

CHAPTER 29

LECTURE OUTLINE

I. INTRODUCTION

- A. Developmental anatomy is the study of the sequence of events from the fertilization of a secondary oocyte to the formation of an adult organism.
 - 1. The first two months following fertilization is the period of embryonic development and the developing human is an embryo.
 - 2. From week nine until birth is the fetal development period and the individual is a fetus.
- B. Embryology is the study of development from fertilization to the fetal period.
- C. Obstetrics is the branch of medicine that deals with the management of pregnancy, labor, and the neonatal period (the first 42 days after birth).
- D. Prenatal development is the time from fertilization until birth. It is divided into three trimesters.

II. EMBRYONIC PERIOD

A. First Week of Development

1. Fertilization

- a. During fertilization, the genetic material from a haploid sperm cell (spermatozoon) and a haploid secondary oocyte merges into a single diploid nucleus.
- b. Fertilization normally occurs in the uterine (Fallopian) tube when the oocyte is about one-third of the way down the tube to the uterus, usually within 12 to 24 hours after ovulation.
- c. The process leading to fertilization begins as peristaltic contractions and the actions of cilia transport the oocyte through the uterine tube.
- d. Sperm swim up the uterus and into the uterine tube by the whip like movements of their tails and muscular contractions of the uterus.
- e. The functional changes that sperm undergo in the female reproductive tract that allow them to fertilize a secondary oocyte are referred to as capacitation.
- f. To fertilize an oocyte, a sperm must penetrate the corona radiata and zona pellucida around the oocyte (Figure 29.1a).
- g. A glycoprotein in the zona pellucida (ZP3) acts as a sperm receptor, binds to specific membrane proteins in the sperm head and triggers the acrosomal reaction, the release of the contents of the acrosome.
- h. The acrosomal enzymes digest a path through the zona pellucida allowing only one sperm to make its way through the barrier and reach the oocyte's plasma membrane.

- i. Fusion of a sperm with a secondary oocyte is called syngamy.
- j. Polyspermy is prevented by chemical changes that prevent a second sperm from entering the oocyte.
- k. Once a sperm enters a secondary oocyte, the oocyte completes meiosis, and the male pronucleus and female pronucleus fuse forming the fertilized ovum or zygote (Figure 29.1c).
 - (1) Dizygotic (fraternal) twins are produced from the independent release of two ova and the subsequent fertilization of each by different spermatozoa. They are the same age and are in the uterus at the same time but are as genetically dissimilar as other siblings.
 - (2) Monozygotic (identical) twins are derived from a single fertilized ovum that splits at an early stage in development. They contain exactly the same genetic material and are always the same sex.

2. Cleavage of the zygote

- a. Early rapid mitotic cell division of a zygote is called cleavage (Figure 29.2).
- b. The cells produced by cleavage are called blastomeres.
- c. Successive cleavages produce a solid mass of cells, called the morula (Figure 29.2).

3. Blastocyst formation

- a. As the number of cells in the morula increases, it moves from the site of fertilization down through the ciliated uterine tube toward the uterus and enters the uterine cavity.
- b. The morula develops into a blastocyst, a hollow ball of cells that is differentiated into a trophoblast (which will form the future embryonic membranes), an inner cell mass or embryoblast (the future embryo), and an internal fluid-filled cavity (Figure 29.2e).
- c. Pluripotent cells currently being used in research are derived from embryos that were to be used for infertility treatment but are no longer needed and from fetuses aborted during the first trimester. Both methods are being investigated as means to treat various diseases (Clinical Connection).

4. Implantation

- a. The blastocyst remains free with the cavity of the uterus for two to four days before it actually attaches to the uterine wall.
- b. The attachment of a blastocyst to the endometrium occurs seven to eight days after fertilization and is called implantation (Figure 29.3).
- c. Following implantation the endometrium is known as the decidua and consists of three regions: the decidua basalis, decidua capsularis, and decidua parietalis (Figure 29.4)

- (1) The decidua basalis lies between the chorion and the stratum basalis of the uterus. It becomes the maternal part of the placenta.
 - (2) The decidua capsularis covers the embryo and is located between the embryo and the uterine cavity.
 - (3) The decidua parietalis lines the noninvolved areas of the entire pregnant uterus.
- d. The major events associated with the first week of development are summarized in Figure 29.5.
 - e. Ectopic pregnancy refers to the development of an embryo or fetus outside the uterine cavity. Most occur in the uterine tube, usually in the ampullar or infundibular portions. Some occur in the ovaries, abdomen, uterine cervix, or broad ligaments. Depending on the location of the ectopic pregnancy, the condition can become life threatening to the mother. (Clinical Connection)

B. Second Week of Development

1. Development of the trophoblast

- a. The trophoblast develops into a syncytiotrophoblast and a cytotrophoblast (Figure 29.6).
 - b. These two layers become part of the chorion as they undergo further growth (Figure 29.11).
 - c. The syncytiotrophoblast cells secrete enzymes that enable the blastocyst to penetrate the uterine lining.
 - d. The trophoblast also secretes human chorionic gonadotropin, which rescues the corpus luteum from degeneration and sustains its function.
2. The cells of the inner cell mass differentiate into two layers the hypoblast (primitive endoderm) and the epiblast (primitive ectoderm); these two layers form a flattened disc referred to as the bilaminar embryonic disc (Figure 29.6).

3. Development of the amnion

- a. A thin, protective membrane called the amnion develops from the epiblast
- b. Initially the amnion overlies only the bilaminar embryonic disc; as the embryo grows it eventually surrounds the entire embryo creating the amniotic cavity (Figure 29.11 a inset).
- c. The amniotic cavity becomes filled with amniotic fluid.
- d. Amniotic fluid protects the developing fetus and can be examined in a procedure known as amniocentesis.

4. Development of the yolk sac

- a. The hypoblast cells migrate and become the exocoelomic membrane.

- b. The hypoblast and the exocoelomic membrane form the yolk sac. (Figure 29.6b)
- c. The yolk sac has several important functions. It transfers nutrients to the embryo, is an early source of blood cells, and produced primitive germ cells, which will become spermatogonia and oogonia.

5. Development of sinusoids

- a. On the ninth day after fertilization the coagulation plug seals the site of implantation.
 - b. The syncytiotrophoblast expands and small spaces called lacunae develop within it (Figure 29.6b).
 - c. By the twelfth the lacunae fuse to form lacunar networks (Figure 29.6c).
 - d. Endometrial capillaries around the developing embryo become dilated and are referred to as sinusoids.
 - e. The syncytiotrophoblast erodes the sinusoids and endometrial glands permitting maternal blood to enter the lacunar networks.
6. After the extraembryonic mesoderm develops, several large cavities develop in the mesoderm. These cavities fuse to form the extraembryonic coelom (Figure 29.6c)

7. Development of the chorion

- a. The chorion develops from extraembryonic mesoderm and the two layers of the trophoblast (Figure 29.6c).
- b. The chorion becomes the principal embryonic part of the placenta.
- c. The chorion secretes hCG, an important hormone of pregnancy (Figure 29.16).

C. Third Week of Development

1. Gastrulation

- a. During gastrulation the two-dimensional bilaminar embryonic disc transforms into a two-dimensional trilaminar embryonic disc consisting the three primary germ layers: the ectoderm, mesoderm, and endoderm.
- b. Gastrulation begins with the development of the primitive streak .
- c. Cells of the epiblast move inward below the primitive streak and detach from the epiblast (Figure 29.7b).
- d. The primary germ layers, ectoderm, mesoderm, and endoderm, form all tissues and organs of the developing organism (Table 29.1)
- e. A solid cylinder of cells the notochord also develops (Figure 29.8). It plays an important role in the process of induction.
- f. The oropharyngeal membrane that will eventually connect the mouth cavity to the pharynx and the remainder of the gastrointestinal tract appears (Figure 29.8 a, b).

- g. The cloacal membrane that will form the openings of the anus and urinary and reproductive tracts also appears.
- h. The allantois, a vascularized out pouching of the yolk sac extends into the connecting body stalk (Figure 29.8b).

2. Neurulation

- a. The notochord induces the ectodermal cells over it to form the neural plate (Figure 29.9a)
- b. The neural plate gives rise to the neural folds and neural groove that will fuse to form the neural tube (Figure 29.9d).
- c. Ectodermal cells from the neural tube migrate to form the neural crest (Figure 14.27) which give rise spinal and cranial nerves and their ganglia, autonomic nervous system ganglia, the meninges of the brain and spinal cord, the adrenal medullae, and several skeletal and muscular components of the head.
- d. The head of the neural tube develops into the three primary vesicles: the prosencephalon, mesencephalon, and the rhombencephalon (Figure 14.28).
- e. Later the secondary vesicles will develop. They are the telencephalon, diencephalon, metencephalon, and myelencephalon.
- f. Neural tube defects (NTDs) are caused by arrest of the normal development and closure of the neural tube. These include anencephaly and spina bifida (Clinical Connection).

3. Development of somites

- a. The somites, a series of paired, cube-shaped structures, develop from the mesoderm.
- b. Eventually 42-44 pairs of somites will develop.
- c. Each somite has three regions, a myotome, dermatome, and sclerotome (Figure 10.19b).

4. Development of the intraembryonic coelom

- a. Small spaces in the lateral plate mesoderm fuse to form a larger cavity, the intraembryonic coelom.
- b. This cavity splits the lateral plate mesoderm into two parts called the splanchnic mesoderm and the somatic mesoderm (Figure 29.9d).
- c. The intraembryonic mesoderm divides into the pericardial, pleural, and peritoneal cavities.
- d. Splanchnic mesoderm forms portions of the heart, respiratory and digestive systems.
- e. Somatic mesoderm gives rise to bones, ligaments, and dermis of the limbs and the parietal layer of the serous membranes.

5. Development of the cardiovascular system

- a. Angiogenesis, the formation of blood vessels, begins in the extraembryonic mesoderm in the yolk sac, connecting stalk, and chorion.
 - (1) Angiogenesis is initiated when angioblasts aggregate to form isolated masses of cells referred to as blood islands (Figure 21.31).
 - (2) Spaces in the blood islands form the lumen of blood vessels.
 - (3) Angioblasts form the walls of the blood vessels
- b. The heart forms in the cardiogenic area of the splanchnic mesoderm.
 - (1) The mesodermal cells form a pair of endocardial tubes (Figure 20.19).
 - (2) The tubes fuse to form a single primitive heart.

6. Development of the chorionic villi and placenta

- a. Chorionic villi develop as projections of the cytotrophoblast that eventually contain blood-filled capillaries (Figure 29.10).
- b. Blood vessels in the chorionic villi connect to the embryonic heart by way of umbilical arteries and veins (Figure 29.10).
- c. The placenta has a fetal portion formed by the chorionic villi of the chorion and a maternal portion formed by the decidua basalis of the endometrium (Figure 29.11a)
 - (1) Functionally the placenta allows oxygen and nutrients to diffuse from maternal blood to fetal blood that carbon dioxide and wastes diffuse from fetal blood into maternal blood.
 - (2) The placenta also serves as a protective barrier, stores nutrients, and secretes several important hormones necessary to maintain the pregnancy.
- d. The connection between the placenta and the embryo is the umbilical cord (Figure 29.11a).
- e. After the birth of the baby, the placenta detaches from the uterus and is therefore termed the afterbirth.
- f. Placenta previa is a condition in which part or the entire placenta becomes implanted in the lower portion of the uterus, near or over the internal os of the cervix. If detected during pregnancy (either by ultrasound or as a result of sudden painless bright red vaginal bleeding during the third trimester), cesarean section is the preferred method of delivery. (Clinical Connection)

D. Fourth week of Development

- 1. Embryonic folding converts the embryo from a flat, two-dimensional trilaminar embryonic disc to a three-dimensional cylinder (Figure 29.12)
- 2. Development of the somites and the neural tube occurs during the fourth week.

3. Several pharyngeal (branchial) arches develop on each side of the future head and neck regions (Figure 29.13). With the pharyngeal clefts and pouches they will form structures of the head and neck.
4. The otic placode is the first sign of a developing ear (Figure 29.13a).
5. The lens placode is the first sign of a developing eye (Figure 29.13a).
6. The upper limb buds appear (Figure 29.13a) in the middle of the fourth week and the lower limb buds appear at the end of the fourth week.

E. Fifth Through Eighth Weeks of Development

1. During the fifth week there is rapid brain development and considerable head growth.
2. During the sixth week the head grows even larger in relation to the trunk, there is substantial limb growth, the neck and trunk begin to straighten, and the heart is now four-chambered.
3. During the seventh week the various regions of the limbs become distinct and the beginnings of the digits appear.
4. By the end of the eighth week all regions of the limbs are apparent, the digits are distinct, the eyelids come together, the tail disappears, and the external genitals begin to differentiate.

III. FETAL PERIOD

- A. During the fetal period, tissue and organs that developed during the embryonic period grow and differentiate. The rate of body growth is remarkable.
- B. A summary of the major developmental events of the embryonic and fetal period is presented in Table 29.2 and Figure 29.14.

IV. TERATOGENS

- A. A given phenotype is the result of the interactions of genotype and the environment. A teratogen is any agent or influence that causes developmental defects in the embryo.

B. Chemicals and Drugs

1. Because the placenta is a porous barrier between the maternal and fetal circulations, any drug or chemical dangerous to an infant may be considered potentially dangerous to the fetus when given to the mother.
2. Alcohol is by far the number one fetal teratogen. Intrauterine exposure to even a small amount of alcohol may result in fetal alcohol syndrome, one of the most common causes of mental retardation and one of the most common preventable causes of birth defects in the United States.
3. Other fetal teratogens include pesticides, industrial chemicals, some hormones, antibiotics, some prescription drugs, and street drugs.

C. Cigarette Smoking

1. Cigarette smoking is implicated as a cause of low birth weight and a higher fetal and infant mortality rate.
2. Cigarette smoke may be teratogenic and cause cardiac abnormalities and anencephaly.
3. Ionizing radiations are potent teratogens.

D. Irradiation

1. X-rays or radioactive isotopes

V. PRENATAL DIAGNOSTIC TESTS

- A. In **fetal ultrasonography**, an image of the fetus, called a sonogram, is displayed on a screen. It is used most often to determine true fetal age when the date of conception is uncertain. It is also used to evaluate fetal viability and growth, determine fetal position, ascertain multiple pregnancies, identify fetal-maternal abnormalities, and serve as an adjunct to special procedures such as amniocentesis and chorionic villus sampling.
- B. **Amniocentesis** is the transabdominal withdrawal of some of the amniotic fluid that bathes the developing fetus and subsequent analysis of the fetal cells and dissolved substances. It is used to test for the presence of certain genetic disorders, such as Down syndrome, spina bifida, hemophilia, Tay-Sachs disease, Sickle-cell disease, and certain muscular dystrophies or to determine fetal maturity and well-being near the time of delivery. The test is usually done at 14-16 weeks gestation to detect suspected genetic abnormalities. To assess fetal maturity, it is usually done after the 35th week of gestation (Figure 29.15a).
- C. **Chorionic villi sampling (CVS)** involves withdrawal of chorionic villi for chromosomal analysis. CVS can be done earlier than amniocentesis (at 8-10 weeks gestation), and the results are available more quickly. The sampling is normally done transvaginally using an ultrasound-guided catheter; transabdominal sampling, similar to amniocentesis, is also possible (Figure 29.15b).
- D. The first **noninvasive prenatal test** was maternal alpha-fetoprotein (AFP) test. This test analyzes the maternal blood for the presence of AFP. A high level of AFP after 16 weeks indicates that the fetus has a neural tube defect. This test is used to screen for Down syndrome, trisomy 18, and neural tube defects. It also helps predict delivery date and may reveal the presence of twins.

VI. MATERNAL CHANGES DURING PREGNANCY

A. Hormones of Pregnancy

1. During the first 3-4 months of pregnancy, the corpus luteum continues to secrete progesterone and estrogens to maintain the uterine lining and prepare the mammary glands to secrete milk.

2. From the third month on, the placenta provides the high levels of estrogens and progesterones necessary to maintain the pregnancy.
3. The chorion of the placenta secretes human chorionic gonadotropin (hGH), relaxin, and human somatomammotropin (hCS).
 - a. Human chorionic gonadotropin (hCG) mimics LH; its primary role is to stimulate continued production by the corpus luteum of estrogens and progesterone - an activity necessary for the continued attachment of the embryo and fetus to the lining of the uterus (Figure 29.16).
 - b. Relaxin, produced by the ovaries, testes, and placenta, inhibits secretion of FSH and might regulate secretion of hGH.
 - c. Human chorionic somatomammotropin (hCS) (also known as human placental lactogen, or hPL), also produced by the chorion, assumes a role in breast development for lactation, protein anabolism, and catabolism of glucose and fatty acids.
4. Corticotropin-releasing hormone (CRH) is thought to be the “clock” that establishes the timing of birth.
5. Early pregnancy tests detect the tiny amounts of hCG in the urine that begin to show up about 8 days after fertilization. (Clinical Connection)

B. Changes During Pregnancy

1. During gestation, several anatomical and physiological changes occur.
 - a. The uterus continuously enlarges, filling first the pelvic and then the abdominal cavity, displacing and compressing a number of structures (Figure 29.17).
 - b. Pregnancy-induced physiological changes include weight gain; increased protein, fat, and mineral storage; marked breast enlargement; and lower back pain.
 - c. Cardiovascular modifications include increase in stroke volume by approximately 30%, rise in cardiac output by approximately 20-30%, increase in heart rate by 10-15%, and increase in blood volume up to 30-50% (mostly during the latter half of pregnancy). The uterus may compress large blood vessels, diminishing blood flow and return to the heart.
 - d. Pulmonary function alternations include increased tidal volume (30-40%), decreased expiratory reserve volume (by up to 40%), increased minute volume of respiration (by up to 40%), decreased airway resistance in the bronchial tree (by up to 36%), and increase in total body oxygen consumption (by 10-20%). Dyspnea also occurs.
 - e. With regard to the gastrointestinal tract, there is an increase in appetite and decreased motility that can result in constipation and delayed gastric emptying. Nausea, vomiting, and heartburn also occur.

- f. Pressure on the urinary bladder increases frequency and urgency of urination; stress incontinence may occur. Glomerular filtration rate rises up to 40%.
 - g. The skin may display increased pigmentation, striae (stretch marks) over the abdomen occur as the uterus enlarges, and hair loss increases.
 - h. In the reproductive system, there is edema and increased vascularity of the vulva and increased pliability and vascularity of the vagina. The weight of the uterus increases 15 to 20-fold during pregnancy due to hyperplasia of muscle fibers (cells) in the myometrium in early pregnancy and hypertrophy of muscle fibers during the second and third trimesters.
2. Approximately 10-15% of all pregnant women in the United States experience pregnancy-induced hypertension, elevated blood pressure associated with pregnancy. The major cause is preeclampsia, in which the hypertension seems to result from impaired renal function. It typically occurs after the 20th week of gestation and there are large amounts of protein in the blood. When associated with convulsions and coma, the condition is termed eclampsia (Clinical Connection)

VII. EXERCISE AND PREGNANCY

- A. Exercise may need to be modified during pregnancy to accommodate the changes in the female's body.
- B. Moderate physical activity does not endanger the fetuses of healthy females who have a normal pregnancy and is beneficial in many aspects.

VIII. LABOR

- A. Labor is the process by which the fetus is expelled from the uterus through the vagina to the outside. Parturition also means giving birth.
 - 1. A decrease in progesterone levels and elevated levels of estrogens, prostaglandins, oxytocin, and relaxin are all probably involved in the initiation and progression of labor.
 - 2. True labor begins when uterine contractions occur at regular intervals, usually producing pain. As the interval between contractions shortens, the contractions intensify. Other signs of true labor may be localization of pain in the back, which is intensified by walking; "show" (discharge of blood-containing mucus from the cervical canal); and dilation of the cervix. In false labor, pain is felt in the abdomen at irregular intervals. The pain does not intensify and is not altered significantly by walking. There is no "show" and no cervical dilation.

- B. The birth of a baby involves three stages: dilation of the cervix, expulsion of the fetus, and delivery of the placenta (Figure 29.18).
1. The stage of dilation is the time from the onset of labor to the complete dilation of the cervix. During this stage, there are regular contractions of the uterus, usually a rupturing of the amniotic sac, and complete dilation (10cm) of the cervix. If the amniotic sac does not rupture spontaneously, it is done artificially.
 2. The stage of expulsion is the time from complete cervical dilation to delivery.
 3. The placental stage is the time after delivery until the placenta or “afterbirth” is expelled by powerful uterine contractions. These contractions also constrict blood vessels that were torn during delivery, reducing the possibility of hemorrhage.
- C. During labor, the fetus is squeezed through the birth canal for up to several hours, resulting in compression of the fetal head and some intermittent hypoxia due to compression of the umbilical cord and placenta during uterine contractions. In response to this compression, the adrenal medullae of a fetus secrete very high levels of epinephrine and norepinephrine. These hormones afford the fetus protection against the stresses of the birth process and prepare the infant to survive extrauterine life.
- D. After delivery of the baby and placenta, there is a period of time, called the puerperium that lasts about six weeks. During this time the reproductive organs and maternal physiology return to the prepregnancy state. The uterus undergoes a remarkable reduction in size called involution and there is a uterine discharge (lochia) of blood and serous fluid for two to four weeks after delivery.
- E. Dystocia, or difficult labor, may result from impaired uterine forces, an abnormal position (presentation) of the fetus, or a birth canal of inadequate size to permit vaginal birth. In these instances, and in certain conditions of fetal or maternal distress during labor, it may be necessary to deliver the baby via cesarean section (C-section). Even a history of multiple C-sections need not preclude a pregnant woman from attempting a vaginal delivery. (Clinical Connection)

IX. ADJUSTMENTS OF THE INFANT AT BIRTH

- A. During pregnancy, the embryo (and later, the fetus) depends on the mother for oxygen and nutrients, removal of wastes, and protection against shocks, temperature changes, and certain harmful microbes. At birth, a physiologically mature baby becomes self-supporting, and the newborn’s body systems must make various adjustments.

B. Respiratory Adjustments

1. After delivery the baby’s supply of oxygen from the mother is stopped.

2. Circulation in the baby continues, and as the blood level of carbon dioxide increases, the respiratory center in the medulla is stimulated. This causes the respiratory muscles to contract, and the baby draws its first breath. Since the first inspiration is unusually deep because the lungs contain no air, the baby exhales vigorously and naturally cries.
3. A full-term baby may breathe 45 times a minute for the first two weeks after birth. The rate is gradually reduced until it approaches a normal rate.

C. Cardiovascular Adjustments

1. The foramen ovale between the atria of the fetal heart closes at the moment of birth. This diverts deoxygenated blood to the lungs for the first time.
 - a. Two flaps of heart tissue that folds together and permanently fuse close the foramen ovale.
 - b. The remnant of the foramen ovale is the fossa ovalis.
 2. Once the lungs begin to function, the ductus arteriosus is shut off by contractions of the muscles in its wall.
 - a. The ductus arteriosus generally does not completely and irreversibly close for about three months following birth.
 - b. The ligamentum arteriosum is the remnant of the ductus arteriosus.
 3. When the umbilical cord is severed, all visceral blood of the fetus goes directly to the infant heart via the inferior vena cava.
 - a. This shunt of blood usually occurs within minutes after birth but may take a week or two to complete.
 - b. The ligamentum venosum, the remnant of the ductus venosus, is well established by the eighth postnatal week.
 4. At birth, the infant's pulse may be from 120 to 160 per minute and may go as high as 180 following excitation.
 5. Several days after birth, there is a greater independent need for oxygen, which stimulates an increase in the rate of erythrocyte and hemoglobin production. This increase usually lasts for only a few days.
 6. The white blood cell count at birth is very high, sometimes as much as 45,000 cells per cubic millimeter, but this decreases rapidly by the seventh day.
- D. Delivery of a physically immature baby carries certain risks. Major problems faced by a premature infant include respiratory distress syndrome, blindness, brain hemorrhages, and digestive disorders. The problems related to survival of premature infants are due to the fact that

they are not yet ready to take over functions the mother's body should be performing. (Clinical Connection)

X. PHYSIOLOGY OF LACTATION

A. Lactation refers to the secretion and ejection of milk by the mammary glands.

1. A principal hormone in promoting lactation is prolactin (PRL) from the anterior pituitary gland.
 - a. PRL levels increase as the pregnancy progresses, but there is no milk secretion because estrogens and progesterone inhibit PRL from being effective.
 - b. Following delivery, estrogens and progesterone decrease, removing their inhibitory effect.
 - c. The principal stimulus in maintaining prolactin secretion during lactation is the sucking action of the infant.
2. Oxytocin (OT) causes release of milk into mammary ducts by the milk ejection reflex (Figure 29.19).
 - a. OT induces smooth muscle cells surrounding the outer walls of the alveoli to contract, thereby compressing the alveoli and ejecting milk. The compression moves milk from the alveoli of the mammary gland into the ducts, where it can be sucked. This process is referred to a milk ejection (let-down) (Figure 29.19).
 - b. Although the actual ejection of milk does not occur from 30 seconds to 1 minute after nursing begins, some milk is stored in lactiferous sinuses near the nipple. Thus, some milk is available during the latent period.
3. During late pregnancy and the first few days after birth, the mammary glands secrete a cloudy fluid called colostrum. It is not as nutritious as true milk but serves adequately until the appearance of true milk on about the fourth postpartum day. Colostrum and maternal milk are thought to contain antibodies that protect the infant during the first few months of life.
4. Nursing causes neural feedback to the hypothalamus and the anterior pituitary gland that stimulates the production of PRF (prolactin releasing factor) and PRL, causing the mammary glands to prepare for the next nursing period.
 - a. Milk secretion can continue for several years if the child continues to suckle. Milk secretion normally decreases considerably within seven to nine months.
 - b. The mammary glands can lose their ability to secrete milk in a period of only a few days if nursing is discontinued or hormonal release is blocked by injury or disease.

5. Lactation often prevents the occurrence of female ovarian cycles for the first few months following delivery if the frequency of nursing is about 8-10 times a day. However, there is no guarantee of contraception.
6. A primary benefit of breast-feeding is nutritional. Other benefits include the baby receiving beneficial cells and molecules from the breast milk, showing a decreased incidence of diseases later in life, as well as other benefits.
7. Nursing stimulates the release of oxytocin and helps promote expulsion of the placenta and the uterus to regain its smaller size.

XI. INHERITANCE

A. Inheritance is the passage of hereditary traits from one generation to another.

1. The branch of biology that deals with inheritance is called genetics.
2. The area of health care that offers advice on genetic problems is called genetic counseling.

B. Genotype and Phenotype

1. Nuclei of all human cells except gametes contain 23 pairs of chromosomes (diploid number).
 - a. One chromosome in each pair came from the mother, and the other came from the Father.
 - b. Homologues, the two chromosomes in a pair, contain genes that control the same traits.
 - c. The two genes that code for the same trait and are at the same location on homologous chromosomes are termed alleles.
 - d. A mutation is a permanent heritable change in a gene that causes it to have a different effect than it had previously.
2. The genetic makeup of an organism is called its genotype.
 - a. Dominant genes control a particular trait; expression of recessive genes is inhibited by the presence of dominant genes.
 - b. An individual with the same genes on homologous chromosomes (e.g., PP or pp) is said to be homozygous for the trait. An individual with different genes on homologous chromosomes (e.g., Pp) is said to be heterozygous for the trait. (By convention, the dominant gene is expressed by a capital letter; and the recessive gene, by a lower case letter.) (Figure 29.20)
3. The traits that are expressed are called its phenotype.
4. Most genes give rise to the same phenotype whether they are inherited from the mother or father; although, in a few cases, the phenotype is dramatically different. This phenomenon is called genomic imprinting.

5. To determine the possible ways that haploid gametes can unite to form diploid fertilized eggs, special charts called Punnett squares are used.
6. Meiosis errors can result in inheritance abnormalities.
 - a. Nondisjunction results in an abnormal number of chromosomes.
 - b. A cell that has one or more chromosomes of a set added or deleted is called an aneuploid.
 - c. In translocation, the location of a chromosome segment is changed, being moved either to another chromosome or to another location within the same chromosome.
7. Table 29.3 lists some dominant-recessive inherited structural and functional traits in humans.

C. Variations on Dominant-Recessive Inheritance

1. Most patterns of inheritance do not conform to the simple dominant-recessive patterns in which only dominant and recessive genes interact.
2. In fact, the phenotypic expression of a particular gene is influenced not only by the alleles of the genes present, but also by other genes and by the environment. Most inherited traits are influenced by more than one gene, and most genes can influence more than a single trait.
3. In incomplete dominance, neither member of an allelic pair dominates; phenotypically the heterozygote is intermediate between the homozygous dominant and homozygous recessive. An example is sickle-cell disease (Figure 29.21).
4. In multiple-allele inheritance, some genes have more than two alternate forms. An example is the inheritance of ABO blood groups. The various possible and impossible blood group phenotypes are illustrated in Figure 29.22.
5. In polygenic inheritance, the combined effects of many genes control an inherited trait. An example is skin color. Figure 29.23 illustrates the inheritance of skin color and the various gradations of skin tone.
6. Complex inheritance refers to the combined effects of many genes and environmental factors.

D. Autosomes, Sex Chromosomes, and Sex Determination

1. In 22 of the 23 pairs of chromosomes, the homologous chromosomes look alike and have the same appearance in both males and females; these 22 pairs are called autosomes. The two members of the 23rd pair are termed the sex chromosomes (Figure 29.24).
 - a. In females, the 23rd pair consists of two chromosomes designated as X chromosomes.
 - b. One X chromosome is also present in the male sex chromosomes, but its mate is a smaller chromosome called a Y chromosome.
 - c. If an X-bearing sperm fertilizes the secondary oocyte, the offspring normally will be female (XX). Fertilization by a Y-bearing sperm normally produces a male (XY). Thus, gender (sex) is determined by the father's sex chromosome (Figure 29.25).

2. Sex is determined by the presence or absence of an SRY (sex-determining region of the Y chromosome) gene on the Y chromosome at fertilization.

E. Sex-Linked Inheritance

1. The sex chromosomes also are responsible for the transmission of several nonsexual traits. Genes for these traits appear on X chromosomes, but many of them are absent from Y-chromosomes. Traits inherited in this manner are called sex-linked or X-linked traits.
2. Red-green color blindness and hemophilia primarily affect males because there are no counterbalancing dominant genes on the Y-chromosome (Figure 29.26). Other sex-linked traits in humans are fragile X syndrome, nonfunctional sweat glands, certain forms of diabetes, some types of deafness, uncontrollable rolling of the eyeballs, absence of central incisors, night blindness, one form of cataract, juvenile glaucoma, and juvenile muscular dystrophy.
 - a. Whereas females have two X chromosomes in every cell, they actually use only one. X-chromosome inactivation or lyonization inactivates one X-chromosome so that its genes are not expressed.
 - b. The inactivated X chromosome shows up as a Barr body in cells.

XII. DISORDERS: HOMEOSTATIC IMBALANCES

A. Infertility

1. Female infertility may be caused by ovarian disease, uterine tube obstruction, conditions in which the uterus is not adequately prepared to receive the fertilized ovum, and inadequate body fat.
2. Male infertility is an inability to fertilize a secondary oocyte.
3. Many fertility-expanding techniques now exist for assisting infertile couples to have a baby.
 - a. In vitro fertilization (IVF) refers to the fertilization of a secondary oocyte outside the body and the subsequent introduction of an 8-cell or 16-cell embryo for implantation and subsequent growth.
 - b. In intracytoplasmic sperm injection, an oocyte may be fertilized by suctioning a sperm or even a spermatid obtained from the testis into a tiny pipette and then injecting it into the oocyte's cytoplasm.
 - c. In embryo transfer, a husband's sperm is used to artificially inseminate a fertile secondary oocyte donor.
 - d. In gamete intrafallopian transfer, a sperm and secondary oocyte are united in the prospective mother's uterine tube.

- B. Down syndrome (DS) is a disorder that results from an error in cell division called nondisjunction, involving chromosome pair #21. This syndrome is caused by trisomy of an autosome rather than aneuploidy of a sex chromosome. Although it is more common as the mother approaches age 35 and beyond, many women under the age of 35 give birth to children with DS.
- C. Congenital defects result from injuries or errors during organogenesis, primarily in the second month. Proper nutrition with adequate folic acid can help prevent neural tube defects.

XIII. **MEDICAL TERMINOLOGY** - Alert students to the medical terminology associated with development and inheritance.