

2

Prenatal Development



LEARNING OBJECTIVES

Conception and Genetics

- 2.1** What are the characteristics of the zygote?
 - 2.1a** What are the risks associated with assisted reproductive technology?
- 2.2** In what ways do genes influence development?

Development from Conception to Birth

- 2.3** What happens in each of the stages of prenatal development?
- 2.4** How do male and female fetuses differ?

- 2.5** What behaviors have scientists observed in fetuses?

Problems in Prenatal Development

- 2.6** What are the effects of the major dominant, recessive, and sex-linked diseases?
 - 2.6a** What techniques are used to assess and treat problems in prenatal development?
- 2.7** How do trisomies and other disorders of the autosomes and sex chromosomes affect development?

- 2.8** How do maternal diseases and environmental hazards affect prenatal development?
 - 2.8a** How has technology changed the way that health professionals manage high-risk pregnancies?
- 2.9** What are the potential adverse effects of tobacco, alcohol, and other drugs on prenatal development?
- 2.10** What are the risks associated with legal drugs, maternal diet, age, emotional distress, and poverty?

Before the advent of modern medical technology, cultures devised spiritual practices that were intended to ensure a healthy pregnancy with a happy outcome. For instance, *godh bharan* is a centuries-old Hindu ceremony that honors a woman's first pregnancy. In the seventh month of her pregnancy, the mother-to-be dresses in formal

garments that are given to her by her mother. A relative ties a yellow thread around the pregnant woman's wrist as ceremony attendees pronounce blessings on the unborn child. The purpose of the thread is to provide mother and baby with the spiritual protection required for a complication-free birth.

zygote The single cell formed from separate sperm and egg cells at conception.

ovum The cell released monthly from a woman's ovaries, which, if fertilized, forms the basis for the developing organism.

fallopian tube The tube between the ovary and the uterus down which the ovum travels to the uterus and in which conception usually occurs.

uterus The female organ in which the embryo/fetus develops (popularly referred to as the *womb*).

sperm The cells produced in a man's testes that may fertilize an ovum following intercourse.

chromosomes The structures, arrayed in 23 pairs, within each cell in the body that contain genetic information. Each chromosome is made up of many segments, called genes.

gametes Sperm and ova. These cells, unlike all other cells of the body, contain only 23 chromosomes rather than 23 pairs.

deoxyribonucleic acid (DNA) The chemical of which chromosomes are composed.

Learning Objective 2.1


What are the characteristics of the Zygote?

 [Watch the Video](#) *Period of the Zygote* at [MyDevelopmentLab](#)

As rates of adverse pregnancy outcomes declined in the twentieth century, the *godh bharan* has become more celebratory than protective in nature. Likewise, a uniquely American prenatal institution, the baby shower, has also grown in popularity as pregnancy and childbirth have become safer. And as U.S.-based entertainment media have spread across the world, *godh bharan* ceremonies and others like it have increasingly come to resemble American baby showers.

The growing popularity and homogenization of prenatal celebrations suggest that the technological advances that have reduced maternal and fetal mortality rates have transformed the subjective and social experience of pregnancy from one of fear and dread to one of joy and anticipation. These advances have also been accompanied by innovations that have allowed researchers and parents-to-be to gain insight into prenatal developmental processes that were shrouded in mystery just a few decades ago. As you explore this chapter, you will become acquainted with some of these insights and, we hope, gain a greater appreciation for the amazing process of prenatal development.

Conception and Genetics

The first step in the development of a human being is that moment of *conception*, when two single cells—one from a male and the other from a female—join together to form a new cell called a **zygote**. This event sets in motion powerful genetic forces that will influence the individual over the entire lifespan.  [Watch at MyDevelopmentLab](#)

The Process of Conception

Ordinarily, a woman produces one **ovum** (egg cell) per month from one of her two ovaries. The ovum is released from an ovary roughly midway between two menstrual periods. If it is not fertilized, the ovum travels from the ovary down the **fallopian tube** toward the **uterus**, where it gradually disintegrates and is expelled as part of the next menstrual flow. If a couple has intercourse during the crucial few days when the ovum is in the fallopian tube, one of the millions of **sperm** ejaculated as part of each male orgasm may travel the full distance through the woman's vagina, cervix, and uterus into the fallopian tube and penetrate the ovum. A child is conceived. The zygote then continues on its journey down the fallopian tube and eventually implants itself in the wall of the uterus. (See *Thinking about Research*.)

THE BASIC GENETICS OF CONCEPTION Except in individuals with particular types of genetic abnormality, the nucleus of each cell in the human body contains a set of 46 **chromosomes**, arranged in 23 pairs. These chromosomes include all the genetic information for that individual, governing not only individual characteristics like hair color, height, body shape, temperament, and aspects of intelligence, but also all those characteristics shared by all members of our species, such as patterns of physical development and inborn biases of various kinds.

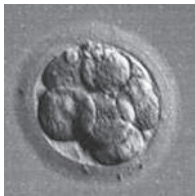
The only cells that do not contain 46 chromosomes are the sperm and the ovum, collectively called **gametes**, or *germ cells*. In the early stages of development, gametes divide as all other cells do (a process called *mitosis*), with each set of 23 chromosome pairs duplicating itself. In the final step of gamete division, however, called *meiosis*, each new cell receives only one chromosome from each original pair. Thus, each gamete has only 23 chromosomes instead of 23 pairs. When a child is conceived, the 23 chromosomes in the ovum and the 23 in the sperm combine to form the 23 pairs that will be part of each cell in the newly developing body.

The chromosomes are composed of long strings of molecules of a chemical called **deoxyribonucleic acid (DNA)**. In an insight for which they won the Nobel Prize in 1953, James Watson and Francis Crick deduced that DNA is in the shape of a double helix, somewhat

Assisted Reproductive Technology

Physicians define *infertility* as the failure to conceive after 12 consecutive months of unprotected intercourse (Mitchell, 2002). To help them conceive and deliver healthy babies, many infertile couples turn to *assisted reproductive techniques (ART)*. One such technique is *in vitro fertilization*. The first step in IVF involves using hormones to stimulate the woman's ovaries to produce multiple eggs. The eggs are then extracted from the ovaries and combined with sperm in a laboratory dish. If conception takes place, one or more embryos—ideally at the six-to-eight-cell stage of development—are transferred to the woman's uterus in the hope that a normal pregnancy will develop. The eggs used in IVF can come from the woman who will carry the child or from a donor. Likewise, the sperm can be from the woman's partner or a donor.

However, IVF is not a highly successful procedure. Less than one-third of such procedures result in a live birth (CDC,



An eight-celled embryo is ideal for an IVF transfer. Pictured here is an embryo on the day of transfer into a woman's uterus.

2009). The older a woman is, the lower the probability that she will be able to have a successful IVF pregnancy. Roughly 40% of 20- to 29-year-old IVF patients achieve a live birth, but only 17% or so of IVF procedures involving women over age 40 are successful (CDC, 2009). Moreover, IVF is expensive and is typically not covered by health insurance (Jain, Harlow, & Hornstein, 2002). As of this writing, surveys show that just 15 states in the United States require that health insurance providers cover IVF treatment (Kaiser Family Foundation, 2010).

Successful IVF carries a different set of risks. The overall rate of birth defects is 30 to 40% higher among IVF newborns than naturally conceived infants (Hansen, Bower, Milne, de Klerk, & Kurincauk, 2005). One key factor influencing this difference is that multiple births are far more frequent among IVF patients, primarily because doctors typically transfer several zygotes at once in order to increase the likelihood of at least one live birth (CDC, 2009). Consequently, 29% of IVF patients deliver twins, and another 2% give birth to triplets (CDC, 2009). Multiple births are associated with premature birth, low birth weight, and birth defects. Thus, specialists in reproductive medicine aim to reduce the frequency of multiple births (Jain, Missmer, & Hornstein, 2004).

Despite the risks associated with IVF, most women who achieve successful pregnancies as a result of this technique

Learning Objective 2.1a

What risks are associated with assisted reproductive technology?

deliver babies who are healthy and normal. Further, studies have shown that children conceived through IVF who are of normal birth weight and who do not have any birth defects develop identically to peers who were conceived naturally (Levy-Shiff et al., 1998; van Balen, 1998). Such findings should give encouragement and hope to those couples who must turn to assisted reproductive technology to fulfill their desire to have children.

CRITICAL ANALYSIS

1. Look back at the discussion of research ethics in Chapter 1. Would it be ethical to use assisted reproductive technology to experimentally manipulate variables associated with conception, such as the timing of conception in relation to the seasons of the year, in order to determine the effects of such variables on development during infancy and childhood? Why or why not?
2. The use of assisted reproductive technology to help postmenopausal women get pregnant is controversial. What are the arguments for and against this practice?

like a twisted ladder. The remarkable feature of this ladder is that the rungs are constructed so that the entire helix can “unzip”; then each half can guide the duplication of the missing part, thus allowing multiplication of cells so that each new cell contains the full set of genetic information.

The string of DNA that makes up each chromosome can be subdivided further into segments called **genes**, each of which controls or influences a particular feature of an organism or a portion of some developmental pattern. A gene controlling or influencing a specific characteristic always appears in the same place (the *locus*; plural is *loci*) on the same chromosome in every individual of the same species. For example, the locus of the gene that determines whether you have type A, B, or O blood is on chromosome 9, and similar genes for blood type are found on chromosome 9 in every other human being. In February, 2001, scientists working on a remarkable group of studies known as the *Human Genome Project (HGP)* announced that they had identified the locus of every human gene (U.S. Department of Energy, 2001) (see Figure 2.1 on page 32). [Watch at MyDevelopmentLab](#)

There are actually two types of chromosomes. In 22 of the chromosome pairs, called *autosomes*, the members of the pair look alike and contain exactly matching genetic loci. The 23rd pair, however, operates differently. The chromosomes of this pair, which determine the child's sex and are therefore called the *sex chromosomes*, come in two varieties, referred to as the X and the Y chromosomes.

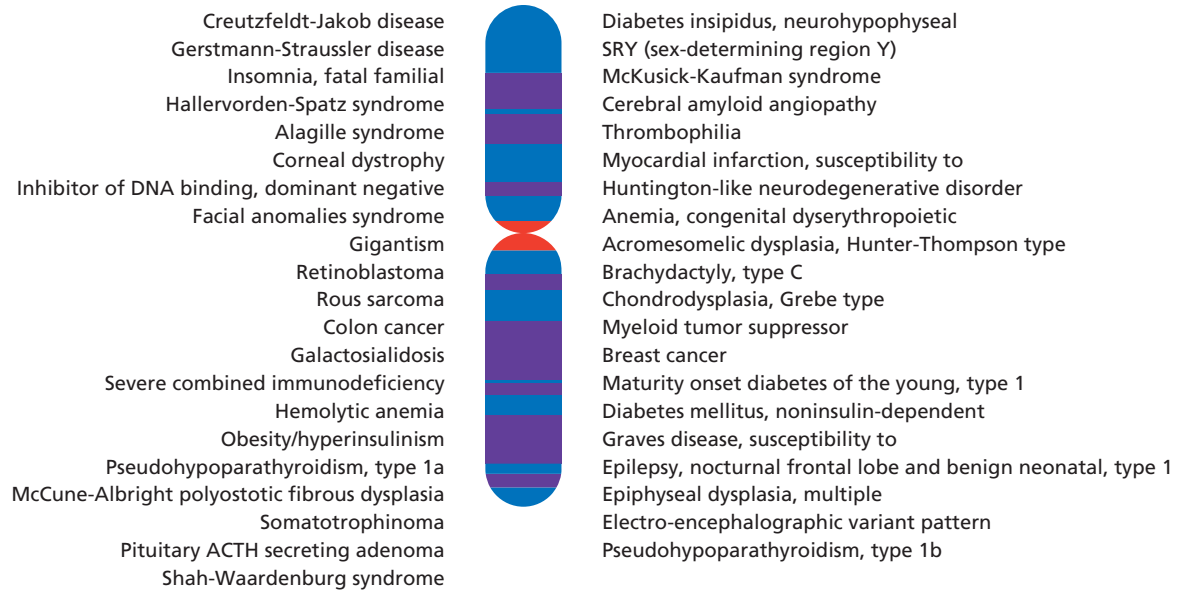
[Watch the Video Junk DNA at MyDevelopmentLab](#)

This photo shows the moment of conception, when a single sperm has pierced the coating around the ovum.



FIGURE 2.1 Human Chromosome #20

This figure represents the genetic “map” of human chromosome #20; the map was produced by scientists associated with the Human Genome Project. Researchers have produced equally specific maps for all 23 human chromosomes. These maps include genes for normal traits (e.g., eye color) as well as for genetic disorders.



Explore the **Concept** *Dominant and Recessive Traits* at **MyDevelopmentLab**

gene A uniquely coded segment of DNA in a chromosome that affects one or more specific body processes or developments.

homozygous Term describing the genetic pattern when the two genes in the pair at any given genetic locus both carry the same instructions.

A normal human female has two X chromosomes in this 23rd pair (an XX pattern), while a normal human male has one X and one Y chromosome (an XY pattern). The X chromosome is considerably larger than the Y chromosome and contains many genetic loci not found on the Y.

Note that the sex of the child is determined by the sex chromosome it receives from the sperm. Because a woman has only X chromosomes, every ovum carries an X. But because a man has both X and Y chromosomes, when the father’s gametes divide, half the sperm will carry an X, and half a Y. If the sperm that fertilizes the ovum carries an X, then the child inherits an XX pattern and is a girl. If the fertilizing sperm carries a Y, then the combination is XY, and the child is a boy.

Geneticists have pushed this understanding a step further, discovering that only one very small section of the Y chromosome actually determines maleness—a segment referred to as SRY (sex-determining region of the Y chromosome). Sometime between 4 and 8 weeks after conception, SRY genetic codes signal the male embryo’s body to begin secreting hormones called *androgens*. These hormones cause male genitalia to develop. If androgens are not present, female genitalia develop, no matter what the embryo’s chromosomal status is.

Learning Objective 2.2 -----> **Genotypes, Phenotypes, and Patterns of Genetic Inheritance**

In what ways do genes influence development?

heterozygous Term describing the genetic pattern when the two genes in the pair at any given genetic locus carry different instructions, such as a gene for blue eyes from one parent and a gene for brown eyes from the other parent.

genotype The pattern of characteristics and developmental sequences mapped in the genes of any specific individual, which will be modified by individual experience into the phenotype.

phenotype The expression of a particular set of genetic information in a specific environment; the observable result of the joint operation of genetic and environmental influences.

When the 23 chromosomes from the father and the 23 from the mother come together at conception, they provide a mix of “instructions.” When the two sets of instructions are the same at any given locus (such as genes for type A blood from both parents), geneticists say that the genetic pattern is **homozygous**. When the two sets of instructions differ, the genetic pattern is said to be **heterozygous**, such as a gene pair that includes a gene for type A blood from one parent and a gene for type O blood from the other. How are these differences resolved? Geneticists are still a long way from having a complete answer to this question, but some patterns are very clear. Table 2.1 gives a few examples of physical characteristics that follow the rules you’ll be reading about in this section. **Explore** at **MyDevelopmentLab**

GENOTYPES AND PHENOTYPES First, it’s important to know that geneticists (and psychologists) make an important distinction between the **genotype**, which is the specific set of “instructions” contained in a given individual’s genes, and the **phenotype**, which is the set of actual observed characteristics of the individual. The phenotype is a product of three things: the genotype, environmental influences from the time of conception onward, and the interaction between the two. A child might have a genotype associated with high IQ, but if his mother drinks too much alcohol during the pregnancy, there may be damage to his nervous

Table 2.1

NORMAL TRAITS

Dominant	Recessive	Polygenic
Freckles	Flat feet	Height
Coarse hair	Thin lips	Body type
Dimples	Rh negative blood	Eye color
Curly hair	Fine hair	Skin color
Nearsightedness	Red hair	Personality
Broad lips	Blond hair	
Rh positive blood	Type O blood	
Types A and B blood		
Dark hair		

Source: Tortora and Grabowski, 1993.

system, resulting in mild retardation. Another child might have a genotype including the mix of genes that contribute to a “difficult” temperament, but if his parents are particularly sensitive and thoughtful, he may learn other ways to handle himself.

DOMINANT AND RECESSIVE GENES Whenever a given trait is governed by a single gene, as is true of some 1,000 individual physical characteristics, inheritance patterns follow well-understood rules. Figure 2.2 offers a schematic look at how the **dominant/recessive pattern of inheritance** works, using the genes for curly and straight hair as an example. Because straight hair is controlled by a recessive gene, an individual must inherit the straight-hair gene from both parents in order for her phenotype to include straight hair. A child who

dominant/recessive pattern of inheritance The pattern of genetic transmission in which a single dominant gene influences a person’s phenotype, but an individual must have two recessive genes to express a recessive trait.

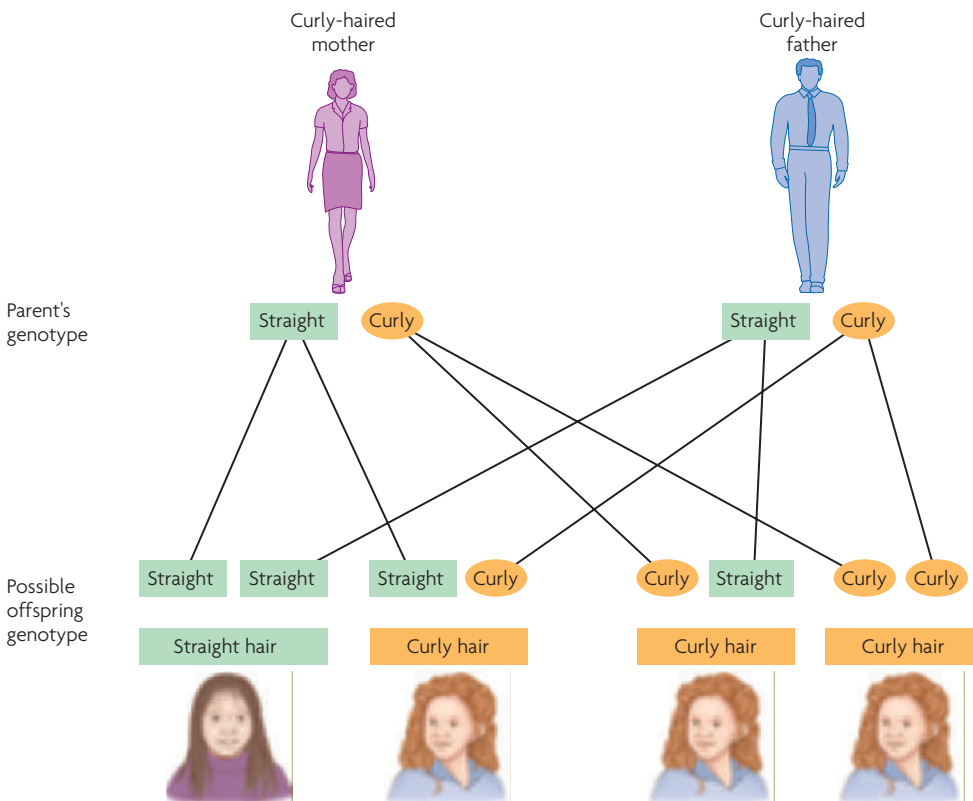


FIGURE 2.2 The Genetics of Hair Type Examples of how the genes for curly and straight hair pass from parents to children.

polygenic pattern of inheritance

Any pattern of genetic transmission in which multiple genes contribute to the outcome, such as is presumed to occur for complex traits such as intelligence or temperament.

multifactorial pattern of inheritance

The pattern of genetic transmission in which both genes and environment influence the phenotype.

receives only one gene for straight hair will have curly hair, but she may pass the straight-hair gene on to her offspring.

Since curly hair is controlled by a dominant gene, a child who inherits a gene for curly hair from either parent will actually have curly hair. However, her hair may not be as curly as that of the parent from whom she received the gene. Genes vary in *expressivity*, a term that simply means that the same gene may be expressed differently in two individuals who have it.

The dominant/recessive pattern doesn't always work in such a straightforward way. For example, humans carry genes for three kinds of blood type: A (dominant), B (dominant), and O (recessive). Each individual has only two of these genes. If one gene is A and the other is O, then the individual's blood type is A. As you know, an individual must inherit two recessive O genes to have type O blood. But what happens if an individual receives an A and a B gene? Since both are dominant, the individual has type AB blood, and the genes are said to be *co-dominant*.

POLYGENIC AND MULTIFACTORIAL INHERITANCE In the **polygenic pattern of inheritance**, many genes influence the phenotype. There are many polygenic traits in which the dominant/recessive pattern is also at work. For example, children get several genes for skin color from each parent (Barsh, 2003). Dark skin is dominant over light skin, but blended skin colors are possible. Thus, when one parent has dark skin and the other has fair skin, their children most likely will have skin that is somewhere between the two. The dark-skinned parent's dominant genes will insure that the children are darker than the fair parent, but the fair-skinned parent's genes will prevent the children from having skin as dark as that of the dark-skinned parent.

Eye color is another polygenic trait with a dominant/recessive pattern (Liu, 2010). Scientists don't know for sure how many genes influence eye color. They do know, however, that the genes don't cause specific colors. Instead, they cause the colored part of the eye to be dark or light. Dark colors (black, brown, hazel, and green) are dominant over light colors (blue and gray). However, blended colors are also possible. People whose chromosomes carry a combination of genes for green, blue, and gray eyes can have phenotypes that include blue-gray, blue-green, or gray-green eye color. Likewise, genes that cause different shades of brown can combine their effects to produce variations in children's phenotypes that are different from those of their brown-eyed parents.

Many genes influence height, and there is no dominant/recessive pattern of inheritance among them. Most geneticists think each height gene has a small influence over a child's size (Tanner, 1990) and that a child's height will be the sum of the effects of all of these genes.

Height, like most polygenic traits, is also a result of a **multifactorial pattern of inheritance**—that is, it is affected by both genes and environment. For this reason, doctors use a child's height as a measure of his general health (Sulkes, 1998; Tanner, 1990). If a child is ill, poorly nourished, or emotionally neglected, he will be smaller than others his age. Thus, when a child is shorter than 97% of his age mates, doctors try to determine if he is short because of his genes or because something is causing him to grow poorly (Tanner, 1990).

GENOMIC IMPRINTING AND MITOCHONDRIAL INHERITANCE Scientists have also discovered a process called *genomic imprinting* in which some genes are biochemically marked at the time ova and sperm develop in the bodies of potential mothers and fathers. Research into the significance of genomic imprinting indicates that some genes are harmful only if they come from the father and others cause disorders only if they originated from the mother (Jirtle & Weidman, 2007). It could be that genomic imprints “turn on” an atypical developmental process or “turn off” a normal one. Alternatively, the imprints may evoke responses in other genes that set the process of atypical development in motion. Some studies suggest that genomic imprints may be particularly important in diseases that appear later in life, including several kinds of cancer, Type II diabetes, and heart disease (Jirtle & Weidman, 2007).

In *mitochondrial inheritance*, children inherit genes located outside the nucleus of the zygote. These genes are carried in structures called *mitochondria* that are found in the fluid that surrounds the nucleus of the ovum before it is fertilized. Consequently, mitochondrial

genes are passed only from mother to child. Geneticists have learned that several serious disorders, including some types of blindness, are transmitted in this way. In most such cases, the mother herself is unaffected by the harmful genes (Chinnery, 2006).

TWINS AND SIBLINGS In most cases, babies are conceived and born one at a time. However, 3 out of every 100 births in the United States today are multiple births (Martin et al., 2010). This number has risen dramatically in recent decades, in large part because widely prescribed new medications given to infertile women frequently stimulate multiple ovulation. The great majority of multiple births in the United States are twins; triplets or higher multiples occur only about once in every 1,000 births (Martin et al., 2010).

Roughly two-thirds of twins are **fraternal twins**. Fraternal twins develop when two ova have been produced and both have been fertilized, each by a separate sperm. Such twins, also called **dizygotic twins**, are no more alike genetically than any other pair of siblings and may not even be of the same sex. The remaining one-third of twins are **identical twins** (also called **monozygotic twins**). In such cases, a single fertilized ovum apparently initially divides in the normal way, but then for unknown reasons separates into two parts, with each part developing into a separate individual. Because identical twins develop from precisely the same original fertilized ovum, they have identical genetic heritages. You'll remember from Chapter 1 that comparison of the degree of similarity of these two types of twins is a major research strategy in the important field of behavior genetics.

Development from Conception to Birth

Little was known about prenatal development until fairly recently. Consequently, there was a lot of confusion about the connection between the experiences of the pregnant woman and the intrauterine development and experiences of the child. For example, pregnancy has traditionally been divided into three *trimesters* of equal length, so doctors as well as expectant couples tended to think of prenatal development as consisting of three analogous stages. Of course, technology has changed all this. Scientists have learned that there are indeed three stages of prenatal development, but the developing child has already reached the *third* stage before the mother ends her first trimester.

The Stages of Prenatal Development

The period of gestation of the human infant is 38 weeks (about 265 days). These 38 weeks are divided into three stages of unequal length, identified by specific changes within the developing organism (see Table 2.2 on page 36).

THE GERMINAL STAGE The **germinal stage** begins at conception and ends when the zygote is implanted in the wall of the uterus. After conception, the zygote spends roughly a week floating down the fallopian tube to the uterus. Cell division begins 24 to 36 hours after conception; within 2 to 3 days, there are several dozen cells and the whole mass is about the size of the head of a pin. Approximately 4 days after conception, the mass of cells, now called a **blastocyst**, begins to subdivide, forming a sphere with two layers of cells around a hollow center. The outermost layer will form the various structures that will support the developing organism, while the inner layer will form the **embryo** itself. When it touches the wall of the uterus, the outer cell layer of the blastocyst breaks down at the point of contact. Small tendrils develop and attach the cell mass to the uterine wall, a process called *implantation*. When implantation is complete (normally 10 days to 2 weeks after conception), the blastocyst has perhaps 150 cells (Tanner, 1990). The sequence is illustrated schematically in Figure 2.3.

fraternal (dizygotic) twins Children carried in the same pregnancy but who develop from two separately fertilized ova. They are no more alike genetically than other pairs of siblings.

identical (monozygotic) twins Children carried in the same pregnancy who develop from the same fertilized ovum. They are genetic clones of each other.

germinal stage The first stage of prenatal development, beginning at conception and ending at implantation of the zygote in the uterus (approximately the first 2 weeks).

blastocyst Name for the mass of cells from roughly 4 to 10 days after fertilization.

embryo The name given to the developing organism during the period of prenatal development between about 2 weeks and 8 weeks after conception, beginning with implantation of the blastocyst in the uterine wall.

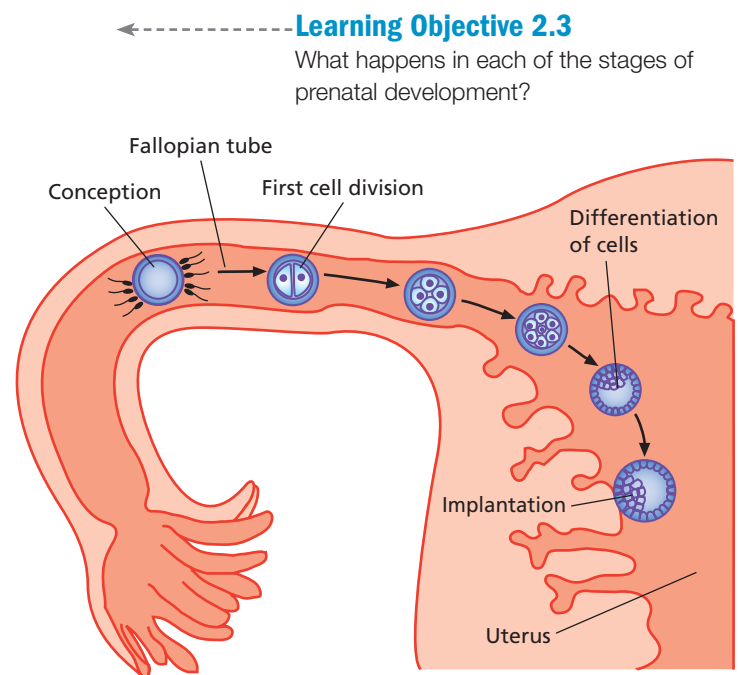


FIGURE 2.3 Migration of the Zygote
This schematic shows the normal progression of development for the first 10 days of gestation, from conception to implantation.

**Table
2.2**

MILESTONES IN PRENATAL DEVELOPMENT

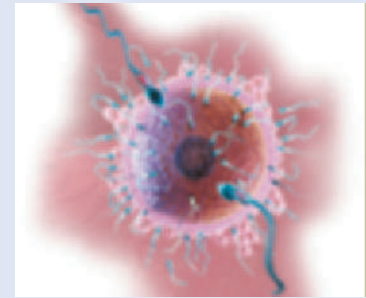
Stage/Time Frame

Milestones

GERMINAL

Day 1:
Conception

Sperm and ovum unite, forming a zygote containing genetic instructions for the development of a new and unique human being.



Sperm and egg

Days 10 to 14:
Implantation

The zygote burrows into the lining of the uterus. Specialized cells that will become the placenta, umbilical cord, and embryo are already formed.

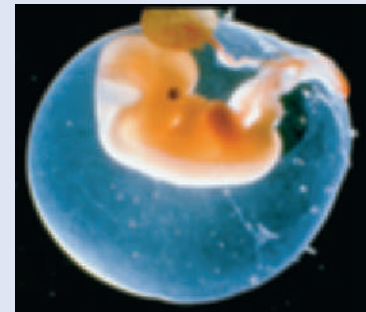


Zygote

EMBRYONIC

Weeks 3 to 8:
Organogenesis

All of the embryo's organ systems form during the 6-week period following implantation.



6-week fetus

Weeks 9 to 38:
Growth and
Organ
Refinement

The fetus grows from 1 inch long and 1/4 ounce to a length of about 20 inches and a weight of 7–9 pounds. By week 12, most fetuses can be identified as male or female. Changes in the brain and lungs make viability possible by week 24; optimum development requires an additional 14 to 16 weeks in the womb. Most neurons form by week 28, and connections among them begin to develop shortly thereafter. In the last 8 weeks, the fetus can hear and smell, is sensitive to touch, and responds to light. Learning is also possible.

FETAL



12-week fetus



14-week fetus



Well-developed fetus (age not given)

Sources: Kliegman, 1998; Tortora & Grabowski, 1993.

THE EMBRYONIC STAGE The **embryonic stage** begins when implantation is complete. The blastocyst's outer layer of cells specializes into two membranes, each of which forms critical support structures. The inner membrane becomes a sac or bag called the **amnion**, filled with liquid (amniotic fluid) in which the embryo floats. The outer membrane, called the **chorion**, develops into two organs, the **placenta** and the **umbilical cord**. The placenta, which is fully developed by about 4 weeks of gestation, is a platelike mass of cells that lies against the wall of the uterus. It serves as the liver and kidneys for the embryo until the embryo's own organs begin to function. It also provides the embryo with oxygen and removes carbon dioxide from its blood.

Connected to the embryo's circulatory system via the umbilical cord, the placenta also serves as a critical filter between the mother's circulatory system and the embryo's. Nutrients such as oxygen, proteins, sugars, and vitamins from the maternal blood can pass through to the embryo or fetus; digestive wastes and carbon dioxide from the infant's blood pass back through to the mother, whose own body can eliminate them. At the same time, many (but not all) harmful substances, such as viruses or the mother's hormones, are filtered out because they are too large to pass through the various membranes in the placenta. Most drugs and anesthetics, however, do pass through the placenta, as do some disease organisms.

While the support structures are developing, the mass of cells that will form the embryo itself is differentiating further into several types of cells that form the rudiments of skin, sense receptors, nerve cells, muscles, circulatory system, and internal organs—a process called *organogenesis*.

A heartbeat can be detected roughly 4 weeks after conception; the beginnings of lungs and limbs are also apparent at this time. By the end of the embryonic period, rudimentary fingers and toes, eyes, eyelids, nose, mouth, and external ears are all present, as are the basic parts of the nervous system; these and other developmental milestones are summarized in Table 2.2. The embryonic stage ends when organogenesis is complete and bone cells begin to form, typically about 8 weeks after conception.

THE FETAL STAGE Once organogenesis is complete, the developing organism is known as a **fetus** and the final phase of prenatal development, the **fetal stage**, begins (lasting from approximately 8 weeks until birth). From a weight of about 1/4 ounce and a length of 1 inch, the fetus grows to a baby weighing about 7 pounds and having a length of about 20 inches, who is ready to be born. In addition, this stage involves refinements of the organ systems that are essential to life outside the womb (see Table 2.3).

embryonic stage The second stage of prenatal development, from week 2 through week 8, when the embryo's organs form.

amnion The sac, or bag, filled with liquid in which the embryo/fetus floats during prenatal life.

chorion The outer layer of cells of the blastocyst during prenatal development, from which both the placenta and the umbilical cord are formed.

placenta An organ that develops between the fetus and the wall of the uterus during gestation.

umbilical cord The cord connecting the embryo/fetus to the placenta, containing two arteries and one vein.

fetus The name given to the developing organism from about 8 weeks after conception until birth.

fetal stage The third stage of prenatal development, from week 8 to birth, when growth and organ refinement take place.

Table 2.3

MILESTONES OF THE FETAL STAGE

Period	What Develops
Weeks 9–12	Fingerprints; grasping reflex; facial expressions; swallowing and rhythmic “breathing” of amniotic fluid; urination; genitalia appear; alternating periods of physical activity and rest
Weeks 13–16	Hair follicles; responses to mother’s voice and loud noises; 8–10 inches long; weighs 6 ounces
Weeks 17–20	Fetal movements felt by mother; heartbeat detectable with stethoscope; lanugo (hair) covers body; eyes respond to light introduced into the womb; eyebrows; fingernails; 12 inches long
Weeks 21–24	Vernix (oily substance) protects skin; lungs produce surfactant (vital to respiratory function); viability becomes possible, although most born now do not survive
Weeks 25–28	Recognition of mother’s voice; regular periods of rest and activity; 14–15 inches long; weighs 2 pounds; good chance of survival if born now
Weeks 29–32	Very rapid growth; antibodies acquired from mother; fat deposited under skin; 16–17 inches long; weighs 4 pounds; excellent chance of survival if delivered now
Weeks 33–36	Movement to head-down position for birth; lungs mature; 18 inches long; weighs 5–6 pounds; virtually 100% chance of survival if delivered
Weeks 37+	Full-term status; 19–21 inches long; weighs 6–9 pounds

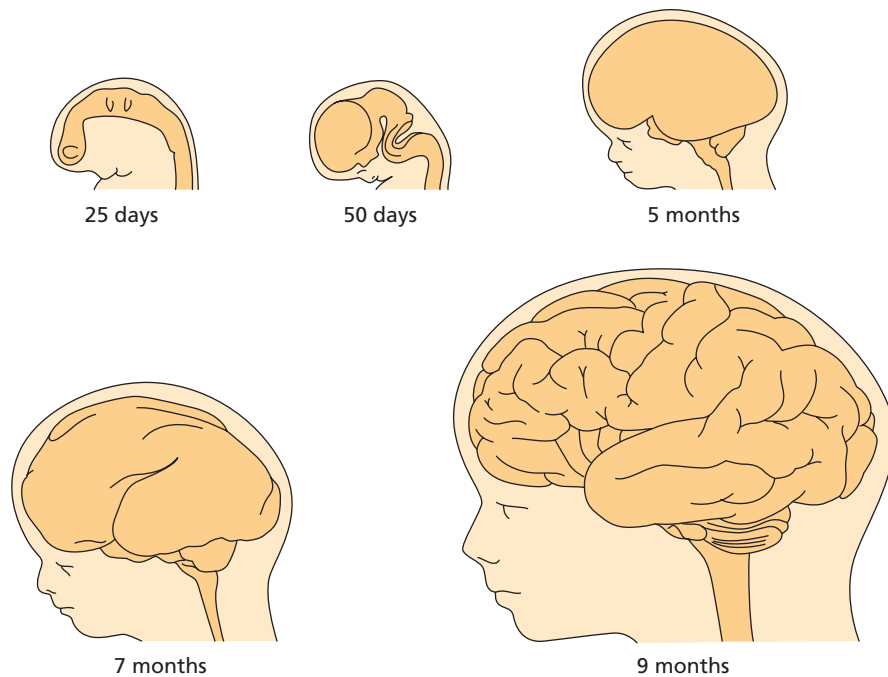


FIGURE 2.4 The Prenatal Brain

Stages in the prenatal development of the brain, beginning with the neural tube in the embryonic period. [Explore at MyDevelopmentLab](#)

(Source: From drawings by Tom Prentiss in "The Development of the Brain" by W. Maxwell Cowan in *Scientific American*, September 1979, pp. 112–114+. Adapted by permission of Nelson H. Prentiss.)

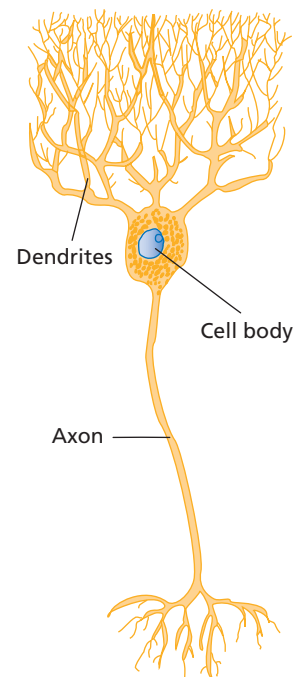


FIGURE 2.5 Structure of the Neuron

The structure of a single developed neuron. The cell bodies are the first to be developed, primarily between 10 and 20 weeks of gestation. Axons and dendrites begin to develop in the last 2 months of gestation and continue to increase in size and complexity for several years after birth.

[Explore the Concept](#) *Dendritic Spreading: Forming Interconnections in the Brain at MyDevelopmentLab*

viability The fetus's capacity for survival outside the womb.

neurons The cells in the nervous system that are responsible for transmission and reception of nerve impulses.

neuronal proliferation The rapid development of neurons between the 10th and 18th week of gestation.

neuronal migration The movement of neurons to specialized regions of the brain.

cell body The part of the cell that contains the nucleus and in which all the cell's vital functions are carried out.

synapses Tiny spaces across which neural impulses flow from one neuron to the next.

axons Tail-like extensions of neurons.

dendrites Branchlike protrusions from the cell bodies of neurons.

By the end of week 23, a small number of babies have attained **viability**, the ability to live outside the womb (Moore & Persaud, 1993). However, most babies born this early die, and those who do survive struggle for many months. Remaining in the womb just 1 week longer, until the end of week 24, greatly increases a baby's chances of survival. The extra week probably allows time for lung function to become more efficient. In addition, most brain structures are completely developed by the end of the 24th week. For these reasons, most experts accept 24 weeks as the average age of viability.

THE FETAL BRAIN As you learned earlier, the foundational structures of all of the body's organ systems are formed during the embryonic stage. Yet most of the formation and fine-tuning of the brain take place during the fetal stage (see Figure 2.4). **Neurons**, the specialized cells of the nervous system, actually begin developing during the embryonic stage, in week 3. But the pace of neural formation picks up dramatically between the 10th and 18th weeks, a process known as **neuronal proliferation**.

Between the 13th and 21st weeks, **neuronal migration** takes place, a process in which newly formed neurons migrate to the specialized regions of the brain where they will reside for the rest of the individual's life (Johnson, M. 2011). While migrating, neurons consist only of **cell bodies**, the part of the cell that contains the nucleus and in which all the cell's vital functions are carried out (see Figure 2.5). Once they have reached their final destinations in the fetal brain, the neurons begin to develop connections. These connections, called **synapses**, are tiny spaces between neurons across which neural impulses travel from one neuron to the next. Several changes in fetal behavior signal that the process of synapse formation is under way. For instance, the fetus exhibits alternating periods of activity and rest and begins to yawn (Walusinski, Kurjak, Andonotopo, & Azumendi, 2005; see Figure 2.6). When observed, these changes tell physicians that fetal brain development is proceeding normally.

Synapse formation requires the growth of two neuronal structures. **Axons** are tail-like extensions that can grow to be several feet in length. **Dendrites** are tentaclelike branches that



FIGURE 2.6 Fetal Yawning

Fetal yawning appears between the 10th and 15th week. Its presence signals the beginning of sleep stages in the fetal brain.

(Source: O. Walusinski et al., “Fetal yawning: A behavior’s birth with 4D US revealed,” *The Ultrasound Review of Obstetrics & Gynecology*, 5 (2005), 210–217. Reprinted with permission.)

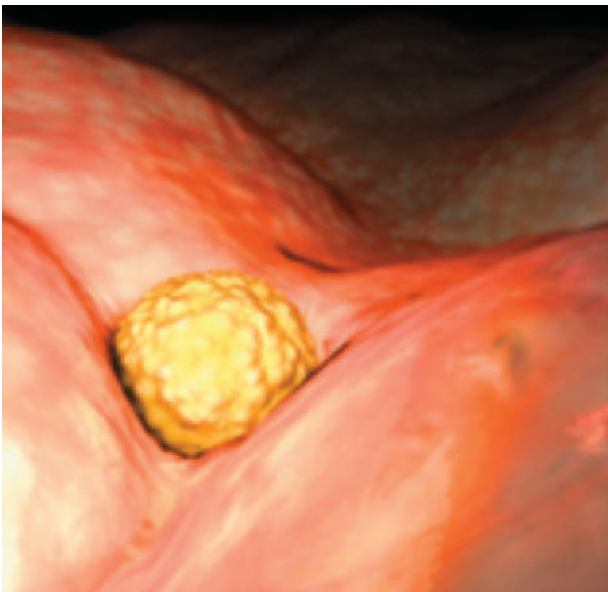


FIGURE 2.7 A Normal Third-Trimester Fetal Brain

Glial cells that develop during the last few months of prenatal development hold neurons together and give form and structure to the fetal brain.

(Source: S. Brown, J. Estroff, and C. Barnewolf, “Fetal MRI,” *Applied Radiology*, 33 (2004): 9–25. Copyright © 2004 by Applied Radiology/Anderson Publishing. Reprinted with permission.)

extend out from the cell body (see Figure 2.5). Dendrite development is thought to be highly sensitive to adverse environmental influences such as maternal malnutrition and defects in placental functioning (Dieni & Rees, 2003).

Simultaneously with neuronal migration, **glial cells** begin to develop. These cells are the “glue” that hold the neurons together to give shape to the brain’s major structures. As glial cells develop, the brain begins to assume a more mature appearance, one that can be observed using magnetic resonance imaging (MRI) and other modern technologies that you will read more about later in the chapter (see Figure 2.7).

glial cells The “glue” that holds neurons together to give form to the structures of the nervous system.

Learning Objective 2.4

How do male and female fetuses differ?

Sex Differences in Prenatal Development

Because nearly all prenatal development is controlled by maturational sequences that are the same for all members of our species—male and female alike—there aren't very many sex differences in prenatal development. Still, there are a few, and they set the stage for some of the physical differences that are evident at later ages.

Sometime between 4 and 8 weeks after conception, the male embryo begins to secrete androgens, including the male hormone testosterone from the rudimentary testes. If this hormone is not secreted or is secreted in inadequate amounts, the embryo will be “demasculinized,” even to the extent of developing female genitalia. Female embryos do not appear to secrete any equivalent hormone prenatally. However, the accidental presence of male hormone at the critical time (such as from some drug the mother may take, or from a genetic disorder called *congenital adrenal hyperplasia*) acts to “defeminize,” or to masculinize, the female fetus, sometimes resulting in malelike genitalia and frequently resulting in masculinization of later behavior, such as more rough-and-tumble play (Cohen-Bendahan, van de Beek, & Berenbaum, 2005). Several hormones that affect the prenatal development of genitalia (particularly testosterone in males) also appear to affect the pattern of brain development, resulting in subtle brain differences between males and females and affecting patterns of growth-hormone secretions in adolescence, levels of physical aggression, and the relative dominance of the right and left hemispheres of the brain (Ruble & Martin, 1998; Todd et al., 1995). Although early research has raised some very intriguing questions, the evidence in this area is still fairly sketchy; it is clear that whatever role such prenatal hormones play in brain architecture and functioning is highly complex (Baron-Cohen, Lutchmaya, & Knickmeyer, 2006).

Girls progress a bit faster in some aspects of prenatal development, particularly skeletal development. They are 4 to 6 weeks ahead in bone development at birth (Tanner, 1990). Despite the more rapid development of girls, boys are slightly heavier and longer at birth, with more muscle tissue and fewer fat cells. For example, in the United States, the average birth length and weight for boys is 20 inches and 7 pounds 11 ounces, compared with slightly more than 19 inches and 7 pounds 3 ounces for girls (Levine, 2011).

Boys are considerably more vulnerable to all kinds of prenatal problems. Many more boys than girls are conceived—on the order of about 120 to 150 male embryos for every 100 female ones—but more of the males are spontaneously aborted. At birth, there are about 105 boys for every 100 girls. Boys are also more likely to experience injuries at birth (perhaps because they are larger), and they have more congenital malformations (Zaslow & Hayes, 1986). Male fetuses also appear to be more sensitive to variables such as cocaine which may negatively affect prenatal development (Levine et al., 2008). The striking sex difference in vulnerability to certain problems seems to persist throughout the lifespan. Males have shorter life expectancy, higher rates of behavior problems, more learning disabilities, and usually more negative responses to stressors such as maternal insensitivity (Warren & Simmens, 2005). One possible explanation for at least some of this sex difference may lie in the basic genetic difference. Because many genes for problems or disorders are recessive and are carried on the X chromosome, the XX combination affords a girl more protection against “bad” recessive genes that may be carried on one X chromosome; the dominant gene on the corresponding X chromosome would be expressed instead. Because boys have only one X chromosome, such a recessive gene is much more likely to be expressed phenotypically in a boy.

Early studies suggest that male fetuses, on average, are more physically active than females (DiPietro, Hodgson, Costigan, Hilton, & Johnson, 1996; DiPietro, Hodgson, Costigan, & Johnson, 1996). However, other studies have shown that a sex difference in wakefulness is responsible for these findings (de Medina, Visser, Huizink, Buitelaar, & Mulder, 2003). That is, male fetuses are awake more often than female fetuses are and, as a result, appear to be more active. When activity levels are measured within periods of wakefulness, male and female fetuses are equally active. By contrast, research showing that female fetuses are more responsive to external stimuli does seem to indicate that there is a real sex difference in responsiveness (Groome et al., 1999).

Prenatal Behavior

In recent years, techniques such as ultrasound imaging have provided researchers with a great deal of information about fetal behavior. Some researchers suggest that establishing norms for fetal behavior would help health-care providers better assess fetal health and predict postnatal problems (DiPietro et al., 2010; Nijhuis, 2003). Thus, in recent years, the number of research studies examining fetal behavior has increased significantly. These studies have produced rather remarkable findings, some of which are shown in Figure 2.8.

For one thing, researchers have learned that the fetus responds to sounds with heart rate changes, head turns, and body movements as early as the 25th week of gestation (Joseph, 2000). Researchers have also shown that it is possible to observe fetal brain activity by scanning the mother's abdomen with the same kinds of techniques used to examine brain function postnatally—techniques such as magnetic resonance imaging (MRI). Studies using these techniques have found that late-term fetuses exhibit neurological as well as behavioral responses to sounds (Moore et al., 2001).

Research also suggests that the fetus can distinguish between familiar and novel stimuli by the 32nd or 33rd week (Sandman, Wadhwa, Hetrick, Porto, & Peeke, 1997). In one classic study, pregnant women recited a short children's rhyme out loud each day between weeks 33 and 37. In week 38, researchers played a recording of either the same rhyme the mother had been reciting or another rhyme and measured the fetal heart rate. Fetal heart rates dropped during the playing of the familiar rhyme, but not during the unfamiliar rhyme, suggesting that the fetuses had learned the sound patterns of the rhyme (DeCasper, Lecanuet, Busnel, Granier-DeFerre, & Maugeais, 1994). The ability to learn in this way seems to emerge between 24 and 38 weeks (Krueger, Holditch-Davis, Quint, & DeCasper, 2004; Pressman, DiPietro, Costigan, Shupe, & Johnson, 1998).

← Learning Objective 2.5

What behaviors have scientists observed in fetuses?

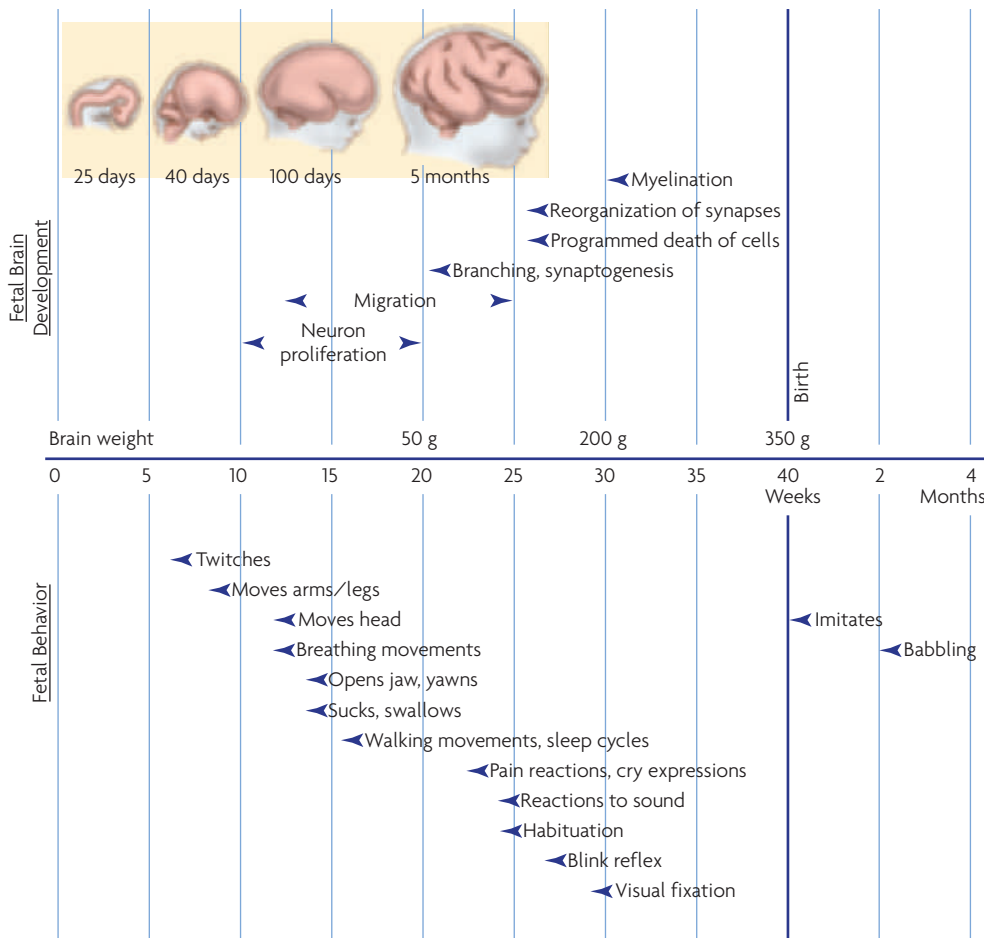


FIGURE 2.8 Correlations between Fetal Behavior and Brain Development
Researchers have discovered numerous correlations between fetal brain development and behavior.

(Source: O. Walusinski et al., "Fetal yawning: A behavior's birth with 4D US revealed," *The Ultrasound Review of Obstetrics & Gynecology*, 5 (2005), 210–217. Reprinted with permission.)

teratogens Substances such as viruses and drugs or events that can cause birth defects.

Evidence for fetal learning also comes from studies in which newborns appear to remember stimuli to which they were exposed prenatally: their mother's heartbeats, the odor of the amniotic fluid, and stories or pieces of music they heard in the womb (Righetti, 1996; Schaal, Marlier, & Soussignan, 1998). In another classic study of prenatal learning, pregnant women read a children's story such as Dr. Seuss's *The Cat in the Hat* out loud each day for the final 6 weeks of their pregnancies. After the infants were born, they were allowed to suck on special pacifiers that turned a variety of sounds off and on. Each kind of sound required a special type of sucking. Researchers found that the babies quickly adapted their sucking patterns in order to listen to the familiar story, but did not change their sucking in order to listen to an unfamiliar story (DeCasper & Spence, 1986). In other words, babies preferred the sound of the story they had heard in utero.

Developmentalists are trying to find out if prenatal learning affects later development, and if so, how (Bornstein et al., 2002). In one study, pregnant women wore waistbands equipped with speakers through which they exposed their fetuses to an average of 70 hours of classical music per week between 28 weeks of gestation and birth (Lafuente et al., 1997). By age 6 months, the babies who had heard the music were more advanced than control infants in many motor and cognitive skills. Of course, the exact meaning of this result is difficult to assess, but it does suggest that the prenatal sensory environment may be important in later development.

Researchers have also been able to identify individual differences in fetal behavior. You have already read about the sex difference in wakefulness. As is true of most sex differences, however, the range of individual differences within each gender is far greater than the difference in *average* activity levels between male and female fetuses. Some studies have shown that very active fetuses, both males and females, tend to become infants who are very active (DiPetro, Ghera, & Costigan, 2008). Moreover, these children are more likely to be labeled "hyperactive" by parents and teachers. In contrast, fetuses who are less active than average are more likely to have mental retardation (Accardo et al., 1997).

Problems in Prenatal Development

In the United States, about 97% of mothers deliver infants who are healthy and problem-free, a phenomenon that illustrates just how remarkably regular and predictable the sequence of prenatal development is (CDC, 2011a). However, this sequence of development is not immune to modification or outside influence, as you'll soon see in detail. The potential problems fall into two general classes: genetic and chromosomal problems that begin at conception, and problems caused by damaging substances or events called **teratogens**.

Learning Objective 2.6

What are the effects of the major dominant, recessive, and sex-linked diseases?

Genetic Disorders

Many disorders appear to be transmitted through the operation of dominant and recessive genes (see Table 2.4). *Autosomal* disorders are caused by genes located on the autosomes. The genes that cause *sex-linked* disorders are found on the X chromosome.

AUTOSOMAL DISORDERS Most recessive autosomal disorders are diagnosed in infancy or early childhood. For example, one recessive gene causes a baby to have problems digesting the amino acid phenylalanine. Toxins build up in the baby's brain and cause mental retardation. This condition, called *phenylketonuria (PKU)*, is found in about 1 in every 10,000 babies in the United States (Seashore, 2011). If a baby consumes no foods containing phenylalanine, however, she will not become mentally retarded. Milk is one of the foods PKU babies can't have, so early diagnosis is critical. For this reason, most states require all babies to be tested for PKU soon after birth.

Like many recessive disorders, PKU is associated with race. Caucasian babies are more likely to have the disorder than infants in other racial groups. Similarly, West African and African American infants are more likely to suffer from *sickle-cell disease*, a recessive disorder that causes red blood cell deformities (Raj & Bertolone, 2010). In sickle-cell disease, the blood

Table 2.4

GENETIC DISORDERS

Autosomal Dominant	Autosomal Recessive	Sex-Linked Recessive
Huntington's disease	Phenylketonuria	Hemophilia
High blood pressure	Sickle-cell disease	Fragile-X syndrome
Extra fingers	Cystic fibrosis	Red-green color blindness
Migraine headaches	Tay-Sachs disease	Missing front teeth
Schizophrenia	Kidney cysts in infants	Night blindness
	Albinism	Some types of muscular dystrophy
		Some types of diabetes

Sources: Amato, 1993; Tortora and Grabowski, 1993.

can't carry enough oxygen to keep the body's tissues healthy. However, with early diagnosis and antibiotic treatment, more than 80% of children diagnosed with the disease survive to adulthood (Raj & Bertolone, 2010).

Almost one-half of West Africans have either sickle-cell disease or sickle-cell trait (Amato, 1998). Persons with *sickle-cell trait* carry a single recessive gene for sickle-cell disease, which causes a few of their red blood cells to be abnormal. Doctors can identify carriers of the sickle-cell gene by testing their blood for sickle-cell trait. Once potential parents know that they carry the gene, they can make informed decisions about future childbearing. In the United States, about 1 in 500 African Americans has sickle-cell disease, and 1 in 12 African Americans has sickle-cell trait (Raj & Bertolone, 2010). Sickle-cell disease and sickle-cell trait also occur more frequently in people of Mediterranean, Caribbean, Indian, Arab, and Latin American ancestry than in those of European ancestry (Raj & Bertolone, 2010).

About 1 in every 3,000 babies born to Jewish couples of Eastern European ancestry suffers from another recessive disorder, *Tay-Sachs disease*. By the time he is 1 to 2 years old, a Tay-Sachs baby is likely to have severe mental retardation and blindness. Very few survive past the age of 3 (Kaelbling, 2009).

Disorders caused by dominant genes, such as *Huntington's disease*, are usually not diagnosed until adulthood (Amato, 1998). This disorder causes the brain to deteriorate and affects both psychological and motor functions. Until recently, children of people with Huntington's disease had to wait until they became ill themselves to know for sure that they carried the gene. Now, doctors can use a blood test to identify the Huntington's gene. Thus, people who have a parent with this disease can make better decisions about their own childbearing and can prepare for living with a serious disorder when they get older. [Watch at MyDevelopmentLab](#)

SEX-LINKED DISORDERS Most sex-linked disorders are caused by recessive genes (see Figure 2.9). One fairly common sex-linked recessive disorder is *red-green color blindness*. People with this disorder have difficulty distinguishing between the colors red and green when they are next to each other. The prevalence of red-green color blindness is 8% in men and 0.5% (1/2 percent) in women (U.S. National Library of Medicine Genetics Home Reference, 2008). Most people learn ways of compensating for the disorder and thus live perfectly normal lives.

A more serious sex-linked recessive disorder is *hemophilia*. The blood of people with hemophilia lacks the chemical components that

[Watch the Video Genetic Counseling at MyDevelopmentLab](#)

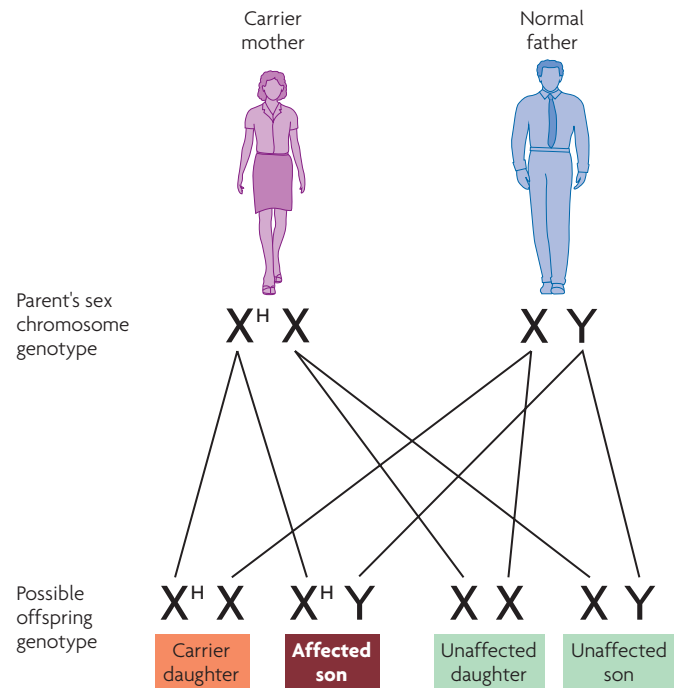



FIGURE 2.9 Sex-Linked Inheritance Compare this pattern of sex-linked transmission of a recessive disease (hemophilia) with the pattern shown in Figure 2.2.

Fetal Assessment and Treatment

Shilpa and Rudy Patel are preparing for the birth of their first child. Like many other couples, they are hoping that their child will be healthy. In their case, however, there is real cause for concern because a genetic disorder known as *fragile-X syndrome* runs in Shilpa's family.  **Watch at MyDevelopmentLab**

One procedure that can be used to test Shilpa's fetus is known as *chorionic villus sampling (CVS)*. CVS and another procedure, *amniocentesis*, can be used to identify chromosomal errors and many genetic disorders prior to birth (Curry, 2002). In CVS, cells are extracted from the placenta and subjected to a variety of laboratory tests during the early weeks of prenatal development. In amniocentesis, a needle is used to extract amniotic fluid containing fetal cells between weeks 14 and 16 of gestation. Fetal cells filtered

out of the fluid are then tested in a variety of ways to diagnose chromosomal and genetic disorders. In addition, *ultrasonography* has become a routine part of prenatal care in the United States because of its usefulness in monitoring fetal growth in high-risk pregnancies. When an ultrasound test suggests that there may be some kind of brain or spinal cord abnormality, follow-up tests using magnetic resonance imaging are sometimes employed (Levine, 2002). These images are more detailed than those that are produced by ultrasonography.

Many laboratory tests that use maternal blood, urine, and/or samples of amniotic fluid also help health-care providers monitor fetal development. For example, the presence of a substance called *alpha-fetoprotein* in a mother's blood is associated with a

Learning Objective 2.6a

What techniques are used to assess and treat problems in prenatal development?

number of prenatal defects, including abnormalities in the brain and spinal cord. Doctors can also use a laboratory test to assess the maturity of fetal lungs (Springer, 2010). This test is critical when doctors have to deliver a baby early because of a pregnant woman's health.

Fetoscopy involves insertion of a tiny camera into the womb to directly observe fetal development. Fetoscopy makes it possible for doctors to surgically correct some kinds of defects (Springer, 2010) and has made techniques such as fetal blood transfusions and bone marrow transplants possible. Specialists also use fetoscopy to take samples of blood from the umbilical cord. Fetal blood tests can help doctors identify a bacterial infection that is causing a fetus to grow too slowly (Springer, 2010). Once diagnosed, the infection can be treated by injecting antibiotics into the amniotic fluid to be swallowed by the fetus or by injecting drugs into the umbilical cord (Springer, 2010).

REFLECTION

1. How do you think you would respond to the news that a child you were expecting was carrying some kind of genetic defect?
2. Suppose Shilpa and Rudy learn that their baby is a girl. Will this news make them more or less concerned about the effect that carrying the fragile-X defect may have on their child's development? Why?




 **Watch the Video** Prenatal Ultrasound at **MyDevelopmentLab**

cause blood to clot. Thus, when a person with hemophilia bleeds, the bleeding doesn't stop naturally. Approximately 1 in 5,000 baby boys is born with this disorder, which is almost unknown in girls (Agaliotis, Zaiden, & Ozturk, 2009).

About 1 in every 4,000 males and 1 in every 8,000 females has a sex-linked disorder called *fragile-X syndrome* (Jewell, 2009). A person with this disorder has an X chromosome with a "fragile," or damaged, spot. Fragile-X syndrome can cause mental retardation that becomes progressively worse as children get older (Jewell, 2009). Fragile-X syndrome is also strongly associated with autism, a disorder that interferes with children's capacity to form emotional bonds with others (Cohen et al., 2005). Fortunately, fragile-X syndrome is one of several disorders that can be diagnosed before birth (see *Developmental Science in the Real World*).

Chromosomal Errors

Over 50 different chromosomal anomalies have been identified, and most result in miscarriage. When babies do survive, the effects of chromosomal errors tend to be dramatic.

TRISOMIES A *trisomy* is a condition in which an individual has three copies of a particular autosome. The most common is **Down syndrome** (also called **trisomy 21**), in which the child has three copies of chromosome 21. Roughly 1 in every 800-1,000 infants is born with this abnormality (Chen, 2010). These children have distinctive facial features, most notably a flattened face and somewhat slanted eyes with an epicanthic fold on the upper eyelid (an extension of the normal eyelid fold), reduced total brain size, and often other physical abnormalities such as heart defects. Typically, they have mental retardation.  [Watch at MyDevelopmentLab](#)


The risk of bearing a child with trisomy 21 varies with the age of the mother. Among women over 35, the chances of conceiving a child with the disorder are 1 in 385 (Chen, 2010). At 40, the risk rises to 1 in 106, and at 45, the chances are 1 in 30. Paternal age is a factor as well (Fisch et al., 2003). Interestingly, with mothers younger than 35, the father's age has no effect on trisomy 21 risk. However, a man over 40 who conceives a child with a woman over 35 is twice as likely to father a child with Down syndrome as a younger father is.

Scientists have identified children with trisomies of the 13th and 18th pairs of chromosomes as well (Best & Greg, 2009; Chen, 2009). These disorders have more severe effects than trisomy 21. Few children with trisomy 13 or trisomy 18 live past the age of 1 year. As with trisomy 21, the chances of having a child with one of these disorders increase with a woman's age.

SEX-CHROMOSOME ANOMALIES A second class of anomalies, associated with an incomplete or incorrect division of either sex chromosome, occurs in roughly 1 out of every 400 births (Berch & Bender, 1987). The most common is an XXY pattern, called Klinefelter's syndrome, which occurs in approximately 1 out of every 1,000 males. Affected boys most often look quite normal, although they have characteristically long arms and legs and underdeveloped testes. Most do not have mental retardation, but language and learning disabilities are common. Somewhat rarer is an XYY pattern. These children also develop as boys; typically they are unusually tall, with mild retardation.

A single-X pattern (XO), called Turner's syndrome, and a triple-X pattern (XXX) may also occur, and in both cases the child develops as a girl. Girls with Turner's syndrome—perhaps 1 in every 3,000 live female births (Tanner, 1990)—show stunted growth and are usually sterile. Without hormone therapy, they do not menstruate or develop breasts at puberty. Neuroimaging studies show that Turner syndrome is associated with abnormal development in both the cerebellum and the cerebrum (Brown et al., 2002). These girls also show an interesting imbalance in their cognitive skills: They often perform particularly poorly on tests that measure spatial ability but usually perform at or above normal levels on tests of verbal skill (Golombok & Fivush, 1994). Girls with an XXX pattern are of normal size but are slow in physical development. In contrast to girls with Turner's syndrome, they have markedly poor verbal abilities and overall low IQ, and they do particularly poorly in school compared with other children with sex-chromosome anomalies (Bender et al., 1995; Rovet & Netley, 1983).

Teratogens: Maternal Diseases

Deviant prenatal development can also result from variations in the environment in which the embryo and fetus is nurtured. A particular teratogen, such as a drug or a disease in the mother, will result in a defect in the embryo or fetus only if it occurs during a particular period of days or weeks of prenatal life. The general rule is that each organ system is most vulnerable to disruption at the time when it is developing most rapidly (Moore & Persaud, 1993). Figure 2.10 on page 46 shows times when different parts of the body are most vulnerable to teratogens. As you can see, the first 8 weeks are the period of greatest vulnerability for all the organ systems.  [Simulate on mydevelopmentlab.com](#)

RUBELLA The first few weeks of gestation comprise a critical period for a negative effect from rubella (also called German measles). Most infants exposed to rubella in the first trimester show some degree of hearing impairment, visual impairment, and/or heart deformity

←----- Learning Objective 2.7

How do trisomies and other disorders of the autosomes and sex chromosomes affect development?



Note the distinctive facial characteristics of this child with Down Syndrome

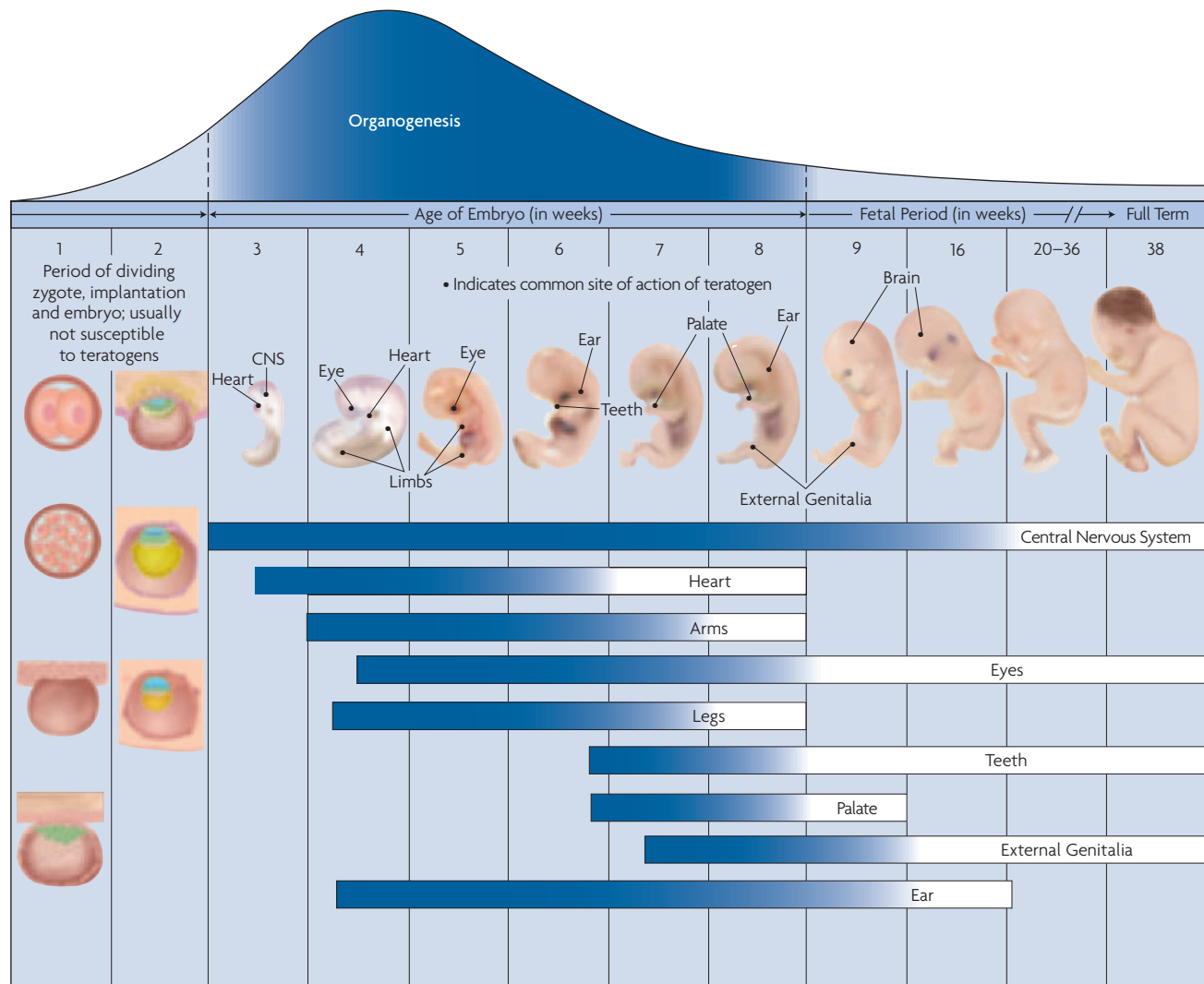
 [Watch the Video Down Syndrome at MyDevelopmentLab](#)

←----- Learning Objective 2.8

How do maternal diseases and environmental hazards affect prenatal development?

 [Simulate the Experiment Teratogens and Their Effects at MyDevelopmentLab](#)

Down syndrome (trisomy 21) A genetic anomaly in which every cell contains three copies of chromosome 21 rather than two. Children born with this genetic pattern have characteristic physical features and usually have mental retardation.



NOTE: Dark portions denote highly sensitive periods; light portions denote less sensitive periods.

FIGURE 2.10 The Timing of Teratogen Exposure

The timing of teratogen exposure is crucial. Notice that teratogens have the most impact during the embryonic stage, except on certain body parts such as the brain and ears, which continue to be at risk for teratogenic effects because they continue to grow and develop during the fetal period.

(Source: From C. Moore, J. Barresi, and C. Thompson, "The cognitive basis of future-oriented prosocial behavior," *Social Development*, 7 (1998): 198–218. Copyright © 1998 by Blackwell Publishers, Inc. Reprinted with permission.)

(Ezike & Ang, 2009) Fortunately, rubella is preventable. A vaccine is available, and it should be given to all children as part of a regular immunization program (American College of Obstetrics and Gynecology [ACOG], 2002). Adult women who were not vaccinated as children can be vaccinated later, but the vaccination must be done at least 3 months before a pregnancy to provide complete immunity. Moreover, the vaccine itself can be teratogenic, another good reason to wait several weeks before attempting to conceive.

HIV/AIDS In the United States, over 6,000 babies are born to women with HIV/AIDS each year (CDC, 2011b). These grim numbers are counterbalanced by some good news, though. First, only about a quarter of infants born to mothers with HIV actually become infected (Springer, 2010). Even more encouraging is the finding that infected women who are treated with *antiretroviral drugs* during their pregnancies have a markedly lower risk of transmitting the disease to their children—as low as 2% (CDC, 2007a). Because most women with HIV are asymptomatic and are unaware they are infected, the Centers for Disease Control recommends routine HIV counseling and voluntary testing for all pregnant women early in their pregnancies so that they can begin taking antiretroviral drugs, should that be necessary.

HIV/AIDS AND PREGNANCY ACROSS CULTURES As you probably know, HIV/AIDS is far more prevalent in some African nations than in any other part of the world. For instance, in South Africa, about 30% of pregnant women are HIV-positive (Johnson, L. 2011). Thanks to international efforts to make antiretroviral drugs available to pregnant women in Africa, the rate of mother-to-fetus transmission of the virus has dropped dramatically in Africa, just as it has in the United States. However, ignorance and fear continue to hamper prevention efforts. For example, one study involving 79 pregnant women with HIV aged 18 to 38, in Burkina Faso, West Africa, found that most participants did not intend to inform their partners about their HIV status because they feared being stigmatized (Issiaka et al., 2001). Moreover, none were aware of community organizations from which individuals with HIV could obtain information and support. Such findings suggest that the need for basic HIV education in the developing world is critical.

CYTOMEGALOVIRUS AND OTHER SEXUALLY TRANSMITTED DISEASES A much less well known but remarkably widespread and potentially serious sexually transmitted disease (STD) is *cytomegalovirus (CMV)*, a virus in the herpes group. It is now thought to be the single most prevalent infectious cause of both congenital mental retardation and deafness. CMV typically has few, if any, symptoms in an adult. In most cases, an affected person doesn't even know she carries this virus, although in an active phase it sometimes creates symptoms that suggest mononucleosis, including swollen glands and low fever. In infants who are infected prenatally or during birth, however, the virus can sometimes produce crippling disabilities.

Roughly half of all women of childbearing age have antibodies to CMV (CDC, 2006a), indicating that they have been infected at some time. Perhaps 2% of babies whose mothers have CMV antibodies become infected prenatally or as a result of breastfeeding (Schleiss, 2010).

Like CMV, the herpes virus can be transmitted to the fetus during delivery if the mother's disease is in the active phase at that time. Not only will the child then periodically experience the genital sores characteristic of the disease, but he or she may suffer other complications, most notably meningoencephalitis, a potentially serious inflammation of the brain and spinal cord. Because of this increased risk, many physicians now recommend surgical delivery (cesarean section) of infants of mothers with herpes, although vaginal delivery is possible if the disease is inactive.

Two additional STDs, *syphilis* and *gonorrhea*, also cause birth defects (Di Mario, Say, & Lincetto, 2007). Unlike most teratogens, a syphilis infection is most harmful during the last 26 weeks of prenatal development and causes eye, ear, and brain defects. Gonorrhea, which can cause the infant to be blind, is also usually transmitted during birth. For this reason, doctors usually treat the eyes of newborns with a special ointment that prevents damage from gonorrhea.

CHRONIC ILLNESSES Conditions such as heart disease, diabetes, and lupus, can also negatively affect prenatal development (Ross & Mansano, 2010). And recent research indicates that prenatal exposure to some maternal health conditions, such as the fluctuations in metabolism rate characteristic of diabetes, may predispose infants to developmental delays (Levy-Shiff, Lerman, Har-Even, & Hod, 2002). One of the most important goals of the new specialty of *fetal-maternal medicine* is to manage the pregnancies of women who have such conditions so that the health of both mother and fetus will be supported. For example, pregnancy often affects a diabetic woman's blood sugar levels so drastically that it becomes impossible for her to keep them under control. In turn, erratic blood sugar levels may damage the fetus's nervous system or cause it to grow too rapidly (Allen & Kisilevsky, 1999; Kliegman, 1998). To prevent such complications, a fetal-maternal specialist must find a diet, a medication, or a combination of the two that will stabilize the mother's blood sugar but will not harm the fetus. With the advent of sophisticated communication technologies, specialists are also capable of monitoring fetal development 24 hours a day while the mother goes about her normal activities (See *Technology and the Developing Child* on page 48.).

ENVIRONMENTAL HAZARDS There are a number of substances found in the environment that may have detrimental effects on prenatal development. For example, women who work with

TECHNOLOGY AND THE DEVELOPING CHILD

High-Tech Monitoring for High-Risk Pregnancies

Sometimes expectant mothers with high-risk conditions such as diabetes must be hospitalized so that their health and that of their fetuses can be constantly monitored. Thanks to recent advances in medical technology, restrictive care of this kind may soon become a thing of the past. For instance, the *mini fetal monitor* may help to prevent preterm labor or even fetal death (“Mini fetal monitor saves lives . . .”, 2009). The monitor resembles an ordinary cell phone. The woman goes about her normal activities with the monitor tucked in her pocket or clipped to her belt while five electrodes placed on her abdomen continuously transmit data to it about fetal movements, position of the fetus in the womb, fetal and maternal heart rates,

and uterine contractions. The monitor records all of the information on a USB drive. Each day the woman visits her clinic or physician’s office where the doctor simply plugs the drive into a computer to find out how mother and baby have fared over the previous 24 hours. And it won’t be long until the office visit may not be required at all unless something is amiss. The manufacturer of the monitor plans to enable it to transmit stored and real-time data wirelessly in the very near future.

FIND OUT MORE

Use your Internet search skills to answer these questions.

Learning Objective 2.8a

How has technology changed the way that health professionals manage high-risk pregnancies?

1. At-home monitoring of fetal and maternal health in high-risk pregnancies is convenient and far less expensive than in-patient care, but what are its disadvantages?
2. Under what conditions might in-hospital monitoring be preferable to at-home monitoring?

mercury (e.g., dentists, dental technicians, semiconductor manufacturing workers) are advised to limit their exposure to this potentially teratogenic substance (March of Dimes, 2011). Consuming large amounts of fish may also expose pregnant women to high levels of mercury (because of industrial pollution of the oceans and waterways). Fish may also contain elevated levels of another problematic industrial pollutant known as polychlorinated biphenyls, or PCBs. For these reasons, researchers recommend that pregnant women limit their consumption of fish, especially fresh tuna, shark, swordfish, and mackerel (March of Dimes, 2011).

There are several other environmental hazards that pregnant women are advised to avoid (March of Dimes, 2011):

- *Lead*, found in painted surfaces in older homes, pipes carrying drinking water, lead crystal glassware, and some ceramic dishes
- *Arsenic*, found in dust from pressure-treated lumber
- *Cadmium*, found in semiconductor manufacturing facilities
- *Anesthetic gases*, found in dental offices, outpatient surgical facilities, and hospital operating rooms
- *Solvents*, such as alcohol and paint thinners
- *Parasite-bearing substances*, such as animal feces and undercooked meat, poultry, or eggs

Learning Objective 2.9 → Teratogens: Drugs


What are the potential adverse effects of tobacco, alcohol, and other drugs on prenatal development?

There is now a huge literature on the effects of prenatal drugs, especially controlled substances such as heroin and marijuana (Barth, 2001). Sorting out the effects of drugs has proved to be an immensely challenging task because many women use multiple substances: Women who drink alcohol are also more likely than nondrinkers to smoke; those who use cocaine are also likely to take other illegal drugs or to smoke or drink to excess, and so on. In addition, many women who use drugs have other problems, such as depression, that may be responsible for the apparent effects of the drugs they use (Pajulo, Savonlahti, Sourander, Helenius, & Piha, 2001). Furthermore, the effects of drugs may be subtle, visible only many years after birth in the form of minor learning disabilities or increased risk of behavior problems.

SMOKING Research suggests that smoking during pregnancy may cause genetic damage in the developing fetus (de la Chica, Ribas, Giraldo, Egozcue, & Fuster, 2005). In addition, the link between smoking and low birth weight is well established. Infants of mothers who smoke

are on average about half a pound lighter at birth than infants of nonsmoking mothers (Mohsin, Wong, Baumann, & Bai, 2003) and are nearly twice as likely to be born with a weight below 2,500 grams (5 pounds 8 ounces), the common definition of low birth weight. The primary problem-causing agent in cigarettes is nicotine, which constricts the blood vessels, reducing blood flow and nutrition to the placenta.

The effects of smoking on both height and weight are still evident when the children of smoking and nonsmoking mothers reach school age (Cornelius, Goldschmidt, Day, & Larkby, 2002). Medical researchers have also found that prenatal smoking increases children's risk of a number of health problems (DiFranza, Aligne, & Weitzman, 2004). These problems include susceptibility to respiratory infections, asthma, and ear infections.

Prenatal exposure to tobacco also appears to have long-term effects on children's cognitive and social development. Some studies suggest that there are higher rates of learning problems and antisocial behavior among children whose mothers smoked during pregnancy (DiFranza, Aligne, & Weitzman, 2004). Moreover, children of women who smoked during pregnancy are more likely than their schoolmates to be diagnosed with attention-deficit hyperactivity disorder (Lindblad & Hjern, 2010).  [Watch at MyDevelopmentLab](#)

DRINKING The effects of alcohol on the developing fetus range from mild to severe. At the extreme end of the continuum are children who exhibit a syndrome called **fetal alcohol syndrome (FAS)**, which affects 1 to 2 of every 1,000 infants in the United States (Vaux & Rosenkrantz, 2010). Projecting these figures to all children born in the United States means that up to 12,000 children with FAS are born every year. These children, whose mothers were usually heavy drinkers or alcoholics, are generally smaller than normal, with smaller brains and often with distinct physical anomalies or deformities. They frequently have heart defects, and their faces have certain distinctive features (visible in the two photos below), including a somewhat flattened nose and nose bridge and often an unusually long space between nose and mouth. However, the disorder is often difficult to diagnose. Experts recommend that physicians who suspect that a child may have FAS carry out a multidisciplinary assessment, one that includes a comprehensive medical and behavioral history of both the mother and the child as well as neuropsychological testing (Vaux & Rosenkrantz, 2010).


The best single study of the consequences of prenatal alcohol exposure has been done by Ann Streissguth and her colleagues (Baer, Sampson, Barr, Connor, & Streissguth, 2003), who followed a group of over 500 women who drank moderate to heavy amounts of alcohol while pregnant and their children. Streissguth tested the children repeatedly, beginning immediately after birth, again later in infancy, at age 4, at school age, and again at ages 11, 14, and 21. She found that the mother's alcohol consumption in pregnancy was associated with sluggishness and weaker sucking in infancy; lower scores on measures of intelligence at 8 months, 4 years,

These two children, from different countries and different racial backgrounds, have both been diagnosed as having fetal alcohol syndrome (FAS). Both are mentally retarded and have relatively small heads. Note also the short nose and low nasal bridge typical of FAS children.



fetal alcohol syndrome (FAS) A pattern of abnormalities, including mental retardation and minor physical anomalies, often found in children born to alcoholic mothers.

 [Watch the Video](#) *Effects of Prenatal Smoking on Children's Development at MyDevelopmentLab*

and 7 years; and problems with attention and vigilance at 4, 7, 11, and 14. Teachers also rated the 11-year-olds on overall school performance and on various behavior problems, and on both of these measures, children whose mothers had consumed the most alcohol during pregnancy were rated significantly worse. Streissguth also asked mothers about their diet, their education, and their life habits. She found that the links between a mother's alcohol consumption and poor outcomes for the child held up even when all these other variables were controlled statistically. Investigators have also found that these children's deficiencies in information-processing skills persist into adulthood (Connor, Sampson, Bookstein, Barr, & Streissguth, 2001). Moreover, they are more likely than peers who were not prenatally exposed to alcohol to have alcohol abuse problems themselves (Baer et al., 2003).  Watch at **MyDevelopmentLab**

COCAINE Significant numbers of pregnant women in the United States (and presumably elsewhere in the world) also take various illegal drugs, most notably cocaine. Early studies found a number of associations between prenatal cocaine exposure and developmental problems such as low birth weight and brain damage (Ornoy, 2002). However, most such studies ignored the fact that most cocaine-using pregnant women are poor and abuse multiple substances, making it difficult to separate the effects of cocaine from those of poverty and other drugs. Studies that separate the effects of all such factors suggest that cocaine alone has no long-term effects on cognitive or social development (Dharan & Parviainen, 2009). However, cocaine can lead to pregnancy complications, such as disruption of placental function and premature labor, that may adversely affect the developing fetus.

MARIJUANA AND HEROIN Prenatal exposure to marijuana appears to interfere with a child's growth (Marrou, 2009). Even at age 6, children whose mothers used the drug during pregnancy are smaller on average than their non-drug-exposed peers (Cornelius et al., 2002). Researchers also have evidence suggesting that prenatal exposure to marijuana adversely affects the developing brain (Wang et al., 2004). These findings may help explain why a number of studies have shown that the behavior of infants and children who were prenatally exposed to the drug differs from that of their agemates. For example, some studies suggest that learning disabilities and attention problems are more common among children whose mothers used marijuana during pregnancy (Fried & Smith, 2001).

Both heroin and methadone, a drug often used in treating heroin addiction, can cause miscarriage, premature labor, and early death (Brockington, 1996; Dharan, Parviainen, Newcomb, & Poleshuck, 2006). Further, 60–80% of babies born to heroin- or methadone-addicted women are addicted to these drugs as well. Addicted babies have high-pitched cries and suffer from withdrawal symptoms, including irritability, uncontrollable tremors, vomiting, convulsions, and sleep problems. These symptoms may last as long as 4 months.

The degree to which heroin and methadone affect development depends on the quality of the environment in which babies are raised. Babies who are cared for by mothers who continue to be addicted themselves usually don't do as well as those whose mothers stop using drugs or who are raised by relatives or foster families (Brockington, 1996). By age 2, most heroin- or methadone-addicted babies in good homes are developing normally.

Learning Objective 2.10 ----->

What are the risks associated with legal drugs, maternal diet, age, emotional distress, and poverty?

Other Teratogens and Maternal Factors

A variety of additional factors, from vitamins to environmental pollutants to maternal emotions, can affect prenatal development. A few are listed in Table 2.5, and others are discussed in more detail in this section.

PRESCRIPTION AND OVER-THE-COUNTER DRUGS In general, doctors advise against taking any unnecessary medicines during pregnancy. But some pregnant women must take drugs in order to treat health conditions that may be threatening to their own and their unborn child's life. For instance, pregnant women with epilepsy must take antiseizure medication because the seizures themselves are potentially harmful to the unborn child. Other drugs that pregnant women may have to risk taking, even though they can be harmful, include medications that treat heart conditions and diabetes, those that control asthma symptoms, and some kinds of psychiatric drugs. In all such cases, physicians weigh the benefits of medication against

**Table
2.5****SOME IMPORTANT TERATOGENS****Teratogen** **Possible Effects on Fetus****Maternal Diseases**

Cancer	Fetal or placental tumor
Toxoplasmosis	Brain swelling, spinal abnormalities
Chicken pox	Scars, eye damage
Parvovirus	Anemia
Hepatitis B	Hepatitis
Chlamydia	Conjunctivitis, pneumonia
Tuberculosis	Pneumonia or tuberculosis

Drugs

Inhalents	FAS-like syndrome, premature labor
Accutane/vitamin A	Facial, ear, heart deformities
Streptomycin	Deafness
Penicillin	Skin disorders
Tetracycline	Tooth deformities
Diet pills	Low birth weight

Sources: Amato, 1998; Kliegman, 1998.

potential teratogenic effects and look for a combination of drug and dosage that will effectively treat the mother's health condition while placing her unborn child at minimal risk.

In contrast to prescription drugs, most people, pregnant or otherwise, take over-the-counter medicines on a casual, as-needed basis without consulting a doctor. Many of these drugs, such as acetaminophen, are safe for pregnant women unless taken to excess (Organization of Teratology Information Specialists, 2005). However, experts advise pregnant women to discuss the medicines they usually take with physicians at the outset of their pregnancies. These discussions should deal with both drugs and any vitamins or supplements that the pregnant woman usually takes. Their doctors will advise them as to which of the substances are safe and which are risky. Often, too, physicians can suggest safer alternatives; typically most look to older drugs that have been thoroughly tested (Vogin, 2005).

DIET Both the general adequacy of a pregnant woman's diet, measured in terms of calories, and the presence of certain key nutrients are critical to prenatal development (Christian & Stewart, 2010). Dieticians recommend that expectant mothers take in about 300 calories more per day than before they were pregnant (March of Dimes, 2011). When a woman experiences severe malnutrition during pregnancy, particularly during the final 3 months, she faces a greatly increased risk of stillbirth, low infant birth weight, or infant death during the first year of life (Di Mario, Say, & Lincetto, 2007). Autopsies show that infants born to malnourished mothers have smaller brains, with fewer and smaller brain cells than normal (Georgieff, 1994).

A vital specific nutrient whose importance during pregnancy has become clear is folic acid, a B vitamin found primarily in liver, beans, leafy green vegetables, broccoli, orange juice, fortified breakfast cereals, and grain products, especially wheat germ. Inadequate

amounts of this nutrient have been clearly linked to the risk of neural tube defects such as *spina bifida*, a deformity in which the lower part of the spine does not close (Ellenbogen, 2009). Many (but not all) such children are retarded; most have some lower-body paralysis. Because the neural tube develops primarily during the very earliest weeks of pregnancy, before a woman may even know she is pregnant, it is important for women who plan a pregnancy to ingest at least the minimum level of folic acid: 400 micrograms daily. To help raise the normal intake above the desired level, new regulations by the Food and Drug Administration in the United States now require that 140 micrograms of folic acid be added to each 100 grams of enriched flour, thus greatly increasing the likelihood that the majority of women will receive sufficient quantities of folic acid. Since the mandate was instituted, the number of infants born with *spina bifida* in the United States has been reduced by about one-third (Ellenbogen, 2009).

There are also risks associated with gaining too much weight during pregnancy. In particular, women who gain too much weight are more likely to have a cesarean section delivery (Takimoto, 2006); they are also prone to postpartum obesity, which carries a whole set of health risks, including heart disease and diabetes (Amorim et al., 2007). Gains within the recommended ranges appear optimal, although there is wide variability from one woman to the next.

Finally, women who are obese before they become pregnant have some additional risks, regardless of the amount of weight they gain. Such women are about twice as likely to have infants with neural tube defects, regardless of their intake of folic acid (Scialli, 2007). Research shows that, for obese women, weight-loss diets that include all of the nutrients needed for prenatal development are safe (Kiel et al., 2007).

THE MOTHER'S AGE Have you heard sensationalized media reports about women giving birth in their 50s and even into their 60s? Such late-in-life births are very rare, but it is the case that the average age at which women give birth for the first time has increased over the past few decades. In 1970, the average age at which a woman in the United States delivered her first child was 21.4 years. By contrast, in 2008, the average age was 25 years (Martin et al., 2010). The shift is largely due to the increasing prevalence of first births among women in their late thirties and early forties.

In most cases, older mothers have uncomplicated pregnancies and deliver healthy babies, but the risks associated with pregnancy do increase somewhat as women get older (Martin et al., 2010). Their babies are also at greater risk of weighing less than 5.5 pounds at birth, a finding that is partly explained by the greater incidence of multiple births among older mothers. Still, infants born to women over the age of 35, whether single or multiple births, are at higher risk of having problems such as heart malformations and chromosomal disorders.

At the other end of the age continuum, when comparing the rates of problems seen in teenage mothers with those seen in mothers in their 20s, almost all researchers find higher rates of problems among the teens. However, teenage mothers are also more likely to be poor, less likely to receive adequate prenatal care, less likely to be married, and more poorly educated about pregnancy and birth than older mothers are (Martin et al., 2005). Thus, it is very hard to sort out the causal factors.

STRESS AND EMOTIONAL STATE The idea that emotional or physical stresses are linked to poor pregnancy outcomes is firmly established in folklore (DiPietro, 2004). Results from studies in animals suggest that these beliefs are justified: Exposure of the pregnant female to stressors such as heat, light, noise, shock, or crowding significantly increases the risk of low-birth-weight offspring as well as later problems in the offspring (Schneider, 1992). Likewise, studies in humans show that stressful life events, emotional distress, and physical stress are all linked to slight increases in problems of pregnancy, such as low birth weight (DiPietro, 2004). Moreover, studies involving experimentally induced stressors (e.g., requiring a pregnant woman to take some kind of cognitive test) show that they seem to cause short-term changes in fetal activity, heart rate, and other responses (DiPietro, Costigan, & Gurewitsch, 2003). Whether such changes are sufficient to affect development in any meaningful way is as yet unknown.

Similarly, maternal emotions are associated with measures of fetal response such as activity level. Researcher Janet DiPietro and her colleagues have found that the fetuses of women who have positive emotions toward their condition are less active than those of mothers who feel more negatively about their pregnancies (DiPietro, Hilton, Hawkins, Costigan, & Pressman, 2002). The long-term effects of this association, if there are any, have been difficult to identify. Some developmental scientists argue that the real connection is a matter of maternal genes and/or parenting style; emotionally negative and depressed mothers may use ineffective parenting strategies or simply be more likely, for genetic reasons, to have children who are less emotionally positive than their peers (Lau, Riisdijk, Gregory, McGuffin, & Elev, 2007).

One fairly consistent finding, however, is that the fetuses of mothers who have been diagnosed with depression tend to grow more slowly than others (Yonkers et al., 2009). Developmentalists hypothesize that this effect may result directly from emotion-related hormones or it may be an indirect effect of the mother's emotional state. A mother with depression may eat less, or her weakened immune system may limit her ability to fight off viruses and bacteria, either of which may retard fetal growth. Consequently, many psychologists suggest that providing stressed and/or depressed pregnant women with social support and counseling may lead to improvements in both maternal and fetal health (Wilén & Mounts, 2006).

POVERTY The basic sequence of fetal development is clearly no different for children born to poor mothers than for children born to middle-class mothers, but many of the problems that can negatively affect prenatal development are more common among the poor. For example, in the United States, mothers who have not graduated from high school are about twice as likely as mothers with a college education to have a low-birth-weight infant or a stillborn infant. Poor women are also likely to have their first pregnancy earlier and to have more pregnancies overall, and they are less likely to be immunized against such diseases as rubella. They are also less likely to seek prenatal care, and if they do, they seek it much later in their pregnancies. A significant portion of this difference could be overcome in the United States: Devoting the resources needed to provide good, universal prenatal care could significantly reduce not only the rate of infant death but also the rate of physical abnormalities and perhaps even mental retardation. Equal access to care is not the only answer. In Canada, for example, in which such care is universally available, social class differences in low-birth-weight deliveries and in infant mortality rates remain (Spencer, 2003).

THINK CRITICALLY

- In your view, what are the advantages and disadvantages of genetic counseling for couples who want to have a child but who are concerned about a genetic or chromosomal disorder that runs in one or both of their families?
- With the advent of antiretroviral drugs, the rate of mother-to-fetus transmission of HIV has been greatly reduced. Do you think that these findings justify mandatory testing and treatment of pregnant women who are at high risk of having HIV/AIDS? Why or why not?

CONDUCT YOUR OWN RESEARCH

In every culture, there are traditional beliefs about pregnancy, many of which are myths. For example, you may have heard that labor is more likely to begin during a full moon or that boys “carry high” but girls “carry low.” Other once-popular ideas include the notion that eating spicy foods or having sex will bring on premature labor. Survey your classmates, friends, and relatives to find out what kinds of things they have heard about pregnancy. If you have access to people from different cultures, analyze the similarities and differences in these beliefs across groups.

Conception and Genetics

- 2.1** What are the characteristics of the zygote?
At conception, 23 chromosomes from the sperm join with 23 from the ovum to make up the set of 46 that will be reproduced in each cell of the new baby's body. Each chromosome consists of a long string of deoxyribonucleic acid (DNA) made up of segments called genes. The baby's sex is determined by the 23rd pair of chromosomes, a pattern of XX for a girl and XY for a boy.
- 2.1a** What risks are associated with assisted reproductive technology?
Assisted reproductive technology fails to result in a live birth in about two-thirds of cases. In addition, it is more likely to lead to multiple birth than natural conception. As a result, infants conceived through ART techniques have higher rates of premature birth and other problems.
- 2.2** In what ways do genes influence development?
Geneticists distinguish between the genotype, which is the pattern of inherited characteristics, and the phenotype, which is the result of the interaction of genotype and environment. Genes are transmitted from parent to child according to complex patterns of inheritance that include dominant/recessive, polygenic, multifactorial, and sex-linked. What are the characteristics of the zygote?

Development from Conception to Birth

- 2.3** What happens in each of the stages of prenatal development?
During the first days after conception, called the germinal stage of development, the zygote (the initial cell formed by egg and sperm) divides, travels down the fallopian tube, and is implanted in the wall of the uterus. The second stage, the period of the embryo, which lasts until 8 weeks after fertilization, includes the development of the various structures that support fetal development, such as the placenta, as well as primitive forms of all organ systems. The final 30 weeks of gestation, called the fetal period, are devoted primarily to enlargement and refinements in all the organ systems.
- 2.4** How do male and female fetuses differ?
During the embryonic period, the XY embryo secretes the hormone testosterone, which stimulates the growth of male genitalia and shifts the brain into a "male" pattern. Boys are more active, have more slowly developing skeletons, are bigger at birth, and are more vulnerable to most forms of prenatal stress.
- 2.5** What behaviors have scientists observed in fetuses?
The fetus is responsive to stimuli and appears to learn in the womb. Temperamental differences in the womb (such as activity level) persist into infancy and childhood, and some aspects of the prenatal sensory environment may be important to future development.

Problems in Prenatal Development

- 2.6** What are the effects of the major dominant, recessive, and sex-linked diseases?
Dominant disorders are not usually manifested until adulthood. Huntington's disease, a fatal affliction of the nervous system, is one such disorder. Recessive disorders affect individuals earlier in life, often leading to mental retardation and/or early death. These disorders include phenylketonuria, sickle-cell disease, and Tay-Sachs disease. A fairly common sex-linked disorder is red-green color blindness. Hemophilia and fragile-X syndrome are more serious sex-linked disorders that affect males far more often than females.
- 2.6a** What techniques are used to assess and treat problems in prenatal development?
Techniques such as fetoscopy, ultrasonography, chorionic villus sampling, and amniocentesis are used to diagnose chromosomal and genetic disorders, and along with laboratory tests identify problems in fetal development. A few such problems can be treated prior to birth with surgery and/or medication.
- 2.7** How do trisomies and other disorders of the autosomes and sex chromosomes affect development?
Abnormal numbers of chromosomes or chromosomal damage cause a number of serious disorders, including Down syndrome.
- 2.8** How do maternal diseases and environmental hazards affect prenatal development?
Some diseases contracted by the mother, including rubella, AIDS, sexually transmitted diseases like genital herpes and CMV, and chronic illnesses, may cause abnormalities or disease in the child. Environmental hazards include pollutants such as mercury and lead as well as parasite-bearing substances such as animal feces. Their effect on the fetus varies with the timing of the exposure.
- 2.8a** How has technology changed the way that health professionals manage high-risk pregnancies?
Health professionals can closely monitor the conditions of both expectant mothers and fetuses with small devices that women can use or wear as they go about their normal activities.
- 2.9** What are the potential adverse effects of tobacco, alcohol, and other drugs on prenatal development?
Drugs such as alcohol and nicotine appear to have harmful effects on the developing fetus; drug effects depend on the timing of exposure and the dosage.

2.10 What are the risks associated with legal drugs, maternal diet, age, emotional distress, and poverty?

Some prescription and over-the-counter drugs have teratogenic effects. Physicians need to know what drugs pregnant women take regularly so that they can provide guidance as to the appropriate use of such drugs during pregnancy. If a mother suffers from poor nutrition, she faces an increased risk of stillbirth, low birth weight, and

infant death during the first year of life. Older mothers and very young mothers also run increased risks, as do their infants. Long-term, severe depression or chronic physical illness in the mother may increase the risk of complications during pregnancy or difficulties in the infant. A number of prenatal risk factors are associated with poverty, including earlier age at first pregnancy and lack of access to prenatal care.

KEY TERMS

amnion (p. 37)	Down syndrome (trisomy 21) (p. 45)	genotype (p. 32)	ovum (p. 30)
axons (p. 38)	embryo (p. 35)	germinal stage (p. 35)	phenotype (p. 32)
blastocyst (p. 35)	embryonic stage (p. 37)	glial cells (p. 39)	placenta (p. 37)
cell body (p. 38)	fallopian tube (p. 30)	heterozygous (p. 32)	polygenic pattern of inheritance (p. 34)
chorion (p. 37)	fetal alcohol syndrome (FAS) (p. 49)	homozygous (p. 32)	sperm (p. 30)
chromosomes (p. 30)	fetal stage (p. 37)	identical (monozygotic) twins (p. 35)	synapses (p. 38)
dendrites (p. 38)	fetus (p. 37)	multifactorial pattern of inheritance (p. 34)	teratogens (p. 42)
deoxyribonucleic acid (DNA) (p. 30)	fraternal (dizygotic) twins (p. 35)	neuronal migration (p. 38)	umbilical cord (p. 37)
dominant/recessive pattern of inheritance (p. 33)	gametes (p. 30)	neuronal proliferation (p. 38)	uterus (p. 30)
	genes (p. 32)	neurons (p. 38)	viability (p. 38)
			zygote (p. 30)