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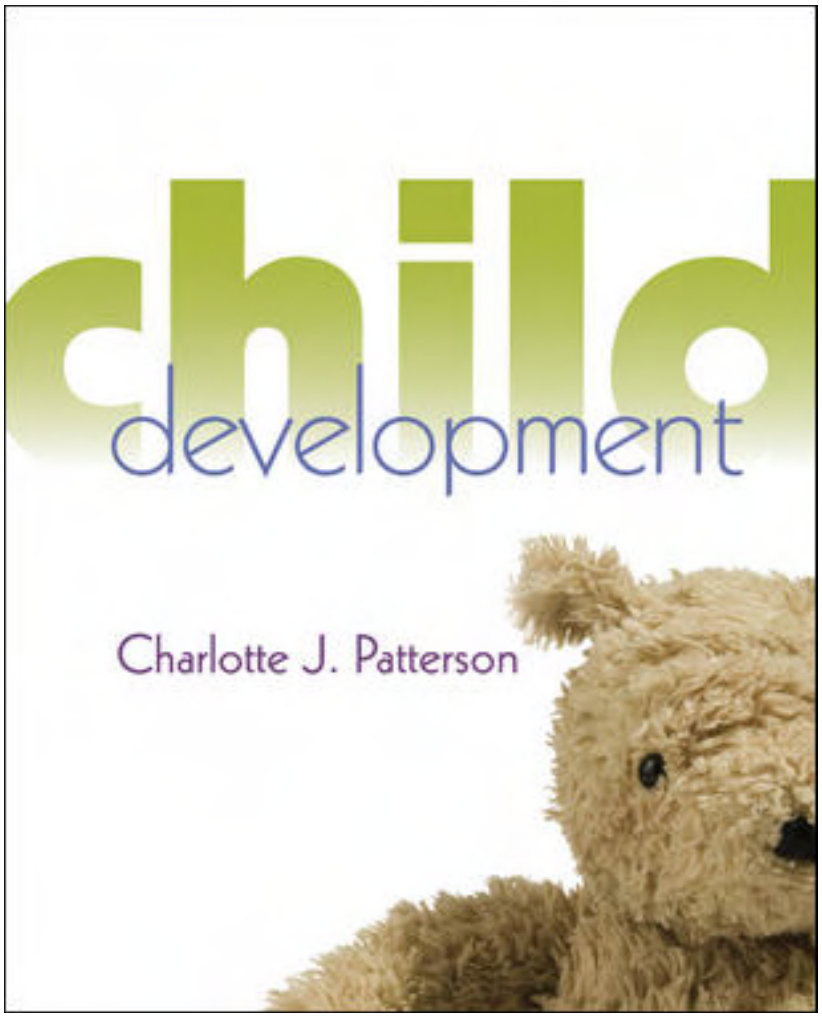
Chapter 2



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Mc Graw Hill Higher Education

CHAPTER TWO

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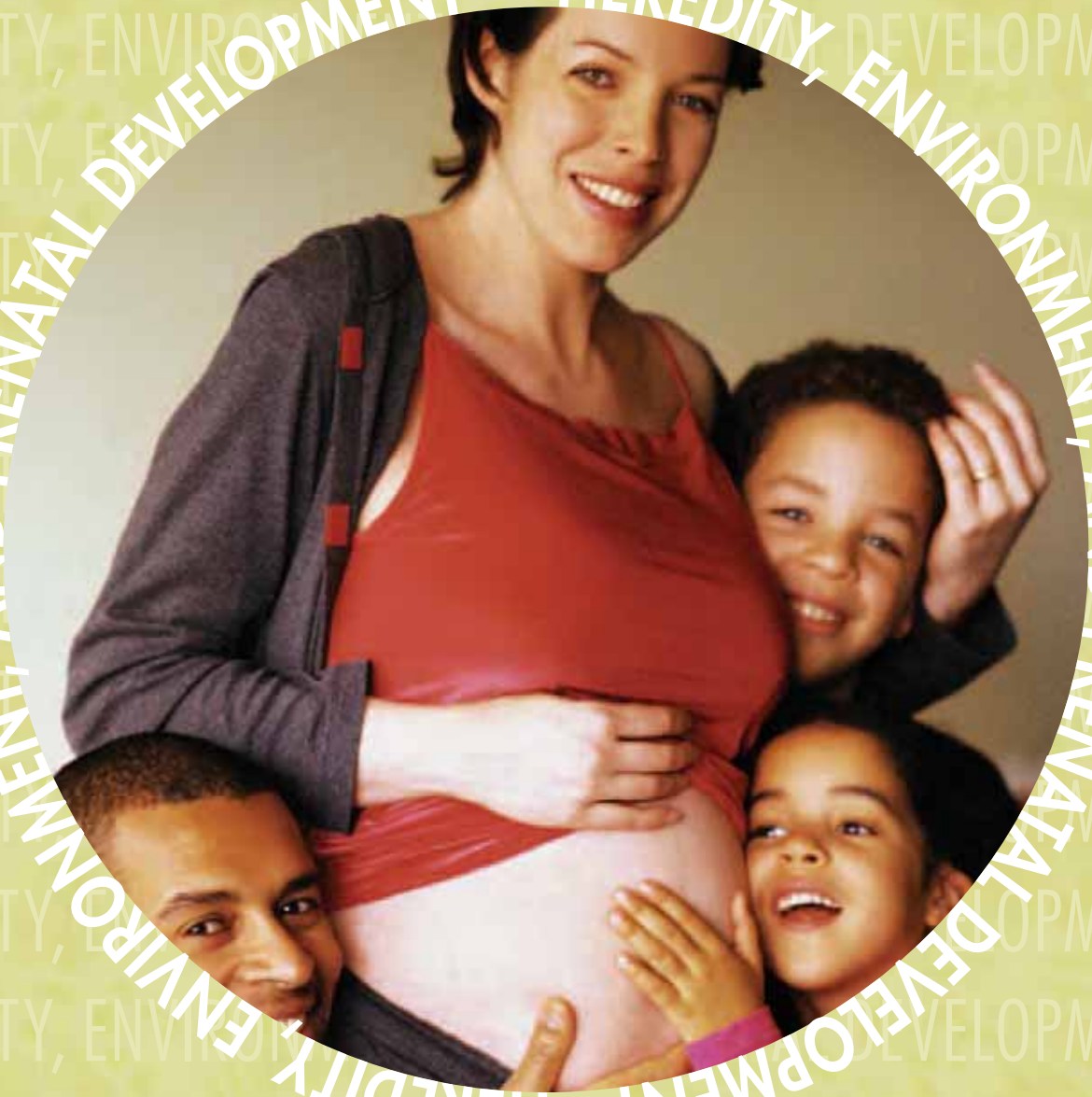
HEREDITY, ENVIRONMENT, AND PRENATAL DEVELOPMENT



In their late 30s, Jim Lewis and Jim Springer both stood 6 feet tall and both weighed 180 pounds. They both had high blood pressure and headaches. As children, both liked math, but not spelling. As adults, they both worked in law enforcement, drove Chevrolets, and took their vacations in Florida. Both married and then divorced women named Linda. Both then later married women named Betty. Both had sons named James and dogs named Toy.

identical twins Siblings conceived from one ovum; after conception, the fertilized ovum splits in half, with each half having the same genetic material; also called monozygotic twins.

These similarities are not coincidental. Jim Lewis and Jim Springer are **identical twins,** who share all their genetic material (Holden, 1980; Wright, 1997). Instead of growing up together, however, they were separated at birth. Brought up in different towns, they did not even know of one another's existence until they met each other as adults. Only then, while participating in a study of twins reared apart, did they discover their remarkable similarities (Bouchard, Lykken, McGue, Segal, & Tellegen, 1990).

Pairs of twins like these raise intriguing questions about the origins of individuality. If what we usually think of as uniquely individual characteristics are shared by identical twins, what does that mean about their underlying causes? What does it mean for notions of freedom of choice? Is our so-called individuality actually given in our genetic makeup?

Other pairs of twins have also shown remarkable similarities. Consider the British twins, Daphne and Barbara, who became known as the "giggle sisters." Reared separately but reunited as adults, they were always making each other giggle and laugh, even though there were no other gigglers in either adoptive family. Each one had a heart murmur, an enlarged thyroid, and identical brain waves (Holden, 1980; Wright, 1997). Or take Bridget and Dorothy, also twins who had been reared separately. When they first met, both were wearing seven rings on one finger, two bracelets on one wrist, and a watch and a bracelet on the other wrist. Bridget had named her son Richard Andrew, and Dorothy had named her son Andrew Richard. Bridget had named her daughter Catherine Louise, and Dorothy had named her daughter Karen Louise. The similarities between pairs of identical twins—even those who have been reared apart—go on and on.

fraternal twins Siblings conceived when two ova are fertilized at the same time; also called dizygotic twins.

These two men are identical twins, but they were separated as children and did not meet until they were adults.

But even identical twins show some distinctiveness. One of the two Jims wore his hair over his forehead, while the other slicked his hair back; one expressed himself better in writing and the other better when speaking. Bridget and Dorothy were reared in homes that differed in social class, and the one whose family was more affluent had better teeth. These differences, though real, were not dramatic.

Now consider a twin pair like Vicky and Daniel, whose mother and I have been friends for many years. They are twins, but Vicky and Daniel look nothing alike. They are **fraternal twins,**

and they share only about half of their genetic material, not all of it, the way identical twins do. Vicky has fair skin and light brown hair, like her mother, who is of Scandinavian descent. Daniel, in contrast, has dark skin, and his hair is almost black. He looks very much like his father, whose ancestors were East Indian. One is artistic and the other is more interested in computers. If you were to meet these two, you would not be certain that they were from the same family, and you would never peg them as twins. When they were children, they used to win "least look-alike twin" contests at the state fair every year. After a few years, they were politely asked not to enter, so that others could have a chance to win the contest at least once.

My own son David, who you met at the beginning of Chapter 1, is also a twin. He and his twin sister Eliza share some family resemblances. They are similar in height and weight, and both have curly light brown hair. Whereas Eliza is highly organized, enjoys reading, and loves libraries, David is conversational and outgoing, enjoys parties, and loves sports. Other than being the same age, they are probably no more alike than any other two siblings.

How can fraternal twins like David and Eliza, growing up together in the same home, be less alike than identical twins like Jim Lewis and Jim Springer who had never even met as children? How important *are* genetic backgrounds in determining the kinds of people we become? And what role do environmental factors play? In this chapter, we address classic questions about the importance of nature and nurture as we examine biological and environmental influences on prenatal development. We begin by examining the basic elements of genetics and heredity.

Genetics and Heredity

Every human body is made up of millions of cells. At the heart of each cell is its nucleus, or control center, which in turn contains its 23 pairs of chromosomes. The 23 pairs of **chromosomes** in each cell are packages, or structures, that contain genetic material. One member of each pair of chromosomes is inherited from the mother and one from the father. Together, these contain the genetic material that makes each of us human and that makes each person an individual.

Genes and Chromosomes

Chromosomes are composed of **deoxyribonucleic acid,** usually called **DNA.** The DNA molecule is in the form of a double helix, shaped like a twisted ladder (see Figure 2-1). Each rung of the ladder is made up of specific pairs of chemical bases, joined across the molecule. There are four bases—adenine (A), cytosine (C), thymine (T), and guanine (G)—that always pair up as adenine-thymine (A-T) and cytosine-guanine (C-G). These pairs of bases can, however, occur in any sequence, and

chromosomes A group of 20,000 to 25,000 genes, arranged in a long string.

deoxyribonucleic acid (DNA) The molecule that contains genetic information; sections of DNA that control development of inherited characteristics are called genes.

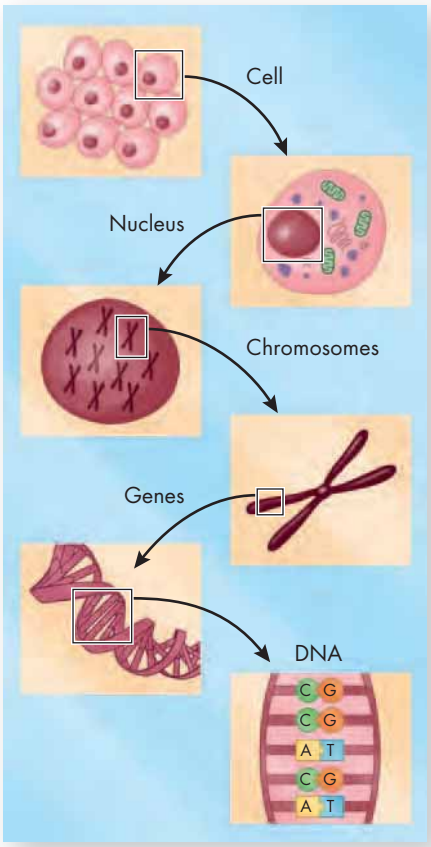


FIGURE 2-1 Cells, Chromosomes, Genes, and DNA. Inside each human cell is a nucleus, and inside the nucleus is the genetic material. Genetic material is made up of chromosomes, which are made up of genes, which are made up of different lengths of deoxyribonucleic acid, or DNA. In the DNA, the chemicals adenine (A), guanine (G), cytosine (C), and thymine (T) link up to form rungs of a twisted ladder. *Source:* "Families and Fragile X Syndrome," NICHD, 2003. Retrieved May 8, 2007, from www.nichd.nih.gov/publications/pubs_details.cfm?from=&pubs_id=280.

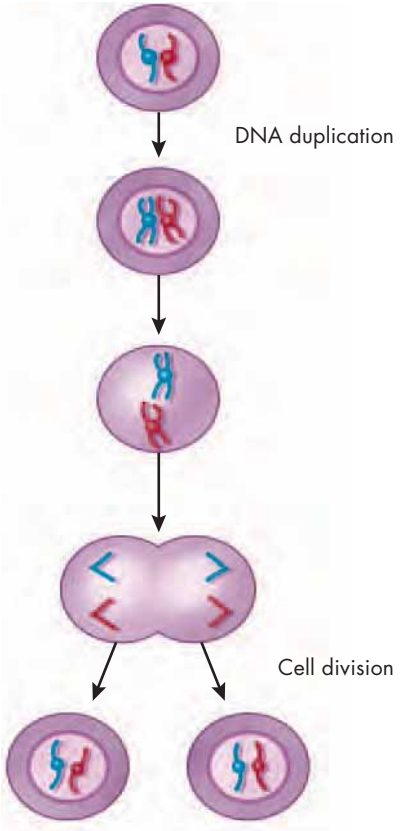


FIGURE 2-2 Mitosis. When cells divide and multiply during mitosis, DNA is duplicated so that each new cell contains an exact copy of the genetic material contained in the DNA. *Source:* "Chromosomes and Heredity," GlaxoSmithKline, 2006. Retrieved May 8, 2007, from http://genetics.gsk.com/chromosomes.htm.

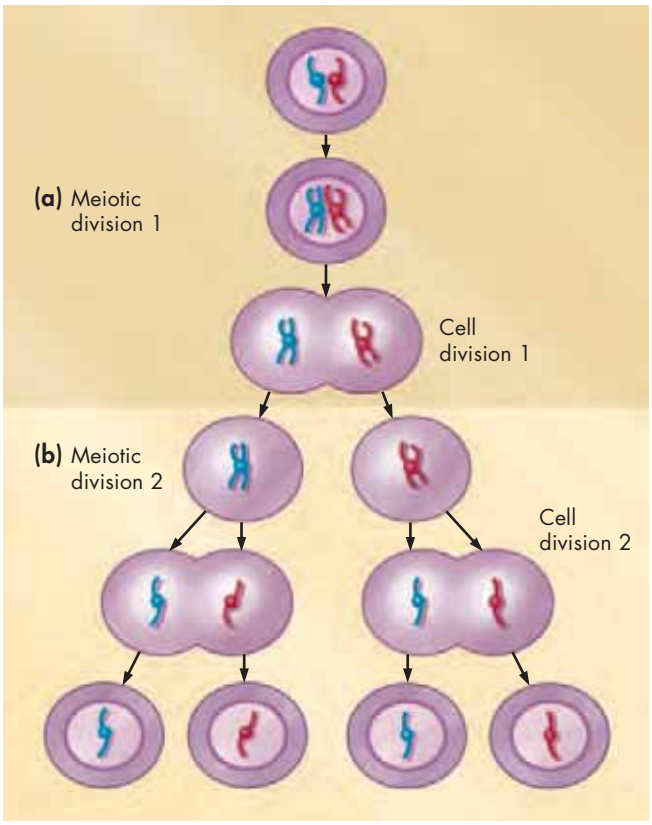


FIGURE 2-3 Meiosis. Gametes are formed through a process of cell division called meiosis, which divides the number of chromosomes in half. *Source:* "Chromosomes and Heredity," GlaxoSmithKline, 2006. Retrieved May 8, 2007, from http://genetics.gsk.com/chromosomes.htm.

gene A section of the DNA molecule that contains the genetic code for inherited characteristics.

mitosis The process by which chromosomes make copies of themselves before cell division takes place.

gamete Reproductive cells that contain 23 chromosomes apiece; a sex cell, either a sperm or an egg.

sperm Male sex cells, produced in the testes.

ovum A mature egg, released from the ovary during ovulation.

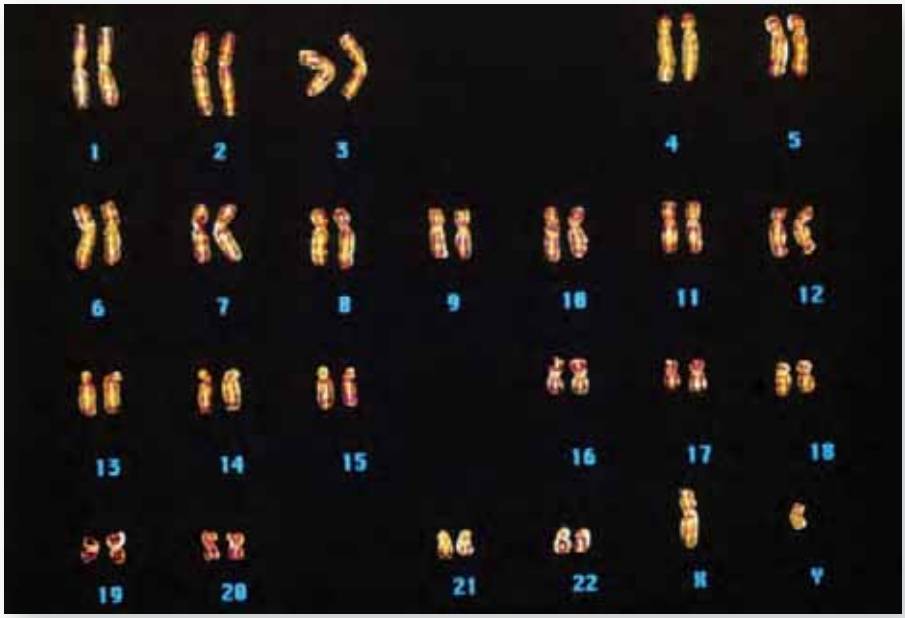
meiosis The process of cell division that produces the gametes, or sex cells, that contain half the usual number of chromosomes.

zygote A fertilized ovum, during the first 2 weeks after conception.

it is the sequences of base pairs that provide genetic instructions to the organism. Groups of base pairs that provide particular instructions are called **genes.** Genes may be made up of hundreds or even thousands of base pairs. Current estimates based on results from the Human Genome Project, an international effort to identify the entire sequence of the human genome, suggest that a human chromosome is made up of about 20,000 to 25,000 genes (International Human Genome Sequencing Consortium, 2004).

DNA can duplicate itself in a process called **mitosis,** illustrated in Figure 2-2. When a cell divides to form two new cells, mitosis allows each new cell to retain an exact copy of the genetic instructions contained in the DNA. For this reason, each cell in the human body contains the same genetic information. When activated, genes manufacture proteins, which carry out genetic instructions by setting off various chemical reactions throughout the body.

Gametes, or sex cells, are special cells that contain only 23 chromosomes, instead of 23 pairs of chromosomes (see Figure 2-3). In males, a gamete is called a **sperm cell,** and in females, it is called an **ovum.** Gametes are formed through a process of cell division called **meiosis,** which divides the number of chromosomes in half. When sperm and ovum unite, at the moment of conception, to form a **zygote**—fertilized ovum—this new cell again contains 23 pairs of chromosomes.



Humans have 23 pairs of chromosomes. These come from a male, as the 23rd pair is XY.

Scientists number the 22 matched pairs of chromosomes in each cell from longest to shortest. The 23rd pair consists of the sex chromosomes, referred to as the XX chromosomes for females, and as the XY chromosomes for males. When the male gametes form, some contain the X and some contain the Y. If an ovum is fertilized by a sperm containing an X chromosome, the offspring will be female. If an ovum is fertilized by a sperm containing a Y chromosome, the offspring will be male. Thus, gender of the offspring is determined by the contributions of the male chromosomes.

Inheritance of Characteristics

Earlier in this chapter, you met Vicky, who has light skin, and her fraternal twin brother Daniel, who has dark skin. Skin color is an inherited characteristic, but how does this inheritance work? As you will see in this section, there is more than one mechanism through which inheritance of characteristics may occur.

For each matching pair of chromosomes, two versions of each gene exist, one from the mother and one from the father. Each version is called an **allele.** In cases where the two alleles for a particular characteristic such as hair color match, the person is called **homozygous** for that characteristic. In cases where the alleles are different, the person is called **heterozygous** for that characteristic.

allele A variant of a gene; alleles usually come in pairs, one located on each of a pair of chromosomes.

homozygous When a person has two matching alleles for a particular characteristic.

heterozygous When a person has two different alleles for a particular characteristic.

When one allele is dominant for a characteristic, it determines the outcome, regardless of the other allele. This is called the **dominant-recessive** pattern of inheritance (see Figure 2-4). If the allele for dark hair is dominant, then when it is present, the person always has dark hair. If the allele for blond hair is recessive, it is expressed only when its matching allele is also one for blond hair. Thus, in order to be blond, Vicky must be homozygous for that allele. Even though they do not look it, heterozygous individuals like Daniel may be *carriers* of alleles for recessive traits like blond hair.

dominant-recessive inheritance Pattern of inheritance that reveals the characteristic of the recessive gene only if no dominant gene is present in the organism.

Another form of genetic transmission is called **codominance,** in which both alleles influence the trait. In this case, the action of the two alleles may be affected by environmental conditions, and neither one may be said to be absolutely dominant

codominant Pattern of inheritance that involves the joint action of many genes, often in conjunction with environmental factors.

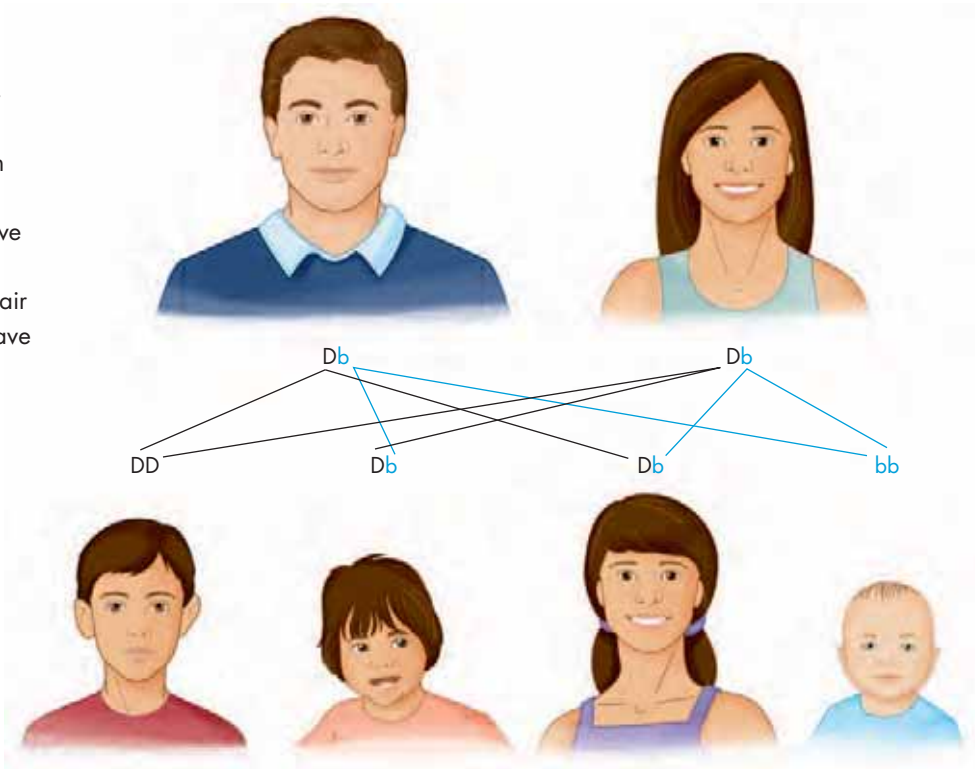


FIGURE 2-4 Dominant-Recessive Inheritance. Illustration of the dominant-recessive pattern of inheritance for blond hair. When both parents are heterozygous (Db) for the recessive gene, one in four of their offspring will have blond hair (bb). The other three will have dark hair.

polygenic inheritance Process of inheritance that involves the input of many genes in order to control the expression of a single characteristic.

X-linked inheritance Pattern of inheritance in which a recessive gene is carried on the X chromosome and is thus expressed mainly in males.

hemophilia Inherited disorder in which blood fails to clot normally

mutation Change or alteration in a gene.

or absolutely recessive. Codominant patterns of inheritance are sometimes also called **polygenic,** meaning that they involve the joint action of many genes, often in conjunction with environmental factors. Skin color is an example of a characteristic that shows polygenic inheritance; multiple genes from mother and father combine to yield a range of different skin colors among the offspring.

Yet another form of genetic transmission is **X-linked inheritance,** which is usually characteristic of males (see Figure 2-5). For example, if an unfavorable allele appears on a woman's X chromosome, she may or may not be able to draw on the other allele to compensate for the problem. If an nfavorable allele appears on a man's X chromosome, however, he often does not have another. The Y chromosome is shorter than the X, and contains fewer genes. Thus, there may be no additional allele to draw upon. For this reason, in X-linked inheritance, boys are more likely than girls to inherit specific characteristics from their mothers. An example is the inherited blood clotting disorder called **hemophilia.** As an X-linked hereditary disorder, the gene for hemophilia is carried on the mother's X chromosome.

Unless something out of the ordinary happens, chromosomes duplicate themselves indefinitely. Every so often, a **mutation,** or change in the gene, may occur. Mutations can arise by chance, or they may be influenced by changes in the environment. For example, although exposure to everyday radiation such as that produced by microwave ovens has no known effect on genetic material, heavy and continuous doses of high-energy radiation such as that in X-rays can result in genetic mutations (Brent, 1999). Some mutations may be favorable, but most probably result in abnormalities.

Inherited and Chromosomal Abnormalities

The child of a mother and father who are both carriers of a recessive trait may get both recessive alleles. In this case, a recessive characteristic will be expressed.

One example is the condition known as **phenylketonuria** or **PKU** (Moore & Persaud, 2003a). In this condition, an infant lacks the enzyme necessary to break down the amino acid phenylalanine into its by-products, which are crucial for the body's functioning. If PKU is left untreated, phenylalanine builds up to toxic levels in the body and eventually damages the central nervous system, causing mental retardation.

Phenylketonuria was discovered in Norway, in the early 1930s, when the parents of two retarded children noticed an unusual odor in their urine and wondered if the odor could be connected to the children's mental retardation. They brought this idea to the attention of a Norwegian medical doctor and researcher, Ashbjorn Folling, who found that the children's urine samples contained abnormally high levels of phenylalanine. Folling was the first to propose that the children's mental retardation was attributable to an error in metabolism, which meant that phenylalanine was not transformed into its by-products (Centerwall & Centerwall, 2000).

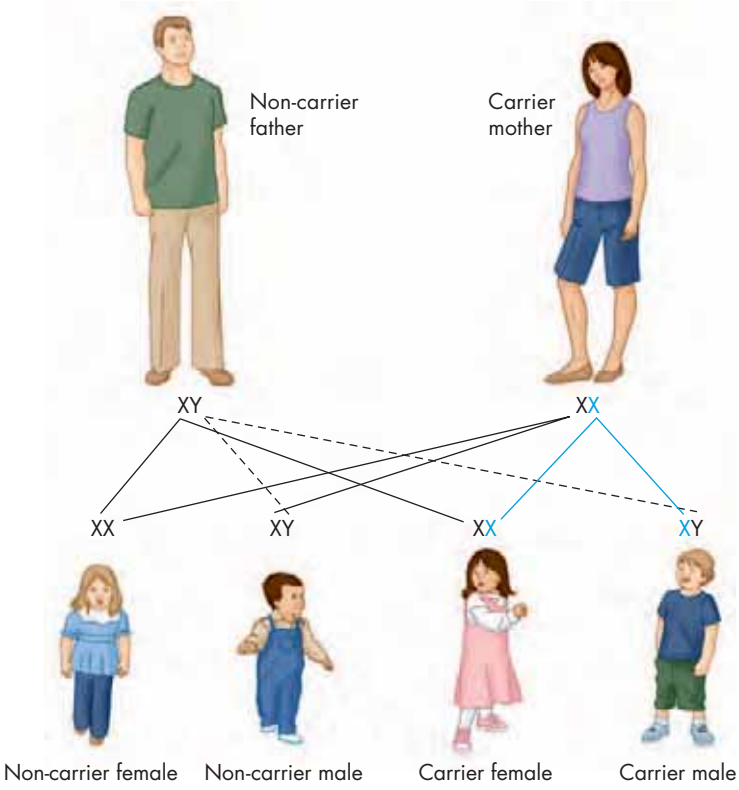


FIGURE 2-5 X-Linked Inheritance. In this example of the X-linked pattern of inheritance, the mother has one recessive allele, and the allele on the father's X chromosome is normal. If this couple has four children, two of each gender, the odds are that one b oy will be affected, one girl will be a carrier, and the other two children will be normal.

For many years after the discovery of PKU, no cure was available, but in the 1950s, a special low-phenylalanine diet was devised. If infants were placed on this diet early in infancy, phenylalanine never built up to toxic levels, and retardation was prevented (Centerwall & Centerwall, 2000). Today, all newborns in the United States are given blood tests to identify PKU. Babies who test positive are fed using the special low-phenylalanine diet, and in this way, the onset of mental retardation is prevented.

Sickle cell anemia is another inherited disease caused by recessive genes (Moore & Persaud, 2003a). In sickle cell anemia, blood cells that are normally smooth and round come to be hard, sticky, and sickled (shaped like crescent moons). When these hard, pointed cells go through small blood vessels, they tend to get stuck and block the flow of blood, causing pain and swelling (see Figure 2-6). This process causes tissue damage and often results in a shortened life span (Ashley-Koch, Yang, & Olney, 2000). Like PKU, sickle cell anemia normally occurs only when the individual inherits two recessive alleles. Individuals who inherit only one sickle cell allele are said to have the sickle cell trait; they do not have sickle cell anemia, but are carriers of the gene that causes the disease.

Sickle cell anemia affects millions of people around the world, but is most common among Africans and among African Americans. The sickle cell allele protects against malaria, which is especially common in Africa. For heterozygous individuals, this allele therefore conveys a survival advantage to those who carry it, so they are more likely to reproduce, thus perpetuating the allele. In the African environment, where malaria is more prevalent, this advantage is valuable, and so the sickle cell allele is thought to have persisted in this population more than in populations not affected as strongly by malaria (Ashley-Koch et al., 2000).

As mentioned earlier, hemophilia, a disorder in which blood fails to clot normally, is inherited in an X-linked process (Moore & Persaud, 2003a). The defective

phenylketonuria (PKU) Genetic disorder that causes damage to the central nervous system if not controlled by special dietary measures.

sickle cell anemia A genetic disorder in which blood cells become sticky and shaped like crescent moons or sickles; the affected blood cells have trouble passing through small blood vessels, thereby causing blood clots to occur.

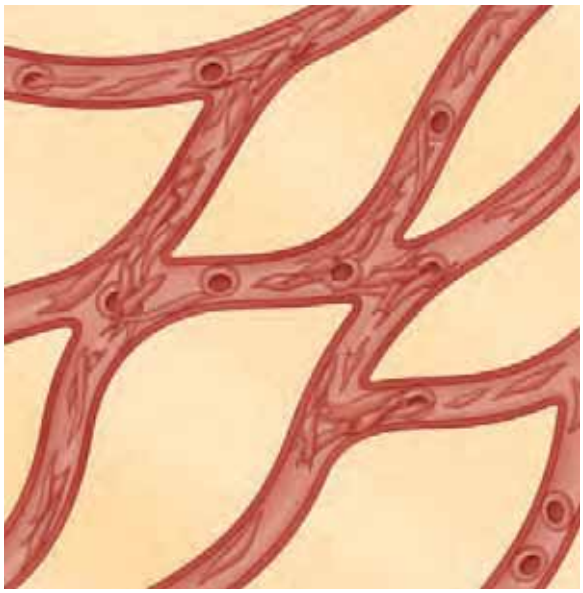


FIGURE 2-6 Sickle Cell Anemia. In sickle cell anemia, half-moon-shaped cells tend to get stuck in narrow blood vessels, blocking the flow of blood. *Source:* "Sickle Cell Anemia," National Heart Lung and Blood Institute, 2006. Retrieved May 8, 2007, from www.nhlbi.nih.gov/health/dci/diseases/sca/SCA_All.html.

gene is located on the X chromosome and is therefore inherited from the mother. Hemophilia is very rare, with an incidence of about 1 in 10,000 male births. For reasons that are not clear, very few female cases of hemophilia have emerged. About half of the male offspring of mothers who carry the gene have the disease. Those who suffer from hemophilia bruise easily and show prolonged or excessive bleeding, even after a minor injury. Medical treatment is usually successful in stemming excess bleeding, and most hemophiliacs live relatively normal lives.

Fragile X syndrome, another X-linked hereditary condition, is caused by a change in a single gene (Moore & Persaud, 2003a). The change makes the gene unable to produce enough of a protein called FMRP (Fragile X Mental Retardation Protein) that is crucial to the functioning of the central nervous system. When there is a full mutation, more than 80% of males with Fragile X syndrome suffer mild or moderate mental retardation. The syndrome is also associated with physical symptoms such as long faces, prominent ears, and short stature; social anxiety; and language delays (see Figure 2-7). The full-blown syndrome occurs in only 1 of 1,200 males and 1 of 2,500 females. Although rare, it is usually more severe in males than in females, perhaps because males do not have another X chromosome to fill in for the shortcomings of the one affected by Fragile X syndrome.

FIGURE 2-7 Child With Fragile X Syndrome This boy with Fragile X syndrome has the typical physical features, such as a longer than average face and large or prominent ears. Short stature is another common characteristic. Other symptoms of Fragile X syndrome are intellectual impairments, attention deficits, hyperactivity, language processing difficulties, and anxiety. *Source:* "Families and Fragile X Syndrome," NICHD, 2005. Retrieved May 8, 2007, from www.nichd.nih.gov/publications/pubs/fragileX/index.cfm.

One of the best known and most common chromosomal abnormalities is **Down syndrome** (Moore & Persaud, 2003a). This syndrome is usually caused by an error in cell division that results in an extra portion of the 21st chromosome. Because there appears to be an extra 21st chromosome, Down syndrome is also called **trisomy 21.** The syndrome was first identified in 1866 by an English doctor named John Langdon Down, who gave the syndrome his name.

The symptoms of Down syndrome include mental handicaps, reduced muscle tone, slow motor development, unusual facial features, and a number of health problems (Roizen & Patterson, 2003). The characteristic look of a child with Down syndrome includes a flat facial profile, almond-shaped eyes, and unusually shaped ears. Chil-

dren with Down syndrome tend to be short and stocky, and they often have heart defects, muscle weakness, and problems with vision and hearing. Although they once had much shorter life expectancies than other children, medical advances have made it possible for many individuals with Down syndrome to live well into adulthood. The median age of death for individuals with Down syndrome has now reached 49 years (Roizen & Patterson, 2003).

The extra chromosome that causes Down syndrome can come from either parent, and the only known risk factor is maternal age. The overall likelihood of a pregnancy resulting in a baby with Down syndrome is about 1 in 1,000 live births. But by age 35, the likelihood has risen to 1 in 400, and by age 40, it has reached 1 in 110. Prenatal tests such as amniocentesis were once recommended only for mothers 35 or older because the likelihood of complications such as infection is less than the likelihood of having a baby with Down syndrome. Today, however, new tests are less invasive and pose fewer risks, so screening for Down syndrome is recommended for all pregnant women, regardless of age (American College of Gynecology Practice Bulletin, 2007).

This child is affected by Down syndrome. Note characteristics such as upward slanted eyes, short neck, and flattened bridge of the nose.

A number of other rare chromosomal abnormalities also occur (Moore & Persaud, 2003a). These include XXY males (also called Klinefelter syndrome), in which males inherit an extra X chromosome, and Triple X syndrome, in which females inherit an extra X chromosome. Interestingly, both of these syndromes are associated with taller than average stature and impaired language skills. For instance, men with Klinefelter syndrome often experience learning disabilities (Geschwind & Dykens, 2004). In XYY syndrome, males inherit an extra Y chromosome. These boys tend to be taller than average and of normal intelligence, but often suffer from severe acne as teenagers. Finally, in Turner syndrome, females have a missing X chromosome; instead of having the XX pattern, they have only one X chromosome. These girls are usually of short stature and have impaired spatial intelligence. For instance, they have difficulties reading maps, telling right from left, and representing things in pictures. All of these conditions are rare, occurring less than once in 500 births. Scientists are working to learn more about why and how their specific symptoms arise, as well as about how they can be prevented.

Research on Hereditary Influences

Researchers who study genetic issues in human development use many methods. In **family studies,** researchers assess the extent to which characteristics such as hair color occur among many members of a single family. If a characteristic is common o the mother's side, but not on the father's side of the family, this fact can provide clues about possible modes of genetic transmission.

One type of family study is called a **twin study,** and it usually compares the prevalence of a characteristic among identical and fraternal twins. Identical twins share all their genetic material, but fraternal twins share only about half of their genetic material. When twins share a characteristic such as eye color, they are called **concordant** for that characteristic. If identical twins are concordant for a particular characteristic more often than fraternal twins, this suggests genetic links.

Fragile X syndrome An X-linked genetic disorder that is a common cause of mental retardation.

Down syndrome A chromosomal disorder that causes short stature, low muscle tone, heart problems, and mental retardation.

trisomy 21 Disorder in which the 21st chromosome pair has an extra chromosome attached to it, also known as Down syndrome.

family studies Research on members of a single family that assesses the extent to which specific characteristics appear, in order to learn more about their hereditary and environmental causes.

twin studies Research on identical versus fraternal twins that compares the prevalence of characteristics so as to learn more about their hereditary and environmental causes.

concordant When both members of a twin pair share a characteristic such as eye color, they are said to be concordant for that characteristics.

behavior genetics The study of hereditary and environmental determinants of human development, using methods such as family studies and twin studies.

Family and twin studies attempt to address questions about the role of nature and nurture in development. When research questions focus on behavioral characteristics such as activity level, this type of research is called **behavior genetics.** Researchers use behavior genetic research techniques to disentangle hereditary and environmental influences on development.

Genetic Counseling

genetic counseling A process in which a trained counselor reviews with a couple their family histories in an effort to assess their likelihood of conceiving a child with chromosomal or other genetic defects.

Couples who want to evaluate their risks of conceiving a baby with chromosomal abnormalities or other birth defects can seek **genetic counseling** (Flanagan, 1996; Nilsson & Hamberger, 2003). A genetic counselor is a specially trained health professional who provides support and information about genetic issues. A genetic counselor interviews couples about any inherited diseases, mental problems, or emotional problems among their biological relatives. Using this information, the counselor creates a family tree that illustrates which relatives show abnormalities. When used together with information about risk, the family tree helps the counselor to calculate the likelihood of any genetic defects being transmitted by the couple to their baby.

Once these calculations have been made, the counselor helps the couple to consider their options in light of any risks that may come to light. Genetic counseling can be especially valuable for those who know of genetic disorders in their families and for those who have had difficulty in conceiving or carrying a child to term. After considering all the available information, some couples may see the genetic risks as too great and decide not to conceive a child together. These couples may decide on a life plan that does not include children, or they may choose to adopt. Others may seek additional information from prenatal testing. Still other couples may uncover few risks, or see the risks as small enough to tolerate, and simply go ahead. As men and women consider parenthood, genetic counseling can help them to make informed decisions.

QUESTIONS TO CONSIDER

GENETICS AND HEREDITY

REVIEW What are the three major patterns of inheritance, and what are five inherited or chromosomal abnormalities?

ANALYZE How do scientists determine how specific characteristics such as eye color are inherited?

APPLY Imagine that you are a genetic counselor whose clients are a 38-year-old woman and her 42-year-old husband, both of whom are African American. What types of prenatal testing would you recommend for this couple?

CONNECT If an infant is born with Down syndrome, what can you predict about the baby's likely development during childhood? How is such a child likely to be different from other children?

DISCUSS If prenatal testing advanced to the point where couples could select their infants' gender, eye color, height, and so forth, would you want to take advantage of these possibilities? Why or why not?

Process of Conception

Though most people want to have children at some point in their lives, not everyone wants to become a parent. Even people who are delighted to become parents at one time in their lives may have felt differently at other times. For instance, a young woman who avidly avoids pregnancy as a high school student may look forward to becoming a mother after she is married. What makes men and women wish to become parents, and how does conception take place? In this section, we discuss motivations for parenthood, the process of conception, difficulties that can interfere with conception, assisted reproductive technologies, multiple births, and alternative routes to parenthood.

Motivations for Parenthood

There are many reasons to prize the experiences of parenthood. Parents cite such benefits as the joy of watching children grow up, love for children and pride in their achievements, the value of sharing their lives, passing along values, feeling needed, and having fun together (Cowan & Cowan, 2000). Having become parents, few would trade the experience for anything else. On the other hand, parenthood also has its costs, including loss of freedom, conflicts between demands of work and family, loss of privacy, less time alone with partner or spouse, economic burdens of supporting children, and worries about bringing up children in a world that is full of dangers. Hoping to become a parent at some point during adult life is not the same thing as feeling ready to have a baby right now.

Researchers have sometimes asked women about their intentions regarding pregnancy. In the National Survey of Family Growth, researchers asked a representative sample of more than 10,000 women in the United States how they felt when they learned of their most recent pregnancy (Finer & Henshaw, 2006). If women said that they were glad to become pregnant at this time in their lives, these were called intended pregnancies. If they said either that the pregnancy was mistimed (that they intended to become pregnant, but not at this time) or that it was unwanted, these were classified as unintended.

An important finding of this study was that almost half of the women interviewed (49%) said that their last pregnancy was unintended (Finer & Henshaw, 2006). Of all the unintended pregnancies in a given year, 14% ended in miscarriages, 42% ended in abortions, and 44% ended in live births. Thus, approximately one in four births in the United States—about 1 million births per year—apparently result from unintended pregnancies. This finding is notable because infants born from unintended pregnancies tend to have much more difficult lives than do others (David, Dytrych, & Matejcek, 2003). On the positive side, however, these results also show that three out of four babies are born as a result of pregnancies that were intended.

Ovulation, Spermatogenesis, and Fertilization

Once each month, in a process called **ovulation,** a woman's ovaries produce a mature egg, called an **ovum.** Almost immediately after its release from the ovary, the ovum is drawn into one of the **fallopian tubes.** As an ovum moves through the fallopian tube, hormones from the ovaries trigger production of a soft lining for the uterus. If the ovum is fertilized, it will ultimately implant into this uterine

ovulation The release of an ovum from the ovaries.

fallopian tube In the female reproductive tract, the structure that extends from ovaries to uterus, along which the fertilized ovum travels on the way to the uterus.

Sperm and ovum must be in close proximity before fertilization can take place.

Fertilization of the ovum occurs when a sperm penetrates its outer covering.

lining, where it will continue to grow. If the ovum is not fertilized within a day or so of its emergence from the ovary, the uterus will later shed its lining, resulting in menstruation (Moore & Persaud, 2003a).

In the male, millions of sperm are produced each day in the testes. As sperm reach maturity, they develop long tails that make them highly mobile. When a man ejaculates, many millions of sperm are released. To fertilize an ovum, the sperm must swim through the female reproductive tract, enter the uterus through the cervix, travel into the fallopian tube, and find the ovum. It is possible for sperm to survive for days, but they usually do not live more than 48 hours. Only about 250 sperm survive all the hazards of the journey to the fallopian tubes (Moore & Persaud, 2003a).

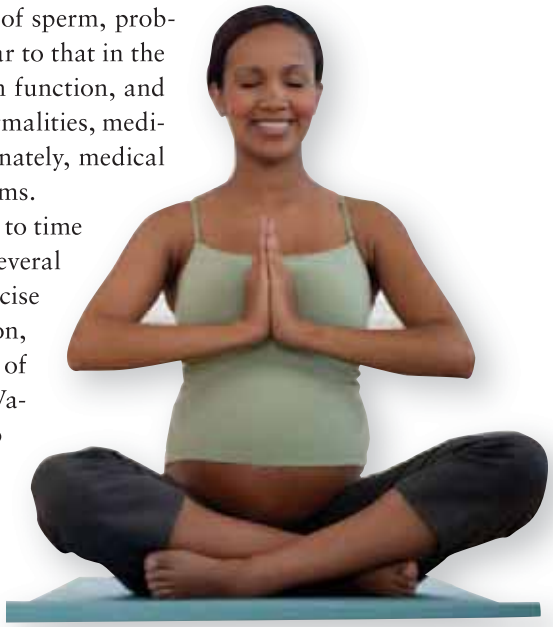
The sperm that find an ovum compete to penetrate its external covering. This penetration of ovum by sperm usually takes place in the fallopian tube and involves a chemical process. As soon as one sperm has made its way into the ovum, a chemical is released that seals the surface of the fertilized ovum, making it much more difficult for another sperm to enter (Nilsson & Hamberger, 2003).

Because neither sperm nor ovum can survive long in the absence of fertilization, there are only a few days each month when conception is likely to occur. The chances of conception are best if sperm enter the female reproductive tract on the day of ovulation, or during the 2 days before ovulation. Conception can occur at other times, but is not as likely. Thus, the highest probability of conception is usually about 2 weeks after the 1st day of a woman's menstrual period (Flanagan, 1996; Nilsson & Hamberger, 2003).

Infertility and Assisted Reproductive Technologies

Most couples who want to become parents conceive without difficulties, but some encounter problems of infertility (Moore & Persaud, 2003a). The most frequently encountered reasons for infertility are damage to or blockage of the fallopian tubes, making it difficult for sperm to reach the ovum or for a fertilized ovum

to reach the uterus. Other causes include inadequate numbers of sperm, problems with sperm function, endometriosis (in which tissue similar to that in the uterine lining grows outside the uterus), problems with ovarian function, and uterine factors. Infertility can be caused by chromosomal abnormalities, medical treatments for cancer, and by some serious illnesses. Fortunately, medical treatments are now available to help with many of these problems.



Couples having trouble conceiving a child are often advised to time the woman's monthly cycle and try for conception on each of several consecutive months. Women may be advised to get regular exercise and minimize the amount of stress in their daily lives. In addition, prospective parents are often advised to minimize their intake of caffeine, alcohol, tobacco, or other drugs (Schettler, Solomon, Valenti, & Huddle, 1999). These kinds of changes are thought to increase the chances of conceiving a healthy child (Augood, Duckitt, & Templeton, 1998).

If, after several months of trying, conception has not occurred, couples may be advised to consider **alternative reproductive technologies,** sometimes abbreviated as **ART** (Wright, Schieve, Reynolds, & Jeng, 2005). A typical ART procedure called **in vitro fertilization (IVF)** involves fertilization of the ovum by the sperm in a lab dish, followed by culture of the zygote—fertilized ovum—in the lab. After growing for 2 or more days in the lab, the zygote is transferred into the woman's uterus, where if all goes well it will implant in the uterine wall and continue to grow. In other ART methods, unfertilized sperm and ova may be transferred into the fallopian tubes; this procedure is known as **gamete intrafallopian transfer,** or **GIFT.** In still other cases, zygotes may be transferred into the fallopian tubes; this is known as **zygote intrafallopian transfer,** or **ZIFT.** All of these are ways of attempting to circumvent problems that may prevent conception.

Since the birth of the first infant through ART in 1978, ART procedures have become more and more common (Wright et al., 2005). Hundreds of medical centers conduct ART procedures in the United States alone; many of them work not only with opposite-sex couples experiencing fertility problems, but also with same-sex female couples and with single women (Brodzinsky, Patterson, & Vaziri, 2002). In 2002, more than 100,000 ART procedures were conducted in the United States, and these resulted in more than 45,000 live births—about 1% of all births in the United States in 2002. Are you curious about how babies conceived via IVF fare as children? The section on Parenting and Development feature on p. 000 gives an overview of research findings about growth and development of these children.

alternative reproductive technology (ART) Technological methods of assisted reproduction, including gamete intrafallopian transfer (GIFT), zygote intrafallopian transfer (ZIFT), and in vitro fertilization (IVF).

in vitro fertilization (IVF) Process that involves removal of ova from the ovaries and mixing them with live sperm in a laboratory environment, in order to fertilize one or more ova; if fertilization is successful, one or more fertilized ova will be returned to the woman's uterus in hopes of continuing the pregnancy and creating a healthy baby.

gamete intrafallopian transfer (GIFT) An assisted reproductive technology technique in which sperm and ova (that is, gametes) are transferred to a woman's fallopian tubes in hopes of creating a pregnancy and ultimately a healthy baby.

zygote intrafallopian transfer (ZIFT) An assisted reproductive technology technique in which zygotes that have been created in a laboratory environment are transferred to a woman's fallopian tubes in hopes of creating a pregnancy and ultimately a healthy baby.

monozygotic twins Twins conceived from ovum; after conception, the fertilized ovum splits in half, with each half having the same genetic material; also called identical twins.

Twins, Triplets, and Higher Order Multiples

One of the striking correlates of ART is multiple births. Twins, triplets, quadruplets, and those born in higher order multiples are all considered multiple births. One type of multiple, **monozygotic twins,** or identical twins, comes from a single fertilized ovum. This happens when an unusual event occurs during the first day or two following fertilization: Cells divide, and instead of staying together to form a single embryo, they come apart and form two separate organisms, each with the same genetic material. The incidence of monozygotic twins is unrelated to ART and has therefore remained unchanged in the last several years at about 1 in 200 to 300 births. The Jim twins, who you met at the beginning of this chapter, are monozygotic twins.

Triplets are rare, but the increasing use of reproductive technology today has made them more common than in earlier years.

dizygotic twins Siblings conceived when two ova are fertilized at the same time; also called fraternal twins.

Dizygotic twins come from more than one ovum. Because IVF may involve transfer of more than one zygote to the mother's body, more than one may implant and grow. This is one reason why dizygotic, or fraternal, twins and higher order multiple births have become more common than ever before. Such twins are born on the same day and usually grow up together, but they share no more of their genetic material than do any other two siblings. Dizygotic twins are especially likely in IVF, but they can occur without any special intervention as well. Dizygotic twins are much more likely in some ethnic groups than in others; for example, they are more common among those of African than Asian descent. Dizygotic twins are also more likely among older than among younger women, probably because ovulation becomes more erratic with age (Mange & Mange, 1998). In the United States today, 3% of live births are of twins and other multiples (Wright et al., 2005).

Multiple births carry with them a number of risks, and these are greater for larger multiples. Infants conceived using ART and born as singletons are slightly more likely than other babies to be born prematurely. Of those conceived using ART and born as twins, the risk of premature birth is elevated; more than half of these babies are born early. Of those conceived using ART and born as triplets or higher multiples, almost all (95%) are born prematurely. Most premature infants are very small, which is another risk to their health, because their organs and bodily systems are underdeveloped. Although twins and other multiples are generally at greater risk than other infants, many—like mine—are born healthy and at or near term.

Alternative Route to Parenthood: Adoption

Many adults who wish to become parents may be single, may wish to avoid passing along genetic disorders, or may simply prefer to have children in their lives without giving birth. For all these individuals, adoption can provide an alternative route to parenthood (Pertman, 2000).

Adoptions can involve related or unrelated infants or children born in the country where adoptive parents live or in a different country. Fifty years ago,

TABLE 2-1
Top 10 Countries From Which Children Were Adopted by Parents in the United States in 2005

COUNTRY OF ORIGIN	NUMBER OF CHILDREN ADOPTED
China	7,906
Russia	4,639
Guatemala	3,783
South Korea	1,630
Ukraine	830
Kazakhstan	755
Ethiopia	441
India	323
Colombia	291
Philippines	271

SOURCE: "Immigrant Visas Issued to Orphans Coming to the United States," U.S. Department of State, 2007. Retrieved May 8, 2007, from www.travel.state.gov/family/adoption/stats/stats_451.html.

adoption agencies attempted to place babies and children with adoptive parents who looked very much like them, and details of adoptions were often kept confidential. Today, adoptions are more likely to involve parents and children of different races. Many children adopted by U.S. adults today come from other countries, especially China and Russia (see Table 2-1). Adoptions today are also more often open, in that adoptive parents and children have some contact with one or more birth parents, and relevant information about adoptions is available to all (Pertman, 2000).

Research on adoptive families suggests that adopted children tend to have somewhat more frequent emotional and behavior problems than do other children, especially in early adolescence (Brodzinsky, Smith, & Brodzinsky, 1998). Problems can involve depressive feelings, anxiety, or oppositional behavior. It does not seem to matter whether adoption is open or confidential, or whether children were born in the home country of the adoptive parents or abroad, but their age at time of adoption is important (von Korff, Grotevant, & McRoy, 2006). Those who are adopted as infants seem to adjust better and to have fewer problems than do those who are adopted later in life (Brodzinsky et al., 1998).

Adoptees might experience difficulties for several reasons. They often come from difficult or deprived backgrounds, which is why they are eligible for adoptive placements. They may have been exposed to dangerous levels of substances such as alcohol and drugs before birth (Barth, Freundlich, & Brodzinsky, 2000). They may have lived in more than one unstimulating orphanage or foster care environment (Rutter, O'Connor, & the ERA Study Team, 2004). They may also have been malnourished or exposed to environmental hazards after birth. It is not surprising, then, that adoptive children may encounter some problems in adjustment.

Of course, not all adoptive children suffer from behavioral or learning difficulties (Brodzinsky et al., 1998; Pertman, 2000). When adopted early in life—especially when adopted in infancy—youngsters have the opportunity to form warm, trusting relationships with their adoptive parents, and these relationships can be protective. When infants encounter sensitive parenting in their adoptive families, they are more likely to develop in positive ways (Stams, Juffer, & van IJzendoorn, 2002). Even children who are adopted at an older age may show behavioral improvements as they come to establish loving relationships with adoptive parents (Sherrill & Pinderhughes, 1999).

DEVELOPMENT OF CHILDREN CONCEIVED VIA IVF

How do they fare?

Elizabeth Carr, the first baby conceived using in vitro fertilization in the United States, was born in Norfolk, Virginia, in 1981. A television news crew filmed her birth, and she appeared on the cover of a national news magazine, wearing nothing but a diaper. News of the birth of this "test-tube baby" was carried all around the world (Szabo, 2004). In the time since, hundreds of thousands of children have been born via IVF (Leiblum, 1997), and more are born each year. Have biomedical advances run too far ahead of our knowledge of the ethical, social, and psychological consequences of reproductive technologies?

There are many questions about the health and well-being of children conceived via IVF. Do IVF children grow into healthy adults? Or are they plagued by birth defects, malformations, and other health problems? What about parent–child relationships? Having gone to such lengths to have a child, would parents be expected to have exaggerated expectations or perhaps act in overprotective ways? In other words, can we expect these children to experience some special problems related to their conception in a petri dish?

Research on IVF infants and children has yielded important findings that help answer these questions (Golombok & MacCallum, 2003). First, to address the question of overall health, because more than one fertilized ovum is often transferred to the mother's uterus to increase the probability of a live birth, IVF pregnancies are more likely than others to yield twins and other multiples. Multiple births carry with them a higher likelihood of premature birth and low birth weight—both risk factors for healthy development. In IVF infants, however, birth defects are no more common than in others, and the motor development of IVF infants seems likewise to be satisfactory. A study of IVF twins at 5 years of age found them to be functioning well (Tully, Moffitt, & Caspi, 2003). The main health risks of IVF seem to be those associated with multiple births, which occur more frequently than normal if more than one fertilized ovum is transferred to the mother's uterus. This risk is under the control of prospective parents and their medical providers, who make decisions together about whether to transfer one, or more than one, fertilized ovum to the mother.

Concerning the quality of parent–child relationships, and of children's adjustment, researchers have found no reasons for concern (Colpin, 2002). Mothers who have had children via IVF may show greater warmth, affection, and emotional involvement with their children than do others. These mothers have been found to be more protective of their children, but there is no indication that children have been harmed. No differences between IVF and non-IVF children have emerged on measures of cognitive or social development (Golombok & MacCallum, 2003). In one study, IVF children were found to have fewer behavior problems than those in a control group (Hahn & DiPietro, 2001).

Two sizable studies of IVF offspring in adolescence have been reported, one conducted in England (Golombok, MacCallum, & Goodman, 2001) and the other in a number of European countries, including Spain, Italy, and the Netherlands (Golombok et al., 2002). Both studies found IVF youngsters to be functioning well, both at home and at school. No evidence of behavioral problems emerged from reports of parents or teachers. The youngsters were described as having good relationships with peers (Golombok et al., 2001, 2002).

Far from being a source of concern, the development of children conceived via IVF appears to be on track (Colpin, 2002; van Balen, 1998). Like Elizabeth Carr, who at last report was a healthy young

Elizabeth Carr, the first IVF baby born in the United States, is shown here at age 17. She has enjoyed good health and developed normally, allaying some fears about the use of assisted reproductive technology. *Source:* "Just Another Girl, Unlike Any Other," (p. A14), by C. Goldberg, Oct. 27, 1999, *New York Times*.

adult working as a journalist (Szabo, 2004), IVF youngsters have proven to have few if any unusual health problems and are generally doing well. Often oblivious to their extraordinary conception, these youngsters seem to be living quite ordinary lives. As Elizabeth Carr once said in response to a reporter's questions, "This is what I am. To me it's normal" (Goldberg, 1999, p. A14).

PROCESS OF CONCEPTION

QUESTIONS TO CONSIDER

REVIEW How does conception occur, and what types of assisted reproductive technology (ART) are available?

ANALYZE What we know about unintended pregnancies comes from the results of interviews with women. If men had also been interviewed, how do you think this might have affected the results of these studies, if at all?

APPLY Imagine that a couple you know has been trying to get pregnant for several months, without success. What advice could you offer about how to improve the odds of pregnancy?

CONNECT When infants are conceived via IVF, what if anything does this predict about their development during childhood and adolescence?

DISCUSS Some people think that ART should be available to all who want it, whereas others argue for limitations on its use. For instance, some people do not believe that ART should be used by low-income or unmarried women. What are your views on this issue?

Stages of Prenatal Development

After conception has occurred, the process of prenatal development begins (Moore & Persaud, 2003a). This process is usually divided into three periods: the germinal period, the embryonic period, and the fetal period. Table 2-2 summarizes the major events of prenatal development. Because the sequence of development is so predictable, it is tempting to see prenatal development as nothing more than the natural unfolding of a genetic blueprint. As we will see in later sections, however, the prenatal environment also exerts powerful effects.

In this discussion, the start of prenatal development is the moment of conception, which is also the point from which we begin to count **gestational age** (sometimes abbreviated as **GA**). From that beginning, a normal pregnancy lasts 38 weeks, or about 9 months. Some obstetricians count in a different way, beginning not from the moment of conception, but from the first day of the woman's last menstrual period, 14 days earlier. Counting this way, a normal pregnancy lasts 40 weeks. These are simply different ways of counting and do not change any of the underlying events or processes.

gestational age (GA) The age of a zygote, embryo, or fetus, usually calculated in weeks after conception.

Yet another way of describing the passage of time during pregnancy is to use 3-month periods called **trimesters.** In this system, the 3 months following conception

trimesters The three equal time periods into which a pregnancy can be divided.

TABLE 2-2
Milestones of Prenatal Development

PERIOD	WEEKS	SIZE	MAJOR EVENTS
Germinal	1–2	Microscopic	Zygote undergoes cell division, becomes a many-celled blastocyst; implants into the uterine wall.
Embryonic	3–8	<1 inch long	Heart, muscles, backbone, brain, and spinal cord begin to form. Arms, legs, toes, and fingers begin to form.
Fetal	9–38	From 2 inches to 20 inches long	Rapid growth in size and maturity. Fetal heartbeat can be heard with stethoscope. Nervous system becomes connected with muscles and organs. Sex of fetus can be ascertained via ultrasound. Mother begins to feel fetal movement. Lungs mature and brain develops.

SOURCE: *Before We Are Born: Essentials of Embryology and Birth Defects* (6th ed.), by K. Moore & T. Persaud, 2003, Philadelphia: W.B. Saunders; *The Developing Human: Clinically Oriented Embryology* (7th ed.), by K. Moore & T. Persaud, 2003, Philadelphia: W.B. Saunders.

are called the first trimester, the second 3 months are called the second trimester, and the last 3 months are called the third trimester. During the first trimester, pregnant women often report symptoms such as nausea, exhaustion, or unexpected food cravings. These symptoms generally subside as the second trimester begins, and the second trimester is a relatively serene part of pregnancy. By the third trimester, as the fetus grows larger, new issues emerge, such as discomfort from the growing baby and anxiety over preparations for the birth.

Germinal Period

The germinal period begins when the fertilized ovum, called the zygote, begins to make its way down the fallopian tube, moving in the direction of the uterus (Moore & Persaud, 2003a, 2003b; Nilsson & Hamberger, 2003). As the zygote moves through the fallopian tube, it begins a process of rapid cell division. One cell divides into 2, then 4, then 8, then 16 cells. These early cells are all identical and are bunched together in a ball, looking something like a mulberry. If, instead of remaining together, the cells separate into two groups, this may lead to identical twins, each developing separately from the same genetic material. By the 4th day, the zygote has multiplied into a ball of more than 50 cells and is called a **blastocyst.** The cells on the inside of this ball—called the *embryonic disk*—will eventually develop into the embryo, and later into the fetus and baby, while the cells on the outside of the ball—called the *trophoblast*—will turn into structures that will support and protect the baby before birth. The events of these early days of pregnancy are shown in Figures 2-8 and 2-9.

blastocyst The multicell organism that grows from a fertilized ovum during the germinal period, before implantation into the uterine wall.

Between 7 and 9 days after conception, the blastocyst, having made its way into the uterus, begins the process of attaching itself to the lining of the uterine wall. This is called **implantation.** The blastocyst sends out tiny **villi,** or hairlike projections, which attach to the uterine wall. These help anchor the blastocyst to the uterus and absorb nutrients from the mother's body. In a normal pregnancy, the blastocyst is fully implanted in the uterine wall by the end of the 2nd week (Flanagan, 1996; Moore & Persaud, 2003a).

implantation The process of a blastocyst attaching itself to the uterine wall; when completed, it signals the end of the germinal period and the beginning of the embryonic period of prenatal development.

villi Hairlike projections from the blastocyst that anchor it to the uterine wall.

If anything happens during the germinal period to interfere with the expected sequence of events, the pregnancy ends and the zygote dies. For instance, if cell

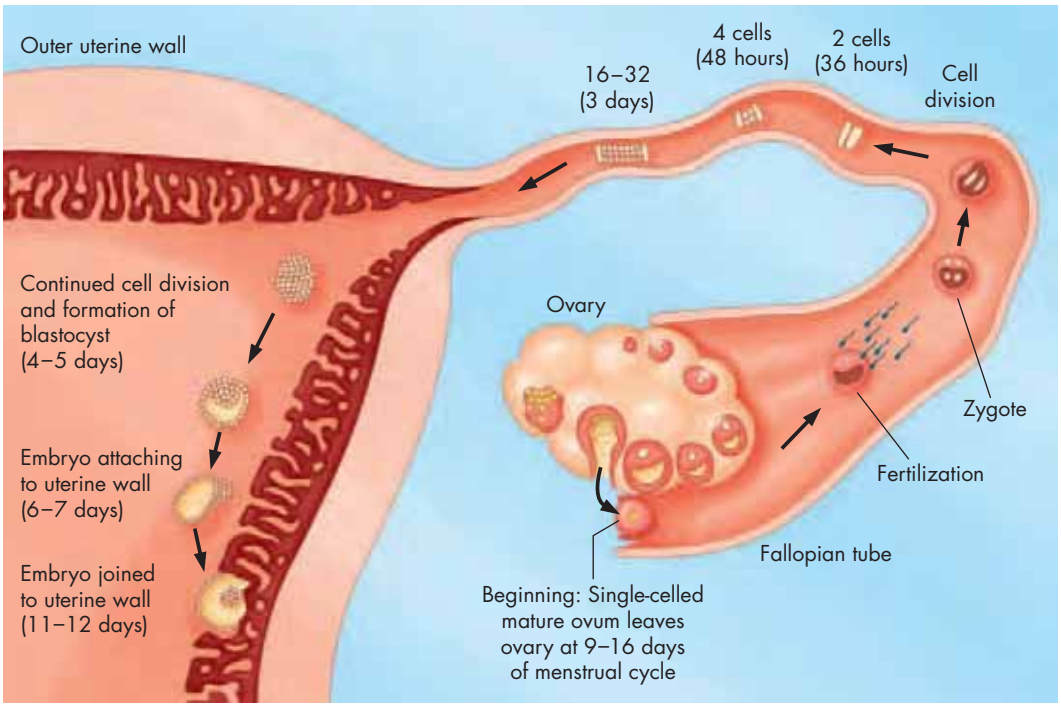


FIGURE 2-8 Conception and Early Prenatal Development. The ovum is fertilized in the fallopian tube. As the zygote grows, it moves through the fallopian tube and into the uterus, where it will implant itself into the uterine wall.

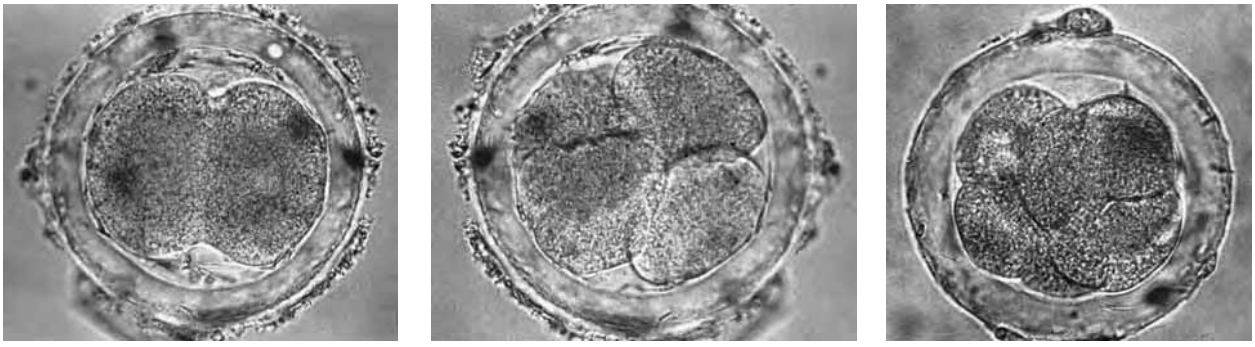


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Photo Researchers, Inc.

FIGURE 2-9 Earliest Stages of Pregnancy. Earliest stages of a pregnancy. During the first few days after conception, the zygote divides into 2 cells (a), 4 cells (b), and 8 cells (c), becoming a blastocyst. Within a week, if all goes well, the blastocyst will contain at least 100 cells. *Source: The Developing Person Through Childhood and Adolescence* (7th ed., p. 99), by K. Berger, 2003, New York: Worth Publishers.

division does not take place in the expected way, or if implantation does not occur, the tiny zygote is simply absorbed into the body. Some experts estimate that this happens between 25% and 40% of the time, usually outside the woman's awareness (Flanagan, 1996).

As it implants in the uterine wall, the inner cell mass of the blastocyst begins to differentiate (Moore & Persaud, 2003a). One layer of cells will become the intestinal system, urinary tract, glands, and lungs. Another layer will eventually turn into the skeleton, muscles, and circulatory system. A third layer will develop into brain, spinal cord, and nerves as well as skin and hair. Simultaneously, the structures that will provide support and nourishment before birth begin to form out of the blastocyst's outer layer of cells. All of this takes place before 2 weeks have passed and before a woman realizes she is pregnant.

Embryonic Period

embryo The developing organism during the embryonic period, from 2 weeks to 8 weeks after conception.

umbilical cord In the womb, a tube containing blood vessels that connects the fetus and the placenta.

placenta The organ that separates the embryonic or fetal bloodstream from that of the mother, while allowing exchange of nutrients and waste.

human chorionic gonadotrophin (hCG) A hormone whose presence signals the beginning of a pregnancy.

neural plate Early in prenatal development, the structure of cells from which the neural tube, and eventually the brain and spinal cord, will develop.

neural tube Early in prenatal development, the structure that grows from the neural plate, and will eventually develop into the brain and spinal cord.

neurons Nerve cells.

proliferation During the embryonic period of prenatal development, the growth of new neural cells.

aggregation In neural development, the tendency of similar cells to clump together and, in so doing, form the beginnings of neural structures.

At the beginning of the embryonic period, 2 weeks after conception, the growing organism, now firmly implanted into the uterine wall, is called an **embryo** (Moore & Persaud, 2003a). The word *embryo* comes from roots that mean "to teem within," and the embryo is indeed teeming with activity. During the embryonic period, this round clump of cells will transform into an oblong body and eventually into an identifiably human embryo. The embryo will be connected to the mother's body by means of an **umbilical cord** and will be nourished by the developing **placenta.** The placenta functions as a support center for the developing embryo, providing nutrients, carrying off waste products, and filtering out substances that would endanger the embryo's development.

The placenta, once formed, begins to give off **human chorionic gonadotrophin (hCG),** a hormone that signals the woman's ovaries that she is pregnant (Moore & Persaud, 2003a, 2003b). The ovaries in turn stop ovulating and give off signals that stop the shedding of the uterine lining each month during menstruation. The hCG circulating in the woman's bloodstream can be detected in her urine within a few days after she has missed her period. Popular pregnancy tests involve dipping a detector stick into a urine sample. If hCG is detected, a blue line appears, indicating that the woman is pregnant. By a week after a missed period, the results of these tests reach above 99% accuracy.

During the embryonic period, the organism grows very fast (Nilsson & Hamberger, 2003). In the 7th week, it actually doubles in size, from about 1/4 inch to almost (inch (1 centimeter) in length. Before the end of the 1st month, the heart has formed. As the cells of the heart begin to contract, the heart begins to beat in a jerky pattern at first, but soon in a smoother and more regular fashion. Also during the 1st month, the eyes, ears, and nose begin to form, as do the arms.

The embryonic period is a critical time in the development of the brain and spinal cord (Couperus & Nelson, 2006). Two to 3 weeks after conception, cells in the *ectoderm*—the outer layer of cells in the embryo—form the **neural plate,** the rudimentary structure from which the brain and spinal cord will develop (see Figure 2-10). In a matter of days, the neural plate buckles and folds inward upon itself to form the **neural tube.** The neural tube fuses into a closed tube, first in the middle, and continuing toward each end until it has closed entirely by 26 days after conception. Eventually, the brain will form at one end of the tube, and the spinal cord will grow at the other end. The neural tube contains cells from which all the cells of the brain and nervous system, called **neurons,** will emerge (Monk, Webb, & Nelson, 2001).

During the remainder of the embryonic period, and extending into the fetal period, many new cells are created and migrate to their destinations in the developing brain (Monk et al., 2001). The creation of new cells through cell division is called **proliferation,** and it results in a dramatic increase in the sheer numbers of neurons. Beginning at about 32 days after conception, and continuing throughout gestation, newly formed neurons move to their final destinations in the developing brain. As they do so, they undergo **aggregation,** which is the tendency of similar cells to clump together. Gradually, aggregated cells come to form all the structures of the brain.

By about 6 weeks of age, the embryo begins to look recognizably human (Moore & Persaud, 2003a, 2003b). The head, which was tipped forward, begins to move back. The head is very large relative to the body, and the upper body is much larger than the lower part of the body. Small arms are visible and have paddles at the end, on which the ridges that will become fingers can be seen. The embryo may begin to move, although it is still so small that the mother will not notice its movements.

VISUALIZING THE DEVELOPING BRAIN

Prenatal Brain Development

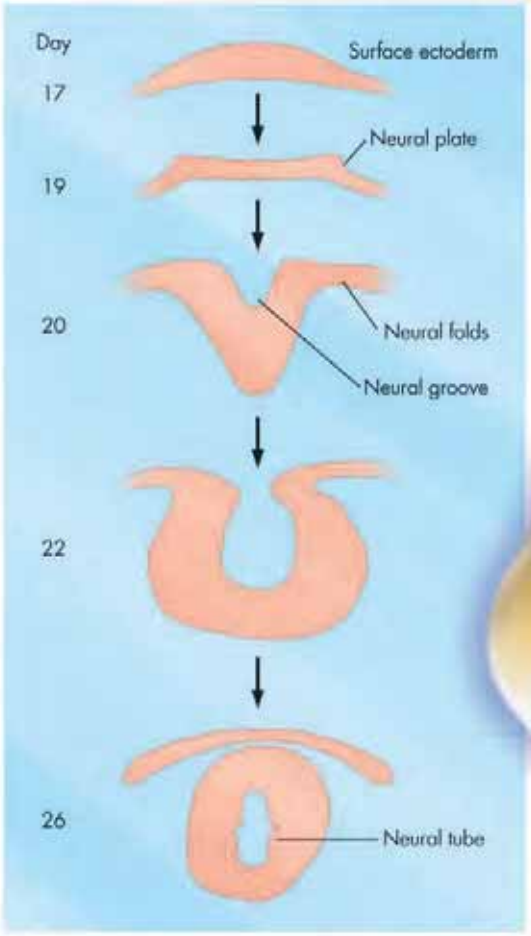
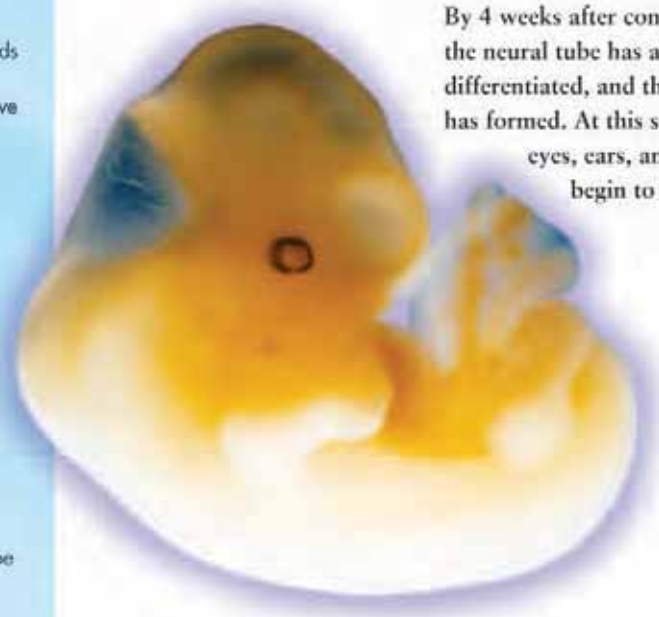
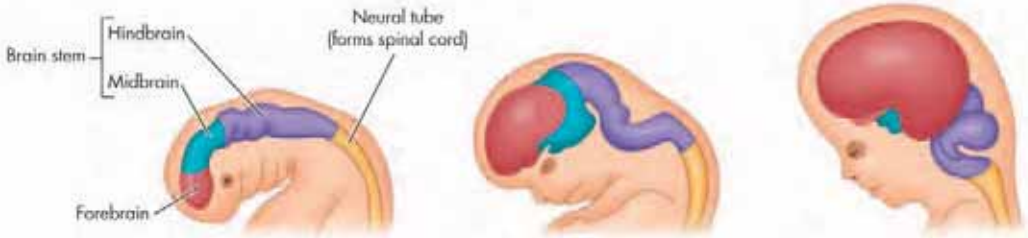


FIGURE 2-10 During the embryonic period, cells in the outer layer— the ectoderm—form the neural plate. Over a period of several days, the neural plate develops into the neural tube. One end of the neural tube later becomes the brain, and the other becomes the spinal cord



By 4 weeks after conception, the neural tube has already differentiated, and the heart has formed. At this stage, the eyes, ears, and nose begin to form.



(a) 25 days (b) 50 days (a) 100 days

Through the proliferation and migration of cells, the brain grows dramatically in size and complexity during the fetal period. By approximately 28 weeks after conception, the brain has the shape of an adult brain.

(d) 20 weeks (e) 36 weeks (full term)

By 8 weeks after conception, the embryo has grown still further, averaging about 1 inch (2.5 cm) in length and just under ½ an ounce in weight (Moore & Persaud, 2003a, 2003b; Nilsson & Hamberger, 2003). Arms have grown longer, and hands have stubby fingers on them. Legs and feet have developed more slowly than arms and hands, but are now clearly visible. The mouth has developed, as have the lips. Both upper and lower jaws have emerged. At the close of this period, the tiny embryo floats in **amniotic fluid,** enclosed in the amniotic sac, nourished by the placenta, and suspended within the mother's uterus.

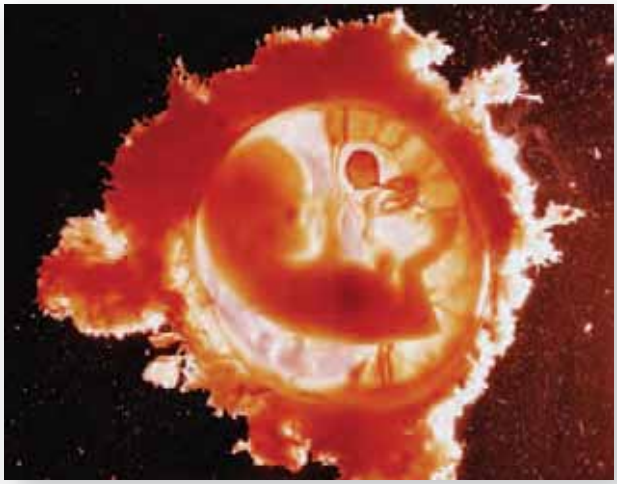
amniotic fluid Transparent fluid inside the amniotic sac.

Fetal Period

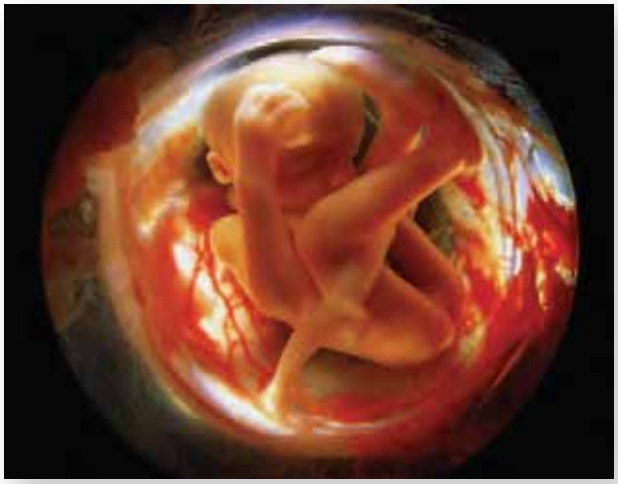
The fetal period begins at 8 weeks after conception and lasts until birth (Moore & Persaud, 2003a). During this period, the **fetus** grows from an inch-long organism weighing less than an ounce to a 20-inch-long baby weighing 7½ pounds

fetus The developing organism during the fetal period, from 8 weeks after conception until birth.

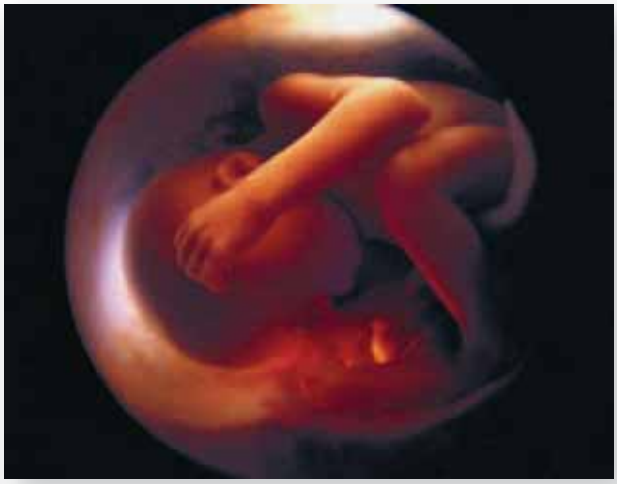
By 6 weeks after conception, the embryo is beginning to look more like a person. Small arms can be seen, and the embryo may begin to move.



By 12 weeks after conception, the fetus has grown to about 3 inches in length.



By 20 weeks after conception, the fetus is gaining rapidly in both size and weight.



By 28 weeks after conception, the fetus is more than 13 inches long and weighs more than 3 pounds.

at birth (the average size of a newborn). The fetal period is one of astounding growth and change.

From 8 to 12 weeks, the fetus grows to about 3 inches in length. Activity levels are high, with the fetus flexing and stretching its body and moving its limbs inside the womb. During this period, the fetal heartbeat can be heard with a stethoscope for the first time. The genitalia are forming, although perhaps not well enough yet to permit visual determination of gender. By 9 weeks of age, the developing fetus can even hiccup and react to very loud noises. Twelve weeks marks the end of the first trimester of pregnancy.

In the second trimester, from the 4th through the 6th months of pregnancy, the fetus continues to grow and change (Moore & Persaud, 2003a). By 15 weeks, the fetus is about 7 inches long, when measured from head to foot, and weighs about 4 ounces (100 grams). The bones begin to harden, especially in the legs, but the skeleton is still soft cartilage. In the 4th month, the fetus continues to be very active, averaging at least one movement per minute. At first there is no apparent pattern to this activity, but by the 6th month, a diurnal pattern is evident, with greater activity at some times of day than at others.

Also during the second trimester, a fine downy fuzz called **lanugo** covers the body of the fetus (Nilsson & Hamberger, 2003). The word lanugo comes from a Latin word for *wool* and refers to the lanugo's wooly appearance. In turn, the lanugo is coated with a thick whitish cream called **vernix,** which protects the skin. When a baby is born at the normal time, most of the lanugo has disappeared, as has all but a few remnants of the vernix. When a baby is born prematurely, however, some lanugo and vernix may still be visible.

lanugo Fine hairy fuzz that grows over the body of a fetus.

vernix A sticky, white, cheesy covering over the skin of the fetus, thought to protect the skin while it is suspended for many weeks in amniotic fluid.

Development of the brain and nervous system proceeds rapidly during the fetal period. After neurons have reached their destinations in the brain, they develop the structures that will allow them to send and receive electrical impulses to and from one another. Neurons are made up of cell bodies, dendrites, and axons (see Figure 2-11). **Dendrites** are fibers that extend outward from the cell body and receive input from neighboring cells. An **axon** is usually a single long fiber that sends signals from the cell body to other neurons; at its tip are the *axon*

dendrites Neural fibers that receive electrical signals from axons and conduct them to other neurons.

axons Neural fibers that conduct electrical signals from the cell bodies of neurons to the dendrites that make connections with other neurons.

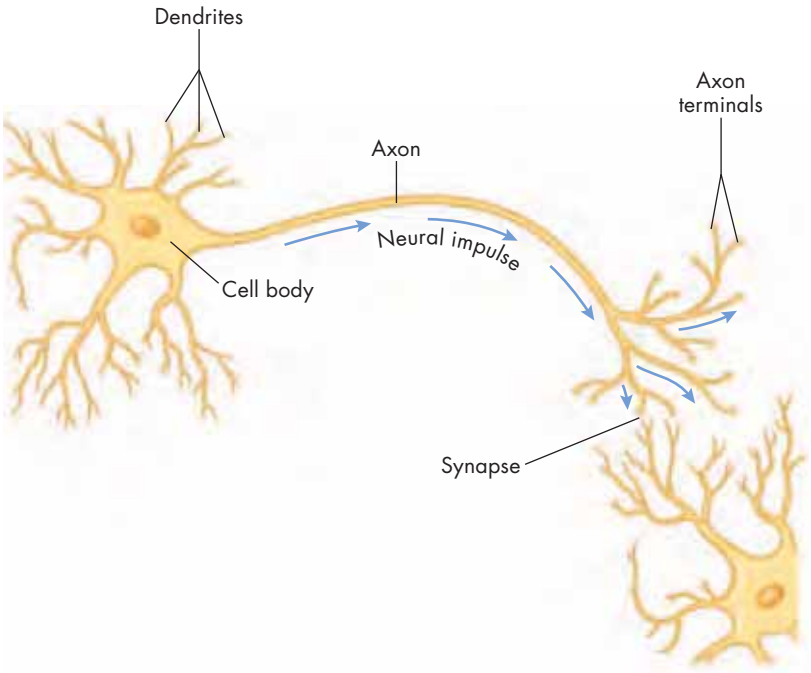


FIGURE 2-11 Neuron. The neuron is made up of a cell body, dendrites, and an axon. Neural signals, or impulses, travel from the cell body, down the axon, to the axon terminals. When the axon is covered by a myelin sheath, impulses travel more rapidly along the axon.

terminals, which transmit the signals to the dendrites of adjacent neurons. Axon growth begins at about 15 weeks after conception in some areas of the brain, but not until 32 weeks after conception in other areas (Couperus & Nelson, 2006). Dendrite formation is stimulated by contact of the cell body with an axon, so it begins shortly after axons reach neural cell bodies. The formation of **synapses,** or connections among neurons, permits the neurons to carry out their function of transmitting and receiving signals. Synapse formation—called **synaptogenesis**—begins before birth, but the peak rates for formation of new synapses occur after birth, during the first 12 months of life (Monk et al., 2001). Thus, the fetal period involves not only physical growth of the brain and its structures, but also the development of connections among neurons (Nelson, de Haan, & Thomas, 2006).

synapse The point of connection between neurons, where the axon of one neuron transmits information to the dendrites of another neuron.

synaptogenesis The creation of synapses, or connections between neurons.

By 24 weeks, the fetus is 12 inches long and weighs almost 2 pounds (Flanagan, 1996). Genitalia are well developed, so it is possible to tell whether a fetus is a boy or a girl. Though still small, babies born at this point in their development have a better than equal chance of survival, especially if good medical care is available. Babies have been born before 24 weeks, weighing less than 1 pound, and survived, but lack of oxygen due to their immature lungs may cause irreversible problems. A fetus that remains in the womb through the third trimester, so that the lungs and other bodily systems can develop fully before birth, has a better start in life.

By the time the third trimester begins, in the 7th month, the fetus is growing very rapidly (Moore & Persaud, 2003a). The fetus will triple its weight during these last 3 months, and the mother's womb will come to seem increasingly cramped. The 28th week is sometimes said to represent the *point of viability,* which means that if the baby were to be born at 28 weeks, it would have a better than even chance of survival without special medical intervention. During these last 3 months, the fetus moves around and practices some behaviors such as "swallowing" and "breathing." Of course, the fetus is swallowing small amounts of amniotic fluid, not breast milk, and the fetus may be moving its chest muscles, but cannot yet breathe air. These movements allow the fetus to practice actions that will be important after birth. The amount of activity slows somewhat, but the movements become more vigorous.

During the last trimester, fetal heart rate slows and becomes more variable as gestation proceeds (DiPietro, Hodgson, Costigan, Hilton, & Johnson, 1996). Fetal movement and fetal heart rate become synchronized (DiPietro, Caulfield, Irizarry, Chen, Merialdi, & Zavaleta, 2006). These changes are related to the growing size of the fetus, on the one hand, and to maturation of the heart, on the other. Even so, these changes are more pronounced in some fetuses than in others. For instance, as shown in Figure 2-12, heart rates decline more rapidly with gestational age among American fetuses in Baltimore than among Peruvian fetuses in Lima (DiPietro et al., 2004). Heart-rate variability also increases more rapidly with gestational age among American fetuses than among Peruvian fetuses (DiPietro et al., 2004). The fact that similar, though less pronounced, differences have been reported as a function of social class within the United States suggests the possible role of maternal stress, nutrition, or related environmental factors (Pressman, DiPietro, Costigan, Shupe, & Johnson, 1998). Researchers have not yet identified the pathways through which such differences emerge, but this is an active area of research (DiPietro, 2004).

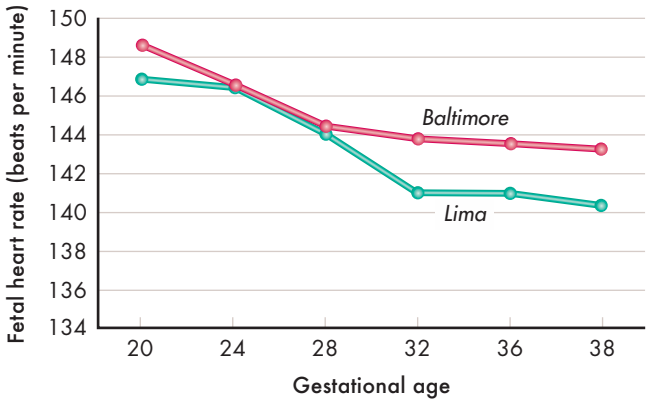


FIGURE 2-12 Comparing Fetal Heart Rate Declines in Two Cultures. At 20 weeks of gestational age, the tiny fetal heart beats very fast. As the due date approaches and the fetus grows larger, the fetal heart rate slows down. The graph shows normal slowing of fetal heart rate was more pronounced among U.S. than among Peruvian babies. American babies were also bigger and heavier at birth, which may account for the difference. *Source:* "Fetal Neurobehavioral Development: A Tale of Two Cities," by J. DiPietro, L. Caulfield, K. Costigan, M. Merialdi, R. Nguyen, N. Zavaleta, et al., *Developmental Psychology, 40,* pp. 445–456 (Fig. 1).

While in the womb, the fetus seems to have sensory experiences. When sucking a thumb or kicking against the uterine wall, the fetus has tactile experiences. The fetus can taste and smell the amniotic fluid (Gandelman, 1992). Sweet tastes are preferred, as one ingenious researcher discovered by adding sugar to a mother's amniotic fluid and observing that her fetus consumed more of it than usual (Gandelman, 1992). Various sounds elicit changes in fetal movement or in fetal heart rates (Kisilevsky & Low, 1998). In particular, the fetal heart rate slows down when the mother's voice is heard, suggesting that the fetus is paying attention (Fifer & Moon, 1995).

Simple sensory experiences aside, does learning take place in the womb? In one study, mothers recited a short rhyme three times a day for 4 weeks during the last trimester of pregnancy. By the time the fetuses were 37 weeks old, their heart rate slowed more to the familiar poem than to a similar but unfamiliar rhyme (DeCasper, Lecanuet, Busnel, Granier-Deferre, & Maugeais, 1994). Thus, even before birth, the fetus seems to learn from experience. In the Development and Education feature on p. 000, you can read about another study to determine whether fetuses react to music.

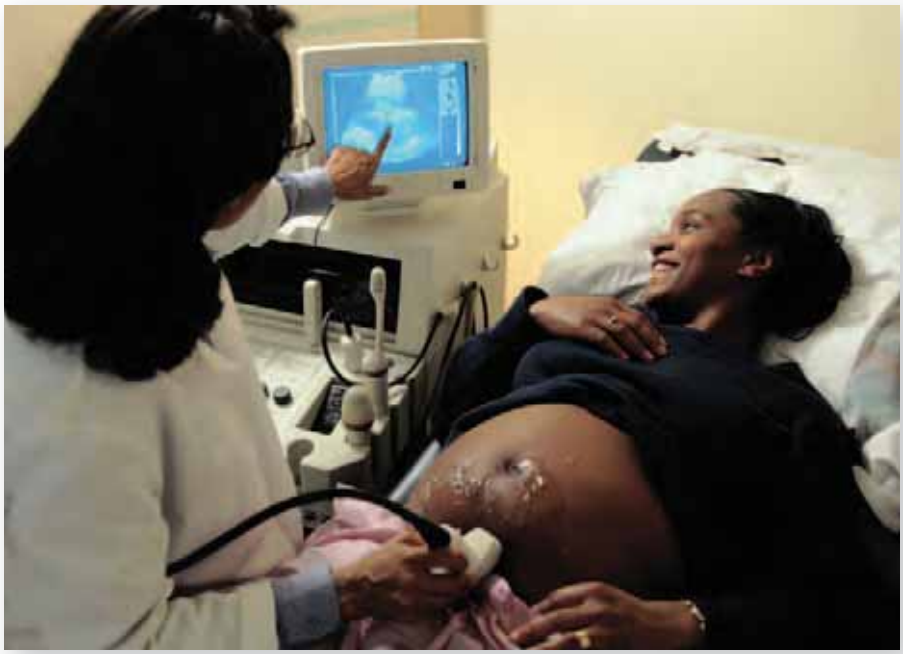
Another classic experiment demonstrates that learning in the womb may affect experience after birth, as well as before. DeCasper and Spence (1986) asked mothers to read aloud a Dr. Seuss rhyme, *The Cat in the Hat,* twice a day during the last 6 weeks of their pregnancies. After the babies were born, the researchers put each one into a special pair of headphones, and gave each one a specially designed pacifier that had been wired to the headphones. When the baby sucked in one pattern, it heard *The Cat in the Hat* through the earphones; if it sucked in any other pattern, or did not suck at all, it heard a different story. Apparently, the babies remembered and preferred the story they had heard, because they quickly adjusted their pattern of sucking so as to hear *The Cat in the Hat* rather than the unfamiliar story. Further studies show that newborns also prefer listening to the language they had heard in the womb; thus, babies with English-speaking mothers prefer to hear English over other languages (Moon, Cooper, & Fifer, 1993).

Using similar methods, researchers have found that newborn infants also respond differently to smells and tastes that are familiar to them from the womb as compared to those that are unfamiliar (Marlier, Schaal, & Soussignon, 1998; Mennella & Beauchamp, 1999). For instance, newborns seem to prefer familiar smells, turning their heads in the direction of a pad soaked with their own mothers' amniotic fluids, in preference to pads soaked with amniotic fluid from other mothers (Marlier et al., 1998). When mothers drank lots of carrot juice during pregnancy, their babies showed decreased preference for carrot flavors, even several months after birth (Mennella & Beauchamp, 1999). Thus, fetal experiences may have lasting effects.

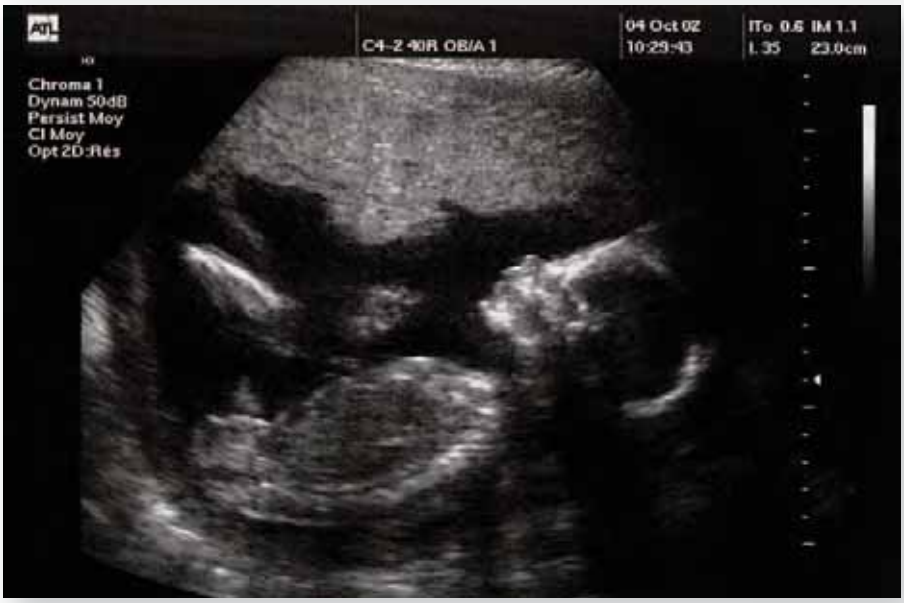
Prenatal Testing

To evaluate the progress of fetal development, and to check on any problems, many prenatal testing options—from routine to complex—are available in the United States today (Moore & Persaud, 2003a). Not every woman needs to have every test, and women may choose to have more or fewer tests done, depending on their health, their risks, and other aspects of their overall situation. In this section, we examine some common prenatal tests and discuss their uses.

Ultrasound testing (a) uses high-frequency sound waves to create images of the fetus on a computer monitor. These images can be used to measure the size and position of the fetus.



Ultrasound images (b) provide expectant parents with their first glimpse of the fetus.



During the earliest weeks of pregnancy, blood and urine tests are commonly run to identify any maternal illnesses or other conditions in need of medical treatment. These can include tests for rubella, HIV, and other diseases or conditions. For example, a mother who has diabetes will be carefully monitored to be sure that her blood sugar remains within a safe range. Many women check on these issues in advance of becoming pregnant, as well as after becoming pregnant.

ultrasound Procedure that uses high-frequency (but inaudible) sound waves to create moving images of embryos and fetuses on a computer screen, used in assessment of prenatal development and for related purposes.

In **ultrasound,** a special wand held against the pregnant woman's abdomen bounces high-frequency, inaudible sound waves off the fetus to create moving images on a computer monitor. These images can be used to measure the baby's size and identify its position, as well as to guide instruments used in other tests. These images can also give parents a surprise when they reveal more than one fetus developing in the womb. As a mother of twins, I can tell you that seeing the image of David and his twin Eliza for the first time on an ultrasound is an experience I will never forget!

Another test that can be done relatively early during pregnancy is **chorionic villus sampling,** or **CVS** (Moore & Persaud, 2003a). In CVS, the physician inserts a small tube into the placenta to draw out a small amount of tissue for testing. The tube can be inserted through the vagina and up into the womb, or—using a needle—through the abdominal wall. The tissue sample obtained in this way is then tested for chromosomal abnormalities such as Down syndrome. This test is usually performed at 10 to 12 weeks' gestational age. The results of this test are definitive, but it is highly invasive and involves some risk of infection to the mother and baby.

chorionic villus sampling (CVS) Procedure for sampling a small amount of the chorionic villi to check for birth defects; can be completed earlier in pregnancy than amniocentesis.

A relatively new test designed to evaluate the risk of Down syndrome is **nuchal translucency screening** (Nilsson & Hamberger, 2003). This test, which is done at a gestational age of 11 to 14 weeks, uses ultrasound techniques to measure the clear space in the tissue at the back of the fetal neck. If there are abnormalities such as Down syndrome, the fetus tends to accumulate fluid at the base of the neck, making the clear space look larger or thicker. When the area is thicker, this indicates greater risk of Down syndrome. This test has been done in the United States since 1995, but it requires special training and equipment (American College of Gynecology Practice Bulletin, 2007). As a result, it is still only available mainly at major medical centers. Nuchal translucency screening is performed later in a pregnancy than CVS and is less definitive, but it is much less invasive and involves fewer risks. If nuchal translucency screening indicates a high risk of Down syndrome, a CVS or other more definitive test can also be performed.

nuchal translucency screening Prenatal test that uses ultrasound imaging to assess the risk of a fetus having Down syndrome; can be conducted earlier than other tests for Down syndrome.

Done later in a pregnancy, **amniocentesis** is another test used to identify Down syndrome and other genetic abnormalities (Moore & Persaud, 2003a). This test, usually done between 15 and 17 weeks' gestational age, involves inserting a needle into the pregnant woman's uterus to collect a small amount of amniotic fluid. This is normally done with guidance from ultrasound, to avoid any injury to the fetus or placenta. The cells retrieved in this way can be analyzed in a laboratory to identify chromosomal or other abnormalities. Results usually take 2 or 3 weeks to be returned. The test results are usually clear, but the test is highly invasive, carries some risk, and cannot be performed until 15 or more weeks into a pregnancy.

amniocentesis Procedure for sampling a small amount of amniotic fluid in order to assess the genetic material of the fetus, usually done between 15 and 17 weeks of gestational age.

The **triple-screen blood test** measures levels of three hormones in the mother's blood: alphafetoprotein (AFP), human chorionic gonadotrophin (hCG), and unconjugated estriol (uE3) (Moore & Persaud, 2003a). Usually given between 16 and 18 weeks' gestational age, this test checks for birth defects such as **spina bifida** (a condition that involves an abnormal opening in the spine). This test can also sometimes identify women who are vulnerable to problems such as premature labor or miscarriage.

triple-screen blood test Prenatal test done to check for birth defects such as spina bifida; usually given between 16 and 18 weeks of gestational age; tests for levels of alphafetoprotein (AFP), human gonadotrophin (hCG), and unconjugated estriol (uE3).

spina bifida A birth defect that involves an abnormal opening in the spine.

What happens if an abnormal test result emerges? Usually, if one test produces an abnormal result, additional tests will be performed to confirm the results and to indicate whether medical intervention can help maintain the health of mother or child. When a woman has seen the results from prenatal testing and discussed them with her physician or other health care provider, she is in a better position to make informed choices about the best course of action.

Not long ago, the results of prenatal testing left women with a choice between continuing or not continuing a pregnancy. Today, many more options are available in this rapidly changing area of medicine. Drugs can be administered and surgery can be performed to correct some neural defects and other fetal abnormalities, even before birth (Flake, 2003). Many of these options also carry with them the risk of complications, however, such as premature birth (Wilson et al., 2004).

Advances in knowledge about the human genome are likely to expand even further the range of options available to expectant parents. Gene therapy, which

involves insertion of functional genes into cells, has already been used to ameliorate hemophilia. *Proteonomics*, in which proteins are modified, is another new set of techniques. These and related developments are likely to become increasingly important in the years ahead (Moore & Persaud, 2003a).

Prenatal testing can help to assure a woman that her pregnancy is proceeding as expected, or it may identify problems. At the same time, it points up the many ways the prenatal environment in the womb influences the development of all infants. In the next section, we consider environmental influences on the development of the embryo and fetus.

BRAHMS AND THE UNBORN BABY

Can a fetus hear music?

Many people believe that playing music to infants will increase their intelligence. Commercial recordings are sold with claims that music will benefit babies' development. None of these claims have yet been borne out by research (Bangerter & Heath, 2004). Of course, there is nothing new about music in the lives of infants. Parents have been singing lullabies to their babies throughout time. Whether or not listening to music makes babies smarter, parents are likely to keep singing. Not nearly as much has been said, however, about the impact of music on babies *before* they are born.

Can a fetus hear music? And, if so, how might a fetus respond—say, to Mom's favorite tune? We know that by the last trimester of pregnancy the fetus can hear (Kisilevsky, Pang, & Hains, 2000). One study even found that by the last trimester fetuses can distinguish between musical notes, between a C and a D, for example (Lecanuet, Granier-Deferre, Jacquet, & DeCasper, 2000). These findings suggest that toward the end of pregnancy a fetus might be able to hear music. Is this the case?

To find out, a team of investigators from Canada and France played a 5-minute recording of the Brahms lullaby for 120 fetuses of different gestational ages, 45 of them in Canada and 75 in France (Kisilevsky, Hains, Jacquet, Granier-Deferre, & Lecanuet, 2004). They played the music over a loudspeaker near the mother's abdomen. During the procedure, the mothers listened to another type of music through headphones, which masked sounds in the room. The mothers could not hear the music played for the fetus. The investigators recorded fetal heart rates and made video recordings of the fetuses' movements, which were visualized using ultrasound techniques.

Results showed that the key determinant of reactions to the music was fetal age. Up to 34 weeks of gestational age, the fetuses showed no particular reactions at all. Fetuses that had reached at least 35 weeks of gestational age showed definite reactions, however. When the music came on, fetal heart rates increased and fetal movements became more frequent and rhythmic—almost as though the fetuses were dancing. When the music stopped, fetuses became quiet again, and their heart rates returned to normal resting levels. The fetuses studied in France were as likely as those in Canada to show these reactions. Thus, on both sides of the Atlantic, near-term fetuses showed that they could hear and respond to music.

Does this mean that a fetus who listens to the Brahms lullaby will be more intelligent than other babies, after birth? Probably not. On the other hand, these results do seem to suggest that music appreciation classes could begin before birth. If Brahms' lullaby makes the fetal heart beat faster, what would happen if fetuses listened to rock and roll?

STAGES OF PRENATAL DEVELOPMENT

QUESTIONS TO CONSIDER

REVIEW What are the major stages of prenatal development, and what are the most important events that occur during each one?

ANALYZE What do you see as the strengths and limitations of methods that scientists use to study sensory experience and learning in the fetus?

APPLY Imagine that your sister has just told you in an excited tone that she is pregnant. What prenatal tests should she have, and when during the course of her pregnancy should she have them?

CONNECT If, after birth, babies prefer to listen to languages that they have heard while in the womb, what impact might this fact have on their acquisition of linguistic skills?

DISCUSS Most prenatal tests carry some health risks, to both mother and infant. Such risks may include bleeding, infection, and miscarriage. How should we decide which risks are acceptable and which are not?

Environmental Influences on Prenatal Development

During pregnancy, the mother's womb provides the baby's first environment, and it affects development in many ways (Moore & Persaud, 2003a). In this section, we examine environmental conditions such as maternal nutrition and stress and how they affect the developing organism in the womb. We also study **teratogens,** environmental agents such as drugs, that can cause birth defects. The word *teratogen* comes from two Greek roots—*teras,* meaning "monster," and *gen,* meaning "source" or "origin." Literally, then, teratogen means "source of monsters." Although teratogenic influences can be very harmful, the mother's womb normally provides a supportive environment for the developing fetus.

teratogen An environmental agent that interferes with normal prenatal development.

Maternal Nutrition

Good nutrition is essential not only for the mother's health during pregnancy, but also for the health of her fetus. Because the fetus depends entirely on its mother for sustenance in the womb, eating a healthy, balanced diet is especially important for pregnant women. As the pregnancy proceeds, the woman's intake should include increasing numbers of calories per day. An extra 100 calories during the first trimester, an added 265 in the second trimester, and an additional 430 calories during the final trimester will help to sustain the mother's health as well as that of her baby (Reifsnider & Gill, 2000).

The importance of good nutrition is shown most clearly by studies of malnutrition. Much of what we know about these matters comes from studies of babies born during times of famine. For instance, during World War II, the Russian city of Leningrad was encircled by attacking German troops, who cut off food supplies in hopes that the city would surrender. A study of childbearing during this period found that fewer than the normal number of babies were born in the ensuing

months. Those who were born were more likely to be premature or to have low birth weights (Antonov, 1947).

Similar events took place in the Dutch cities of Amsterdam and Leiden during World War II. In 1944–1945, the German army occupying western Holland imposed an embargo on food supplies to Rotterdam, in retribution for Dutch cooperation with the Allies. For several months, food was in very short supply, and nutritional deficiencies were severe. Studies of subsequent fertility in Holland showed increased numbers of stillbirths, malformations, and spontaneous abortions when mothers had been malnourished (Stein, Susser, Saenger, & Marolla, 1975). When mothers were malnourished during the first trimester, they were most likely to have miscarriages. When mothers were malnourished during the second and third trimesters of pregnancy, their babies survived, but were more likely to be born at low birth weights than were those in a control group from other parts of Holland (Stein et al., 1975). Subsequent studies even showed that when mothers were malnourished in the first and second trimesters of pregnancy, their surviving offspring were more prone to aggressive and criminal behavior as adults (Neugebauer, Hoek, & Susser, 1999). Thus, maternal malnutrition is associated with many negative outcomes, both in infancy and in later life.

Even though a well-rounded diet is universally agreed to be vital for the health of mothers and their unborn infants, many low-income women may have difficulty obtaining adequate nutrition. To overcome this problem, the U. S. Special Supplemental Nutrition Program for Women, Infants, and Children (often abbreviated WIC), begun in 1970, provides healthy food for low-income pregnant women or nursing mothers (Black et al., 2004). Evaluations of the program have revealed that infants born to WIC mothers are healthier and developed better than did those born to non-WIC mothers matched on age, race, education, and other factors (Black et al., 2004; Kotelchuck, Schwartz, Anderka, & Finison, 1984). Thus, when low-income women who might otherwise have had poor nutrition are given supplemental food, it benefits their infants.

Adequate maternal nutrition also requires sufficient intake of vitamins and minerals. For instance, adequate amounts of vitamin—help to ensure the growth of the placenta and, therefore, the fetus. The vitamin D status of pregnant women is related to bone growth among their offspring. Mothers who received insufficient amounts of vitamin D during pregnancy have offspring whose bones are smaller, even in middle childhood (Javaid et al., 2006). Mothers with insufficient calcium are vulnerable to high blood pressure and premature births (Moore & Persaud, 2003a).

Folic acid, a B vitamin found in leafy green vegetables and some fruits, helps to prevent neural tube defects such as spina bifida, a condition in which the spinal cord or its coverings fails to develop normally. Because the intake of folic acid during pregnancy has been found to reduce the incidence of spina bifida and other neural tube defects, the U.S. government requires the addition of folic acid to the grain used in packaged bread and rolls. Studies both in the United States and Canada have found that rates of spina bifida fell by anywhere from 20% to 50% after the mandatory use of folic acid to fortify grains began (Eichholzer, Tonz, & Zimmermann, 2006).

Thus, women should strive to eat enough calories while pregnant, but caloric intake in itself does not assure healthy development of the fetus. Adequate intake of vitamins and minerals is also important. Prenatal malnutrition can lead to problems in brain development in areas such as neurogenesis and migration (movement of neurons from one part of the brain to another). These often lead to

learning disabilities and to attentional problems (Morgane et al., 1993). When nutrition is good, chances that the fetus will develop in healthy ways are improved.

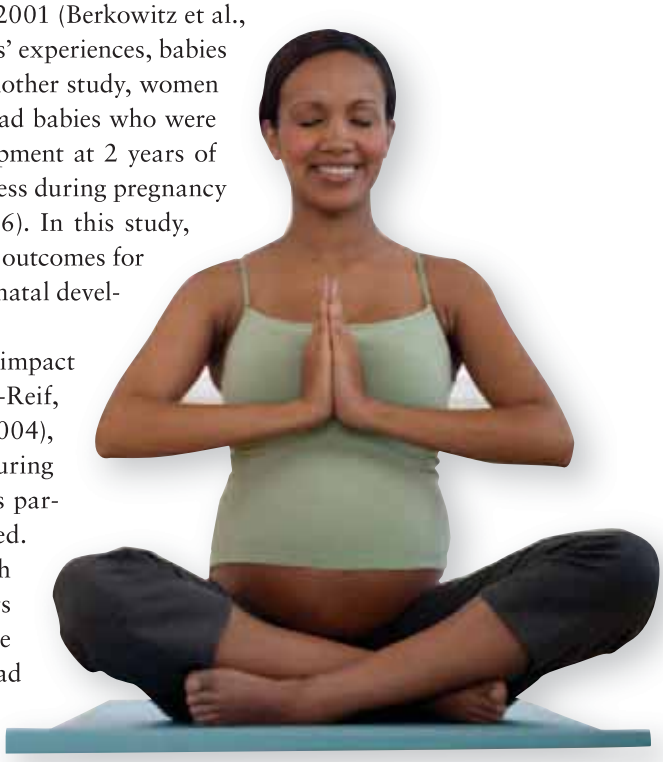
Maternal Stress

Does maternal stress affect prenatal development? Many folk ideas link maternal stress with problems for the offspring. For instance, it was once commonly believed that if a pregnant woman had a severe fright, her baby would be born with a birthmark. Few subscribe to this view today, but researchers are actively studying ways in which stress and anxiety may affect the fetal environment and, in this way, affect prenatal development.

Some studies have found links between maternal stress and fetal behavior. For instance, Janet DiPietro and her colleagues asked women at the end of their pregnancies to evaluate how stressful this period of their lives had been, while also observing fetal behavior using ultrasound techniques (DiPietro, Hilton, Hawkins, Costigan, & Pressman, 2002). Women who described their pregnancies as more stressful had more active fetuses than those of women who viewed their pregnancies as more relaxed (DiPietro et al., 2002). An active fetus is likely also to become an active infant, so these differences could indicate diverging paths of later development (DiPietro, 2004).

Stressors are a diverse group of stimuli. Some may be mild—like working a few extra hours at a familiar job. Others may be intense—such as surviving a major earthquake. Reactions are also affected by appraisals of the stressors. Working overtime may be seen as beneficial if it leads to higher earnings, but as problematic if it does not bring rewards. It is not surprising, then, that studies of stress during pregnancy have had varied results (Kofman, 2002).

Some studies have described negative effects of stress during pregnancy, but other investigators have not found any negative impact of stress. One report was based on experiences of pregnant women who had been in or near the World Trade Center towers when they collapsed on September 11, 2001 (Berkowitz et al., 2003). Despite the intensely stressful nature of mothers' experiences, babies were born on time and at normal birth weights. In another study, women who experienced moderate stress during pregnancy had babies who were actually more advanced in mental and motor development at 2 years of age than the babies of mothers who reported lower stress during pregnancy (DiPietro, Novak, Costigan, Atella, & Reusing, 2006). In this study, moderate levels of stress were associated with positive outcomes for infants. The exact associations between stress and prenatal development have yet to be established (DiPietro, 2004).



In related work, researchers have also studied the impact of maternal depression (Diego, Field, & Hernandez-Reif, 2005; Field et al., 2004). In one study (Field et al., 2004), mothers with and without depressive symptoms during their second trimester of pregnancy were recruited as participants, and their biochemical profiles were assessed. Of those followed throughout pregnancy, mothers with depressive symptoms were more likely than mothers without symptoms to deliver prematurely and to have small babies. After birth, newborns whose mothers had felt depressed showed delayed development and less well developed sleep patterns relative to infants of

mothers who were not depressed. Prenatal maternal depressive symptoms were accompanied by higher levels of the hormones cortisol and norepinephrine, which may result in restriction of fetal growth and premature birth. Moreover, infants of mothers who were depressed were themselves born with heightened levels of cortisol and norepinephrine (Field et al., 2004). Thus, maternal depressive symptoms seem to affect both fetal growth and infant development after birth.

Prescription and Nonprescription Drugs

All types of drugs, from alcohol and tobacco to antibiotics, can be important environmental influences on prenatal development. In this section, we examine historical and current knowledge about the impact of both prescription and nonprescription drugs on the developing fetus.

Thalidomide, DES, and Other Prescription Drugs. A sedative prescribed in the late 1950s and early 1960s to help alleviate nausea experienced by some women during the early weeks of the first trimester of pregnancy, **thalidomide** caused no ill effects in women who used it (Moore & Persand, 2003a). However, thalidomide was taken early in pregnancy, when the limbs are developing, and thousands of babies were born with major birth defects, such as missing or deformed arms. Once the devastating impact of the drug was recognized, it was quickly withdrawn from the market. Thalidomide has recently been used in treatment of leprosy and other serious diseases, but only after ensuring that no pregnancies can be affected.

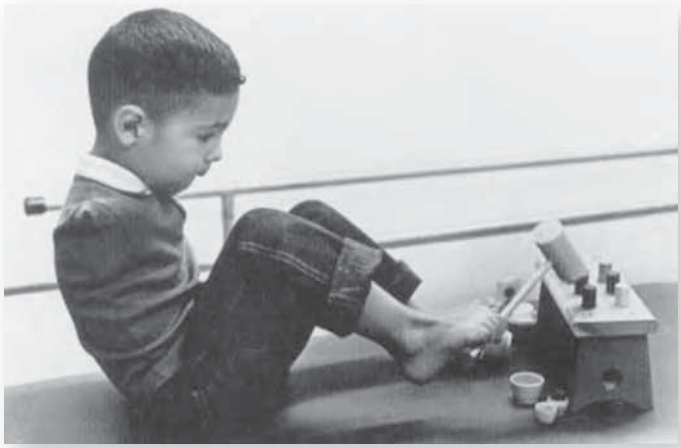
thalidomide A sedative that was once prescribed during the first trimester of pregnancy, to relieve nausea and other symptoms; it resulted in devastating birth defects and has been withdrawn.

Another medicine, **diethylstilbestrol (DES)**, was also prescribed during the 1950s and 1960s for pregnant women, as it was thought to prevent miscarriages. As the daughters of women who took the drug reached adolescence, they showed many fertility-related problems. For instance, they had elevated rates of cancer of the vagina. If they had children of their own, their pregnancies were more prone to difficulties than were the pregnancies of other women. The sons of women who had taken DES during pregnancy had higher incidences of cancer of the testes, and they showed more genital irregularities. Due to these and related problems, DES was also taken off the market (Hammes & Laitman, 2003; Palmer et al., 2001).

diethylstilbestrol (DES) A medicine once prescribed to pregnant women in an effort to prevent miscarriages, found to create reproductive defects, cancer, and other genital irregularities in the offspring; has been taken off the market.

Today, we know that many common drugs can act as teratogens (see Table 2-3). Antibiotics (such as tetracycline and streptomycin), some anticoagulants (such as warfarin), anticonvulsants (such as dilantin), and many other drugs have all been shown to have teratogenic effects if taken at high enough doses. Even aspirin, if taken in large doses, may have harmful effects on fetal development (Moore & Persaud, 2003a). Thus, pregnant women are advised to consult with their health care professional before consuming any drugs, even those commonly available over the counter.

Thalidomide was prescribed to counter nausea experienced by some women early in pregnancy. Although it had no ill effects on the women themselves, it caused birth defects, as seen here. For this reason, thalidomide was taken off the market.



Tobacco. In the United States, a recent study reported that 18% of women smoked during their pregnancies (Martin, Kochanek, Strobino, Guyer, & MacDorman, 2005) (see Figure 2-13). Negative effects of smoking during pregnancy have been reported by many investigators and include fetal growth restriction, low birth weight, and greater risk of infant mortality (Cnattingius, 2004; Ernst, Moolchan, & Robinson, 2001). Mothers

TABLE 2–3
Teratogenic Effects of Common Drugs

DRUG	NORMALLY USED TO TREAT	TERATOGENIC EFFECTS
Accutane	Severe acne	Heart and craniofacial defects (ears, eyes, bones), brain abnormalities.
Flagyl	Vaginal infections	Birth defects reported by some researchers but not by others; effects are not clear.
Ibuprofen	Arthritis, headaches,	Risk of miscarriage may be elevated; fetal heart problems; problems with amniotic fluid.
Lithium	Bipolar disorder	May cause heart defects if taken in first trimester of pregnancy.
Paxil	Depression, anxiety	Related to birth defects in some studies but not in others; effects are not clear.
Prozac	Depression	Related to minor birth defects and premature deliveries in some studies, not others.
Tetracycline	Respiratory infections	May cause problems with calcification of bones and teeth, permanent discoloration of teeth.

SOURCE: Organization of Teratology Information Services (OTIS) Information Sheets. Retrieved May 8, 2007, from http://otispregnancy.org/otis_fact_sheets.asp.

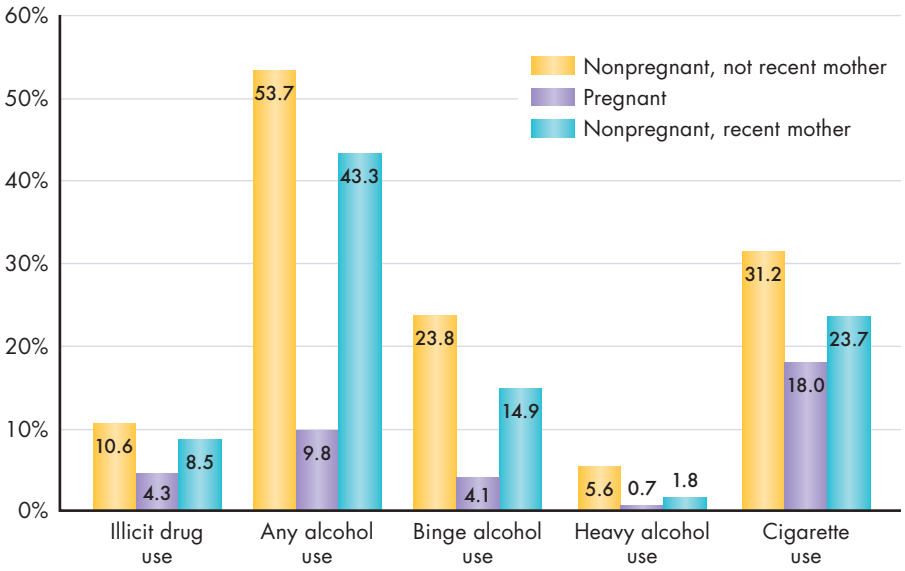


FIGURE 2-13 Substance Use by Pregnant and Nonpregnant Women and Women Recently Giving Birth (United States, 2002–2003) In the United States, pregnant women are much less likely than nonpregnant women to report using tobacco, alcohol, and illicit drugs. Even during pregnancy, however, almost 1 in 5 women report smoking cigarettes, and almost 1 in 10 report drinking alcoholic beverages. Interestingly, rates of substance use among new mothers are higher than those during pregnancy but do not return immediately to prepregnancy levels. *Source:* The National Survey on Drug Use and Health Report: Substance Use During Pregnancy: 2002 and 2003 Update, SAMHSA Office of Applied Studies, 2005. Retrieved May 8, 2007, from http://oas.samhsa.gov/2k5/pregnancy/pregnancy.cfm.

who smoke during pregnancy may also be more likely to have babies with colic (repeated spells of persistent crying during infancy), shorter attention spans, poor memory, and other behavioral and cognitive difficulties in infancy and early childhood (Cornelius, Ryan, Day, Goldschmidt, & Willford, 2001; Wasserman, Liu, Pine, & Graziano, 2001; Sondergaard, Henriksen, Obel, & Wisborg, 2001).

Not only do smokers themselves appear to put their babies at risk, but women who live in homes where others smoke also appear to suffer similar risks. Exposure to environmental tobacco smoke is related to slower fetal growth, low birth weight, and greater risk of infant mortality, as well as to cognitive and attentional problems after birth (Dejin-Karlsson, Hanson, Estergren, Sjoeberg, & Marsal, 1998). The impact of environmental tobacco smoke seems to be especially negative among pregnant women living in poverty (Rauh et al., 2004).

Why does tobacco smoke have so many negative effects? The nicotine in cigarettes makes blood vessels constrict, thereby reducing blood flow to the placenta, reducing the nutrients available to the fetus, and inhibiting fetal growth. Increased concentrations of carbon monoxide associated with smoking may also inhibit growth by reducing the amount of oxygen available to the fetus (Rauh et al., 2004). Maternal smoking during pregnancy may even increase the risk of asthma and diabetes after birth (Jaakkola & Gissler, 2004; Montgomery & Ekbom, 2002).

fetal alcohol spectrum disorders (FASD) An umbrella term that includes all the syndromes and birth defects caused by maternal alcohol consumption during pregnancy (FAS, ARND, and ARBD).

fetal alcohol syndrome (FAS) Disorder caused by maternal alcohol use during pregnancy, the symptoms of which are facial abnormalities, growth deficiencies, and central nervous system problems; those affected usually have low IQ, learning and attention problems.

Alcohol. About half of American women of childbearing age (18–44 years of age) report having used alcohol in the last 30 days, and about 12–13% report frequent drinking (seven or more drinks in a week) or binge drinking (more than five drinks on a single occasion) (Tsai & Floyd, 2004). Because many women are aware of warnings about the damaging effects of alcohol on fetal development, these numbers drop sharply when women become pregnant. Still, 10% of American women report using alcohol during pregnancy, and 4% report binge drinking during pregnancy (SAMHSA Office of Applied Studies, 2005).

When women drink alcoholic beverages or use tobacco during pregnancy, they endanger their unborn infant's health.

What is the impact of alcohol intake on the unborn child? Maternal alcohol use during pregnancy results in many serious problems for the unborn child that are referred to collectively as **fetal alcohol spectrum disorders (FASD)** (Moore & Persaud, 2003a). Of these, the most serious is **fetal alcohol syndrome (FAS),** which is characterized by abnormal facial features, growth deficiencies, and serious central nervous system problems (Sokol, Delaney-Black, & Nordstrom, 2003). Individuals with FAS are small for gestational or chronological age, show facial abnormalities such as small eye openings (see Figure 2-14), poor coordination, hyperactive behavior, learning disabilities, low IQ, and poor reasoning or judgment (National Center on Birth Defects and Developmental Disabilities, 2005). In the United States, the incidence of FAS has been estimated at between 1 and 4 in 1,000 births (Sokol et al., 2003). There are large differences in the prevalence of FAS among ethnic groups. According to one study, African Americans are 5 times more likely and Native Americans are 15 times more likely than other Americans to exhibit FAS (Sokol, et al., 2003).

Under the umbrella term of FASD, those with less severe but nevertheless significant alcohol-related problems were once described as suffering from fetal alcohol effects (FAE). Since 1996, they have been characterized instead

using two differentiated terms (National Center on Birth Defects and Developmental Disabilities, 2005), that focus on the nature of their difficulties. Those with **alcohol-related neurodevelopmental disorder (ARND)** have mental or functional problems associated with prenatal alcohol exposure; for instance, they may have low IQ scores and poor school performance. Those with **alcohol-related birth defects (ARBD)** have physical problems with the heart, kidneys, bones, and/or hearing. In the United States, the incidence of all disorders in the fetal alcohol spectrum (including FAS, ARND, and ARBD) has been estimated at nearly 1% of all births (Sokol et al., 2003). Prenatal alcohol exposure is thus the most common preventable cause of birth defects in the United States today. To learn more about the impact of prenatal alcohol exposure in adolescence and adult life, see the Diversity in Development feature on p. 000.

FIGURE 2-14 Child With Fetal Alcohol Syndrome. This child, who has fetal alcohol syndrome, shows characteristic facial features, such as small eye openings, widely spaced eyes, and narrow upper lip. These facial features are accompanied by mental retardation and problems of attention and judgment. *Source:* "Fetal Alcohol Spectrum Disorder," by R. Sokol, V. Delaney-Black, & B. Nordstrom, 2003, *Journal of the American Medical Association, 290,* pp. 2996–2999 (Fig. 1).

How does alcohol damage the unborn baby? A number of pathways have been identified (Guerrini, Thomson, & Gurling, 2007). If alcohol suppresses neural activity during significant periods of time, development can be disrupted, causing millions of brain cells to die (Farber & Olney, 2003). This massive cell death may be the cause of smaller than expected brain sizes observed in autopsy studies of the brains of children affected by FAS (Chen, Maier, Parnell, & West, 2003). Neural imaging studies have also shown that prenatal alcohol exposure is associated with the size and shape of the *corpus callosum,* the brain structure that allows communication between the two sides of the brain (Bookstein, Streissguth, Sampson, Connor, & Barr, 2002). When compared to unaffected individuals, those with FASD show more variability in the shape of the corpus callosum, and that variability is related to the nature of deficits in functioning. When the corpus callosum is too thick, deficits occur in executive function such as planning and organizing activities, but when it is too thin, deficits occur in motor function such as balance and coordination. Recent studies confirm that brain damage to the corpus callosum from prenatal alcohol use can be observed in young infants (Bookstein et al., 2005). Changes in other brain structures have also been reported, and research in this area is moving rapidly (Spadoni, McGee, Fryer, & Riley, 2007).

Although the devastating impact of maternal alcoholism on the fetus is well documented, the effects of light or moderate alcohol use during pregnancy are not as clear. One study of more than 8,000 mothers and their children found that, although heavy alcohol exposure during prenatal development had negative effects, light and moderate alcohol prenatal exposure had no effect on children's physical development (O'Callaghan, O'Callaghan, Najman, Williams, & Bor, 2003). In another study, however, children whose mothers had ingested any alcohol during pregnancy—even as little as one drink per week—had children whose behavior at 6 years of age was more aggressive and disruptive than that of other children (Sood et al., 2001). Still another study reported that individuals exposed to one or more episodes of binge drinking before birth were more likely to receive a psychiatric diagnosis later in life (Barr et al., 2006). In the face of varied results, the medical advice that most pregnant women hear is to avoid alcohol use altogether.

alcohol-related neurodevelopmental disorders (ARND) Mental or functional problems, such as poor school performance or low IQ, that are associated with prenatal alcohol exposure.

alcohol-related birth defects (ARBD) Physical problems with heart, kidneys, bones, and/or auditory system that are associated with prenatal alcohol exposure.

Cocaine. Devastating effects of heavy prenatal alcohol exposure are well established, but the impact of maternal use of drugs like cocaine and marijuana on prenatal development is much less clear (Moore & Persaud, 2003a). Women who use cocaine and marijuana also often use other substances, such as alcohol and tobacco, and it can be difficult to separate the effects of one substance from those of the others. Also, many aspects of women's lives in addition to substance use may differ between those who do and those who do not use cocaine and

marijuana. A major task for researchers is to understand the impact of cocaine or marijuana use separately from that of other substance use and of life conditions associated with substance abuse (Zuckerman, Frank, & Mayes, 2002).

One group of investigators, led by Lynn Singer, has followed from birth a group of more than 400 children, some of whom were exposed to cocaine during prenatal development and some of whom were not. The researchers reported cognitive problems and evidence of developmental delays among cocaine-exposed children at 2 years of age (Singer et al., 2002). They also reported expressive language difficulties and specific cognitive impairments among the cocaine-exposed children at 4 years of age (Lewis et al., 2004). Other reports of cognitive and social deficits among cocaine-exposed infants and children have also appeared, leading to concern about fetal cocaine exposure (Seifer et al., 2004; Shankaran et al., 2004; Singer et al., 2005).

Other investigators who have studied infants and children have observed no effects that can be attributed specifically to cocaine (Brown, Bakeman, Coles, Platzman, & Lynch, 2004; Frank et al., 2005). After controlling for risks to children's well-being that are attributable to maternal mental health problems, lack of education, and use of other drugs, little if any measurable impact of cocaine use itself could be observed. In light of these findings, it has been suggested that cocaine use may be a marker for other problems rather than a causal factor in itself (Messinger et al., 2004). In other words, cocaine use itself may not put the fetus at risk, but it is likely to signal use of alcohol or other drugs that can be harmful to the fetus. Still, even after controlling for confounding factors, other investigators report that children whose mothers used cocaine during pregnancy are more likely to suffer intellectual problems such as learning disabilities during childhood (Morrow et al., 2006), and the matter remains unsettled.

Marijuana. The most frequently used illicit drug among pregnant women in the United States today is marijuana. In a recent national survey, almost 3% of pregnant women reported having used marijuana during the previous month (Gray, Day, Leech, & Richardson, 2005). One large prospective study of prenatal exposure to marijuana in a mainly middle-class group of mothers and children found that marijuana had no significant effects (Fried, O'Connell, Watkinson, 1992; Fried, Watkinson & Siegel, 1997).

Another study, with a low-income group of families, reported lower reading ability and school performance among 10-year-old children who had been exposed prenatally to marijuana than among those in a similar group that had not been exposed (Goldschmidt, Richardson, Cornelius, & Day, 2004). In this study, 10-year-olds who had been exposed to marijuana before birth also reported more depressive symptoms, even after controlling for many other possible confounding factors (Gray et al., 2005). As shown in Figure 2-15, the heavier the mother's use of marijuana during her pregnancy, the more likely her 10-year-old child was to report many depressive symptoms (Gray et al., 2005).

Recent research also reveals that young adults who were exposed to marijuana before birth show characteristic irregularities in neural activity, especially in cortical areas of the brain, during cognitive tasks (Smith et al., 2004). Research findings are not completely consistent across studies, but there does seem to be cause for concern about the impact of prenatal marijuana exposure. For women who want to safeguard their unborn babies, the safest overall course of action is to avoid using substances such as alcohol, tobacco, cocaine, and marijuana during pregnancy.

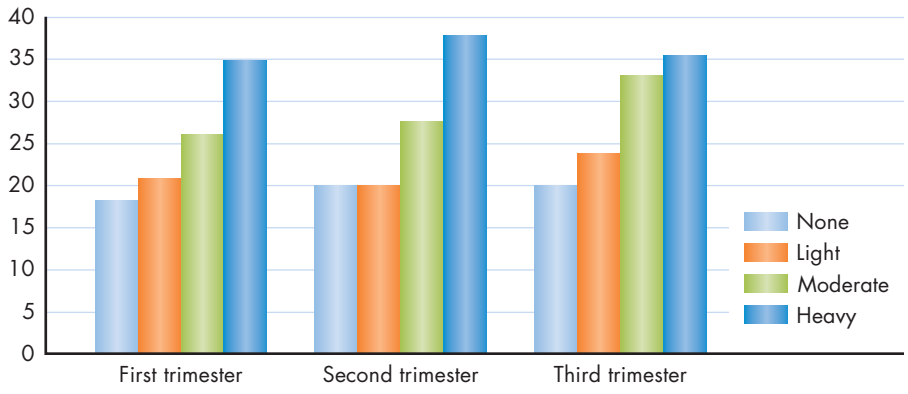


FIGURE 2-15 Mothers' Prenatal Exposure to Marijuana and Children's Reports of Depressive Symptoms at Age 10. When mothers reported moderate or heavy use of marijuana during their pregnancies, their children were more likely to report depressive symptoms at 10 years of age. Moderate use of marijuana was defined as four to five cigarettes per week, and heavy use was defined as seven or more cigarettes per week. After controlling for possible confounding variables such as maternal tobacco use, the effect remained significant. *Source:* "Prenatal Marijuana Exposure: Effect on Child Depressive Symptoms at Ten Years of Age," by K. Gray, N. Day, S. Leech, & G. Richardson, 2005, *Neurotoxicology and Teratology* (Fig. 1).

Effects of Diseases on Prenatal Development

Pregnant women, like anyone else, are vulnerable to viral and bacterial infections. Most viruses are variations of the flu or are common colds and pose no special risk to the developing embryo or fetus. However, some serious viral infections can cause damage.

One of these infections is **rubella,** sometimes called German measles or three-day measles. In the mid-20th century, studies of measles epidemics showed that women who contracted rubella during the first trimester of their pregnancies—when eyes, ears, and central nervous system structures are beginning to form—were more likely than others to have babies with serious birth defects (Moore & Persaud, 2003a).

rubella Three-day measles, sometimes called German measles.

The connection between rubella and birth defects was discovered in the early 1940s, when an Australian opthalmologist named Norman Gregg noticed an increase in infant blindness and other vision problems following an epidemic of rubella in Australia. Collecting information from his colleagues, Gregg noted that, of 78 infants who visited a doctor in Sydney early in 1941 for blindness, 68 had been exposed to rubella before birth (Brown & Susser, 2002). Realizing that the association between infant blindness and exposure to rubella was far greater than what one would expect, Gregg wrote a scientific paper describing his findings (Gregg, 1941).

Following a rubella epidemic in Australia in 1941, eye surgeon **NORMAN GREGG** noted that the association between infant blindness and exposure to rubella was far greater than one would expect.

Gregg was an eye surgeon, and his paper mentioned nothing about any other problems suffered by the infants he studied. Nevertheless, on the very day that Gregg's work was reported in Sydney's popular press, two mothers telephoned him. The mothers did not know each other, but each one described having rubella early in her pregnancy. Neither of their infants was blind, but both were deaf. Following this lead, another researcher studied Australian medical records back to 1879 and found that outbreaks of rubella had regularly been followed, 9 months later, by epidemics of infant deafness (Forrest et al., 2002). A worldwide rubella epidemic in the 1960s provided more information about the impact of the disease. Today it is well known that if mothers are infected with rubella in the first trimester of a pregnancy, their infants are more likely to be born deaf or blind and to suffer many other medical problems. (Forrest et al., 2002).

The development and use of vaccines in widespread immunization programs has all but eliminated the problems caused by rubella in many countries (Makela,

Nuorti, & Peltola, 2002). In the United States, and in many other countries, infants and children are routinely vaccinated against measles, mumps, and rubella, using the MMR vaccination. These immunizations have been described as the most effective health interventions, after clean water and sewage disposal, and they have dramatically reduced the incidence of these diseases (Makela et al., 2002). Vaccination is not universal, however, and outbreaks of these diseases are still possible. Women who are planning a pregnancy may want to check their immunities and, if need be, seek vaccination before becoming pregnant.

acquired immunodeficiency syndrome (AIDS) The autoimmune disease caused by HIV.

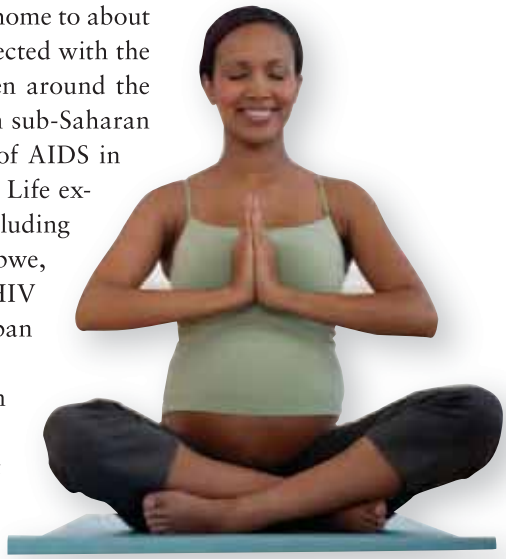
human immunodeficiency virus (HIV) The virus that causes AIDS.

The risks posed by HIV/AIDS have become well known over the past few decades. Left untreated, **AIDS (acquired immunodeficiency syndrome)** attacks the immune system, making the body vulnerable to a range of opportunistic infections and leading ultimately to death. Pregnant women who are infected with HIV (**human immunodeficiency virus,** which causes AIDS) are at risk of passing the virus to their unborn babies. Transmission from mother to child can occur through the mother's bloodstream before birth, through contact with the mother's blood at birth, or through contact with the virus in the mother's milk during breastfeeding. If left untreated in infants, AIDS rapidly overwhelms the body's defenses and usually results in death before the age of 5 (King, 2004).

Fortunately, many treatment options for AIDS are available. In the United States today, HIV-infected pregnant women are generally given combination drug treatments that include zidovudine (ZDV), are advised to give birth via cesarean section to avoid the infant's contact with infected blood during delivery, and are counseled not to breastfeed (King, 2004). When all these conditions are met, mother-to-child transmission rates are very low. A study conducted in the state of New Jersey found that, in 1994, only 13% of HIV-positive pregnant women took ZDV; by 2002, 89% did. As a result, mother-to-child transmission rates in New Jersey fell from 21% in 1993 to less than 2% in 2002 (Sia, Paul, Martin, & Cross, 2004).

A mother who has not received prenatal care may not be aware of her HIV status. If so, HIV infection may be discovered only by routine testing during labor and delivery. In this case, if HIV is discovered, the infant's blood is tested at birth, again at 1 to 2 months of age, and again at 3 to 4 months of age, to rule out possible HIV infection in the child. Should all tests be negative, they are repeated at 12 and 18 months; a negative test at 18 months is considered definitive (King, 2004). If infection with the HIV virus is identified, the baby is started on combination drug treatments. Newer drug regimens are relatively effective in stemming the progression of disease and appear to have few if any serious side effects (Storm et al., 2005). Thus, even for those infected with the HIV virus, life expectancy and quality of life have improved (UNAIDS, 2002).

In the industrialized world, mother-to-child transmission of HIV infection can be minimized through appropriate prenatal care and medical treatment of the mother during pregnancy. In the developing world, however, and especially in Africa, the picture is different (Foster, 2006). Soaring rates of HIV infection among adult women, together with lack of access to expensive treatments, have contributed to high rates of mother-to-child transmission (Mofenson, 1999).



The situation is particularly severe in sub-Saharan Africa, which is home to about 10% of the world's population, but more than 60% of all those infected with the HIV virus (UNAIDS, 2005a). Of the more than 2 million children around the world who are infected with the HIV virus, more than 85% live in sub-Saharan Africa. Of the more than 500,000 children worldwide who died of AIDS in 2004, almost 90% lived in sub-Saharan Africa (UNAIDS, 2005a). Life expectancy has fallen below 40 years in nine African countries, including Zimbabwe, Zambia, Rwanda, Botswana, and Malawi. In Zimbabwe, for instance, the life expectancy of a baby born in 1990, before the HIV epidemic, was 52 years. A baby born in 2003 had an expected life span of 34 years.

As devastating as the direct effects of AIDS on infants and children have been, the impact of AIDS is not limited to pediatric mortality. Most of the victims of AIDS have been adults, and much of the impact of the epidemic on children has been indirect, through the illness and premature death of parents. According to recent estimates, more than 15 million children worldwide have lost at least one parent to AIDS (UNAIDS, 2005a). By the year 2010, it is estimated that almost 10 million African children will have lost both parents to AIDS (Foster, 2006). The orphaning of millions of African children due to AIDS is not itself a teratogenic influence, but its staggering toll on human lives cannot be overlooked.

Principles of Teratogenic Influences

Having examined what is known about possible effects of different teratogens on prenatal development, we turn now to the principles that apply more generally to all teratogenic influences (Moore & Persaud, 2003a). In so doing, we will see how environmental factors ("nurture") affect the unfolding of the genetic blueprint ((nature"). Thus, the principles can be seen as rules for the interactions of nature and nurture during prenatal development.

The first such principle is that timing is crucial. The gravest risk to life is during the first 2 weeks, because if anything goes wrong then, the zygote will die. Once the various systems of the body have begun to form, each one is most vulnerable at the time of its initial growth spurt. It was for this reason that thalidomide, which was taken to counter nausea that is common during the first trimester, affected the growth of arms and legs (which begin their growth spurt at about 25 days after conception).

The second principle is that each teratogen has a characteristic pattern of action. Thalidomide affects the development of the limbs, but not cortical development. Maternal use of tobacco during pregnancy may result in overall restriction of fetal growth, including that of the brain, but it does not affect the formation of arms or legs.

The third principle is that not everyone is affected equally by teratogens. For instance, about 30% of babies born to alcohol-dependent mothers show full-blown FAS; others show only more subtle difficulties associated with FASD, but some show no impairment at all (Barth et al., 2000). Similar results occur for other teratogens. Researchers do not yet know exactly why some babies are affected by teratogenic influences and others are not, but there is clear evidence that supportive postnatal environments are helpful to infant development, as you will see in the Diversity in Development feature on p. 000.

The fourth principle is that susceptibility to teratogens depends in part upon the mother's state. Maternal age is a factor, for example: Rates of birth defects

are higher among mothers under 20 and also among mothers over 40 years of age (Moore & Persaud, 2003a). Diseases, nutritional deficiencies, and other health problems in the mother can also raise levels of susceptibility. Teratogens are least likely to affect the babies of healthy women.

Finally, the fifth principle is that teratogens also show dosage effects (Moore & Persaud, 2003a). Substantial exposure to teratogens is more likely than minor exposure to inflict damage on a developing fetus. For example, heavy maternal marijuana use was associated with a greater likelihood of depressive symptoms among children who were exposed than was lighter usage. Moreover, the dosage levels for mothers and for infants are not the same. As in the case of thalidomide, doses of a teratogen that have little impact on a pregnant woman may nevertheless have dramatic effects on the development of a tiny fetus.

Thus, the course of prenatal development is strongly influenced by the timing, character, and strength of environmental influences. It is also affected by maternal health and well-being. Prenatal development involves the unfolding of a genetic blueprint, but many important facets of the unfolding depend upon the qualities of environments.

Importance of Prenatal Care

In some instances, as when a woman is aware of having been infected with the HIV virus, the need for prenatal care is clear. For other women, the importance of seeking prenatal care early in a pregnancy may not be as obvious. What does adequate prenatal care consist of, and why should women seek it?

Prenatal care usually involves monthly visits to a doctor or other health care provider during the first several months of pregnancy, two visits in the 8th month, and weekly visits in the last month before birth. In addition to answering questions, the health care provider checks the mother's health, tracks her weight, and assesses the health of the embryo or fetus. Any preexisting illnesses or medical conditions will be monitored, and any problems can be addressed before they get out of control. For instance, a woman with diabetes must be monitored closely to protect her health and that of her baby.

toxemia A complication in pregnancy in which swelling of hands and feet is accompanied by a rise in blood pressure; also called preeclampsia.

Toxemia (sometimes called *preeclampsia*) is a complication that emerges for a small number of women toward the end of pregnancy (Moore & Persaud, 2003a). It is especially likely among African Americans and among women who suffer from diabetes or high blood pressure. In toxemia, swelling of the hands and feet is accompanied by a sudden rise in blood pressure. It can usually be treated with bed rest and drugs to lower blood pressure. If left untreated, toxemia can endanger the life of both mother and infant. Prenatal care helps to identify and treat this and other complications of pregnancy so that they do not interfere with the birth of a healthy baby.

Despite the importance of prenatal care, about 16% of American women do not seek it during the first trimester of pregnancy, and about 3% never receive prenatal care at all (Martin et al., 2005). Teenagers and women from ethnic minority or low-income backgrounds are especially unlikely to receive prenatal care early in their pregnancies, and their babies are more likely to be born at low birth weights (Martin et al., 2005). Many reasons may be offered for avoiding care, including lack of health insurance, inability to pay for medical treatment, psychological or family problems, and negative feelings about the pregnancy. In fact, the women who are least likely to seek prenatal care are among those who need it most (Mofenson, 1999). Fortunately, the large majority of women in the United States today receive adequate prenatal care, and most give birth to healthy babies.

LONG-TERM EFFECTS OF PRENATAL ALCOHOL EXPOSURE

What is the impact in adolescence and adulthood?

Prenatal alcohol exposure causes many problems for infants, but what happens to these babies as they grow older? Do youngsters outgrow their early difficulties? Or are these children doomed by the nature of their prenatal experiences to have problems that are essentially incurable? To find out more about the long-term effects of prenatal alcohol exposure, researchers have followed infants and children with FASD into adolescence and adulthood.

In one study, Ann Streissguth and her colleagues at the University of Washington have followed a group of more than 400 individuals whose mothers engaged in alcohol abuse while pregnant and who were later diagnosed with one of the birth defects within the FASD spectrum (Streissguth, Barr, Sampson, & Bookstein, 1994a; Streissguth et al., 1994b; Streissguth et al., 2004). When the youngsters were 14 years of age, on average, and again when they reached 21 years of age, the researchers assessed several adverse life outcomes and also examined some life circumstances that might be protective. The results suggest that there are serious problems, but they also leave room for hope.

The lives of individuals who had been exposed prenatally to alcohol were very difficult. Most of their biological mothers were unable to bring them up. Whether because their mothers had died, been convicted of child abuse, or been declared unfit for another reason, 80% of these youngsters were not reared by their biological mothers (Streissguth et al., 2004). As adolescents, most had been suspended or expelled from school at least once, and most had been in trouble with the law. By midadolescence, 66% had been arrested for and/or convicted of crimes such as shoplifting, burglary, and assault. Half had been in jail or in prison, or confined in a psychiatric or alcohol/drug treatment setting. Almost half (49%) had shown inappropriate sexual behaviors, such as engaging in extreme promiscuity, exposing themselves, or making inappropriate sexual advances. Almost a third of these adolescents (29%) already had alcohol or drug problems (Streissguth et al., 1994b, 2004).

By adulthood, many problems had intensified. Among those over 21 years of age, 87% had been in trouble with the law. Alcohol and/or drug abuse problems were noted in almost half (46%) of the adults. Prenatal alcohol exposure predicted alcohol problems at 21, even after controlling for exposure to nicotine and many other related factors (Baer, Sampson, Barr, Connor, & Streissguth, 2003). Men were more likely than women to experience adverse outcomes, and adverse outcomes were as likely among those without a full-blown FAS diagnosis as they were among those who were diagnosed as suffering from FAS. Overall, the effects of FASD were substantial, and they lasted well into adolescence and adulthood (Baer et al., 2003; Streissguth et al., 1994a, 2004). The results showed clearly that people do not grow out of FASD.

Even in this generally troubled group, however, some people did better than others. Why might this be the case? To find out, Streissguth and her colleagues (2004) studied a number of variables that might have protected babies and children. They found that two factors in particular were linked with more favorable outcomes. Infants and children who lived most of their lives in stable, nurturing homes were much less likely to fall victim to the adverse outcomes described here. By adulthood, it was also clear that those who received an FASD diagnosis early in life were more likely than others to avoid dropping out of school, getting into trouble with the law, and other adverse outcomes (Streissguth et al., 2004).

Despite real damage from their mothers' drinking during pregnancy, children with FASD who are diagnosed early and brought up in stable, supportive homes can grow up to have relatively more successful lives. Even with consistent help and support, these youngsters cannot entirely wipe away the effects of alcohol on their lives. They can, however, grow up to use the skills and capabilities that they do have in constructive ways (Kulp & Kulp, 2000).

ENVIRONMENTAL INFLUENCES ON PRENATAL DEVELOPMENT

QUESTIONS TO CONSIDER

REVIEW What are the main environmental factors that affect prenatal development?

ANALYZE What are some of the challenges to research on the effects of drugs on prenatal development, and how have scientists tried to surmount them?

APPLY If you were a health care provider for a newly pregnant woman, what advice would you give her about diet, exercise, and the use of alcohol, tobacco, and other drugs?

CONNECT How does heavy use of alcohol during pregnancy affect the unborn baby's development during adolescence and early adulthood?

DISCUSS Exposure to tobacco smoke has deleterious effects on prenatal development, whether it comes from maternal smoking or from maternal exposure to environmental tobacco smoke. For this reason, some people argue that smoking should be outlawed in public places. Do you agree or disagree with this position? Explain why you answered as you did.

PUTTING IT ALL TOGETHER

From the instant of conception to the moment of birth, prenatal development is an amazing and fast-moving process. Some of the most important aspects of prenatal development—such as cell differentiation to produce cells that will make up the central nervous system—occur during the first 2 weeks, before the mother usually knows that she is pregnant. Within 2 weeks, the organism has implanted into the wall of the uterus, where it will grow, and the embryonic period has begun. During the ensuing weeks, arms and legs form, and the embryo takes on a recognizably human form. By the end of 8 weeks, at the beginning of the fetal period, the 1-inch-long fetus weighs less than 1 ounce. During the remainder of pregnancy, the fetus grows rapidly, and all of the features of the human infant develop. At 38 weeks, if all goes well, a healthy, full-term baby is born—at about 20 inches in length and weighing 7½ pounds—ready to live in the world outside the womb.

Within the universal timetable of growth, however, there are many individual variations. Some prospective parents undergo genetic counseling in hopes of not handing down inherited difficulties to a baby. Other prospective parents must seek alternative reproductive technologies to help them conceive and, as a result, are more likely to have twins or other multiples. Still others decide on adoption rather than conceiving a child that is biologically related to them. Prenatal devel-

opment is affected by maternal nutrition, stress, disease, and use of substances such as alcohol, tobacco, and other drugs. Still, given how many things could go wrong, it is amazing but true that most babies are born healthy.

KEY TERMS

acquired immunodeficiency syndrome (AIDS)
aggregation
alcohol-related birth defects (ARBD)
alcohol-related neurodevelopmental disorders (ARND)
allele
alternative reproductive technology (ART)
amniocentesis
amniotic fluid
axons
behavior genetics
blastocyst
chorionic villus sampling (CVS)
chromosomes
codominant
concordant
corpus callosum
dendrites
deoxyribonucleic acid (DNA)
diethylstilbestrol (DES)
dizygotic twins
dominant-recessive inheritance
Down syndrome
embryo
fallopian tube
family studies
fetal alcohol spectrum disorders (FASD)
fetal alcohol syndrome (FAS)
fetus
Fragile X syndrome
fraternal twins
gamete
gamete intrafallopian transfer (GIFT)
gene
genetic counseling
gestational age (GA)
hemophilia
heterozygous
homozygous
human chorionic gonadotrophin (hCG)
human immunodeficiency virus (HIV)
identical twins
implantation
in vitro fertilization (IVF)
lanugo
meiosis
mitosis
monozygotic twins
mutation
neural induction
neural plate
neural tube
neurons
nuchal translucency screening
ovulation
ovum
phenylketonuria (PKU)
placenta
proliferation
polygenic inheritance
rubella
sickle cell anemia
sperm
spina bifida
synapse
synaptogenesis
teratogen
thalidomide
toxemia
trimesters
triple-screen blood test
trisomy 21
twin studies
ultrasound
umbilical cord
vernix
villi
X-linked inheritance
zygote
zygote intrafallopian transfer (ZIFT)