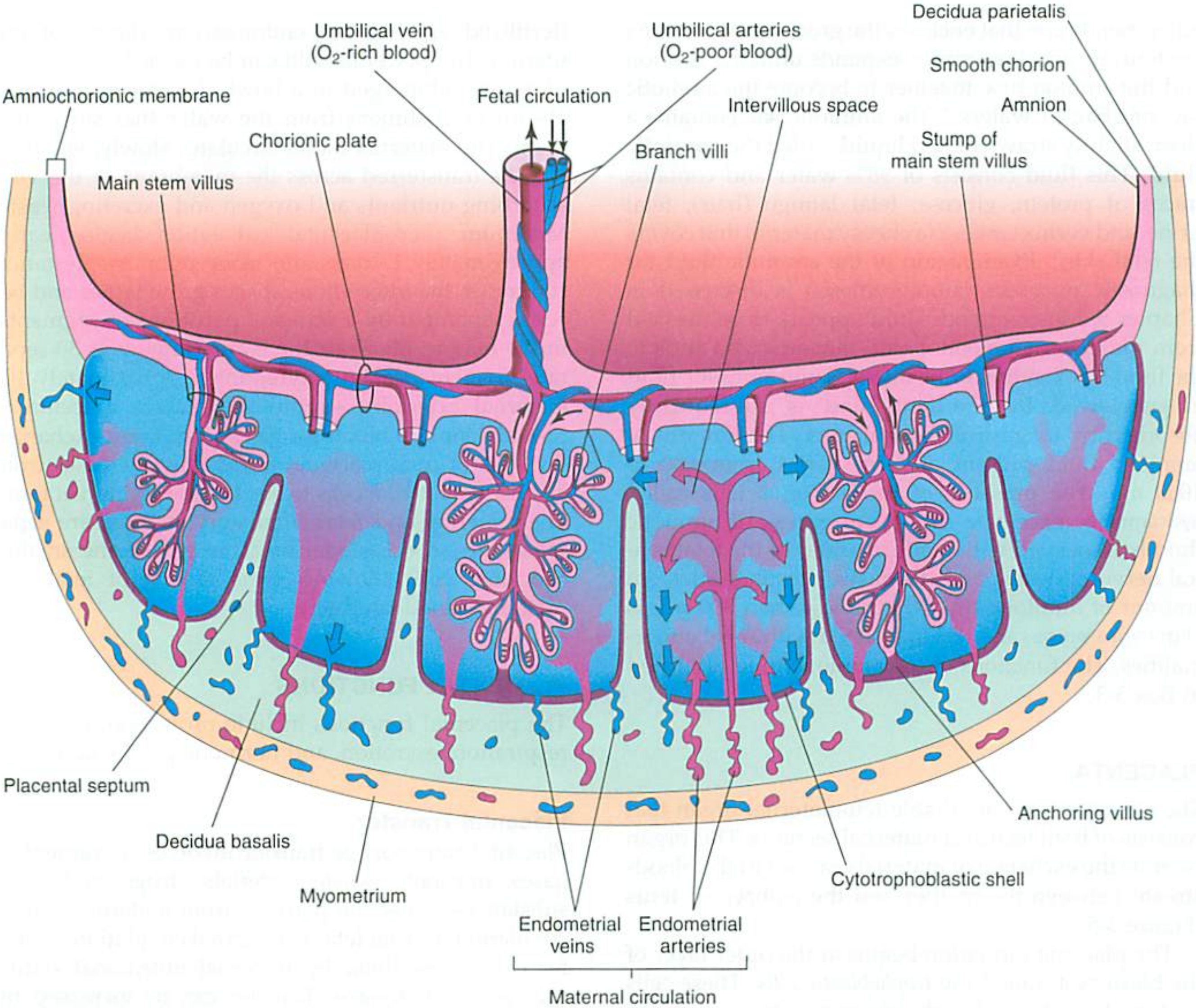


FIGURE 3-5 Placental circulation. The blood of the fetus flows through the umbilical arteries into the fetal capillaries in the villi and then back to the fetal circulation through the umbilical vein. Maternal blood is transported by the uterine spiral arteries to the intervillous space, and it leaves by the uterine veins to return to the maternal circulation. Metabolic and gaseous exchange occurs as the blood flows slowly around the villi. *Fetal and maternal blood do not mix together.*

Placental Blood Flow

Placental blood flow can be reduced if the uterine artery is constricted because of certain maternal diseases, such as hypertension. Substances that can cross the placental barrier and harm the fetus are alcohol, nicotine, carbon monoxide, and some prescription and recreational drugs. Uterine contractions will decrease the amount of blood flow to the intervillous spaces because the spiral arterioles travel through the myometrium. Therefore, the uterus should be monitored for relaxation between contractions. Position change from supine to side-lying position will increase the blood flow.

Placental Hormones

Four hormones are produced by the placenta: progesterone, estrogen, human chorionic gonadotropin (hCG), and human placental lactogen (hPL).

Progesterone. Progesterone is first produced by the corpus luteum and later by the placenta. It has the following functions during pregnancy:

- Maintain the uterine lining for implantation of the zygote
- Reduce uterine contractions to prevent spontaneous abortion
- Prepare the glands of the breasts for lactation
- Stimulate testes to produce testosterone, which aids the male fetus in developing the reproductive tract

Estrogen. Estrogen has the following important functions during pregnancy:

- Stimulate uterine growth
- Increase the blood flow to uterine vessels
- Stimulate the development of the breast ducts to prepare for lactation

The effects of estrogen not directly related to pregnancy include:

- Increased skin pigmentation (such as the "mask of pregnancy")
- Vascular changes in the skin and the mucous membranes of the nose and mouth
- Increased salivation

UMBILICAL CORD

The lifeline linking the fetus with the placenta is the umbilical cord. It extends from the umbilicus (navel) of the fetus to the placenta. Within the cord are two umbilical arteries and one umbilical vein. The cord is embedded in **Wharton's jelly**, a thick substance that is a physical buffer to prevent kinking of the cord and interference with circulation.

In contrast to the pattern of circulation after birth, the umbilical arteries carry deoxygenated blood, and the umbilical vein carries oxygenated blood. Blood from the fetus flows through the umbilical arteries to the placenta, where it releases carbon dioxide and other waste products. The umbilical vein carries oxygen and nutrients from the placenta to the fetus (Figure 3-6).

Memory Jogger

Umbilical Vessels

An easy way to remember the number and types of umbilical vessels is to use the mnemonic *AVA*, which stands for *A*rtery, *V*ein, *A*rtery.

CIRCULATION BEFORE AND AFTER BIRTH

Embryonic Circulation

The developing fertilized ovum derives nutrition first from its own cytoplasmic mass and then from the decidua (the thickened lining of the uterus) by the activity of the trophoblastic cells. At approximately the fourth week, the embryo gains circulation and nourishment from the yolk sac. Later, the fetus relies on circulation of oxygenated blood from chorionic villi in the placenta through the umbilical vein.

Fetal Circulation

After the fourth week of gestation, blood circulation through the placenta to the fetus is well established (Figure 3-7). Because the fetus does not breathe, and the liver does not have to process most waste products, several physiologic diversions in the prebirth circulatory route are needed. The three fetal circulatory shunts are as follows:

1. **Ductus venosus**, which diverts some blood away from the liver as it returns from the placenta
2. **Foramen ovale**, which diverts most blood from the right atrium directly to the left atrium, rather than circulating it to the lungs
3. **Ductus arteriosus**, which diverts most blood from the pulmonary artery into the aorta

Circulation Before Birth

Oxygenated blood enters the fetal body through the umbilical vein. About half of the blood goes to the liver through the portal sinus, with the remainder entering the inferior vena cava through the ductus venosus. Blood in the inferior vena cava enters the right atrium, where most passes directly into the left atrium through the foramen ovale. A small amount of blood is pumped to the lungs by the right ventricle. The rest of the blood from the right ventricle joins that from the left ventricle through the ductus arteriosus. After circulating through the fetal body, blood containing waste products is returned to the placenta through the umbilical arteries (Table 3-1).

Circulation After Birth

Fetal shunts are not needed after birth once the infant breathes and blood is circulated to the lungs. The foramen ovale closes because pressure in the right side of the heart falls as the lungs become fully inflated and there is now little resistance to blood flow. The infant's blood oxygen level rises, causing the ductus arteriosus to constrict. The ductus venosus closes when the flow from the umbilical cord stops (Table 3-2).

Closure of Fetal Circulatory Shunts. The foramen ovale closes functionally (temporarily) within 2 hours after birth and permanently by age 3 months. The ductus arteriosus closes functionally within 15 hours and closes permanently in about 3 weeks. The ductus venosus closes functionally when the cord is cut and closes permanently in about 1 week. After permanent closure, the ductus arteriosus and ductus venosus become ligaments.

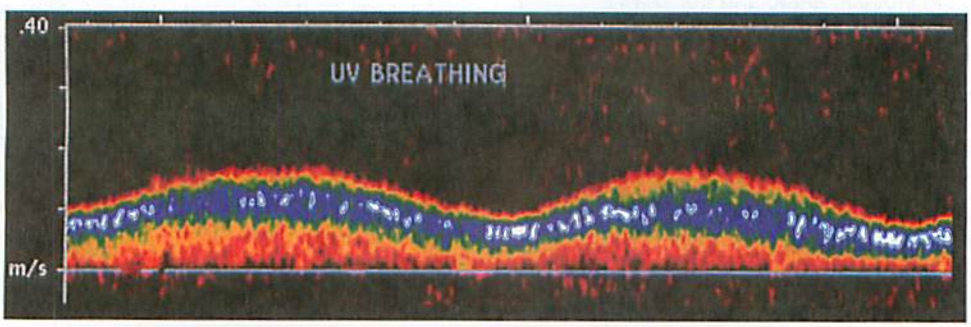


FIGURE 3-6 An ultrasound of the umbilical cord showing circulation.

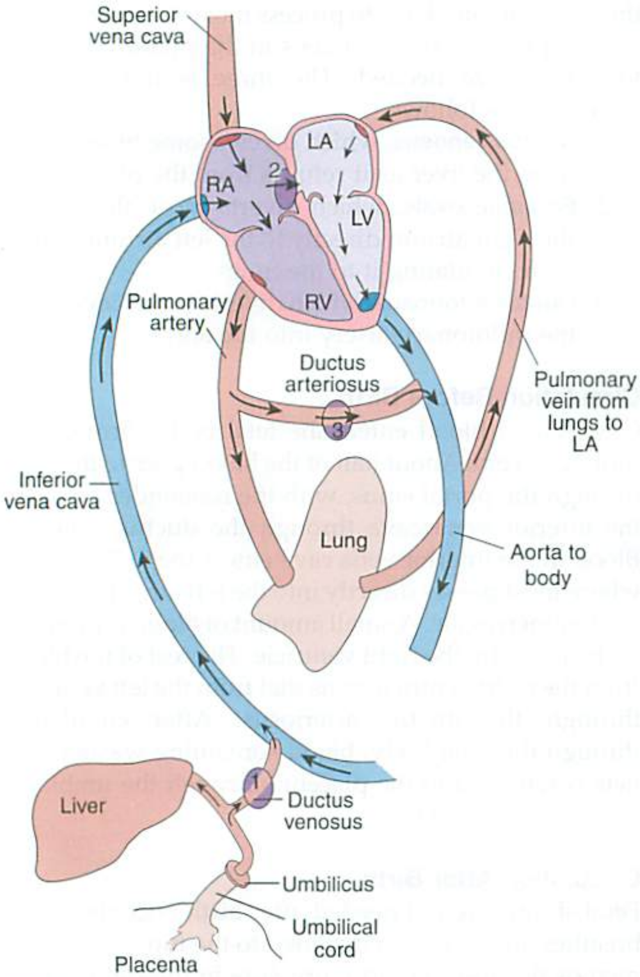


FIGURE 3-7 Fetal circulation. Three shunts exist to allow most blood from the placenta to bypass the fetal lungs and liver: ductus venosus (*1*), foramen ovale (*2*), and ductus arteriosus (*3*). *LA*, Left atrium; *LV*, left ventricle; *RA*, right atrium; *RV*, right ventricle.

Table 3-1 Structures in Fetal Circulation

STRUCTURE	DESCRIPTION
Placenta and vessels	Vessels necessary for oxygenation and exchange of waste products.
Umbilical vein	One vein that carries oxygenated blood from the placenta to the fetus.
Umbilical arteries	Two arteries that carry deoxygenated blood from the fetus to the placenta
Foramen ovale	Opening between the right and left atria of the heart
Ductus arteriosus	Fetal blood vessel connecting the pulmonary artery and the aorta
Ductus venosus	Fetal blood vessel connecting the umbilical vein with the inferior vena cava

Because they are functionally closed rather than permanently closed, some conditions may cause the foramen ovale or ductus arteriosus to reopen after birth. A condition that impedes full lung expansion (e.g., respiratory distress syndrome) can increase the resistance to blood flow from the heart to the lungs, causing the foramen ovale to reopen. Similar conditions often reduce the blood oxygen levels and can cause the ductus arteriosus to remain open. See Chapter 16 for further discussion of newborn congenital cardiac problems. Details concerning the onset of respirations and the changes in body functions in the newborn are discussed in Chapter 9.

Table 3-2 Circulatory Changes After Birth

CIRCULATORY FEATURE	CHANGES
Umbilical vessels	The umbilical vessels are clamped and cut; to receive oxygen, the infant must use the lungs.
Lungs	Aeration occurs; blood is circulated through the lungs.
Pattern of blood flow	Blood flow pattern changes from fetal to newborn as the infant begins to breathe.
Circulation to lungs	As the infant inflates the lungs, pressure is released on the lungs' blood vessels.
Line of least resistance	As the blood vessels open in the lungs, blood is no longer diverted through ductus arteriosus; rather, following the line of least resistance, blood enters the vessels leading to the lungs.
Increased pressure	The change in blood flow increases pressure in the left atrium, which causes the foramen ovale to close.
Heart functions with two separate pumps	The right side of the heart receives deoxygenated blood and pumps it to the lungs; the oxygenated blood is directed to the left side of the heart, where it is pumped through the aorta to other parts of the body.
Ductus arteriosus	The ductus arteriosus functionally closes; therefore, deoxygenated blood cannot mix with oxygenated blood.
Ductus venosus	The ductus venosus functionally closes, and the blood flows through the portal system (the liver).

FETAL DEVELOPMENT

Among factors that may affect the development of the embryo and fetus are the quality of the ovum and sperm, the inherited characteristics from the mother and father, the intrauterine environment, and injury by exposure to teratogenic chemicals. Genetic counseling and education about any known risk factors are essential (see Chapter 16). Studies have shown that undernutrition in utero can result in permanent changes in the developing fetus that can influence the development of conditions such as heart disease and stroke later in life.

The fetus develops in an orderly fashion. Developmental milestones exist in fetal growth and development as they do in growth and development after birth. The three basic developmental stages include the ***zygote*** (conception to second week), the ***embryo*** (second to eighth weeks), and the ***fetus*** (ninth week to birth). By the second week after fertilization, the *ectoderm, endoderm*, and amnion begin to develop. By the third week, the *mesoderm* and neural tube form, and the primitive heart begins to pump. At this time, the mother may first recognize she may be pregnant. Neural tube defects can be prevented by folic acid supplements, which are very important during the first few weeks of pregnancy. By the end of the seventh week, the beginnings of all major fetal organs and systems are present. At first, the functions of most organs are minimal; however, by the end of 9 months, the fetus is prepared structurally, functionally, and metabolically for extrauterine life.

Nutrition Considerations

Folic Acid Supplementation

Folic acid supplements can prevent most neural tube defects such as spina bifida. Because it is possible for a neural tube defect to occur before the woman knows she is pregnant, early prenatal care and good nutrition for all women during the childbearing years are important.

The most critical time for fetal development is the first 8 weeks; this is called the **organogenesis period.** In addition, each organ has a critical period when insults, such as teratogenic agents (agents in the environment that cause damage to the developing fetus), can easily cause physical and functional defects (Figure 3-8). The potential for harm caused by maternal malnutrition, chronic and acute diseases, and teratogens, such as drugs, continues until birth. Teaching the pregnant woman about maintaining her health, avoiding teratogens, and protecting her unborn infant is an important nursing responsibility. The growth of the fetus is limited by the nutrients and oxygen received from the mother.

Health Promotion

Good Health Practices

A mother's ability to nourish her fetus is established in her own fetal life and by her adult nutritional experience. Therefore, to prevent illness in the next generation, there must be a focus on the health practices of this generation.

A healthy mother can produce a healthy child who is less prone to develop illness. Part of the goal of *Healthy People 2020* is to enable all people to develop a healthy lifestyle so that, as parents, they can nourish and parent healthy children for the next generation (U.S. Department of Health and Human Services, 2010).

At the fourteenth week, fetal movement in response to stimuli cannot be felt by the mother, and, by 20 weeks' gestation, the fetus may survive outside of the uterus. (This is called the **age of viability**.) However, special care in the neonatal intensive care unit (NICU) is required, and many preterm infants born at this stage do not survive for long. Surfactant, which helps keep the alveoli in the lungs open during respiration, is minimal even at 28 weeks' gestation (see Chapter 15). At 40 weeks' gestation, the fetus is considered full-term and ready to be born. Table 3-3 describes and illustrates the growth and development that occurs during fetal life.

The fetus that is born past 42 weeks' gestation is termed **postterm** or **postmature.** The postterm infant typically has long nails, an abundance of hair on the head, a diminished amount of vernix caseosa, diminished adipose tissue, and dry, peeling skin. A major concern in postmaturity is the decreased efficiency of the aging placenta. As the placenta ages, the fetus often is deprived of essential support, such as adequate oxygenation and waste removal. Therefore, the postterm infant is at risk for having life-threatening problems. Care of the postterm newborn is discussed in Chapter 15.

MULTIFETAL PREGNANCY

A **multifetal pregnancy** is one in which more than one fetus develops in the uterine cavity at the same time. Twins can be classified as **monozygotic** (identical twins) or **dizygotic** (fraternal twins).

MONOZYGOTIC TWINS

When twins result from the splitting of one fertilized egg (monozygotic), they are called identical twins. They are produced from the fertilization of a single ovum by one sperm. The ovum splits into two identical monozygotes sometime before the fifteenth day of gestation (Figure 3-9). If this division is incomplete, conjoined (formerly called Siamese) twins will result. The amniotic sacs and placentas may be shared or separate. These twins are always the same sex and are mirror images of each other.

DIZYGOTIC TWINS

If two ova are fertilized by two sperm, fraternal, or nonidentical (dizygotic), twins will result. Each fetus has its own amniotic sac and placenta. The twins can be the same sex or opposite sexes. The resemblance to each other is no closer than to other siblings. The use of fertility drugs and in vitro fertilization has increased the incidence of multifetal pregnancy (twins, triplets, quadruplets, etc.). The incidence is also increased in women who are older and have a higher parity (see Chapter 14).

Many twin or higher multiples are born prematurely because the uterus becomes overdistended. The placenta may not be able to supply sufficient nutrition to both fetuses, resulting in one or both twins being smaller than expected.

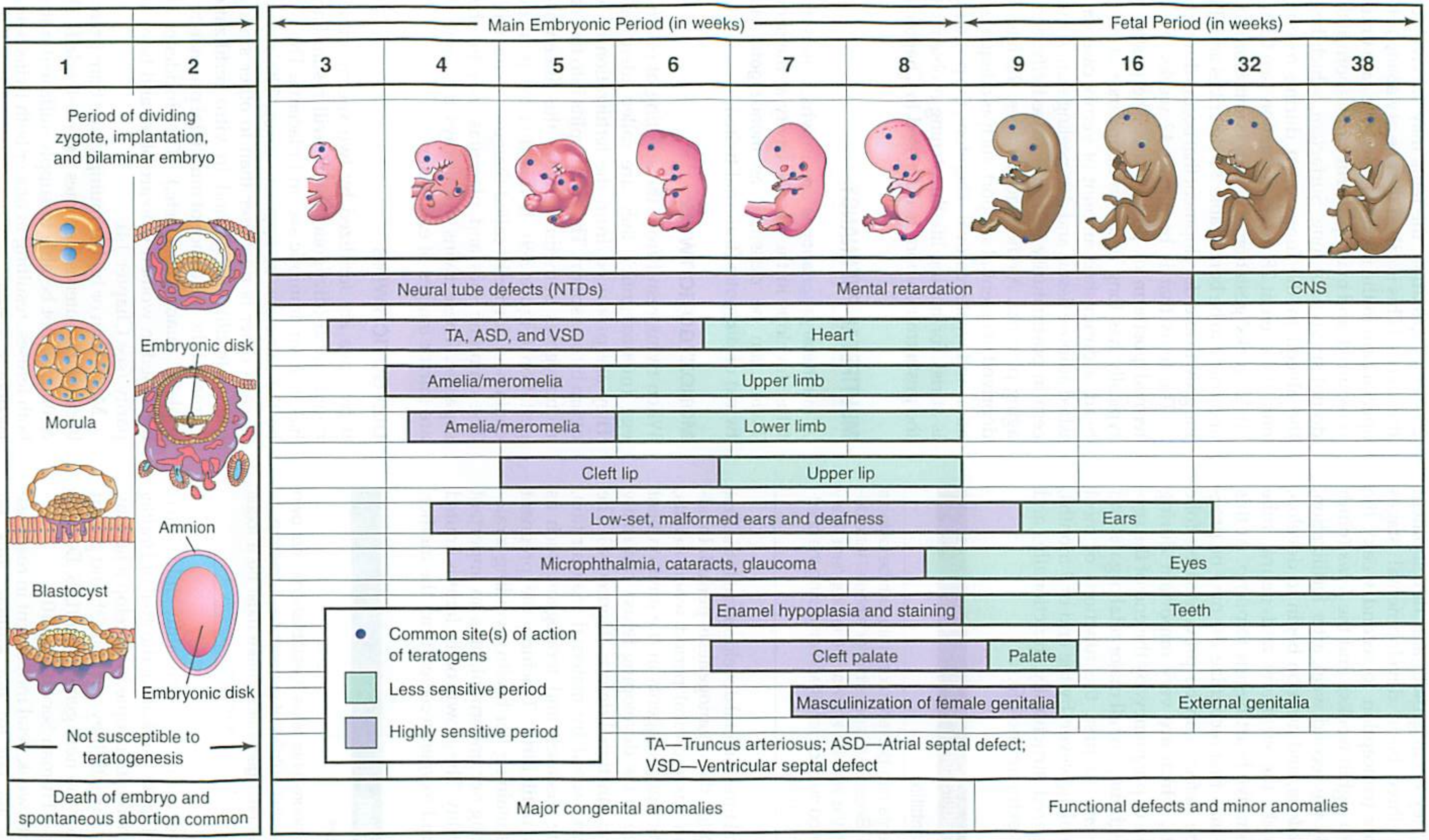
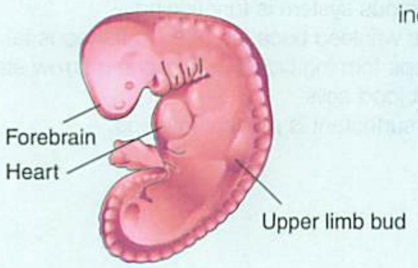


FIGURE 3-8 The sensitive or critical periods in human prenatal development. During the first 2 weeks of development, the embryo is affected by maternal influences such as nutrition status; a teratogen either damages all or most of the cells, resulting in death of the embryo, or damages only a few cells, allowing the conceptus to recover and the embryo to develop. Darker color denotes highly sensitive periods when major defects may be produced (e.g., amelia, or absence of limbs). Lighter color indicates stages that are less sensitive to teratogens when minor defects may be induced (e.g., hypoplastic thumbs). *CNS*, central nervous system.

Table 3-3 Fetal Development

AGE	LENGTH AND WEIGHT	DEVELOPMENT
Week 4 	3.5-4 mm (0.137-0.157 inches) 0.4 g (0.0008 lbs)	*Cardiovascular:* Heart pumps blood. *Gastrointestinal:* Esophagus and trachea separate; stomach forms. *Nervous:* Neural tube closes; forebrain forms. *Musculoskeletal:* Upper and lower limb buds appear. *Senses:* Ears and eyes begin to form.
Week 8 	30 mm (1.18 inches) crown to rump 6 g (0.013 lbs)	Heartbeat is detectable on sonography. Embryo has distinct human appearance. Movements occur. Tail has disappeared. Sex organs form. Beginnings of most external and internal structures are formed. Enters fetal period.
Week 17 	150 mm (5.9 inches) crown to rump 260 g (0.573 lbs)	Genitalia are visible during ultrasound imaging, and leg movements may be felt by the mother. Bones are ossified. Eye movements occur. Fetus sucks and swallows amniotic fluid. Ovaries contain ova. No subcutaneous fat is present. Thin skin allows blood vessels of scalp to be visible.
Week 25 	28 cm (11.0 inches) crown to heel 780 g (1 lbs, 10 oz)	Wrinkled skin, lean body results from lack of subcutaneous fat. Eyes are open. Ears can hear. Fetus is viable. Mother feels stronger movement (quickening). Fetus has schedule of sleeping and moving. Vernix caseosa is present on skin. Lanugo covers body. Brown fat is formed. Lungs begin to secrete surfactant. Fingernails are present. Respiratory movements begin.

Continued

Table 3-3 Fetal Development—cont'd

AGE	LENGTH AND WEIGHT	DEVELOPMENT
Week 29 	38 cm (15 inches) crown to heel 1260 g (2 lbs, 10 oz)	Fetus assumes stable (cephalic) position in utero. Central nervous system is functioning. Skin is less wrinkled because of subcutaneous fat. Spleen stops forming blood cells; bone marrow starts to form blood cells. Increased surfactant is present in lungs.
Week 36 	48 cm (19 inches) crown to heel 2500 g (5 lbs, 12 oz)	Subcutaneous fat is present. Skin is pink and smooth. Grasp reflex is present. Circumferences of head and abdomen are equal. Surge of lung surfactant is produced. Lanugo is decreasing.

Data from Patton, K. T., & Thibodeau, G. A. (2010). *Anatomy and physiology* (7th ed.). St. Louis: Mosby; Moore, K. L., & Persaud, T. V. N. (2008). *The developing human* (8th ed.). Philadelphia: Saunders; Blackburn, S. (2007). *Maternal, fetal, and neonatal physiology: A clinical perspective* (3rd ed.). Philadelphia: Saunders; & Moore, K. L., Persaud, T. V. N., & Shiota, K. (2000). *Color atlas of clinical embryology* (2nd ed.). Philadelphia: Saunders.

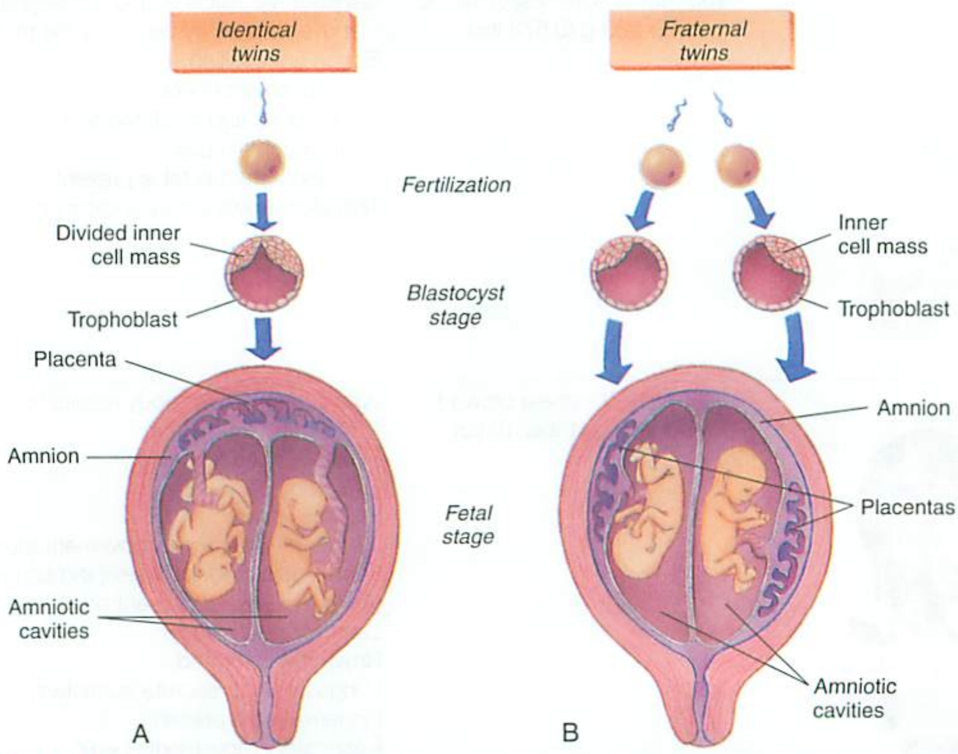


FIGURE 3-9 Multiple births. A, Identical (monozygotic) twins develop when the embryonic tissue from a single egg splits to form two individuals. The placenta is shared by the twins. **B,** Fraternal twins (dizygotic) develop when two different ova are fertilized by two separate sperm producing separate zygotes. Each twin has its own placenta, amnion, and chorion.

Get Ready for the NCLEX® Examination!

Key Points

- A new human life begins with the fusion of a sperm and ovum.
- What we inherit from our parents is determined by genes contained in chromosomes, which are located within the nucleus of each body cell.
- Chromosomes are located in the cell nucleus and are made up of long chains of building blocks of DNA. Genes, a segment of the DNA chain, are coded for inherited traits. In the tiny gene, four-protein molecules (A, T, C, and G) carry dominant and recessive traits.
- Every soma (body) cell has 46 chromosomes arranged in 22 pairs of autosomes and one pair of sex chromosomes (one from each parent) within the nucleus.
- The determination of fetal sex depends on whether the female X chromosome unites with the X or Y chromosome from the male. An XY match produces a male, and an XX match produces a female.
- Fertilization (fusion of the nuclei of the sperm and ovum) normally takes place in the outer third of the fallopian tube (uterine tube) 6 to 24 hours after ovulation.
- Approximately 2 to 3 weeks after fertilization, three cell layers form the ectoderm, mesoderm, and endoderm. These cell layers later differentiate to become all of the tissues and organs of the embryo.
- Embryonic membranes are the amnion (inner layer, which contains amniotic fluid and the embryo) and chorion (outer layer that encloses the amnion).
- The preembryonic period begins with conception and ends at 3 weeks' gestation. Early organ formation occurs.
- The embryonic period lasts through 8 weeks' gestation, with continued development of organs with limited function. Teratogenic agents are most likely to disturb development and cause damage to the embryo during the first 8 weeks of gestation.
- The fetal period (9 weeks until birth) is when the organs continue to develop, and the body systems get ready for extrauterine life.
- The placenta is an organ that provides for fetal respiration, nutrition, and excretion. It is also a temporary endocrine gland, producing progesterone, estrogen, hCG, and hPL.
- The umbilical cord contains two arteries that carry deoxygenated blood away from the fetus and one vein that carries oxygenated blood to the fetus. The cord is embedded in Wharton's jelly, which prevents kinking.
- The placenta, umbilical cord, and fetal circulation support fetal growth and development.
- Changes in fetal circulation at birth include closing of the ductus arteriosus, ductus venosus, and foramen ovale, which occurs as the umbilical cord is cut and blood flows to the lungs for oxygenation.
- Multifetal pregnancy means that more than one fetus develops in the uterus at the same time.
- Identical twins develop from a single fertilized ovum, and nonidentical (or fraternal) twins occur when two ova are fertilized by two separate sperm.

Additional Learning Resources

SG Go to your Study Guide on page 477 for additional Review Questions for the NCLEX® Examination, Critical Thinking Clinical Situations, and other learning activities to help you master this chapter content.

evolve Go to your Evolve website (http://evolve.elsevier.com/Leifer/maternity) for the following FREE learning resources:

- Animations
- Answer Guidelines for Critical Thinking Questions
- Answers and Rationales for Review Questions for the NCLEX® Examination
- Concept Map Creator
- Glossary with pronunciations in English and Spanish
- Patient Teaching Plans
- Skills Performance Checklists and more!

Online Resources

- www.fetal.com/gen_risk.htm
- www.cyber-north.com/anatomy/reproduc.htm

Review Questions for the NCLEX® Examination

1. Spiral structures found within the nucleus of each cell made up of building blocks of DNA are:
   1. Genes
   2. Chromosomes
   3. Gametes
   4. Molecules
2. The amount of amniotic fluid normally present at term is approximately:
   1. Less than 300 milliliters
   2. 1000 milliliters
   3. 2 liters
   4. 4 liters
3. The umbilical vein:
   1. Prevents kinking of the umbilical cord
   2. Carries deoxygenated blood
   3. Carries oxygen and nutrients from the placenta to the fetus
   4. Releases carbon dioxide and other waste products
4. The nurse tells a pregnant patient that the fetus is first capable of surviving outside of the uterus at:
   1. 8 weeks' gestation
   2. 10 weeks' gestation
   3. 16 weeks' gestation
   4. 20 weeks' gestation
5. The fetal heartbeat is first detectable on sonography at week:
   1. 4
   2. 8
   3. 17
   4. 25

6. The placenta's function(s) include: *(Select all that apply.)*
   1. Protection
   2. Nutrition
   3. Respiration
   4. Excretion
   5. Hormone production

7. Amniotic fluid has which function(s)? *(Select all that apply.)*
   1. Fetal oxygenation and exchange of waste products
   2. Formation of tissues and organs of the embryo
   3. Prevention of umbilical cord compression
   4. Maintenance of a constant temperature
   5. Provision of immunologic function for the fetus

8. Put the following stages of embryonic development in sequential order by numbering 1 *(first)* to 5 *(last).*

   ___ Formation of zygote
   ___ Fertilization
   ___ Blastocyst formation
   ___ Implantation
   ___ Morula formation

Critical Thinking Questions

1. The embryonic period presents the greatest risk of cell injury (by teratogens) to the embryo. What would you include in a preconception health teaching plan?

2. A prenatal patient at 18 weeks' gestation asks you how and when the sex of the baby is decided. What would you tell her? Remember to formulate your response in terms that she can understand.