

# 2

## BIOLOGICAL AND ENVIRONMENTAL FOUNDATIONS AND PRENATAL DEVELOPMENT



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“Rico and Remmy couldn’t be more different,” marveled their mother. “People are surprised to find out they are brothers.” Rico is tall and athletic, with blond hair and striking blue eyes. His older brother, Remmy, has a smaller frame and wears thick glasses over his dark brown eyes. She wondered, “Where did Rico get such blue eyes and blond hair? He looks different from everyone in our family. Maybe I did something different when I was pregnant with him? Eat or do something unusual?” In this chapter, we examine processes of genetic inheritance that can help us understand how members of a family can share a great many similarities and also many differences. We also explore the process of **prenatal development**, or how a single cell develops into a newborn.

### GENETIC FOUNDATIONS OF DEVELOPMENT

#### LEARNING OBJECTIVE

- 2.1** Discuss patterns of genetic inheritance and examples of genetic disorders and chromosomal abnormalities.

We are born with a hereditary “blueprint” that influences our development and determines our traits, such as appearance, physical characteristics, health, and even personality.

#### Genetics

The human body is composed of trillions of units called cells, each with a nucleus containing 23 matching pairs of rod-shaped structures called **chromosomes** (Finegold, 2019). Each chromosome holds

the basic units of heredity, known as genes, composed of stretches of **deoxyribonucleic acid (DNA)**, a complex molecule shaped like a twisted ladder or staircase. **Genes** carry the plan for creating all of the traits that organisms carry. It is estimated that 20,000 to 25,000 genes reside within the chromosomes, comprising the human genome and influencing all genetic characteristics (Taneri et al., 2020). People around the world share 99.9% of their genes (Lewis, 2017; National Human Genome Research Institute, 2018). Although all humans share the same basic genome, every person has a slightly different code, making him or her genetically distinct from other humans.

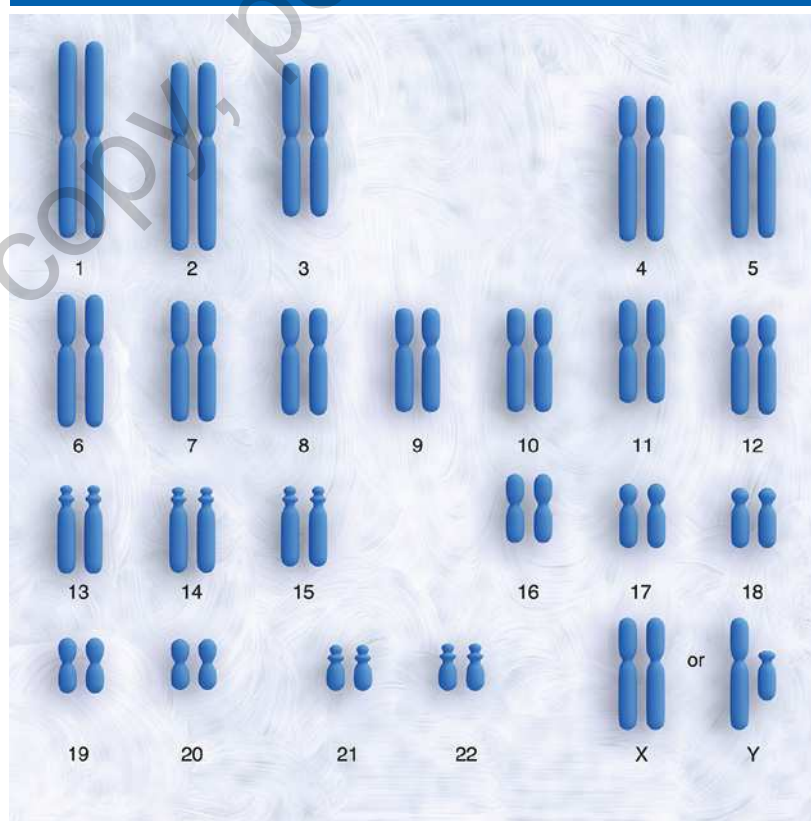
### Cell Reproduction

Most cells in the human body reproduce through a process known as **mitosis**, in which DNA replicates itself, duplicating the 46 chromosome pairs, resulting in new cells with identical genetic material (Sadler, 2018). **Gametes**, or sex cells that are specialized for reproduction (such as the ova and sperm), reproduce in a different way, through **meiosis**. First, the 46 chromosomes begin to replicate as in mitosis, duplicating themselves. But before the cell completes dividing, the DNA segments cross over, moving from one member of the pair to the other, essentially “mixing up” the DNA and creating unique combinations of genes (Finegold, 2019). The resulting gametes, ova and sperm, consist of only 23 single, unpaired sex chromosomes. At fertilization ova and sperm join to produce a fertilized egg, or **zygote**, with 46 chromosomes forming 23 pairs, half from the biological mother and half from the biological father. Each gamete has a unique genetic profile, and it is estimated that individuals can produce millions of genetically different gametes (U.S. National Library of Medicine, 2020).

### Sex Determination

Twenty-two of the 23 pairs of chromosomes are matched pairs (see Figure 2.1). They contain similar genes in almost identical positions and sequence, reflecting the distinct genetic blueprint of the biological mother and father. The 23rd pair of chromosomes are not identical because they are sex

FIGURE 2.1 ■ Chromosomes



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chromosomes that specify the genetic sex of the individual. In females, sex chromosomes consist of two large X-shaped chromosomes (XX). Males' sex chromosomes consist of one large X-shaped chromosome and one much smaller Y-shaped chromosome (XY).

Because females have two X sex chromosomes, all their ova contain one X sex chromosome. A male's sex chromosome pair includes both X and Y chromosomes; therefore, one half of the sperm males produce contain an X chromosome and one half contain a Y. The Y chromosome contains genetic instructions that will cause the fetus to develop male reproductive organs. Thus, whether the fetus develops into a boy or girl is determined by which sperm fertilizes the ovum. If the ovum is fertilized by a Y sperm, a male fetus will develop, and if the ovum is fertilized by an X sperm, a female fetus will form (see Figure 2.2).

## Patterns of Genetic Inheritance

Researchers are just beginning to uncover the instructions contained in the human genome, but we have learned that traits and characteristics are inherited in predictable ways.

### Dominant-Recessive Inheritance

Some genes are passed through **dominant-recessive inheritance** in which some genes are *dominant* and are always expressed regardless of the gene they are paired with. Examples of dominant genes include those for dark (brown or black) hair color and brown eyes. Other genes, such as for blond or red hair and blue eyes, are *recessive* and will be expressed only if paired with another recessive gene (see Figure 2.3 and Table 2.1).

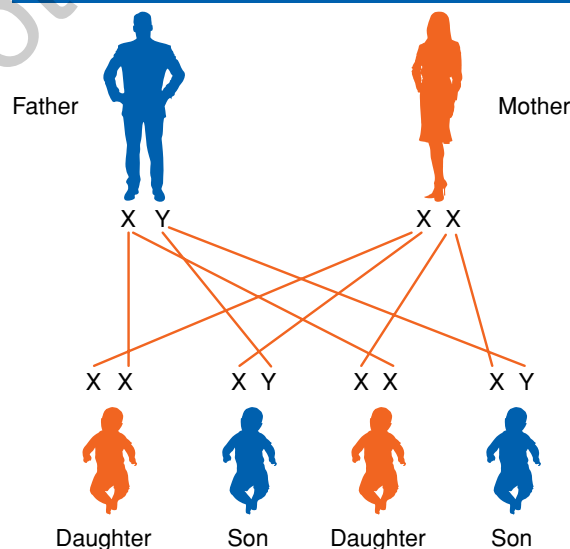
### Incomplete Dominance

**Incomplete dominance** is a genetic inheritance pattern in which both genes jointly influence the characteristic (Knopik et al., 2017). Consider blood type. Neither the alleles for blood type A nor B dominate each other. A person with the alleles for blood types A and B will express both A and B alleles and have blood type AB.

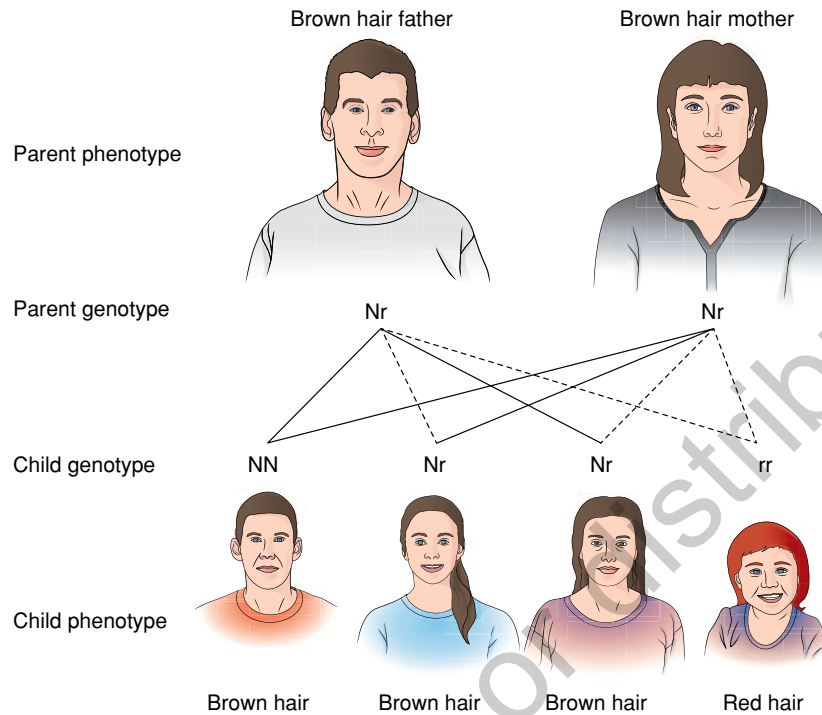
### Polygenic Inheritance

Most characteristics result from the interaction of many genes, known as **polygenic inheritance**. Examples of polygenic traits include height, intelligence, personality, and susceptibility to certain forms of cancer (Bouchard, 2014; Flint et al., 2020; Penke & Jokela, 2016). As the number of genes that contribute to a trait increases, so does the range of possible traits. Table 2.2 summarizes the three patterns of inheritance.

FIGURE 2.2 ■ Sex Determination



**FIGURE 2.3** ■ Dominant-Recessive Inheritance



**TABLE 2.1** ■ Dominant and Recessive Characteristics

Dominant Trait	Recessive Trait
Dark hair	Blond hair
Curly hair	Straight hair
Hair	Baldness
Non-red hair	Red hair
Facial dimples	No dimples
Brown eyes	Blue, green, hazel eyes
Second toe longer than big toe	Big toe longer than second toe
Type A blood	Type O blood
Type B blood	Type O blood
Rh-positive blood	Rh-negative blood
Normal color vision	Color blindness

Source: McKusick-Nathans Institute of Genetic Medicine, 2020.

**TABLE 2.2** ■ Summary: Patterns of Genetic Inheritance

Inheritance Pattern	Description
<b>Dominant-recessive inheritance</b>	Genes that are dominant are always expressed, regardless of the gene they are paired with. Recessive genes are expressed only if paired with another recessive gene.
<b>Incomplete dominance</b>	Both genes influence the characteristic, and aspects of both genes appear.
<b>Polygenic inheritance</b>	Polygenic traits are the result of interactions among many genes.

## Chromosomal and Genetic Problems

Many disorders are the result of chromosomal abnormalities passed through genetic inheritance. Many hereditary and chromosomal abnormalities can be diagnosed prenatally. Others are evident at birth or can be detected soon after an infant begins to develop. Some are discovered only over a period of many years.

Disorders and abnormalities that are inherited through the parents' genes are passed through the inheritance processes that we have discussed. Some are highly visible and some may go unnoticed throughout an individual's life.

### Dominant-Recessive Genetic Disorders

Recall that in dominant-recessive inheritance, dominant genes are always expressed regardless of the gene they are paired with and recessive genes are expressed only if paired with another recessive gene. Some diseases are inherited through dominant-recessive patterns (see Table 2.3). Few severe disorders are inherited through dominant inheritance because individuals who inherit the allele often do not survive long enough to reproduce and pass it to the next generation. One exception is Huntington disease, a fatal disease in which the central nervous system deteriorates (Ghosh & Tabrizi, 2018; McKusick-Nathans Institute of Genetic Medicine, 2020). Individuals with the Huntington allele develop normally in childhood, adolescence, and young adulthood. Symptoms of Huntington disease do not appear until age 35 or later. By then, many individuals have already had children, and one half of them, on average, will inherit the dominant Huntington gene.

**TABLE 2.3** ■ Diseases Inherited Through Dominant-Recessive Inheritance

Disease	Occurrence	Mode of Inheritance	Description	Treatment
Huntington disease	1 in 20,000	Dominant	Degenerative brain disorder that affects muscular coordination and cognition	No cure; death usually occurs 10 to 20 years after onset
Cystic fibrosis	1 in 2,000–2,500	Recessive	An abnormally thick, sticky mucus clogs the lungs and digestive system, leading to respiratory infections and digestive difficulty	Bronchial drainage, diet, gene replacement therapy
Phenylketonuria (PKU)	1 in 10,000–15,000	Recessive	Inability to digest phenylalanine, which, if untreated, results in neurological damage and death	Diet
Sickle cell anemia	1 in 500 African Americans	Recessive	Sickling of red blood cells leads to inefficient distribution of oxygen throughout the body that leads to organ damage and respiratory infections	No cure; blood transfusions, treat infections, bone marrow transplant; death by middle age
Tay-Sachs disease	1 in 3,600–4,000 descendants of Central and Eastern European Jews	Recessive	Degenerative brain disease	None; most die by 4 years of age

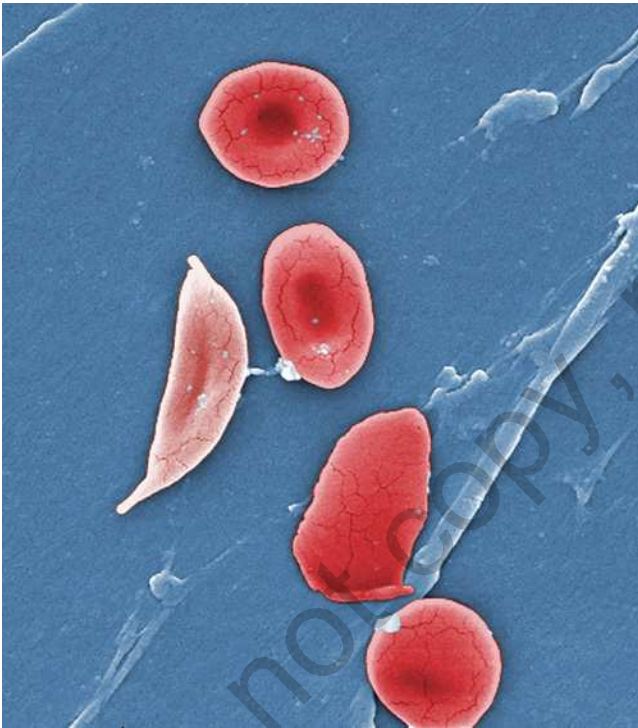
Source: McKusick-Nathans Institute of Genetic Medicine, 2020.





A blood sample to detect PKU is taken from this newborn. Phenylketonuria (PKU) is a genetic disorder in which the body lacks the enzyme that breaks down phenylalanine. Without treatment, the phenylalanine builds up to toxic levels and can damage the central nervous system.

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Recessive sickle cell alleles cause red blood cells to become crescent shaped and unable to distribute oxygen effectively throughout the circulatory system. Alleles for normal blood cells do not mask all of the characteristics of recessive sickle cell alleles, illustrating incomplete dominance.

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**Phenylketonuria (PKU)** is a common recessive disorder that prevents the body from producing an enzyme that breaks down phenylalanine, an amino acid in proteins (McKusick-Nathans Institute of Genetic Medicine, 2020). Without treatment the phenylalanine builds up quickly to toxic levels that damage the central nervous system, contributing to intellectual developmental disability, once known as mental retardation, by 1 year of age. The United States and Canada require all newborns to be screened for PKU (Camp et al., 2014).

PKU illustrates how genes interact with the environment to produce developmental outcomes. Intellectual disability results from the interaction of the genetic predisposition and exposure to phenylalanine from the environment (Blau, 2016). Children with PKU can process only very small amounts of phenylalanine. If the disease is discovered, the infant is placed on a diet low in phenylalanine. Yet it is very difficult to remove nearly all phenylalanine from the diet. Individuals who maintain a strict diet usually attain average levels of intelligence, though they tend to score lower than those without PKU (Hofman et al., 2018; Romani et al., 2017). Some cognitive and psychological problems may appear in childhood and persist into adulthood (Christ et al., 2020; Erlich, 2019; Ford et al., 2018; Hawks et al., 2018; Jahja et al., 2017). The emotional and social challenges associated with PKU, such as the pressure of a strict diet and surveillance from parents, may worsen these symptoms, and dietary compliance tends to decline in adolescence when young people push boundaries and seek independence (Medford et al., 2017).

The **sickle cell trait**, carried by about 5% of African American newborns (and relatively few Caucasians or Asian Americans) causes another recessive disorder, sickle cell anemia (Ojodu et al., 2014). In sickle cell anemia, red blood cells become crescent, or sickle, shaped. Cells that are sickle shaped cannot distribute oxygen effectively throughout the circulatory system and can cause inflammation and damage the blood vessels (Ware et al., 2017). Unlike other recessive disorders, the genes for normal blood cells do not mask all of the characteristics of recessive sickle cell genes. This is known as incomplete dominance. People who carry a single recessive sickle cell gene do not develop full-blown sickle cell anemia but may show some symptoms, such as reduced oxygen distribution throughout the body and exhaustion after exercise (Xu & Thein, 2019; Chakravorty & Williams, 2015).

### X-Linked Genetic Disorders

A special instance of the dominant-recessive pattern occurs with genes that are located on the X chromosome (Shah et al., 2017). Recall that males (XY) have both an X and a Y chromosome. Some recessive genetic disorders, like the gene for red-green colorblindness, are carried on the X-chromosome (see Table 2.4). Males are more likely to be affected by X-linked genetic disorders because they have only one X chromosome and therefore any genetic marks on their X chromosome are displayed. Females (XX) have two X chromosomes; a recessive gene located on one X chromosome will be masked by a dominant gene on the other X chromosome. Females are therefore less likely to display X-linked genetic disorders because both of their X chromosomes must carry the recessive genetic disorder for it to be displayed.

**TABLE 2.4** ■ Diseases Acquired Through X-Linked Inheritance

Syndrome/Disease	Occurrence	Description	Treatment
Color blindness	1 in 12 males	Difficulty distinguishing red from green; less common is difficulty distinguishing blue from green	No cure
Duchenne muscular dystrophy	1 in 3,500 males	Weakness and wasting of limb and trunk muscles; progresses slowly but will affect all voluntary muscles	Physical therapy, exercise, body braces; survival rare beyond late 20s
Fragile X syndrome	1 in 4,000 males and 1 in 8,000 females	Symptoms include cognitive impairment; attention problems; anxiety; unstable mood; long face; large ears; flat feet; and hyperextensible joints, especially fingers	No cure
Hemophilia	1 in 3,000–7,000 males	Blood disorder in which the blood does not clot	Blood transfusions

Source: McKusick-Nathans Institute of Genetic Medicine, 2017.

**Fragile X syndrome** is a dominant-recessive disorder carried on the X chromosome (Hagerman et al., 2017; Salcedo-Arellano et al., 2020). Because the gene is dominant, it need appear on only one X chromosome to be displayed, so it occurs in both males and females. Fragile X syndrome (FXS) is the most common inherited form of intellectual disability (Doherty & Scerif, 2017), and children with Fragile X syndrome tend to show moderate to severe intellectual disability and problems with executive function (Schmitt, Shaffer, Hessel, & Erickson, 2019; Raspa et al., 2017). Several behavioral mannerisms are also common, including poor eye contact and repetitive behaviors such as hand flapping, hand biting, and mimicking others, behaviors also common in individuals with autistic spectrum disorders (Hagerman et al., 2017; Salcedo-Arellano et al., 2020). Fragile X syndrome is often codiagnosed with autism; it's estimated about 40%–60% of boys and 16%–20% of girls with Fragile X syndrome meet the diagnostic criteria for autism (Bagni & Zukin, 2019; Kaufmann et al., 2017).

**Hemophilia**, a condition in which the blood does not clot normally, is another example of a recessive disease inherited through genes on the X chromosome (McKusick-Nathans Institute of Genetic Medicine, 2020; Shah et al., 2017). Daughters who inherit the gene for hemophilia typically do not show the disorder because the dominant gene on their second X chromosome promotes normal blood clotting (d'Oiron, 2019). Sons who inherit the gene will display the disorder because the Y chromosome does not have the corresponding genetic information to counter the hemophilia gene.

### Chromosomal Abnormalities

Chromosomal abnormalities are the result of errors during cell reproduction or damage caused afterward. Occurring in about 1 of every 1,500 births, the most widely known chromosome disorder is trisomy 21, more commonly called **Down syndrome** (de Graaf et al., 2017; McKusick-Nathans Institute of Genetic Medicine, 2020). Down syndrome occurs when a third chromosome appears alongside the 21st pair of chromosomes. Down syndrome is associated with marked physical, health, and cognitive attributes, including a short, stocky build; a round face; almond-shaped eyes; and a flattened nose



Down syndrome is the most common cause of intellectual disability. Interventions that encourage children to interact with their physical and social environment can promote motor, social, and emotional development.

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(Antonarakis et al., 2020; Bull, 2020). Children with Down syndrome tend to show delays in physical and motor development relative to other children, and health problems such as congenital heart defects, vision impairments, poor hearing, and immune system deficiencies (Diamandopoulos & Green, 2018; Morrison & McMahon, 2018; Roizen et al., 2014; Zampieri et al., 2014).

Down syndrome is the most common genetic cause of intellectual developmental disability (Vissers et al., 2016), but children's abilities vary. Infants and children who participate in early intervention and receive sensitive caregiving and encouragement to explore their environment show positive outcomes, especially in the motor, social, and emotion areas of functioning (Bull, 2020; Næss et al., 2017; Wentz, 2017).

Some chromosomal abnormalities concern the 23rd pair of chromosomes: the sex chromosomes. These abnormalities result from either an additional or missing sex chromosome. Given their different genetic makeup, sex chromosome abnormalities yield different effects in males and females (see Table 2.5).

**Klinefelter syndrome**, in which males are born with an extra X chromosome (XXY), occurs in 1 in 1,000 males (McKusick-Nathans Institute of Genetic Medicine, 2020; Wistuba et al., 2017). Many males are unaware they have the disorder until they are tested for infertility in adulthood (Bird & Hurren, 2016; Gravholt et al., 2018). Severe characteristics of Klinefelter syndrome include a high-pitched voice, short stature, feminine body shape, breast enlargement, and infertility (Bonomi et al., 2017). As adults, men with Klinefelter syndrome are at risk for a variety of disorders that are more common in women, such as osteoporosis (Juul et al., 2011).

**Jacob's syndrome**, also known as XYY syndrome, causes men to produce high levels of testosterone (McKusick-Nathans Institute of Genetic Medicine, 2017; Pappas et al., 2017). Most men with XYY syndrome are unaware that they have a chromosomal abnormality. The prevalence of XYY syndrome is uncertain given that most men go undiagnosed.

Females are susceptible to a different set of sex chromosome abnormalities. About 1 in 1,000 females are born with three X chromosomes, known as **triple X syndrome** (McKusick-Nathans Institute of Genetic Medicine, 2020; Wigby et al., 2016). Women with triple X syndrome tend to be about an inch or so taller than average with unusually long legs and slender torsos, as well as normal development of sexual characteristics and fertility. Some may score lower on intelligence tests or have learning difficulties. Because many cases of triple X syndrome often go unnoticed, little is known about the syndrome.

The sex chromosome abnormality known as **Turner syndrome** occurs when a female is born with only one X chromosome (McKusick-Nathans Institute of Genetic Medicine, 2020). Girls with Turner syndrome show abnormal growth patterns. They show delayed puberty, their ovaries do not

**TABLE 2.5** ■ Sex Chromosome Abnormalities

Male Genotype	Syndrome	Description	Prevalence
XO	Turner	Abnormal growth patterns, delayed puberty, lack of prominent female secondary sex characteristics, and infertility. Short adult stature, webbing around the neck.	1 in 2,500 females
XXX	Triple X	Grow about an inch or so taller than average with unusually long legs and slender torsos, and show normal development of sexual characteristics and fertility. Because many cases of triple X syndrome often go unnoticed, little is known about the syndrome	Unknown; many cases go unnoticed.
Female Genotype	Syndrome		
XXY	Klinefelter	High-pitched voice, short stature, feminine body shape, and infertility. Increased risk for osteoporosis and other disorders that are more common in women.	1 in 1,000 males
XYY	Jacob's Syndrome	Accompanied by high levels of testosterone	Unknown; many cases go unnoticed.



develop normally, they do not ovulate and are infertile (Culen et al., 2017; Davis et al., 2020). As adults, they are short in stature and often have small jaws with extra folds of skin around their necks (webbing) and lack prominent female secondary sex characteristics such as breasts (Gravholt et al., 2019). Its prevalence is estimated to be 1 in 2,500 worldwide (National Library of Medicine, 2019). If Turner syndrome is diagnosed early, regular injections of human growth hormones can increase stature, and hormones administered at puberty can result in some breast development and menstruation (Culen et al., 2017; Klein et al., 2020).

## Mutation

Not all inborn characteristics are inherited. Some result from **mutations**, which are sudden changes and abnormalities in the structure of genes that occur spontaneously or may be induced by exposure to environmental toxins such as radiation and agricultural chemicals in food. It is estimated that as many as one half of all conceptions include mutated chromosomes (Taneri et al., 2020). Most mutations are fatal—the developing organism dies very soon after conception, often before the woman knows she is pregnant (Sadler, 2018).

Sometimes mutations are beneficial. This is especially true if the mutation is induced by stressors in the environment and provides an adaptive advantage to the individual. For example, the sickle cell gene (discussed earlier in this chapter) is a mutation that originated in areas where malaria is widespread, such as Africa (Ware et al., 2017) and serves a protective role against malaria (Uyoga et al., 2019). Children who inherited a single sickle cell allele were more resistant to malarial infection and more likely to survive and pass it along to their offspring (Croke et al., 2017; Gong et al., 2013). The sickle cell gene is not helpful in places where malaria is not a risk.

## Thinking in Context: Biological Influences

1. Consider your own physical characteristics, such as hair and eye color. Are they indicative of recessive traits, or dominant ones? Do you think that you might be a carrier of recessive traits? Why or why not?
2. Recall from Chapter 1 that most developmental scientists agree that nature and nurture interact to influence development. Choose a genetic or chromosomal disorder discussed in this section and explain how it illustrates the interaction of genes and context.

## Thinking in Context: Lifespan Development

Chromosomal and genetic problems can result in a variety of impairments. How might contextual factors, such as a supportive environment, aid individuals' development? Describe a specific problem or mutation. What environmental conditions might best promote healthy adjustment for individuals with this disorder?

## Thinking in Context: Applied Developmental Science

Your friend, a “study buddy,” is confused about the differences between disorders that are passed through genetic inheritance and chromosomal abnormalities. Explain how genetic disorders are transmitted, including examples. What are some examples of chromosomal disorders?

## HEREDITY AND ENVIRONMENT

### LEARNING OBJECTIVE

- 2.2** Describe behavior genetics and interactions among genes and environment, such as gene-environment correlations, gene-environment interactions, and the epigenetic framework.

Our **genotype**, or genetic makeup, inherited from our biological parents, is a biological contributor to all of our observable traits, from hair and eye color to personality, health, and behavior. However, genotypes alone do not determine our **phenotype**—the traits, characteristics, or personality that we display. Phenotypes result from the interaction of genotypes and our experiences.

### Behavior Genetics

**Behavior genetics** is the field of study that examines how genes and experience combine to influence the diversity of human traits, abilities, and behaviors (Knopik et al., 2017; Plomin, 2019). Behavior geneticists assess the hereditary contributions to behavior by conducting selective breeding and family studies.

*Selective breeding studies* entail deliberately modifying the genetic makeup of animals to examine the influence of heredity on attributes and behavior. Mice can be bred to be very physically active by mating highly active mice only with other highly active mice or to be sedentary by breeding mice with very low levels of activity with each other (Schwartz et al., 2018). Selective breeding in rats, mice, and chickens has revealed genetic contributions to many traits and characteristics, such as aggressiveness, emotionality, sex drive, and maze learning (Bubac et al., 2020).

Behavior geneticists conduct *family studies* to compare people who live together and share varying degrees of relatedness. Two kinds of family studies are common: twin studies and adoption studies (York, 2020). *Twin studies* compare identical and fraternal twins to estimate how much of a trait or behavior is attributable to genes. Identical twins are genetically identical; they share 100% of their genes. Fraternal twins share 50% of their genes; they are genetically similar to non-twin siblings. If genes affect a given attribute, identical twins should be more similar than fraternal twins because identical twins share identical genes whereas fraternal twins share about half of their genes.

*Adoption studies* compare the degree of similarity between adopted children, their biological parents whose genes they share (50%), and their adoptive parents with whom they share an environment but not genes (York, 2020). If the adopted children share traits with their biological parents even though they were not raised by them (and do not share an environment), it suggests that the traits are genetic. If the children share traits with their adoptive parents, it indicates the traits are influenced by the environment.

Genes contribute to many traits, such as sociability, temperament, emotionality, and susceptibility to various illnesses including obesity, heart disease and cancer, anxiety, poor mental health, and a propensity to be physically aggressive (Bralten et al., 2019; Goodarzi, 2018; Morneau-Vaillancourt et al., 2019; Purves et al., 2019; Trucco et al., 2018). Yet even traits with a strong genetic component, such as growth, body weight, and height, are modified by environmental circumstances and opportunities that influence whether genetic potentials are realized (Dubois et al., 2012; Jelenkovic et al., 2016). Even identical twins who share 100% of their genes are not 100% alike because of the influence of environmental factors, which interact with genes in a variety of ways.

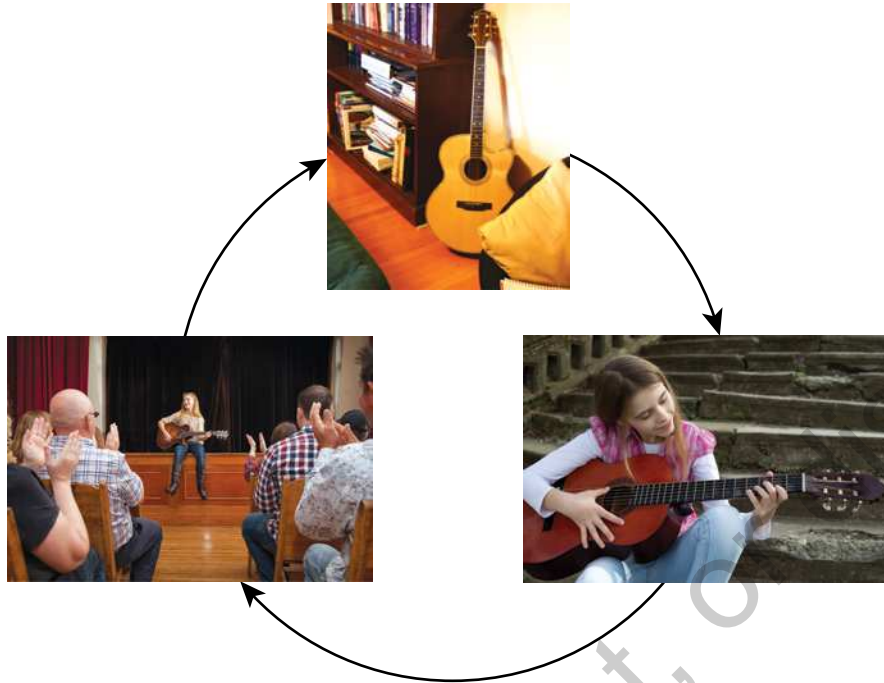
### Gene-Environment Correlations

Genes and environment influence development and behavior independently, but they also are correlated. Environmental factors often support hereditary traits (Briley et al., 2019; Saltz, 2019; Scarr & McCartney, 1983). Gene-environment correlation refers to the finding that many genetically influenced traits tend to be associated with environmental factors that promote their development (Lynch, 2016). That is, genetic traits influence children's behavior, which is often supported or encouraged by the environment (Knafo & Jaffee, 2013). There are three types of gene-environment correlations: passive, reactive, and active.

Parents create homes that reflect their own genotypes. Because parents are genetically similar to their children, the homes that parents create support their own preferences but also correspond to their child's genotype—an example of a *passive gene-environment correlation* (Wilkinson et al., 2013). It is a passive **gene-environment correlation** because it occurs regardless of the child's behavior. For example, parents might provide genes that predispose a child to develop musical ability and then create a home environment that supports the development of musical ability, such as by playing music in the home and owning musical instruments (Corrigan & Schellenberg, 2015; see Figure 2.4). This type of

### FIGURE 2.4 ■ Gene-Environment Correlation

The availability of instruments in the home corresponds to the child's musical abilities, and they begin to play guitar (passive gene-environment correlation). As they play guitar, they evoke positive responses in others, increasing their interest in music (evocative gene-environment correlation). Over time, they seek opportunities to play, such as performing in front of an audience (niche picking).



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gene-environment correlation tends to occur early in life because parents create rearing environments for their infants and young children.

People naturally evoke responses from others and the environment, just as the environment and the actions of others evoke responses from the individual. In an *evocative gene-environment correlation*, a child's genetic traits (e.g., personality characteristics such as openness to experience) influence the social and physical environment, which shape development in ways that support the genetic trait (Pieters et al., 2015; Saltz, 2019). A child with a genetic trait for music talent will evoke pleasurable responses (e.g., parental approval) when she plays music; this environmental support, in turn, encourages further development of the child's musical trait.

Children also take a hands-on role in shaping their development. Recall from Chapter 1 that a major theme in understanding human development is the finding that individuals are active in their development; here we have an example of this theme. As children grow older, they have increasing freedom to choose their own activities and environments. An *active gene-environment correlation* occurs when the child actively creates experiences and environments that correspond to and influence his or her genetic predisposition. For example, the child with a genetic trait for interest and ability in music actively seeks experiences and environments that support that trait, such as friends with similar interests and after-school music classes (Corrigall & Schellenberg, 2015). This tendency to actively seek out experiences and environments compatible and supportive of our genetic tendencies is called **niche picking** (Saltz, 2019; Scarr & McCartney, 1983).

### Gene-Environment (G x E) Interactions

Although behavior geneticists have learned a great deal about genetic influences on behavior, effects are often unpredictable (Flint et al., 2020). The effects of genes vary with environmental influences and not all genotypes respond to environmental influences in the same way (Fowler-Finn & Boutwell, 2019). Consider a classic study that followed a sample of boys from birth to adulthood and found that



Not all children exposed to adversity experience negative outcomes. Genes, such as MAOA, influence children's sensitivity to maltreatment.

FatCamera/ Getty Images

the effects of experiencing childhood maltreatment varied with boys' genotypes. The boys who experienced maltreatment were twice as likely to develop problems with aggression, violence, and to even be convicted of a violent crime—but only if they carried a specific form of the gene that controls monoamine oxidase A (MAOA), an enzyme that regulates chemicals in the brain. These findings have been replicated in another 30-year longitudinal study of boys (Fergusson et al., 2011) as well as a meta-analysis of 27 studies (Byrd & Manuck, 2014).

MAOA gene-environment interactions influence other mental health outcomes such as antisocial personality disorder and depression (Beach et al., 2010; Cicchetti et al., 2007; Manuck & McCaffery, 2014; Nikulina et al., 2012). Gene-environment interactions determine the effects of many genes. For example, the 5-HTTLPR gene, responsible for regulating specific chemicals in the brain, interacts with environmental factors

to influence parenting sensitivity, depression, stress, and responses to trauma (Baião et al., 2020; Li et al., 2013). Genes and the environment work together in complex ways to determine our characteristics, behavior, development, and health (Morgan et al., 2020; Ritz et al., 2017).

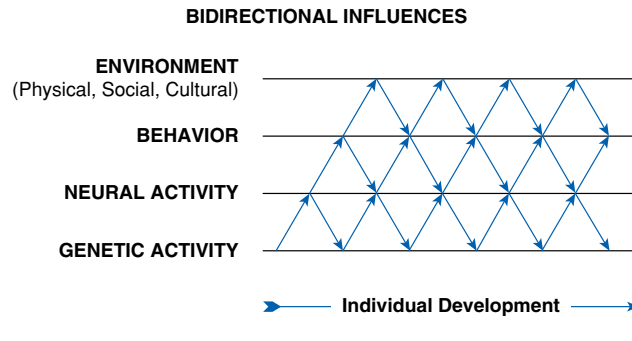
### Epigenetic Framework

As we have seen, development is influenced by the dynamic interaction of biological and contextual forces. Genes provide a blueprint for development, but phenotypic outcomes—individuals' characteristics—are not predetermined; they vary with environmental factors. Recently scientists have determined that environmental factors do not simply interact with genes to determine people's traits. Instead, they *determine how* genes are expressed through a process known as **epigenetics** (Carlberg & Molnar, 2019; Moore, 2017). The epigenome is a molecule that stretches along the length of DNA and provides instructions to genes, determining how they are expressed, that is, whether they are turned on or off.

At birth, each cell in our body turns on only a fraction of its genes. The epigenome instructs genes to be turned on and off over the course of development and also in response to the environment (Meaney, 2017). Epigenetic mechanisms determine how genetic instructions are carried out to determine the phenotype (Lester et al., 2016; Pinel et al., 2018). Environmental factors such as toxins, injuries, crowding, diet, and responsive parenting can influence the expression of genetic traits by determining which genes are turned on and off (O'Donnell & Meaney, 2020).

Epigenetic processes also influence human development. Consider brain development (O'Donnell & Meaney, 2020). Providing infants with a healthy diet and opportunities to explore the world will support the development of brain cells, governed by epigenetic mechanisms that switch genes on and off. Conversely, epigenetic changes that accompany exposure to toxins or extreme trauma might suppress the activity of some genes, potentially negatively influencing brain development. In this way, brain development is influenced by epigenetic interactions among genes and contextual factors that determine infants' phenotypes (Lerner & Overton, 2017). These complex interactions are illustrated in Figure 2.5 (Dodge & Rutter, 2011). Interactions between heredity and environment change throughout development, as does the role we play in constructing environments that support our genotypes, influence our epigenome, and determine who we become (Lickliter & Witherington, 2017).

Perhaps the most surprising finding emerging from animal studies of epigenetics is that the epigenome can be passed by males and females from one generation to the next (Legoff et al., 2019; Szyf, 2015). This means that what you eat and do today could affect the epigenome—the development, characteristics, and health—of your children, grandchildren, and great-grandchildren (Bošković & Rando, 2018; Grover & Jenkins, 2020; Vanhees et al., 2014).

**FIGURE 2.5** ■ Epigenetic Framework

Source: Gottlieb, 2007.

### Thinking in Context: Lifespan Development

1. Describe a skill or ability at which you excel. How might your ability be influenced by your genes and your context?
  - a. Identify passive gene-environment correlation that may contribute to your ability. How has your environment influenced your ability?
  - b. Provide an example of an evocative gene-environment correlation. How have you evoked responses from your context that influenced your ability?
  - c. Explain how your ability might reflect an active gene-environment correlation.
  - d. Which of these types of gene-environment correlation do you think best accounts for your ability? Why?

### Thinking in Context: Biological Influences

1. Considering the research on epigenetics, what can you do to protect your epigenome? What kinds of behavioral and contextual factors might influence your epigenome?
2. If some genes may be protective in particular contexts, should scientists learn how to turn them on? Should scientists learn to turn off genes that might increase risks in particular contexts? Why or why not?

### Thinking in Context: Applied Developmental Science

Imagine that you are a researcher planning to conduct a twin study and an adoption study on intelligence, personality, academic achievement, or another topic. What are the advantages and disadvantages of each method? What are some challenges in obtaining participants for these studies? Using the twin approach, how might you determine the genetic and environmental influences on your topic of interest? How does this differ in adoptive studies?

What conclusions do you draw about these types of studies? Which do you prefer and why?

## PRENATAL DEVELOPMENT

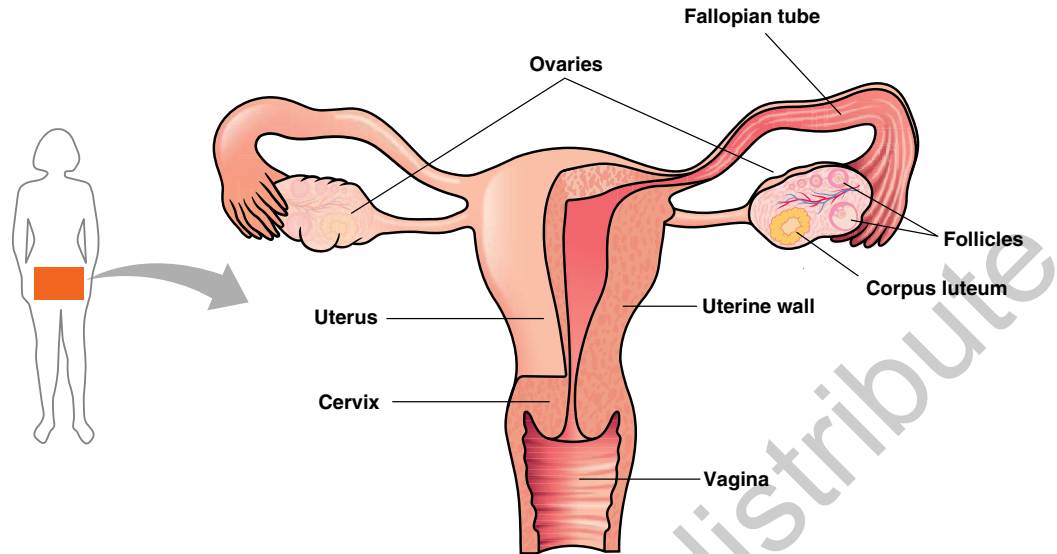
### LEARNING OBJECTIVE

- 2.3** Describe the three periods of prenatal development.

**Prenatal development** is a dramatic process in which a single cell transforms and grows into a **neonate**, or newborn. Conception, the union of ovum and sperm, marks the beginning of prenatal development. Over the next 38 weeks, the human progresses through several periods of development from fertilization to birth.



FIGURE 2.6 ■ Female Reproductive System



### Conception

A woman can conceive only during a short window of time each month. About every 28 days, an ovum bursts from one of the ovaries into the long, thin fallopian tube that leads to the uterus; this event is known as ovulation (see Figure 2.6). Over several days, the ovum travels down the fallopian tube, which connects the ovaries to the uterus, while the woman's hormones cause the lining of the uterus to thicken in preparation for the fertilized ovum (Sadler, 2018). If fertilization does not occur, the lining of the uterus is shed through menstruation about 2 weeks after ovulation.

Conception, of course, also involves the male. Each day a man's testes produce millions of sperm, which are composed of a pointed head packed with 23 chromosomes' worth of genetic material and a long tail. During ejaculation, about 360 million, and as many as 500 million, sperm are released, bathed in a protective fluid called semen (Moore et al., 2019). On average, only about 300 sperm reach the ovum within the fallopian tubes, if an ovum is present (Webster et al., 2018). As soon as one sperm penetrates the ovum the sperm's tail falls off, and the sperm's genetic contents merge with that of the ovum. After fertilization, the zygote rapidly transforms into a multicelled organism. Prenatal development takes place over three developmental periods: (1) the germinal period, (2) the **embryonic period**, and (3) the fetal period.

### Germinal Period (0 to 2 Weeks)

During the **germinal period**, also known as the period of the zygote, the newly created zygote begins cell division as it travels down the fallopian tube, where fertilization took place, toward the uterus. About 30 hours after conception, the zygote then splits down the middle, forming two identical cells (Webster et al., 2018). This process is called cleavage, and it continues at a rapid pace. The two cells each split to form four cells, then eight, and so on (see Figure 2.7).

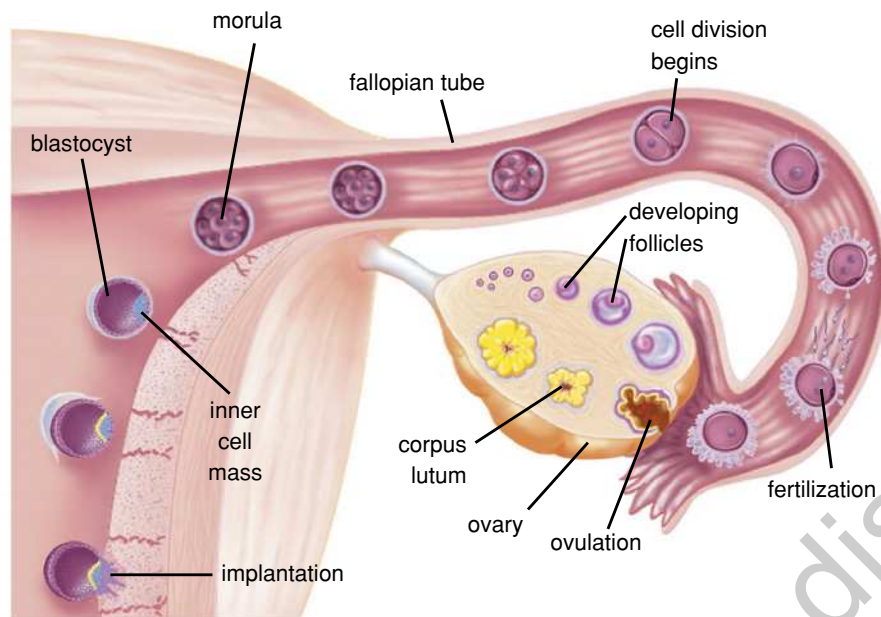
After four days, the organism consists of about 60 to 70 cells formed into a **blastocyst**, a fluid-filled ball of cells surrounding an inner cluster of cells from which the embryo will develop. **Implantation**, in which the blastocyst burrows into the wall of the uterus, begins at about day 6 and is complete by about day 11 (Moore et al., 2019).



This ball of cells, known as a morula, is formed at about three days after conception. Each of these cells is identical. Differentiation has not yet begun.

Pascal Goetgheluck/Science Source

FIGURE 2.7 ■ Germinal Period



### Embryonic Period (3 to 8 Weeks)

After implantation, during the third week after conception, the developing organism, now called an **embryo**, begins the most rapid period of structural development in the lifespan. The mass of cells composing the *embryonic disk* forms layers, which will develop into all the major organs of the body. The *ectoderm*, the upper layer, will become skin, nails, hair, teeth, sensory organs, and the nervous system. The *endoderm*, the lower layer, will become the digestive system, liver, lungs, pancreas, salivary glands, and respiratory system. The middle layer, the *mesoderm*, forms later and will become muscles, skeleton, circulatory system, and internal organs.

As the embryo develops, support structures form to protect it, provide nourishment, and remove wastes. The **amnion**, a membrane that holds amniotic fluid, surrounds the embryo providing temperature regulation, cushioning, and protection from shocks. The **placenta**, a principal organ of exchange between the mother and developing organism, begins to form. It will act as a filter, enabling the exchange of nutrients, oxygen, and wastes to occur through the umbilical cord, and as a protective barrier, preventing some toxins from entering the embryo's bloodstream.

About 22 days after conception marks a particularly important change: The ectoderm folds to form the **neural tube**, which will develop into the central nervous system (brain and spinal cord; Webster et al., 2018). The head can be distinguished and a blood vessel that will become the heart begins to pulse and blood begins to circulate throughout the body. During days 26 and 27, arm buds appear, followed by leg buds on days 28 through 30 (Sadler, 2018). The brain develops rapidly and the head grows faster than the other parts of the body during the fifth week of development. The eyes, ears, nose, and mouth begin to form during the sixth week. Upper arms, forearms, palms, legs, and feet appear.

During the seventh week a ridge called the **indifferent gonad** appears that can develop into the male or female genitals, depending on the fetus's sex chromosomes (XY for males and XX for females; Moore et al., 2019). The sex organs take several weeks to develop. The external genital organs are not apparent until about 12 weeks.

At the end of the embryonic period, 8 weeks after conception, the embryo weighs about one-seventh of an ounce and is 1 inch long. All of the basic organs and body parts have formed in a very rudimentary way. The embryo displays spontaneous reflexive movements, but it is still too small for the movements to be felt by the mother (Hepper, 2015). Serious defects that emerge during the embryonic period most often occur before the pregnancy is detected, are the result of chromosomal abnormalities, and often cause a miscarriage (loss of the embryo; Chou et al., 2020).



Development proceeds very quickly during the embryonic period. Note the dramatic changes from the fifth week (left) to the seventh week (right) of prenatal development.

Petit Format/Science Source; Professor Pietro M. Motta/Science Source

### Fetal Period (9 Weeks to Birth)

During the **fetal period**, from the ninth week to birth, the organism, called a **fetus**, grows rapidly, and its organs become more complex and begin to function. Now all parts of the fetus's body can move spontaneously, the legs kick, and the fetus can suck its thumb (an involuntary reflex; Sadler, 2018).

By the 14th week, limb movements are coordinated, but they will be too slight to be felt by the mother until about 17 to 20 weeks. The heartbeat gets stronger. Eyelids, eyebrows, fingernails, toenails, and tooth buds form. During the last 3 months of pregnancy, the fetal body grows substantially in weight and length; specifically, it typically gains more than 5 pounds and grows 7 inches (Moore et al., 2019). At about 28 weeks after conception, the cerebral cortex develops convolutions and furrows, taking on the brain's characteristic wrinkly appearance (Andescavage et al., 2016). The fetal brain wave pattern shifts to include occasional bursts of activity, similar to the sleep-wake cycles of newborns.

### Prenatal Diagnosis

Prenatal development is monitored through several methods. The most widespread and routine diagnostic procedure is **ultrasound**, in which high-frequency sound waves directed at the mother's abdomen provide clear images of the womb represented on a video monitor. Ultrasound enables physicians to observe the fetus, measure fetal growth, judge gestational age, reveal the sex of the fetus, detect multiple pregnancies (twins, triplets, etc.), and determine physical abnormalities in the fetus. Many deformities can be observed, such as cardiac abnormalities, cleft palate, and microencephaly (small head size). At least 80% of women in the United States receive at least one prenatal ultrasound scan (Sadler, 2018). Three to four screenings over the duration of pregnancy are common to evaluate fetal development. Repeated ultrasound of the fetus does not appear to affect growth and development (Abramowicz, 2019; Stephenson, 2005).



Ultrasound technology provides clear images of the womb, permitting physicians to observe the fetus, measure fetal growth, judge gestational age, reveal the sex of the fetus, detect multiple pregnancies, and determine physical abnormalities in the fetus.

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**Fetal MRI** applies MRI technology (see Chapter 1) to image the fetus's body and diagnose malformations (Aertsen et al., 2020). It is often used as a follow-up to ultrasound imaging to provide more detailed views of suspected abnormalities (Milani et al., 2015). Unlike ultrasound, fetal MRI can detect abnormalities throughout the body, including in the central nervous system (Griffiths et al., 2017; Masselli et al., 2020). Fetal MRI is safe for mother and fetus in the second and third trimesters but is expensive and has limited availability in some areas (Patenaude et al., 2014).

**Amniocentesis** involves sampling the amniotic fluid surrounding the fetus by extracting it from the mother's uterus through a long, hollow needle that is guided by ultrasound as it is inserted into the mother's abdomen (Odibo, 2015). The amniotic fluid contains fetal cells, which are grown in a laboratory dish to create enough cells for genetic analysis. Genetic analysis is then performed to detect chromosomal anomalies and defects. Amniocentesis is less common than ultrasound, as it poses greater risk to the fetus, but it is safe (Homola & Zimmer, 2019). It is recommended for women aged 35 and over, especially if the woman and partner are both known carriers of genetic diseases (Vink & Quinn, 2018a). Usually amniocentesis is conducted between the 15th and 18th week of pregnancy. Conducted any earlier, an amniocentesis may increase the risk of miscarriage (Akolekar et al., 2015). Test results generally are available about two weeks after the procedure because it takes that long for the genetic material to grow and reproduce to the point where it can be analyzed.

**Chorionic villus sampling (CVS)** also samples genetic material and can be conducted earlier than amniocentesis, between 9 and 12 weeks of pregnancy (Vink & Quinn, 2018b). CVS requires obtaining a small amount of tissue from the chorion, part of the membrane surrounding the fetus, by using a long needle inserted either abdominally or vaginally, depending on the location of the fetus. Results are typically available about one week following the procedure. CVS is relatively painless and, like amniocentesis, has a 100% diagnostic success rate. Generally, CVS poses few risks to the fetus. (Salomon et al., 2019; Shim et al., 2014). However, CVS should not be conducted prior to 10 weeks gestation as some studies suggest an increased risk of limb defects and miscarriages (Shahbazian et al., 2012).

**Noninvasive prenatal testing (NIPT)** screens the mother's blood to detect chromosomal abnormalities in the fetus. Cell-free fetal DNA (chromosome fragments that result in the breakdown of fetal cells) circulates in maternal blood in small concentrations (Hartwig et al., 2017; Warsof et al., 2015). Testing can be done after 10 weeks; it's typically done between 10 and 22 weeks. Given that the test involves drawing blood from the mother, there is no risk to the fetus. The use of NIPT has increased dramatically in the U.S. and other countries (Hui et al., 2017). NIPT can provide accurate sex determination but cannot detect as many chromosomal abnormalities as amniocentesis or CVS and with less accuracy (Hartwig et al., 2017; Vilella et al., 2019). Pregnant women and their partners, in consultation with their obstetrician, should carefully weigh the risks and benefits of any procedure designed to monitor prenatal development (see Table 2.6).

**TABLE 2.6** ■ **Methods of Prenatal Diagnosis**

	Explanation	Advantages	Disadvantages
<b>Ultrasound</b>	High-frequency sound waves directed at the mother's abdomen provide clear images of the womb projected on to a video monitor.	Enables physicians to observe the fetus, measure fetal growth, reveal the sex of the fetus, and to determine physical abnormalities in the fetus.	Many abnormalities and deformities cannot be easily observed.
<b>Amniocentesis</b>	A small sample of the amniotic fluid containing fetal cells is extracted from the mother's uterus. The fetal cells are grown in a laboratory dish and analyzed.	Permits a thorough analysis of the fetus's genotype. There is 100% diagnostic success rate.	Safe, but poses a greater risk to the fetus than ultrasound, especially if conducted before the 15th week of pregnancy.
<b>Chorionic villus sampling (CVS)</b>	A small amount of tissue is sampled from the chorion, grown in a laboratory dish, and studied to detect chromosomal abnormalities.	Permits a thorough analysis of the fetus's genotype. There is 100% diagnostic success rate. CVS can be conducted earlier than amniocentesis, between 10 and 12 weeks.	It is safe but may pose a risk of spontaneous abortion and limb defects when conducted prior to 10 weeks' gestation.
<b>Fetal MRI</b>	Uses a magnetic resonance imaging scanner to record detailed images of fetal organs and structures.	Provides the most detailed and accurate images available	It is expensive, but safe.
<b>Noninvasive prenatal testing (NIPT)</b>	Cell-free fetal DNA is examined by drawing blood from the mother.	There is no risk to the fetus. It can diagnose several chromosomal abnormalities.	It cannot detect the full range of abnormalities and may be less accurate than other methods.

Sources: (Akolekar et al., 2015; Chan et al., 2013; Gregg et al., 2013; Odibo, 2015; Shahbazian et al., 2012; Shim et al., 2014; Theodora et al., 2016)



### Thinking in Context: Lifespan Development

What might be some of the implications of the timing of prenatal development—that is, when the major body systems develop—for the behavior of pregnant women and those who are considering becoming pregnant?

### Thinking in Context: Applied Developmental Science

1. Petra noticed that her abdomen has not grown much since she became pregnant three months ago. She concluded that the fetus must not undergo significant development early in pregnancy. How would you respond to Petra?
2. Suppose that you are a health care provider tasked with explaining prenatal diagnostic choices to a 38-year-old woman pregnant with her first child. How would you explain the various choices? What information would you provide about their purpose and the advantages and disadvantages of each? Which tests are most relevant to your patient? What would you advise? Why?

## ENVIRONMENTAL INFLUENCES ON PRENATAL DEVELOPMENT

### LEARNING OBJECTIVE

- 2.4** Explain how exposure to environmental factors can influence the prenatal environment and provide examples.

Prenatal development unfolds along a programmed path, a predictable pattern of change, but it can be disrupted by environmental factors called **teratogens**. A teratogen is an agent, such as a disease, drug, or other environmental factor, that can cause prenatal abnormalities, defects, and even death.

### Principles of Teratology

Several principles can account for the varied effects of exposure to teratogens on prenatal development (Moore et al., 2019; Sadler, 2018).

#### Critical Periods

The developing organism is more susceptible to the harmful effects of teratogens during certain stages of development (Nelson & Gabard-Durnam, 2020). The embryonic period is the most sensitive stage of development (Webster et al., 2018). In addition, each organ of the body has a sensitive period during which it is most susceptible to damage from teratogens such as drugs, alcohol, and environmental contaminants (see Figure 2.8). Once a body part is fully formed, it is less likely to be harmed by exposure to teratogens, but some body parts, like the brain, remain vulnerable throughout prenatal development.

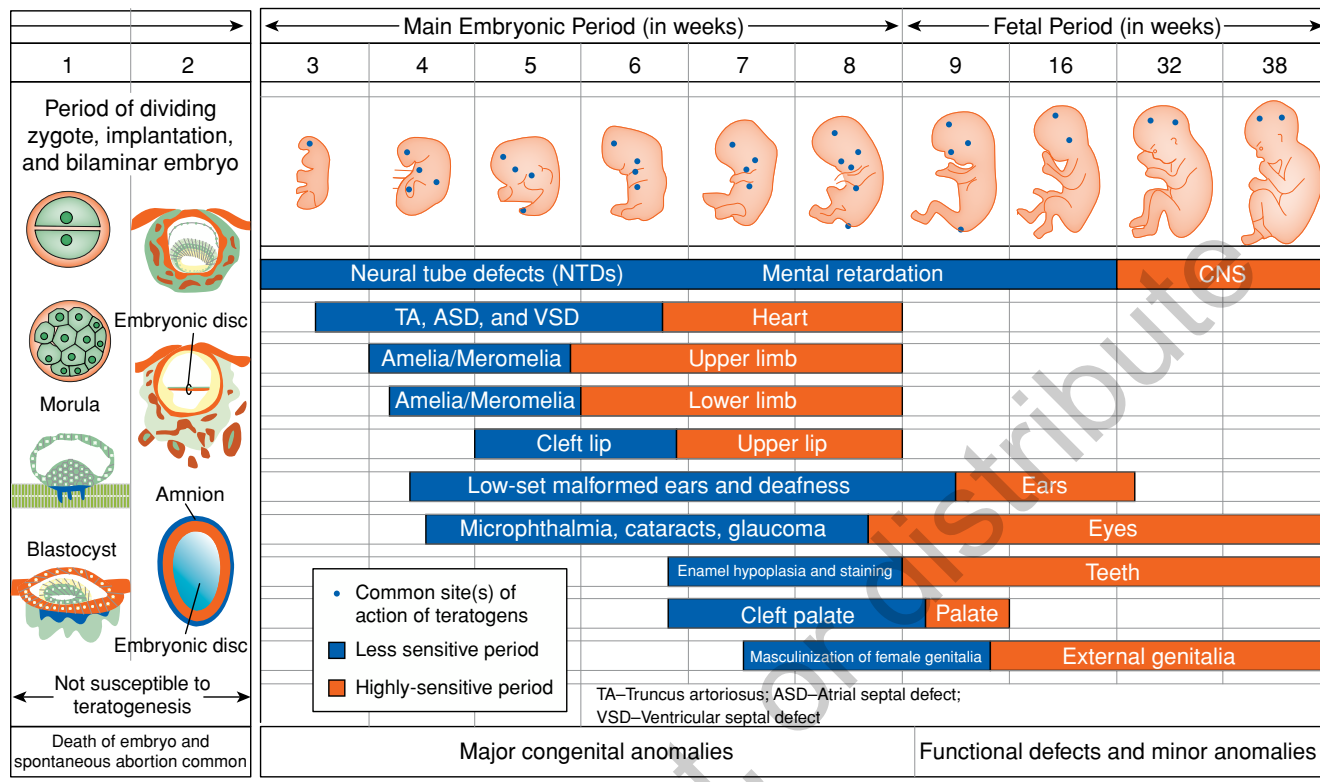
#### Dose

The amount of exposure (i.e., dosage) to a teratogen influences its effects. Generally, the greater the dose and the longer the period of exposure, the more damage to development, but teratogens also differ in their strength. Some, like alcohol, display a powerful dose-response relationship so that larger doses, or heavier and more frequent drinking, predictably result in greater damage (Bandoli et al., 2019).

#### Individual Differences

Individuals vary in their susceptibility to particular teratogens based on the genetic makeup of both the organism and mother, as well as the quality of the prenatal environment. Organisms might show a range of responses to a given teratogen, such that some show severe defects, others more mild defects, and some may display normal development (Kaminen-Ahola, 2020).



**FIGURE 2.8** ■ Critical Periods in Prenatal Development

Adapted from Moore et al, 2019

## Types of Teratogens

Prenatal development can be influenced by many contextual factors: maternal consumption of over-the-counter (OTC), prescription, and recreational drugs; illness; environmental factors; and more.

### Prescription and Nonprescription Drugs

More than 90% of pregnant women take prescription or OTC medications (Servey & Chang, 2014; Stanley et al., 2019). Prescription drugs that can act as teratogens include antibiotics, certain hormones, antidepressants, anticonvulsants, and some acne drugs (Tsamantioti & Hashmi, 2020).

Nonprescription drugs, such as diet pills and cold medicine, can also act as teratogens, but research on OTC drugs lags far behind research on prescription drugs, and we know little about the teratogenic effect of many OTC drugs (Tsamantioti & Hashmi, 2020). Caffeine, found in coffee, tea, cola drinks, and chocolate, is the most common OTC drug consumed during pregnancy. Prenatal caffeine exposure is associated with smaller size for gestational age (Modzelewska et al., 2019) and large doses are associated with an increased risk for miscarriage and low birthweight (Chen et al., 2014; Chen et al., 2016; Qian et al., 2020).

Some drugs show complicated effects on development. High doses of aspirin early in pregnancy are associated with increased risk of miscarriage and poor fetal



More than 90% of pregnant women take prescription or over-the-counter (OTC) medications. The findings regarding the teratogenic effects of drugs are mixed, with some studies suggesting potential harm and others suggesting no ill effects of a given drug. In addition, low doses of aspirin may have benefits in treating preeclampsia and high blood pressure during pregnancy.

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Fetal alcohol syndrome is associated with distinct facial characteristics, growth deficiencies, and deficits in intellectual development, language, motor coordination, and the combined abilities to plan, focus attention, and problem solve that persist throughout childhood and into adulthood.

Susan Astley PhD/University of Washington

growth (Antonucci et al., 2012). Yet later in pregnancy, low doses of aspirin are often prescribed to prevent and treat preeclampsia (dangerously high blood pressure in pregnancy that can cause organ damage; Loussert et al., 2020; Roberge et al., 2017).

### Alcohol

An estimated 10% to 20% of Canadian and U.S. women report consuming alcohol during pregnancy (Alshaarawy et al., 2016; Popova et al., 2017). Alcohol abuse during pregnancy is the leading cause of developmental disabilities (Webster et al., 2018). **Fetal alcohol spectrum disorders** refer to the continuum of effects of exposure to alcohol, which vary with the timing and amount of exposure (Hoyme et al., 2016). Fetal alcohol spectrum disorders are estimated to affect as many as 2% to 5% of younger schoolchildren in the United States and Western Europe (May et al., 2014, 2018).

**Fetal alcohol syndrome (FAS)** is a cluster of defects that occur with heavy prenatal exposure to alcohol. FAS is associated with physical characteristics (often small head circumference, short nose, and small midface), growth deficiencies, and deficits in motor coordination and in a range of cognitive abilities that affect attention, planning, and problem solving (Gupta et al., 2016; Looock et al., 2020; Wozniak et al., 2019). Cognitive and behavioral problems can persist from childhood and adolescence through adulthood (Dejong et al., 2019; Mamluk et al., 2017; Mattson et al., 2019). Children exposed to smaller amounts of alcohol prenatally may display *fetal alcohol effects*, which are some but not all of the problems of FAS (Hoyme et al., 2016).

There appears to be no safe level of drinking (Sarman, 2018; Shuffrey et al., 2020). Even less than one drink per day has been associated with poor fetal growth, preterm delivery, and abnormal brain activity in newborns (Mamluk et al., 2017; Shuffrey et al., 2020).

### Cigarette Smoking and E-Cigarette Use

About 7% to 10%, and in some studies as many as 17%, of women report smoking cigarettes during pregnancy (Agrawal et al., 2019; Kondracki, 2019). Fetal deaths, premature births, and low birthweight are nearly twice as frequent in mothers who are smokers than in those who do not smoke (Juárez & Merlo, 2013; Soneji & Beltrán-Sánchez, 2019). Infants exposed to smoke while in the womb are prone to congenital heart defects, respiratory problems, and sudden infant death syndrome and, as children, show more behavior problems, attention difficulties, and lower scores on intelligence and achievement tests (Froggatt et al., 2020; He et al., 2017; Sutin et al., 2017). Even babies born to light smokers (one to five



Smoking cigarettes during pregnancy can have adverse consequences.

iStock/Jan-Otto

cigarettes per day) show poorer fetal growth and higher rates of low birthweight than do babies born to nonsmokers (Berlin et al., 2017; Brand et al., 2019; Tong et al., 2017). Maternal smoking during pregnancy shows epigenetic effects on offspring, influencing predispositions to illness and disease in childhood, adolescence, and even middle adulthood (Joubert et al., 2016; Kaur et al., 2019; Nguyen et al., 2018).

About 10% to 15% of women report using e-cigarettes during pregnancy and the prevalence is rising (Wagner et al., 2017; Whittington et al., 2018). E-cigarettes are commonly believed to be “safer” than cigarettes, but exposure to e-cigarette vapor prenatally has similar toxic effects on prenatal development as traditional cigarettes, including increased risk for asthma and cognitive and neurological problems (Church et al., 2020; Greene & Pisano, 2019; Nguyen et al., 2018)

### Marijuana

About 4% to 7% of pregnant women report using marijuana (Brown et al., 2017; Young-Wolff et al., 2019). The main active ingredient of marijuana, THC, readily crosses the placenta to affect the fetus (Alvarez et al., 2018). Marijuana use during early pregnancy negatively affects fetal growth, birthweight, and preterm birth, and is associated with a thinner cortex in late childhood (El Marroun et al., 2018). There are long-term neurological effects including impairments in attention, memory, and executive function as well as impulsivity in children, adolescents, and young adults (Grant et al., 2018; Sharapova et al., 2018; Smith et al., 2016).

### Cocaine

Prenatal exposure to cocaine is associated with low birthweight, impaired motor skills and reflexes, and reduced brain volume at birth and in infancy (dos Santos et al., 2018; Grewen et al., 2014). Exposure has long-term effects on children through its effect on brain development, particularly the regions associated with attention, arousal, regulation, and executive function (Bazin et al., 2016). It has a small but lasting effect on attention, emotional control, and behavioral problems through early adolescence and even emerging adulthood (Buckingham-Howes et al., 2013; Min et al., 2014; Richardson et al., 2015, 2019; Singer et al., 2015)

### Opioids

Opioids are a class of drugs that include the illegal drugs heroin and synthetic opioids such as fentanyl, as well as prescription pain relievers, such as oxycodone and morphine. Prenatal exposure to opioids is associated with low birthweight, smaller head circumference, and altered brain development (Azuine et al., 2019; Monnelly et al., 2018; Towers et al., 2019). Newborns exposed to opioids prenatally may show signs of addiction and withdrawal symptoms, including tremors, irritability, abnormal crying, disturbed sleep, and impaired motor control (Conrad et al., 2019; Raffaelli et al., 2017). As children and adolescents they tend to show difficulty with attention, learning, managing arousal, and behavioral control; show more emotional and behavior problems than peers; and have reduced brain volume and smaller cortical surface area (Levine & Woodward, 2018; Nygaard et al., 2018; Sirnes et al., 2017; Yeoh et al., 2019).

### Maternal Illness

Not all teratogens are drugs. Depending on the type and when it occurs, an illness experienced by the mother during pregnancy can have grave consequences for the developing fetus. Rubella (German measles) prior to the 11th week of pregnancy can cause a variety of defects, including blindness, deafness, heart defects, and brain damage, but after the first trimester, adverse consequences are less common (Bouthry et al., 2014; Singh, 2020). Chicken pox can produce birth defects affecting the arms, legs, eyes, and brain; mumps can increase the risk of miscarriage (Mehta, 2016; Webster et al., 2018). Some sexually transmitted infections (STIs), such as syphilis, can be transmitted to the fetus during pregnancy (Tsimis & Sheffield, 2017). HIV, the virus that causes acquired immune deficiency syndrome (AIDS), a disease affecting the immune system, can be transmitted during birth and through bodily fluids, including by breastfeeding.





Prenatal exposure to radiation increases genetic mutation, leading to impaired development. After the nuclear power accident at Chernobyl, a significant rise in congenital conditions, or birth defects, were reported.

Sean Gallup / Staff / Getty Images

## Environmental Hazards

Prenatal exposure to chemicals, radiation, air pollution, and extremes of heat and humidity can impair development. Exposure to heavy metals, such as lead and mercury, is associated with lower scores on tests of cognitive ability and higher rates of childhood illness (Sadler, 2018; Vigehe et al., 2014; Xie et al., 2013). Prenatal exposure to radiation can cause genetic mutations and is associated with Down syndrome, reduced head circumference, intellectual disability, reduced cognitive and school performance, and heightened risk for cancer from childhood through adulthood (Black et al., 2019; Chang et al., 2014).

## Contextual Factors and Teratogens

Our discussion of teratogens thus far has examined the effects of each teratogen independently, which is misleading because infants are often exposed to multiple teratogens. Most infants exposed to opioids or cocaine were also exposed to other substances, including tobacco, alcohol, and marijuana, making it difficult to isolate the effect of each drug on prenatal development. The effects of prenatal exposure to drugs are also influenced by parenting and other postnatal factors (Lee et al., 2020).

Once contextual factors in the home and neighborhood, such as parenting, the caregiving environment, socioeconomic status, and exposure to violence are controlled, child and adolescent behavior problems are reduced and often eliminated (Brodie et al., 2019; Buckingham-Howes et al., 2013; Calhoun et al., 2015). Disentangling the long-term effects of prenatal exposure to substances, subsequent parenting, and contextual factors is challenging.

In addition, we must be cautious in interpreting findings about illicit drug use and the effects on prenatal development because race and ethnicity, maternal age, socioeconomic status, and region combine to influence the immediate and long-term outcomes of prenatal substance use for women and their infants. Many U.S. states treat maternal substance use as fetal abuse and construct laws that threaten women who use substances with involuntary treatment or protective custody during pregnancy (Atkins & Durrance, 2020; Seiler, 2016). About one-half of U.S. states classify controlled substance use during pregnancy as child abuse and require that substance use by pregnant mothers be reported to child protective services, which may lead to removing the newborn from parental custody or even terminating parental rights altogether (Guttmacher Institute, 2020).

Policies criminalizing maternal substance use discriminate against women of color and those in low socioeconomic brackets; low-income African American and Hispanic women are disproportionately tested and reported to child protective services for substance use (Paltrow & Flavin, 2013) (Hoerr et al., 2018; Rebbe et al., 2019). Criminal sanctions for maternal drug use can discourage women from seeking prenatal and postnatal care and undermine the physician-patient relationship (American College of Obstetricians and Gynecologists, 2011; American Medical Association, 2014). In contrast, women who live in states that adopt multiple policies, including those that reward abstinence, invest in family and community supports, and promote contact with health care and social support services, hold the most promise for encouraging women to seek treatment and for promoting health outcomes (Bada et al., 2012; Hui et al., 2017; Kozhimannil et al., 2019)

## Maternal and Paternal Influences on Prenatal Development

A pregnant woman's characteristics, such as her nutritional status, emotional well-being, and age, may also influence prenatal outcomes.

### Nutrition

Most women need to consume 2,200 to 2,900 calories per day (and gain about 25 to 30 pounds in total) to sustain a healthy pregnancy (Kaiser et al., 2008). Yet about 14.3 million United States households (about 11%) reported food insecurity in 2018 (United States Department of Agriculture, 2019).

Fetal malnutrition is associated with poor growth before and after birth as well as effects that can last into adulthood (Han & Hong, 2019; Kim et al., 2017).

In addition to calories, specific nutrients are also needed for healthy prenatal development. Folic acid (a B vitamin) is essential in preventing neural tube defects. **Spina bifida** occurs when the lower part of the neural tube fails to close and spinal nerves begin to grow outside of the vertebrae, often resulting in paralysis and malformations in brain development and impaired cognitive development (Avagliano et al., 2019; Donnan et al., 2017). Another neural tube defect, **anencephaly**, occurs when the top part of the neural tube fails to close and all or part of the brain fails to develop, resulting in death shortly after birth (Avagliano et al., 2019). Neural tube defects can be prevented by consuming 0.4 to 0.8mg of folic acid daily. Many foods are fortified with folic acid, but a dietary supplement is safe and ensures that prenatal needs are met (Bibbins-Domingo et al., 2017).

### Emotional Well-Being

Exposure to chronic and severe stress during pregnancy, such as from living in unsafe environments, experiencing traumatic life events, or exposure to racism and discrimination, poses risks for prenatal development, including low birthweight, premature birth, and a longer postpartum hospital stay (Lima et al., 2018; Schetter & Tanner, 2012). Long-term exposure to stress hormones in utero is associated with higher levels of stress hormones at birth and in infancy (Kapoor et al., 2016; McGowan & Matthews, 2018; Nazzari et al., 2019).

Infants prenatally exposed to high levels of maternal stress experience higher rates of emotional and behavior problems in infancy, childhood, and adolescence and increased risk for neurodevelopmental disorders such as autism and attention deficit disorder (Hentges et al., 2019; MacKinnon et al., 2018; Madigan et al., 2018; Manzari et al., 2019). Prenatal stress may also have epigenetic effects on development, influencing stress responses throughout the lifespan and perhaps transmitting them across generations (DeSocio, 2018).

Children who experience prenatal stress also tend to experience postnatal stress, making it difficult to separate their effects on children (Hartman et al., 2020; Lin et al., 2017). Children who are exposed to prenatal stress show greater emotional problems when they are also exposed to postnatal maternal depression and anxiety, as compared with those who are exposed to less maternal postnatal depression (Hartman et al., 2020). Contextual factors that influence pre- and postnatal maternal depression, such as exposure to poverty, racism and discrimination, and environmental stressors, are also experienced by children and influence their development and reactions to stress.

### Maternal Age

Since 1990, the birth rate has increased for women ages 35 to 39 and 40 to 44 (Hamilton et al., 2017; see Figure 2.9). The risk of birth complications increases in the late 30s and especially after age 40. Women who give birth after the age of 40 are at greater risk for pregnancy and birth complications, including hypertension, gestational diabetes, and miscarriage, than are younger women (Londero et al., 2019; Magnus et al., 2019; Marozio et al., 2019).

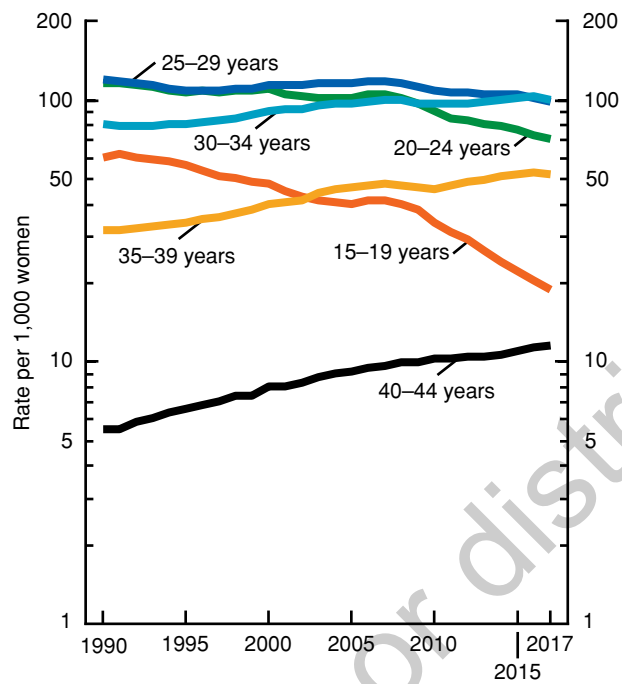
Their newborns are at increased risk for low birthweight, preterm birth, respiratory problems, and other conditions requiring intensive neonatal care (Frederiksen et al., 2018; Grotegut et al., 2014; Kenny et al., 2013; Khalil et al., 2013). The risk of having a child with Down syndrome also increases sharply with maternal age, especially after age 40 (Diamandopoulos & Green, 2018; Hazlett et al., 2011; see Figure 2.10). Although risks for complications rise linearly with each year (Yaniv et al., 2011), it is important to know that the majority of women over age 35 give birth to healthy infants.

### Paternal Characteristics

Fathers influence prenatal development indirectly, such as through secondhand smoke and their interactions with pregnant mothers (Braun et al., 2020; Glover & Capron, 2017). Biological fathers also influence prenatal development directly. Advanced paternal age (over 40) is associated with damage to sperm and DNA and an increased risk for birth defects, chromosomal abnormalities, and developmental disorders (Brandt et al., 2019; Herati et al., 2017; Rosiak-Gill et al., 2019). Alcohol use, substance use, smoking, and exposure to toxins can impair sperm production and quality, including increasing

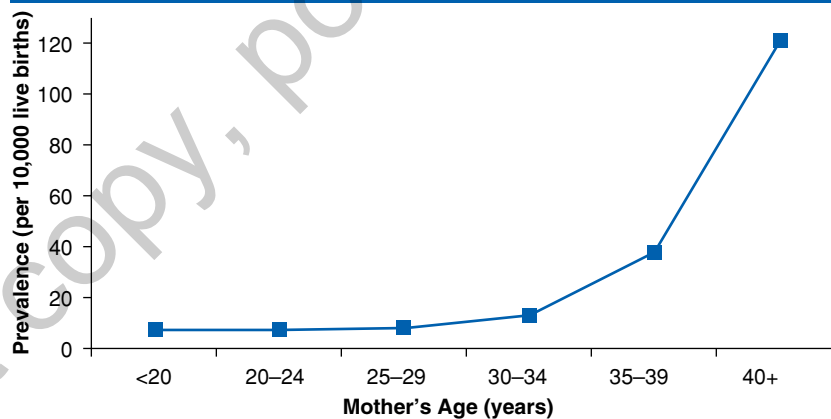


**FIGURE 2.9** ■ Birth Rates by Age of Mother, United States, 2017



Source: Martin et al, 2018.

**FIGURE 2.10** ■ Maternal Age and Down Syndrome



Source: Centers for Disease Control and Prevention, 2019.

the risk of DNA damage and mutations (Beal et al., 2017; Borges et al., 2018). In addition to DNA, fathers (and mothers) pass on epigenetic markers that can influence their offspring’s health throughout life and may even be passed to their offspring’s children (Estill & Krawetz, 2016).

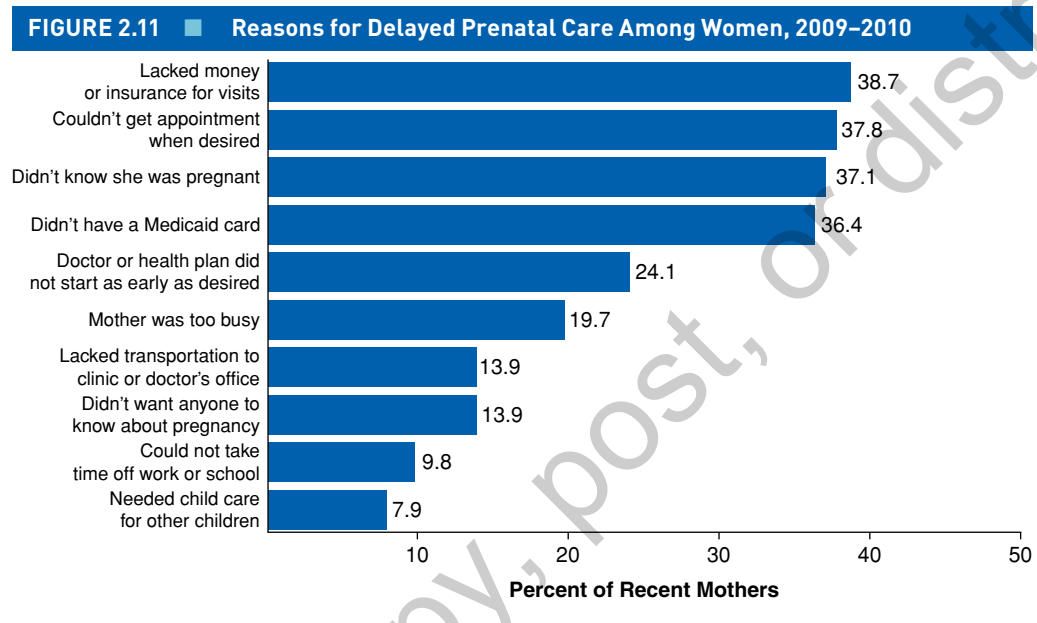
### Prenatal Care

**Prenatal care**, a set of services provided to improve pregnancy outcomes and engage the expectant mother, family members, and friends in health care decisions, is critical for the health of both mother and infant. Prenatal care visits typically include a physical exam, weight check, and diagnostic procedures, such as ultrasound, to assess the fetus’s health. These visits also provide women the opportunity to ask questions and obtain health care information and advice about nutrition, prenatal care, and preparing for birth.

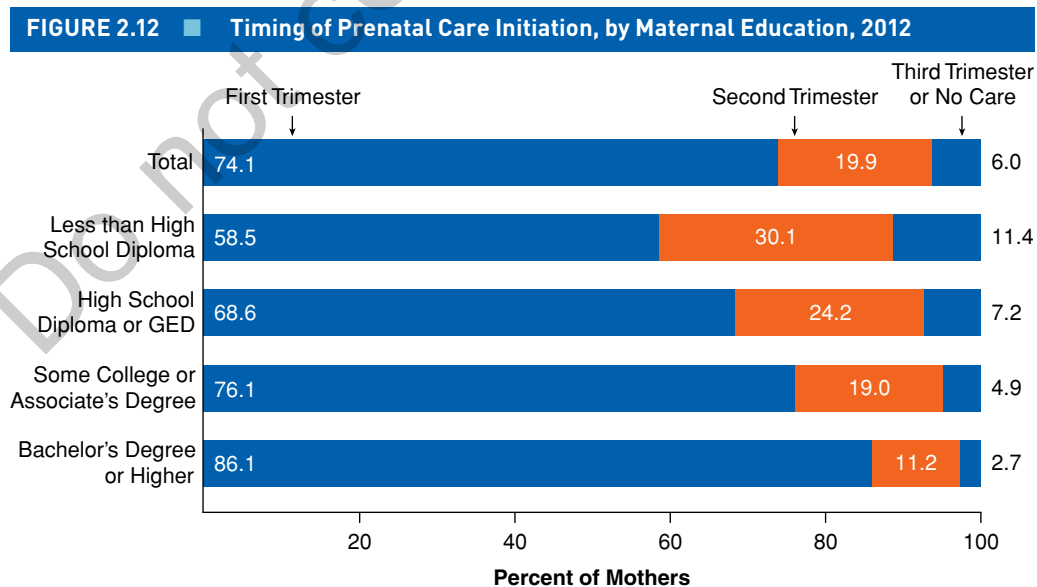
About one-quarter of pregnant women in the United States do not obtain prenatal care until after the first trimester; 6% obtain prenatal care at the end of pregnancy or not at all (U.S. Department of Health and Human Services, 2014). Inadequate prenatal care is a risk factor for low birthweight and preterm births as well as infant mortality during the first year (Partridge et al., 2012; Xaverius et al., 2016). The use of prenatal care predicts pediatric care, and thereby health and development, throughout childhood (Deaton et al., 2017).

Common reasons for insufficient prenatal care include lacking health insurance (Baer et al., 2018), difficulty in finding a doctor, lack of transportation, demands of caring for young children, poor prior experiences in the health care system, and family crises (see Figure 2.11; Daniels et al., 2006; Heaman et al., 2015; Mazul et al., 2017). Black and Latina women report nearly twice as many barriers to accessing care as white women (Fryer et al., 2021).

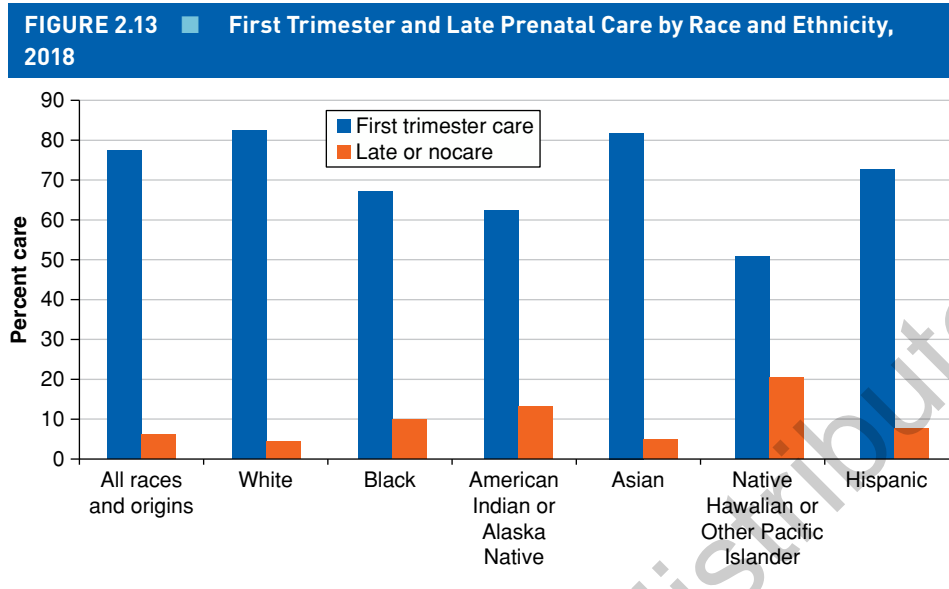
There are significant ethnic and socioeconomic disparities in prenatal care. Prenatal care is closely linked with maternal education (see Figure 2.12; Blakeney et al., 2019).



Source: U.S. Department of Health and Human Services, 2013.



Source: U.S. Department of Health and Human Services, 2015.



Source: Hamilton et al., 2018.

Women of color are disproportionately less likely to receive prenatal care during the first trimester and are more likely to receive care beginning in the third trimester or receive no care (Blakeney et al., 2019; see Figure 2.13). Native Hawaiian and Native American women are least likely to obtain prenatal care during the first trimester, followed by Black, Hispanic, Asian American, and white American women (Hamilton et al., 2018). Ethnic differences are influenced by socioeconomic factors, as the ethnic groups least likely to seek early prenatal care are also the most economically disadvantaged members of society and are most likely to live in communities with fewer health resources, such as access to physicians and hospitals, sources of health information, and nutrition and other resources.

Cultural factors may also protect some women and infants from the negative consequences of inadequate prenatal care. For example, Latina mothers in the United States face multiple barriers to prenatal care, yet their rates of low birthweight and infant mortality are below national averages. This is known as the *Latina paradox*. These favorable birth outcomes are striking because Latinos as a group are among the most socioeconomically disadvantaged ethnic populations in the United States (McGlade et al., 2004; Ruiz et al., 2016). Protective cultural factors, such as strong social support, support for maternity, the norm of selfless devotion to the maternal role (known as *marianismo*), and informal systems of health care among Latina women—in which women tend to take responsibility for the health needs of those beyond their nuclear households—account for the Latina paradox (Fracasso & Busch-Rossnagel, 1992; McGlade et al., 2004).

However, the Latina birth advantage may decline in subsequent American-born generations, perhaps because the negative effects of socioeconomic disadvantage cannot be easily ameliorated by cultural supports (Hoggatt et al., 2012; Sanchez-Vaznaugh et al., 2016). Yet Latina women who express a bicultural identity, identifying with both Latin and continental U.S. cultures, experience lower stress levels than those with low acculturation (Chasan-Taber et al., 2020), suggesting that the Latina paradox is complex, influenced by many intersecting social factors.

### Thinking in Context: Lifespan Development

Consider the influence of teratogens from the perspective of Bronfenbrenner's model (Chapter 1). Identify examples of teratogens, such as the factors we have discussed, at each bioecological level: microsystem, mesosystem, exosystem, and macrosystem. How might this model be used to help promote healthy prenatal development?

### Thinking in Context: Intersectionality

1. The issue of substance use in pregnant women is complicated. Consider the effects of teratogens on fetuses and the rights of pregnant women. How might they conflict? How do issues of justice and equity influence whether women are likely to be discovered, receive treatment, and/or be charged with maltreatment? Are all women, regardless of age, ethnicity and race, and SES, equally likely to be discovered and charged? Why or why not?
2. What are some examples of barriers to receiving prenatal care? In what ways do factors such as race, ethnicity, socioeconomic status, and culture influence whether women receive prenatal care? Would you expect all women—white, Asian American, Black, Hispanic, Pacific Islander, and Native American—to experience and perceive similar barriers? Why or why not? What environmental factors might contribute to these differences?

### Thinking in Context: Applied Developmental Science

Suppose that you plan to study the presence and effects of teratogens on prenatal development. Choose a teratogen that you believe is most relevant to prenatal health.

1. How might you measure the fetus's or embryo's exposure to the teratogen? What effects would you study?
2. To what degree are other teratogens likely to be present? How might this complicate your results?
3. How will you obtain participants (pregnant women)? How might you ensure that your participants are diverse in terms of race, ethnicity, and SES? Are there other relevant variables on which women might differ?
4. In what ways might interactions among race, ethnicity, and SES influence your results? Why or why not?

## CHILDBIRTH

### LEARNING OBJECTIVE

- 2.5 Summarize the process of childbirth and the risks for, and characteristics of, low birthweight infants.

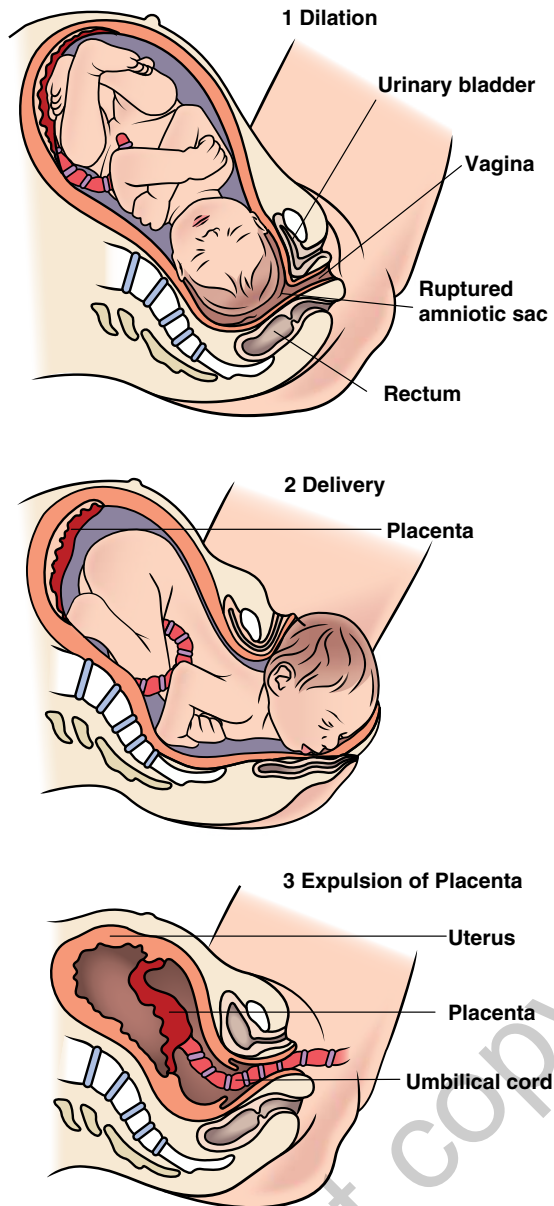
At about 40 weeks of pregnancy, or 38 weeks after conception, childbirth, also known as **labor**, begins.

### Labor

Labor progresses in three stages. The first stage of labor, dilation, is the longest. It typically lasts 8 to 14 hours for a woman having her first child; for later-born children, the average is 3 to 8 hours. Labor begins when the mother experiences regular uterine contractions spaced at 10- to 15-minute intervals. Initial contractions may feel like a backache or menstrual cramps or may be extremely sharp. The amniotic sac, a membrane containing the fetus surrounded by fluid, may rupture at any time during this stage, often referred to as the “water breaking.” The contractions, which gradually become stronger and closer together, cause the cervix to dilate so that the fetus's head can pass through, as shown in Figure 2.14.

The second stage of labor, delivery, begins when the cervix is fully dilated to 10 cm and the fetus's head is positioned at the opening of the cervix—known as “crowning.” It ends when the baby emerges

FIGURE 2.14 ■ Stages of Labor



completely from the mother's body. It is during this stage that the mother typically feels an urge to push or bear down with each contraction to assist the birth process.

In the third stage of labor, shortly after birth, the placenta separates from the uterine wall and is expelled by uterine contractions.

### Medication During Delivery

Medication is administered in more than 80% of births in the United States (Declercq et al., 2014). There are two main types of medications administered during labor. *Analgesics*, such as tranquilizers, reduce the perception of pain and can help the mother relax. But these drugs pass through the placenta to the fetus and are associated with decreases in heart rate and respiration (Hacker et al., 2016). Newborns exposed to some medications show signs of sedation and difficulty regulating their temperature (Gabbe et al., 2016).

*Anesthetics* are painkillers that block overall sensations or feelings. General anesthesia (getting “knocked out”) blocks consciousness entirely; it is no longer used because it is transmitted to the fetus and can slow labor and harm the fetus. Today, the most common anesthetic is an **epidural**, in which a pain-relieving drug is administered to a small space between the vertebrae of the lower spine, numbing the woman's lower body. Epidurals are associated with a longer delivery as they weaken uterine contractions and may increase the need for a **cesarean section**, as discussed next (Gabbe et al., 2016; Herrera-Gómez et al., 2017). Epidurals do not appear to affect newborns (Wang et al., 2018). The American College of Obstetricians and Gynecologists (2017) has concluded that the proper administration of medication poses few risks to the newborn and pain medication should be available to all women.

### Cesarean Delivery

Sometimes a vaginal birth is not possible because of concerns for the health or safety of the mother or fetus. A cesarean section is a surgical procedure that removes the fetus from the uterus through the abdomen. About 32% of U.S. births were by cesarean section in 2018 (Hamilton et al., 2018; Martin et al., 2018). Cesarean sections are performed when labor progresses too slowly, the fetus is in breech position (legs first) or transverse position (crosswise in the uterus), the head is too large to pass through the pelvis, or the fetus or mother is in danger (Jha et al., 2015; Visscher & Narendran, 2014). Babies delivered by cesarean are exposed to more maternal medication and secrete less of the stress hormones that occur with vaginal birth, which are needed to facilitate respiration, enhance circulation of blood to the brain, and help the infant adapt to the world outside of the womb.

### Natural Childbirth

**Natural childbirth** is an approach to birth that emphasizes preparation by educating mothers and their partners about childbirth, helping them to reduce their fear, and teaching them pain management techniques that do not rely on medication. The most widely known natural childbirth method, the Lamaze method, entails teaching pregnant women (and partners) about their bodies, including detailed anatomical information, as well as breathing techniques, with the intent of reducing anxiety and fear. Many women seek the help of a **doula**, a caregiver who provides support to an expectant mother and her partner throughout the birth process (Kang, 2014). The doula is present during birth, whether at



a hospital or other setting, and helps the woman carry out her birth plans. The presence of a doula is associated with less pain medication, fewer cesarean deliveries, and higher rates of satisfaction in new mothers (Gabbe et al., 2016; Kozhimannil et al., 2016). Many women combine medication with natural childbirth methods, such as breathing techniques.

### Home Birth

Although common in nonindustrialized nations, home birth is rare in the U.S., comprising 1.5% of all births in 2016 in the United States (MacDorman & Declercq, 2016). Most home births are managed by a **midwife**—a health care professional, usually a nurse, who specializes in childbirth. Midwives provide health care throughout pregnancy and supervise home births. A healthy woman who has received prenatal care and is not carrying twins is unlikely to encounter problems and may be a good candidate for a home birth (Wilbur et al., 2015). Although unpredictable events can occur and immediate access to medical facilities can improve outcomes, studies from Europe indicate that home birth is not associated with greater risk of perinatal mortality. However, home birth is far more common in many European countries than in the United States (20% in the Netherlands, 8% in the United Kingdom, and about 1% in the United States; Brocklehurst et al., 2011; de Jonge et al., 2015). The few U.S. studies that have examined planned home birth compared with hospital birth have found no difference in neonatal deaths, and women who have a planned home birth report high rates of satisfaction (Jouhki et al., 2017; Zielinski et al., 2015).



A midwife prepares a mother to give birth in her home. Birth practices vary by culture.  
Viviane Moos / Getty Images

### Apgar Score

Immediately after birth, newborns are evaluated to determine their **Apgar score**, which provides a quick overall assessment of the baby's health. The Apgar score is composed of five subtests: appearance (color), pulse (heart rate), grimace (reflex irritability), activity (muscle tone), and respiration (breathing). The newborn is rated 0, 1, or 2 on each subtest for a maximum total score of 10 (see Table 2.7). A score of 4 or lower means that the newborn is in serious condition and requires immediate medical attention. The rating is conducted twice, 1 minute after delivery and again 5 minutes after birth; this timing ensures that hospital staff will monitor the newborn over several minutes. A low Apgar score is associated with an increased risk of neonatal death, but an increase in score after 10 minutes lowers the risk of problems (Chen et al., 2014). More than 98% of all newborns in the United States achieve a 5-minute score of 7 to 10, indicating good health (Martin et al., 2013).

**TABLE 2.7** ■ Apgar Scoring System

Indicator	Rating (Absence–Presence)		
	0	1	2
Appearance (color)	Blue	Pink body, blue extremities	Pink
Pulse (heart rate)	Absent	Slow (below 100)	Rapid (over 100)
Grimace (reflex irritability)	No response	Grimace	Coughing, crying
Activity (muscle tone)	Limp	Weak and inactive	Active and strong
Respiration (breathing)	Absent	Irregular and slow	Crying, good

Source: Adapted from Apgar, 1953.

## Low-Birthweight Infants: Preterm and Small-for-Date Babies

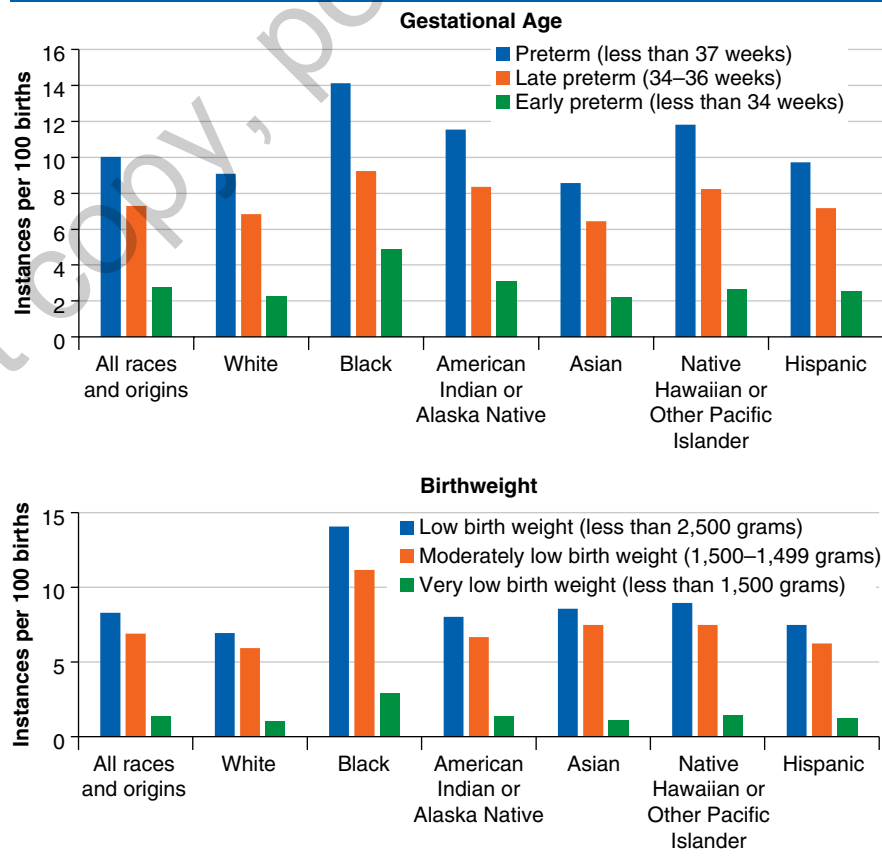
About 8% of infants born in the United States each year are low birthweight (Martin et al., 2018). Infants are classified as **low birthweight** when they weigh less than 2,500 grams (5.5 pounds) at birth; **very low birthweight** refers to a weight less than 1,500 grams (3.5 pounds); and **extremely low birthweight** refers to a weight less than 750 grams (1 lb. 10 oz.). Low-birthweight (LBW) infants may be **preterm** (premature, i.e., born before their due date) or **small for date** (full term but have experienced slow growth and are smaller than expected for their gestational age). Low birthweight is the second leading cause of infant mortality (Murphy et al., 2018; Mathews & MacDorman, 2013).

### Contextual Risks for LBW

Socioeconomic status is associated with LBW. In the United States, socioeconomic status is associated not simply with income, but with access to social services, such as health care, that determine birth outcomes. In one international comparison of U.S. births with those in the UK, Canada, and Australia—countries with health care and social services available to all individuals—the most disadvantaged women in all four countries were more likely to give birth to LBW infants, but SES was most strongly linked with LBW in the United States, where health care is privatized (Martinson & Reichman, 2016).

Socioeconomic disadvantage interacts with race and ethnicity in complex ways to influence LBW in the U.S. (see Figure 2.15). In 2016, non-Hispanic Black infants were more than twice as likely to be born low birthweight (11%) than non-Hispanic white and Hispanic infants (5% and 6%, respectively; Womack et al., 2018). SES plays a role in these differences, but it is not the whole story. In one study, LBW rates were higher for non-Hispanic Black mothers than non-Hispanic white mothers, but the racial difference declined (but did not disappear) when the researchers took into account

**FIGURE 2.15** ■ Gestational Age and Birthweight, by Race and Ethnicity: United States, 2018



Source: Centers for Disease Control and Prevention; National Center for Health Statistics.

financial and relationship stresses, suggesting a role for SES in racial differences, but also the presence of other factors (Almeida et al., 2018). In another study of more than 10,000 Californian women, the most economically disadvantaged Black and white women showed similar LBW rates, but increase in income was more strongly associated with improvement in LBW rates among white than Black women (Braveman et al., 2015). As SES advantage increased for both white and Black women, the racial disparity in LBW outcomes grew. Racial differences in LBW are not only a function of income, but also of other factors such as racism and discrimination (Ncube et al., 2016; Ramraj et al., 2020).



Low birthweight infants require extensive care. They are at risk for poor developmental outcomes and even death.

AFP Contributor / Contributor / Getty

### Characteristics of LBW Infants

At birth, LBW infants often experience difficulty breathing and have difficulty maintaining homeostasis, a balance in their biological functioning. (Charles et al., 2018). The deficits that LBW infants experience correspond closely to the infant's birthweight (Hutchinson et al., 2013). LBW infants are at higher risk for poor growth, cerebral palsy, seizure disorders, neurological difficulties, respiratory problems, and illness (Adams-Chapman et al., 2013; Charles et al., 2018; Durkin et al., 2016; Miller et al., 2016). They often experience difficulty in self-regulation and cognitive problems that may persist into adulthood (Eryigit Madzwamuse et al., 2015; Hutchinson et al., 2013; MacKay et al., 2010).

As children and adolescents, they are more likely to show problems with inattention, hyperactivity, and experience emotional and behavioral problems (Jaekel et al., 2018; Mathewson et al., 2017; Franz et al., 2018). They tend to show poor social competence and poor peer relationships, including peer rejection and victimization in adolescence (Georgsdottir et al., 2013; Ritchie et al., 2015; Yau et al., 2013). As adults, LBW individuals may experience social difficulties and may score high on measures of anxiety (Eryigit Madzwamuse et al., 2015; Mathewson et al., 2017).

Parenting a LBW infant is stressful because such infants tend to be easily overwhelmed by stimulation and difficult to soothe (Howe et al., 2014; Gardon et al., 2019). LBW infants are slow to initiate social interactions and do not attend to caregivers, looking away or otherwise resisting attempts to attract their attention (Eckerman et al., 1999; Provasi, 2019). Because LBW infants often do not respond to attempts to solicit interaction, they can be frustrating to interact with and are at risk for less secure attachment to their parents (Jean & Stack, 2012; Wolke et al., 2014). Research also indicates that they may experience higher rates of child abuse, partly because of their special needs but also because the risk factors for LBW, such as prenatal exposure to substances or maternal illness, also pose challenges for postnatal survival and are themselves associated with abuse (Cicchetti & Toth, 2015; Puls et al., 2019).

### Promoting Positive Outcomes for LBW Infants

The parenting context is an important influence on LBW infant health (Pierrehumbert et al., 2003; Provasi, 2019). When mothers have knowledge about child development and how to foster healthy development, are involved with their children, and create a stimulating home environment, LBW infants tend to have good long-term outcomes (Benasich & Brooks-Gunn, 1996; Jones et al., 2009; Lynch & Gibbs, 2017). A study of LBW children showed that those who experienced sensitive parenting showed faster improvements in executive function and were indistinguishable from their normal-weight peers by age 5; however, those who experienced below-average levels of sensitive parenting showed lasting deficits (Camerota et al., 2015). In contrast, longitudinal research has found that LBW children raised in unstable, economically disadvantaged families tend to remain smaller in stature, experience more emotional problems, and show more long-term deficits in intelligence and academic performance than do those raised in more advantaged homes (Taylor et al., 2001).

Interventions to promote the development of LBW children often emphasize helping parents learn coping strategies for interacting with their infants and managing parenting stress (Chang et al., 2015; Lau & Morse, 2003). One intervention common in developing countries where mothers may not have access to hospitals is **kangaroo care**, in which the infant is placed vertically against the parent's chest, under the shirt, providing skin-to-skin contact (Charpak et al., 2005). As the parent goes about daily activities, the infant remains warm and close, hears the voice and heartbeat, smells the body, and feels constant skin-to-skin contact. Kangaroo care is so effective that the majority of hospitals in the United States offer kangaroo care to preterm infants. Babies who receive early and consistent kangaroo care grow more quickly, sleep better, score higher on measures of health, and show more cognitive gains throughout the first year of life (Boundy et al., 2015; Jefferies, 2012; Sharma et al., 2019).

### Thinking in Context: Lifespan Development

1. Ask adults of different generations, perhaps a parent or an aunt and a grandparent or family friend, about their birth experiences. How do these recollections compare with current birthing practices?
2. A basic tenet of development is that individuals are active in their development, influencing the world around them (see Chapter 1). Consider LBW infants: How might their characteristics and abilities influence their caregivers? Why is caring for LBW infants challenging?
3. Parental responses to having a LBW infant influence the child's long-term health outcomes. How might contextual factors influence parents' responses? What supports from the family, community, and broader society can aid parents in helping their LBW infants adapt and develop healthily?

### Thinking in Context: Applied Developmental Science

Create a birth plan for a healthy woman in her 20s. What type of birth will you choose? Why? How might you address pain relief? Consider a healthy 39-year old woman; in what ways might your birth plan change (or not)? Why?

## CHAPTER SUMMARY

### 2.1 Discuss patterns of genetic inheritance and examples of genetic disorders and chromosomal abnormalities.

Some genes are passed through dominant-recessive inheritance, in which some genes are dominant and will always be expressed and others are recessive, only expressed if paired with another recessive gene. Incomplete dominance is a genetic inheritance pattern in which both genes influence the characteristic. Polygenic traits are the result of interactions among many genes. Genetic disorders carried through dominant-recessive inheritance include PKU (recessive allele) and Huntington disease (dominant allele). Some recessive genetic disorders are carried on the X chromosome. Males are more likely to be affected by X-linked genetic disorders. Examples of X-linked disorders include hemophilia, Fragile X, and color blindness. Some disorders, such as trisomy 21, known as Down syndrome, are the result of chromosomal abnormalities. Abnormalities resulting from additional or missing sex chromosomes include Klinefelter syndrome, Jacob's syndrome, triple X syndrome, and Turner syndrome. Other disorders result from mutations—genetic abnormalities that may occur randomly or as the result of exposure to toxins.

### 2.2 Describe behavior genetics and interactions among genes and environment, such as gene-environment correlations, gene-environment interactions, and the epigenetic framework.



Behavior genetics is the field of study that examines how genes and experience combine to influence the diversity of human traits, abilities, and behaviors. Behavior genetic research includes three types of studies: selective breeding studies, family studies, and adoption studies. Genetics contributes to many traits. Passive, evocative, and active gene–environment correlations illustrate how traits often are supported by both our genes and environment. People’s genes and environment interact in complex ways such that the effects of experience may vary with a person’s genes. The epigenetic framework is a model for understanding the dynamic ongoing interactions between heredity and environment whereby the epigenome’s instructions to turn genes on and off throughout development are influenced by the environment.

### 2.3 Describe the three periods of prenatal development.

Conception occurs in the fallopian tube. During the germinal period, the zygote begins cell division and travels down the fallopian tube toward the uterus. During the embryonic period, from weeks 2 to 8, the most rapid developments of the prenatal period take place. From 9 weeks until birth, the fetus grows rapidly, and the organs become more complex and begin to function. There are several diagnostic methods used to examine the developing organism: ultrasound, amniocentesis, chorionic villus sampling, fetal MRI, and noninvasive prenatal testing (NIPT) screens.

### 2.4 Explain how exposure to environmental factors can influence the prenatal environment and provide examples.

Teratogens include diseases, drugs, and other agents that influence the prenatal environment to disrupt development. Generally, the effects of exposure to teratogens on prenatal development vary depending on the stage of prenatal development and dose. There are individual differences in effects, different teratogens can cause the same birth defect, a variety of birth defects can result from the same teratogen, and some teratogens have subtle effects that result in developmental delays that are not obvious at birth or not visible until many years later. Prescription and nonprescription drugs, maternal illnesses, and smoking and alcohol use can harm the developing fetus. Prenatal development can also be harmed by factors in the environment as well as by maternal and paternal characteristics and behaviors.

### 2.5 Summarize the process of childbirth and the risks for, and characteristics of, low birthweight infants.

Childbirth progresses through three stages. The first stage of labor begins when the mother experiences regular uterine contractions that cause the cervix to dilate. During the second stage, the fetus passes through the birth canal. The placenta is passed during the third stage. Medication is used in most births, often in combination with breathing and relaxation techniques characteristic of natural births. About one third of U.S. births are by cesarean section. There are two types of low-birthweight infants: those who are preterm and those who are small for date. Low-birthweight infants struggle to survive and experience higher rates of sensory, motor, and language problems; learning disabilities; behavior problems; and deficits in social skills into adolescence. The long-term outcomes for low birthweight infants vary considerably and depend on the environment in which the children are raised.

## KEY TERMS

amniocentesis (p. 49)

amnion (p. 47)

anencephaly (p. 55)

Apgar score (p. 61)

behavior genetics (p. 42)

blastocyst (p. 46)

cesarean section (p. 60)

chorionic villus sampling (CVS) (p. 49)

chromosomes (p. 33)

deoxyribonucleic acid (DNA) (p. 34)

dominant-recessive inheritance (p. 35)

doula (p. 60)

Down syndrome (p. 39)

embryo (p. 47)

embryonic period (p. 46)

epidural (p. 60)

- epigenetics (p. 44)
- extremely low birthweight (p. 62)
- fetal alcohol spectrum disorders (p. 52)
- fetal alcohol syndrome (FAS) (p. 52)
- fetal MRI (p. 48)
- fetal period (p. 48)
- fetus (p. 48)
- Fragile X syndrome (p. 39)
- gametes (p. 34)
- gene-environment correlation (p. 42)
- gene-environment interactions (p. 44)
- genes (p. 34)
- genotype (p. 42)
- germinal period (p. 46)
- hemophilia (p. 39)
- implantation (p. 46)
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- Jacob's syndrome (p. 40)
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- zygote (p. 34)

## PART 1 LIFESPAN DEVELOPMENT AT WORK: FOUNDATIONS OF LIFESPAN HUMAN DEVELOPMENT

One of the tenets of lifespan development is that it is a multidisciplinary field, integrating findings from many settings. In this feature that appears at the end of each major part of this book, we explore some of the career choices for students interested in lifespan development.

Students with interests in human development select many different college majors, such as human development and family studies, psychology, social work, education, nursing, and more. What these diverse fields hold in common, beside a grounding in human development, is training in transferable skills that are valuable in a variety of employment settings.

### Transferable Skills

Just as it sounds, a *transferable skill* is one that can *transfer* or be applied in multiple settings. Employers value transferable skills. Consider the top five attributes that employers seek in potential employees, shown in Table 1.

It might be quickly apparent that none of these attributes refers directly to any specific college major. Instead, these are skills that students of all disciplines who study human development have the opportunity to hone. Let's take a closer look at some of these transferable skills.

Perhaps not surprising, the skill employers view as most valuable is *problem solving*. Individuals who are successful at problem solving can gather and synthesize information from a variety of sources. They learn to weigh multiple sources of information, determine the degree of support for each position, and generate solutions based on the information at hand. Effective problem solving relies on *analytical skills*. Exposure to diverse perspectives and ideas about human development trains students to think flexibly and to accept some ambiguity because solutions to complex problems are often not clear cut.

Students in human development fields learn *teamwork skills* to work with others in coursework and placements. For example, nursing, psychology, and human development and family studies students

**TABLE 1 ■ Top 5 Attributes Employers Prefer in Applicants**

Desired Attribute	Percentage of Employers Endorsing
Problem-solving skills	91
Ability to work in a team	86
Strong work ethic	80
Analytical/quantitative skills	79
Communication skills (written)	78

Source: (NACE, 2020)

may work together as lab members. Education students may collaborate on group projects, such as designing curricula, and social work students may get hands-on experience working with others in field placements. These valuable experiences foster the ability to effectively work with teams, a skill coveted by employers in all fields.

Students in human development and family studies, psychology, social work, education, and nursing take coursework relevant to their discipline, but success in each of these fields requires a *strong work ethic* and good *communication skills*. Succeeding in challenging courses like anatomy and physiology, research methods, and statistics requires dedication and consistent work. Oral and written communication skills are developed in coursework, but also in field and practicum experiences when students learn to communicate with children, adolescents, adults, and supervisors.

### Lifespan Development Fields

As we consider career opportunities in lifespan development, we break them into several areas: education; health care and nursing; social work, counseling, and psychology; and research and advocacy.

#### EDUCATION

Perhaps the most obvious career for students interested in human development is educator, or teacher. Educators who work with young children include *early childhood educators* and *preschool teachers*. Educators who work with older children and adolescents include *elementary school teachers* and *high school teachers*. Some educators specialize in working with children with specific developmental needs (*special education teachers*). Other teachers specialize in teaching English as a Second Language (*ESL teachers*) and work with children, adolescents, and adults. Becoming a teacher requires a bachelor's degree and certification.

*Career and technical education teachers* provide vocational training to adolescents and adults in subjects such as auto repair, cosmetology, and culinary arts. *Adult literacy teachers* instruct adults in literacy skills such as reading and writing. *GED teachers or instructors* help students earn their GED certificate, a high school equivalency diploma.

The education field also includes careers in administration, overseeing educational programs and educators. *Preschool and childcare center directors* work with early childhood educators to design educational plans for young children, oversee staff, and prepare budgets and are responsible for all aspects of the program. *Elementary school principals*, *middle school principals*, and *high school principals* oversee all school operations, including the work of teachers and other personnel, curricula, and daily school activities, and they promote a safe and productive learning environment.

Perhaps the most visible career at the college level is *college professor*. Becoming a professor requires education beyond the bachelor's degree, sometimes a master's degree but more typically a doctoral degree. However, there are many opportunities to work on a college campus with a bachelor's degree. For example, every college and university sponsors student activities, such as clubs, student government, and fraternities and sororities. *Student activities directors*, or *directors of student services*, oversee the development and organization of the college or university's extracurricular programs, including approving funding for student activities and overseeing students and staff who organize and supervise

student activities. *Resident directors* oversee the residence halls, ensuring that they are safe, supportive environments for students living on campus.

#### HEALTH CARE AND NURSING

An understanding of human development is helpful to all who work in health care settings. There are many kinds of nurses, and nurses of any specialty can benefit from understanding development. Examples of nurses who specialize in human development include *geriatric nurses*, who provide care for elderly patients. *Pediatric nurses* work with infants, children, and adolescents. *Neonatal nurses* provide care to infants who are born preterm, low birthweight, or suffer health problems, from birth until they are discharged from the hospital. A *nurse midwife* provides gynecological care, especially concerning pregnancy, labor, and delivery.

All physicians must learn about human development as part of their medical education, but only some specialize in working with people of particular ages. *Obstetrician-gynecologists* are physicians who specialize in female reproductive health, pregnancy, and childbirth. *Pediatricians* treat infants, children, and adolescents and *geriatricians* treat older adults. *Psychiatrists* are medical doctors who treat patients, conduct therapy, and prescribe medication to patients. To specialize, physicians must complete additional training, often a fellowship after earning their medical degree and obtaining licensure.

Allied health is a field of health care whose functions include assisting, facilitating, or complementing the work of nurses, physicians, and other health care specialists. *Recreational therapists* assess clients and provide recreational activities to individuals with physical or emotional disabilities in a variety of medical and community settings. *Physical therapists* design and provide treatments and interventions for individuals suffering pain, loss of mobility, or other physical disabilities. *Occupational therapists* help patients with physical, developmental, or psychological impairments, helping patients develop, recover, and maintain skills needed for independent daily living and working. Physical therapists and occupational therapists must earn graduate degrees, but *assistant physical therapists* and *assistant occupational therapists* may be hired with specialized associate degrees and certification.

Other allied health care specialists include *speech-language pathologists*, who assess, diagnose, and treat speech, language, and social communication disorders in children, adolescents, and adults. A speech-language pathologist must earn a graduate degree and *assistant speech-language pathologists* may be hired with associate or bachelor's degrees with specialized coursework and certification, depending on U.S. state. *Child life specialists* typically work in hospital settings, helping children and families adjust to a child's hospitalization by educating and supporting families in the physically and emotionally demanding process of caring for hospitalized or disabled children. An entry-level position as child life specialist requires a bachelor's degree and certification.

Knowledge about health and development is also needed to become a health educator. *Health educators* design and implement educational programs (classes, promotional pamphlets, community activities) to educate individuals and communities about healthy lifestyles and wellness.

#### SOCIAL WORK, COUNSELING, AND PSYCHOLOGY

Children and adolescents have different needs and abilities to communicate than adults and older adults. Professionals who work closely with individuals must understand how they change over their lives.

*Social workers* help people improve their lives by identifying needed resources (such as housing or food stamps) and providing guidance. *Clinical social workers* also conduct therapy and implement counseling treatments with individuals and families. Entry-level social workers earn a bachelor's degree whereas clinical social workers must earn a graduate degree and seek licensure.

There are many different types of counselor positions, which generally require master's degrees. *Mental health counselors* help people manage and overcome mental and emotional disorders. *School counselors* help elementary, middle, and high school students develop skills to enhance personal, social, and academic growth. *Marriage and family therapists* focus on the family system and treat individuals, couples, and families to help people overcome problems with family and relationships. *Substance use counselors* help people who suffer from addictions, helping them to recover and modify behaviors through individual and group therapy sessions.



*Applied behavior analysts* apply scientific principles of learning to modify people's behavior to improve social, communication, academic, and adaptive skills in children, adolescents, and adults. They teach parents, teachers, and support professionals how to implement behavioral procedures, skills, and interventions. A position as an applied behavior analyst requires a graduate degree. *Assistant behavior analysts* support the work of applied behavior analysts. They assist in gathering data or information about clients, monitoring client progress and maintaining records, and administering assessments and treatment under the supervision of the applied behavior analysts.

Psychologists are doctoral-level mental health professionals. *Clinical psychologists* and *counseling psychologists* conduct therapy with children, adolescents, adults, and families. Clinical psychologists specialize in treating mental disorders and counseling psychologists emphasize helping people adjust to life changes. *School psychologists* work within school settings, assessing individuals' learning and mental health needs; collaborating with parents, teachers, and school administrators; designing interventions to improve students' well-being; and counseling students. *Applied developmental psychologists* may, depending on their training, assess and treat children, adolescents, and adults and design and evaluate intervention programs to address problems and enhance the development of people of all ages.

### RESEARCH AND ADVOCACY

Developmental scientists design and conduct research on social problems and apply their findings to advocate on behalf of individuals and families. They are employed at social service agencies, nonprofits, and think tanks conducting research to gather information about social problems and policies; assess and improve programs for children, youth, and families; and write reports and other documents to inform policymakers and the public. Some work as program directors and administrators for these programs. Others assess programs.

Some developmental scientists head nonprofit organizations as *foundation directors*. They develop goals and strategies in line with the foundation's mission statement and oversee all activities within an organization, including program delivery, program evaluation, finance, and staffing. Other developmental scientists work as *grant writers*, submitting proposals to fund programs. Organizations that award grants to others have *grant directors* who oversee the funding process by analyzing grant proposals, communicating with applicants, and determining which proposals are suitable for funding.

Developmental scientists conduct research in a variety of settings. Some work at universities and apply their research findings to help people. For example, a *researcher* might conduct experiments in a lab to identify influences of electronic cigarette use on children, adolescents, and adults and then apply the findings to develop prevention programs tailored to each age group. Developmental scientists who work for the government might evaluate government-supported social media health initiatives (such as those targeting distracted driving) or educational initiatives, such as the effects of providing free kindergarten to children.

Developmental scientists working in business and industry help companies design materials such as toys, products, and media that fit people's needs and abilities. They might determine the developmental appropriateness of toys and provide insight into children's abilities or examine children's and parents' reactions to particular toys, advertising, and promotional techniques. Others might provide developmental and educational advice to creators of children's media, such as by interpreting research on children's attention spans to inform creative guidelines for television programs such as *Sesame Street*.

Developmental scientists also assist companies in developing and marketing products that are appropriate for older adults. A consultant might suggest modifying the design of product packaging by using contrasting colors and larger print easier for older adults to read. A developmental scientist might research ways of modifying a car's dashboard to include displays and knobs that can be easily viewed and used by older adult drivers.

## CAREERS IN GENETICS AND PRENATAL DEVELOPMENT

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### Genetic Counselor

As we have seen in Chapter 2, many chromosomal abnormalities are passed through genetic inheritance. Genetic counselors help assess the risk of an individual or couple passing a genetic disorder to their offspring.

Genetic counselors interview individuals and couples to gather information about their family history, educate them about the risks for particular genetic conditions in their offspring, and inform them about the different genetic tests available to them. Genetic counselors also help individuals and couples understand that results of DNA and other laboratory tests and the potential implications for offspring. Genetic counselors typically work in a hospital or clinic setting but may work in private practice.

Genetic counselors typically have a master's degree in genetics or genetic counseling from a program certified by the Accreditation Council for Genetic Counseling and pass a national certification exam. Some genetics counselors specialize in particular area, such as cancer, psychiatric, or genomic health. The median annual wage for genetic counselors was \$85,700 in May 2020 (U.S. Bureau of Labor Statistics, 2021).

### Midwife

A midwife is a health care professional who supports and cares for women throughout their pregnancy, including delivering babies during childbirth. They collaborate with other health care professionals, including obstetricians, nurses, and hospital staff.

There are two main paths to becoming a midwife, with different levels of expertise, certification, and autonomy. Some midwives are referred to as direct-entry midwives because, after earning a bachelor's degree, they are trained and certified (through the North American Registry of Midwives) but do not have a nursing degree. The legal status and requirements to become a direct-entry midwife vary by state, but many states do not permit midwives without nursing degrees. Carefully research state requirements before choosing this option.

The second path to becoming a midwife is to earn a nursing degree and complete a master's program in nurse-midwifery education. A certified nurse-midwife can practice independently in every state. Most people are familiar with the labor and delivery activities of nurse-midwives. Nurse-midwives may focus on all or part of pregnancy and birth, from preconception to postpartum. The nurse-midwife practice includes a variety of services: reproductive health visits, preventative care, and postmenopausal care. They can prescribe medication and admit or discharge patients if needed.

Nurse-midwives can work in a variety of settings, including hospitals, birth centers, health centers, and in private practice. The median annual wage for nurse-midwives was about \$111,000 in 2020 (U.S. Bureau of Labor Statistics, 2021).

### Doula

Doulas provide physical, emotional, and educational support to expectant mothers prior to birth, during labor, and immediately after birth through the first few weeks. Doulas provide education about labor, medication, and comfort during the birth process. Doulas also support the partner and family to aid their participation in the birth process.

The educational requirements to become a doula include a high school degree and completion of a doula education program. Some employers prefer college credits or a degree. Doulas work in hospitals, private practices, birth centers, or community organizations. Doulas' earnings vary with work setting, experience, and location. A common national hourly rate is about \$45 per hour, as high as \$70 in large urban cities and as low as \$25 per hour in small towns.