## >> Prenatal Growth

The most dramatic and extensive transformation of the entire life span occurs before birth. To make it easier to study, prenatal development is often divided into three main periods. The first two weeks are called the **germinal period;** the third through the eighth week is the **embryonic period;** the ninth week until birth is the **fetal period.** (Alternative terms are explained in Table 4.1, which also explains why sometimes pregnancy is dated from the woman's last menstrual period rather than from conception).

**germinal period** The first two weeks of prenatal development after conception, characterized by rapid cell division and the beginning of cell differentiation.

**embryonic period** The stage of prenatal development from approximately the third through the eighth week after conception, during which the basic forms of all body structures, including internal organs, develop.

**fetal period** The stage of prenatal development from the ninth week after conception until birth, during which the fetus gains about 7 pounds (more than 3,000 grams) and organs become more mature, gradually able to function on their own.

### Germinal: The First 14 Days

You learned in Chapter 3 that the one-celled zygote, traveling slowly down the fallopian tube toward the uterus, begins to duplicate and multiply (see Figure 4.1). At about the eight-cell stage, differentiation begins as those early cells take on distinct characteristics and gravitate toward particular locations.

About a week after conception, the multiplying cells (now numbering more than 100) separate into two distinct masses. The outer cells form a shell that will become the *placenta* (the organ that surrounds and protects the developing creature), and the inner cells form a nucleus that will become the embryo.

The first task of the outer cells is to achieve **implantation**—that is, to embed themselves in the nurturing lining of the uterus. This is far from automatic; about 50 percent of natural conceptions and an even larger percentage of in vitro conceptions never implant (see Table 4.2). Most new life ends before an embryo begins (Sadler, 2009).

**implantation** The process, beginning about 10 days after conception, in which the developing organism burrows into the placenta that lines the uterus, where it can be nourished and protected as it continues to develop.

### Embryo: From the Third Through the Eighth Week

The start of the third week after conception initiates the *embryonic period,* during which the formless mass of cells becomes a distinct being—not yet recognizably human but worthy of a new name, **embryo.** (The word *embryo* is often used loosely, but each stage of development has a particular name; here, embryo refers to the developing human from day 14 to day 56.)

**embryo** The name for a developing human organism from about the third through the eighth week after conception.

First, a thin line (called the *primitive streak*) appears down the middle of the embryo, becoming the neural tube 22 days after conception and eventually developing into the central nervous system, the brain, and spinal column (Sadler, 2009). The head appears in the fourth week, as eyes, ears, nose, and mouth start

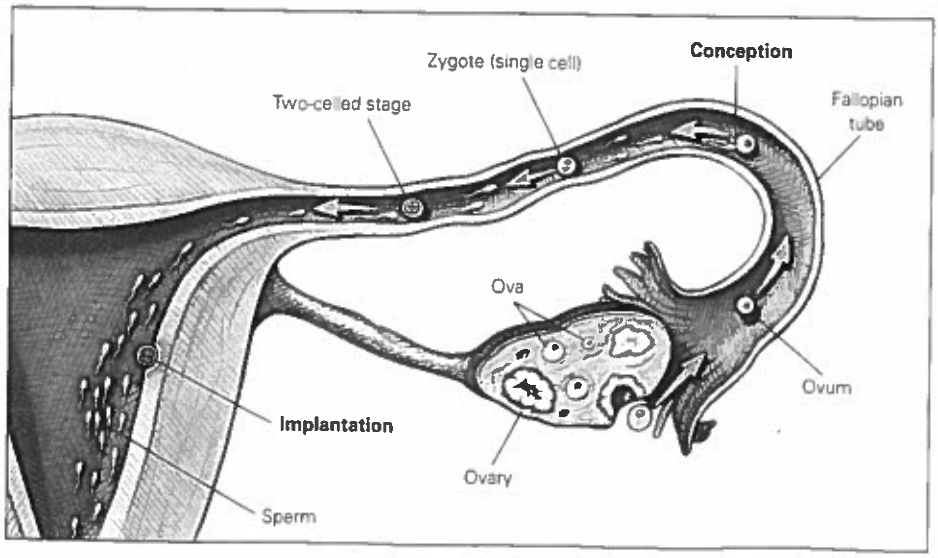



**FIGURE 4.1**

**The Most Dangerous Journey** In the first 10 days after conception, the organism does not increase in size because it is not yet nourished by the mother. However, the number of cells increases rapidly as the organism prepares for implantation, which occurs successfully about one-half of the time.

**TABLE 4.1 Timing and Terminology**

Popular and professional books use various phrases to segment the stages of pregnancy. The following comments may help to clarify the phrases used.

- *Beginning of pregnancy:* Pregnancy begins at conception, which is also the starting point of *gestational age*. However, the organism does not become an *embryo* until about two weeks later, and pregnancy does not affect the woman (and is not confirmed by blood or urine testing) until implantation. Perhaps because the exact date of conception is often unknown, some obstetricians and books for laypeople calculate from the woman's last menstrual period (LMP), usually about 14 days *before* conception.
- *Length of pregnancy:* Full-term pregnancies last 266 days, or 38 weeks, or 9 months. If the LMP is used as the starting time, pregnancy lasts 40 weeks, sometimes expressed as 10 lunar months. (A lunar month is 28 days long.)
- *Trimesters:* Instead of *germinal period, embryonic period,* and *fetal period,* some writers divide pregnancy into three-month periods called *trimesters*. Months 1, 2, and 3 are called the *first trimester;* months 4, 5, and 6, the *second trimester;* and months 7, 8, and 9, the *third trimester*.
- *Due date:* Although doctors assign a specific due date based on the LMP, only 5 percent of babies are born on that exact date. Babies born between three weeks before and two weeks after that date are considered *full term,* although labor is often induced if the baby has not arrived within 7 days of the due date. Babies born more than three weeks early are *preterm,* a more accurate term than *premature*.

**TABLE 4.2 Vulnerability During Prenatal Development**

**The Germinal Period**

About half* of all conceptions fail to grow or implant properly and thus do not survive the germinal period. Most of these organisms are grossly abnormal.

**The Embryonic Period**

About 20 percent of all embryos are aborted spontaneously,** most often because of chromosomal abnormalities.

**The Fetal Period**

About 5 percent of all fetuses are aborted spontaneously before viability at 22 weeks or are stillborn (defined as born dead after 22 weeks).

**Birth**

About 31 percent of all zygotes grow and survive to become living newborn babies.

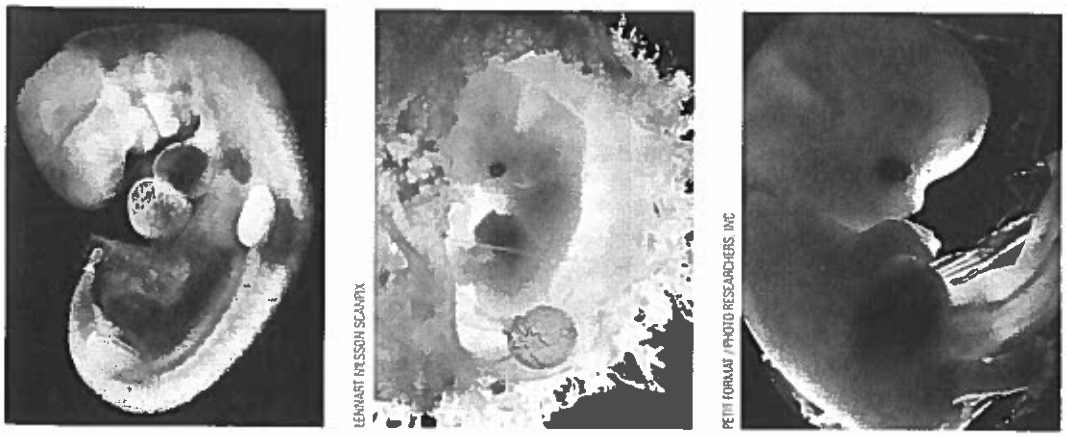
*The rate of very early pregnancy failures could be higher, as often no one realizes that pregnancy occurred when it stops so early.

**Spontaneous abortions are also called miscarriages. The rate of induced abortions varies depending on availability of contraception and on culture, induced abortions are not included in this table.

*Sources:* Bentley & Mascie-Taylor, 2000; Sadler, 2009; Schorge et al., 2008.

to form. Also in the fourth week, a minuscule blood vessel that will become the heart begins to pulsate. By the fifth week, buds that will become arms and legs emerge. The upper arms and then forearms, palms, and webbed fingers grow. Legs, knees, feet, and webbed toes, in that order, are apparent a few days later, each having the beginning of a skeletal structure. Then, 52 and 54 days after conception, respectively, the fingers and toes separate (Sadler, 2009).

As you can see, prenatally, the head develops first, in a *cephalocaudal* (literally, "head-to-tail") pattern, and the extremities form last, in a *proximodistal* (literally, "near-to-far") pattern. At the end of the eighth week after conception (56 days), the embryo weighs just one-thirtieth of an ounce (1 gram) and is about 1 inch (2½ centimeters) long. It has all the basic organs and body parts (except sex organs) of a human being, including elbows and knees. It moves frequently, about 150 times per hour, but such movement is random and imperceptible (Piontelli, 2002).



O.L.K./RON / PHOTO RESEARCHERS, INC. LENNART NILSSON SCANPIX PETIT FORMAT / PHOTO RESEARCHERS, INC.

**The Embryonic Period** *(a)* At 4 weeks past conception, the embryo is only about ⅛ inch (3 millimeters) long, but already the head has taken shape. *(b)* At 5 weeks past conception, the embryo has grown to twice the size it was at 4 weeks. Its primitive heart, which has been pulsing for a week now, is visible, as is what appears to be a primitive tail, which will soon be enclosed by skin and protective tissue at the tip of the backbone (the coccyx). *(c)* By 7 weeks, the organism is somewhat less than an inch (2½ centimeters) long. Eyes, nose, the digestive system, and even the first stage of toe formation can be seen.

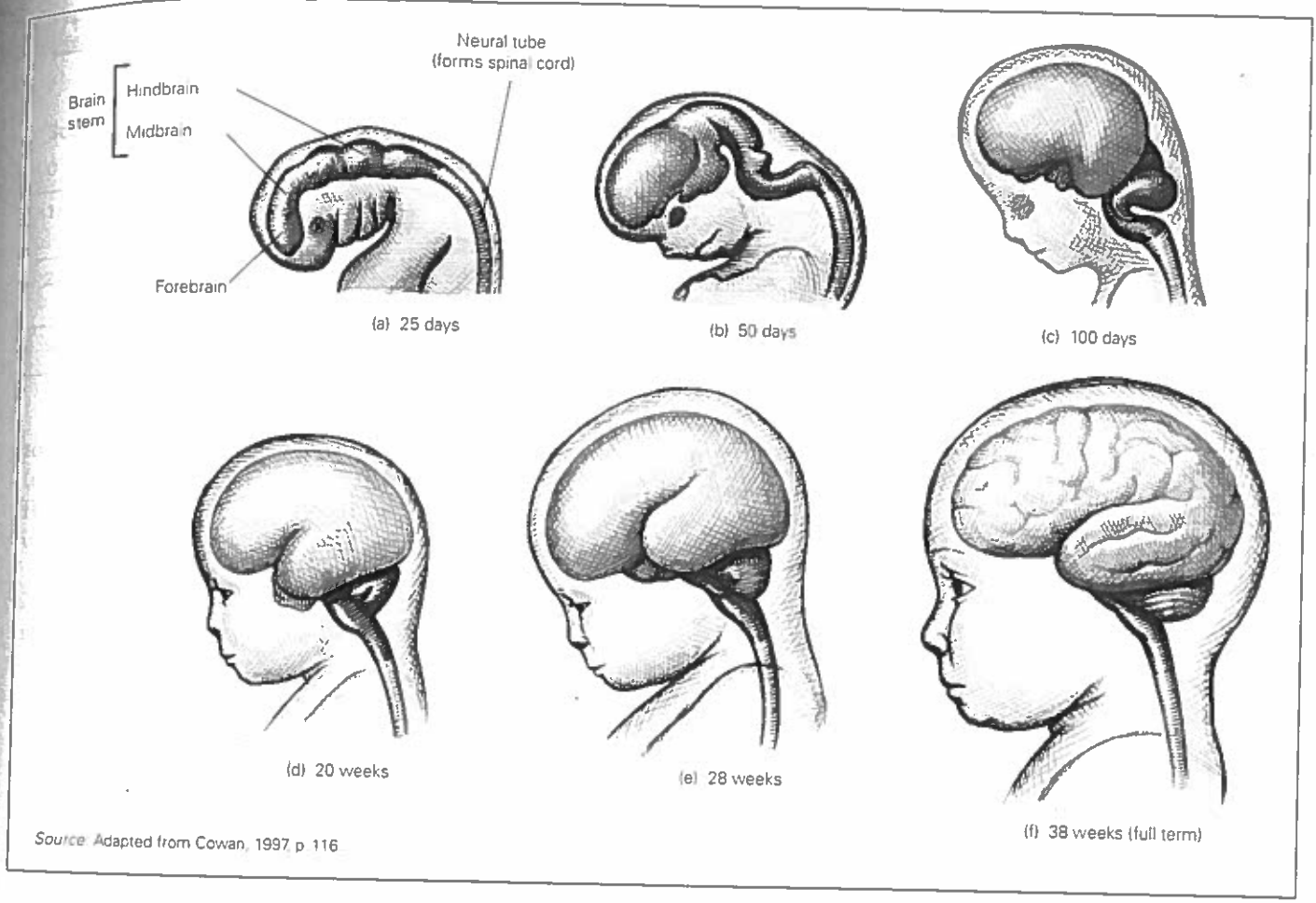



**FIGURE 4.3**

**Prenatal Growth of the Brain** Just 25 days after conception *(a)*, the central nervous system is already evident. The brain looks distinctly human by day 100 *(c)*. By the 28th week of gestation *(e)*, at the very time brain activity begins, the various sections of the brain are recognizable. When the fetus is full term *(f)*, all the parts of the brain, including the cortex (the outer layers), are formed, folding over one another and becoming more convoluted, or wrinkled, as the number of brain cells increases.

weeks, all the body structures, except male and female sex organs, are in place. Fetal growth then proceeds rapidly, including mid-trimester weight gain (about 2 pounds, or 1 kilogram) and brain maturation, which make viability possible. By full term, all the organs function well in the 35- to 40-week newborn, who weighs about 7 pounds (about 3,200 grams).

## Birth

About 38 weeks (266 days) after conception, when the fetus weighs 6 to 8 pounds (3,000 to 4,000 grams), the fetal brain signals the release of hormones, specifically *oxytocin*, which prepares the fetus for delivery and starts labor. The average baby is born after 12 hours of active labor for first births and 7 hours for subsequent births (Moore & Persaud, 2003), although labor may take twice or half as long. The definition of "active" labor varies, which is one reason some women believe they are in active labor for days and others say 10 minutes.

Women's birthing positions also vary—sitting, squatting, lying down. Some women give birth while immersed in warm water, which helps the woman relax (the fetus continues to get oxygen via the umbilical cord). However, some physicians believe water births increase the rate of infection, and the final emergence of the head is difficult for the medical team to monitor (Tracy, 2009). Preferences and opinions on positions are partly cultural and partly personal. In general,

## AT ABOUT THIS TIME
### Average Prenatal Weights*

| Period of Development | Weeks Past Conception | Average Weight (nonmetric) | Average Weight (metric) | Notes |
|---|---|---|---|---|
| End of embryonic period | 8 | 1/30 oz. | 1 g | Most common time for spontaneous abortion (miscarriage). |
| End of first trimester | 13 | 3 oz. | 85 g | |
| At viability (50/50 chance of survival) | 22 | 20 oz. | 570 g | A birthweight less than 2 lb., 3 oz. (1,000 g) is extremely low birthweight (ELBW). |
| End of second trimester | 26–28 | 2–3 lb. | 900–1,400 g | Less than 3 lb., 5 oz. (1,500 g) is very low birthweight (VLBW). |
| End of preterm period | 35 | 5½ lb. | 2,500 g | Less than 5½ lb. (2,500 g) is low birthweight (LBW). |
| Full term | 38 | 7½ lb. | 3,400 g | Between 5½ lb. and 9 lb. (2,500–4,000 g) is considered normal weight. |

*To make them easier to remember, the weights are rounded off (hence the imprecise correspondence between metric and nonmetric). Actual weights vary. For instance, normal full-term infants weigh between 5½ and 9 pounds (2,500 and 4,000 grams), viable preterm newborns, especially twins or triplets, weigh less than shown here.

N. BROMHALL / PHOTO RESEARCHERS, INC.

**Can He Hear?** A fetus, just about at the age of viability, is shown fingering his ear. Such gestures are probably random; but, yes, he can hear.

The fetus usually gains at least 4½ pounds (2.1 kilograms) in the thir trimester, increasing to almost 7½ pounds (about 3.4 kilograms) at birt (see At About This Time). By full term, human brain growth is so e tensive that the *cortex* (the brain's advanced outer layers) forms sever folds in order to fit into the skull (see Figure 4.3). Although some larg mammals (whales, for instance) have bigger brains than humans, no oth creature needs as many folds as humans do, because the human corte contains much more material than the brains of nonhumans.

The relationship between mother and child intensifies during the fin three months, for fetal size and movement make the pregnant woman ver aware of it. In turn, her sounds, the tastes of her food (via amniotic fluid and her behavior patterns become part of fetal consciousness. Auditor communication from mother to child begins at the 28th week and im proves each week as fetal hearing (or newborn hearing if a baby is born early becomes more acute (Bisiacchi et al., 2009). The fetus startles and kicks at lou noises, listens to the mother's heartbeat and voice, and is comforted by rhythmi music and movement, such as when the mother sings as she walks. If the mothe is fearful or anxious, the fetal heart beats faster and body movements increas (DiPietro et al., 2002).

**>> Response for Biologists** (from page 96) Only one of the 46 human chromosomes determines sex, and the genitals develop last in the prenatal sequence, suggesting that dramatic male–female differences are cultural. On the other hand, several sex differences develop before birth.

## SUMMING UP

In two weeks of rapid cell duplication, differentiation, and finally implantation, the newly conceived organism is transformed from a one-celled zygote to a many-celle embryo. The embryo soon develops the beginning of the central nervous syster (3 weeks), a heart and a face (4 weeks), arms and legs (5 weeks), hands and fee (6 weeks), and fingers and toes (7 weeks) while the inner organs take shape. By 8

**TABLE 4.3 Criteria and Scoring of the Apgar Scale**

| | Five Vital Signs | | | | |
|---|---|---|---|---|---|
| Score | Color | Heartbeat | Reflex Irritability | Muscle Tone | Respiratory Effort |
| 0 | Blue, pale | Absent | No response | Flaccid, limp | Absent |
| 1 | Body pink, extremities blue | Slow (below 100) | Grimace | Weak, inactive | Irregular, slow |
| 2 | Entirely pink | Rapid (over 100) | Coughing, sneezing, crying | Strong, active | Good; baby is crying |

*Source:* Apgar, 1953.

to newborn health. Since 1950, birth attendants worldwide have used the Apgar (often using the name as an acronym: Appearance, Pulse, Grimace, Activity, and Respiration) at one minute and again at five minutes after birth, assigning each vital sign a score of 0, 1, or 2.

If the five-minute Apgar is 7 or higher, all is well. If the five-minute total is below 7, the infant needs help. If the score is below 4, a neonatal pediatrician is summoned to the delivery room (the hospital loudspeaker may say "paging Dr. Apgar").

## Medical Assistance

How closely any particular birth matches the foregoing depends on the parents' preparation, the position and size of the fetus, and the customs of the culture. In developed nations, births almost always include sterile procedures, electronic monitoring, and drugs to dull pain or speed contractions.

AP / THE ASSOCIATED PRESS

**Modern Intervention** He was born by C-Section, as are more than half of all Brazilian babies, especially those born to poor young women like this 16-year-old indigenous mother. At least she is breast feeding, a traditional practice likely to be better for him than formula.

### Surgery

Midwives are as skilled at delivering babies as physicians, but only medical doctors are licensed to perform surgery. More than one-third of U.S. births occur via **cesarean section (c-section,** or simply *section*), whereby the fetus is removed through incisions in the mother's abdomen. Cesareans are controversial: The World Health Organization suggests that c-sections are medically indicated in only 15 percent of births.

Culture and cohort affect the rates: Most nations have fewer cesareans than the United States, but some—especially in Latin America—have more (see Figure 4.5). In every nation, both the safety and the incidence of cesareans have increased over the past two decades, with the most dramatic increases in China. In that nation, rates were 5 percent in 1991, 20 percent by 2001, and 46 percent in 2008 (Guo et al., 2007; Juan, 2010). In the United States, the rate rose every year between 1996 and 2008 (from 21 percent to 34 percent). Cesareans are usually safe for mother and baby and have many advantages for hospitals (easier to schedule, quicker, and more expensive than vaginal deliveries), but they also bring more complications after birth and reduce breast-feeding (Malloy, 2009).

Less studied is the *epidural*, an injection in a particular part of the spine of the laboring woman to alleviate pain. Epidurals are often used in hospital births, but they increase the rate of cesarean sections and decrease the readiness of newborn infants to suck immediately after birth (Bell et al., 2010). Another medical

**cesarean section (c-section)** A surgical birth, in which incisions through the mother's abdomen and uterus allow the fetus to be removed quickly, instead of being delivered through the vagina. (Also called simply *section*.)

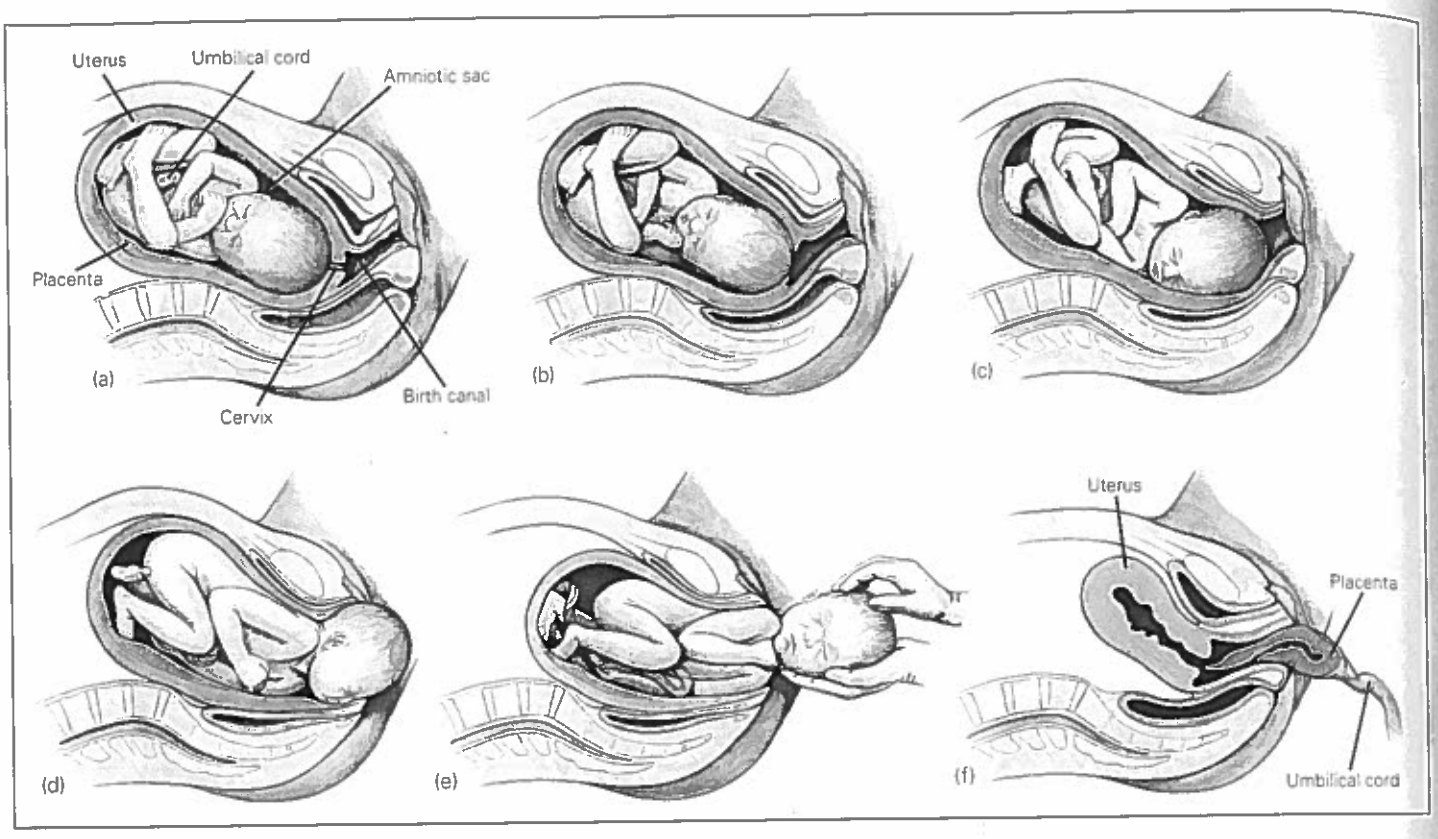



**FIGURE 4.4**

**A Normal, Uncomplicated Birth** *(a)* The baby's position as the birth process begins. *(b)* The first stage of labor: The cervix dilates to allow passage of the baby's head. *(c)* Transition: The baby's head moves into the "birth canal," the vagina. *(d)* The second stage of labor: The baby's head moves through the opening of the vagina ("crowns") and *(e)* emerges completely. *(f)* The third stage of labor is the expulsion of the placenta. This usually occurs naturally, but it is crucial that the whole placenta be expelled, so birth attendants check carefully. In some cultures, the placenta is ceremonially buried, to commemorate the life-giving role it plays.

**Observation Quiz** In drawing *(e)*, what is the birth attendant doing as the baby's head emerges? (see answer, page 102)

**Apgar scale** A quick assessment of a newborn's health. The baby's color, heart rate, reflexes, muscle tone, and respiratory effort are given a score of 0, 1, or 2 twice—at one minute and five minutes after birth—and each time the total of all five scores is compared with the maximum score of 10 (rarely attained).

physicians find it easier to see the head emerge if the woman lies on her back and many women find it easier to push the fetus out if they sit up, but these generalities do not hold for every individual. Figure 4.4 shows the universal stages of birth.

## The Newborn's First Minutes

Newborns usually breathe and cry on their own. Between spontaneous cries, the first breaths of air bring oxygen to the lungs and blood, and the infant's color changes from bluish to pinkish. (Pinkish refers to blood color, visible beneath the skin, and applies to newborns of all hues.) Eyes open wide; tiny fingers grab; even tinier toes stretch and retract. The newborn is instantly, zestfully, ready for life.

Nevertheless, there is much to be done. Mucus in the baby's throat is removed, especially if the first breaths seem shallow or strained. The umbilical cord is cut to detach the placenta, leaving an inch or so of the cord, which dries up and falls off to leave the belly button. The infant is examined, weighed, and given to the mother to preserve its body heat and to breast-feed a first meal of colostrum, a thick substance that helps the newborn's digestive and immune systems.

One widely used assessment of infant health is the **Apgar scale** (see Table 4.3), first developed by Dr. Virginia Apgar. When she graduated from Columbia medical school with her MD in 1933, Apgar wanted to work in a hospital but was told that only men did surgery. Consequently, she became an anesthesiologist. She saw that "delivery room doctors focused on mothers and paid little attention to babies. Those who were small and struggling were often left to die" (M. Beck, 2009, p. D-1). To save those young lives, Apgar developed a simple rating scale of five vital signs—color, heart rate, cry, muscle tone, and breathing—to alert doctors

CUSTOM MEDICAL STOCK PHOTO

REUTERS / ENRIQUE CASTRO MENDIVIL

**The Same Situation, Many Miles Apart: A Better Position** The most obvious diffe ence between these births in Chicago, Illin (*left*), and Cuzco, Peru, is the mother's bod position. In the United States, the horizont position was designed to give doctors a be ter view when the head emerges (*left*). In Peru, women prefer "vertical births," and t maternity center boasts more patients as a result of its willingness to perform them. Note other differences—the father presen in Chicago, the protective head coverings i Cuzco. It is not so clear-cut which practice make better medical sense and which are simply social customs.

### Research Design

**Scientists:** Susan McGrath and John Kennell.

**Publication:** *Birth* (2008).

**Participants:** A total of 420 pregnant women, all healthy, middle class, and accompanied by their male partner when they arrived in labor at a major hospital in Cleveland, Ohio. They gave birth to their first baby, attended by their obstetrician or midwife.

**Design:** All 420 received the usual medical care as well as the support of their partners, but, on admission to the hospital, half were randomly assigned a doula. The doula stayed with the couple, providing physical care (e.g., massage), expertise, and reassurance until the birth. Mothers and their partners were questioned 24 hours and 6 weeks later.

**Major conclusion:** The doula births were less often cesareans (13 versus 25 percent) and involved fewer epidurals (65 versus 76 percent). More than 99 percent of the women and their partners rated the doula's help positively or very positively. The conclusion: "Continuous labor support by a doula is a risk-free obstetric technique that could benefit all laboring women" (p. 97).

**Comments:** Three factors in this design add confidence to the conclusion: (1) Random assignment avoided selection factors (women who choose doulas tend to be healthy and well-educated); (2) the fathers' presence for all women proved that not merely the presence of a support person caused the benefits; (3) the doula appeared only when the couple arrived at the hospital (avoiding the confounds of doula help in early labor).

found that doulas benefit low-income women with no partner, decreasing the disparity in birth outcomes between middle-class and poor women (Vonderheid et al., 2011). It is now believed that doulas benefit anyone giving birth, rich or poor, married or not. For example, in one study, 420 middle-class married women were randomly assigned a doula (McGrath & Kennell, 2008). Those with doulas needed less intervention (see the Research Design).

## SUMMING UP

Most newborns score at least 7 out of 10 on the Apgar scale, and thrive without medical assistance. If necessary, neonatal surgery and intensive care save lives. Although modern medicine has reduced maternal and newborn deaths, many critics deplore treating birth as a medical crisis rather than a natural event. Responses to this critique include women choosing to give birth in hospital labor rooms rather than operating rooms, in birthing centers instead of hospitals, or even at home. The assistance of a doula is another recent practice that reduces medical intervention. ■

**>> Answer to Observation Quiz** (from page 103) Probably ten minutes or less. H umbilical cord is still attached to the place which is still inside the woman. Usually placentas are expelled with contractions a few minutes after birth.

**The Same Situation, Many Miles Apart: Getting Ready** There are many similarities here. Six adult and three fetuses on the left and six adults and two fetuses (twins) on the right. But the differences a tragic, evident in the face of the expectant mother on the right. The husbands in the Netherlands are learning how to help their wives give birth at home, as most Dutch couples do. The Afghan doctor on the right, however, is explaining why this woman's labor will be induced, with neither baby expected t survive—a devastating blow this woman has already faced, having twice lost a baby less than a week

**doula** A woman who helps with the birth process. Traditionally in Latin America, a doula was the only professional who attended childbirth. Now doulas are likely to arrive at the woman's home during early labor and later work alongside a hospital's staff.

In the first part of the twentieth century, in advanced nations, women in l pitals labored by themselves until birth was imminent; fathers and other fa members were kept away. Almost everyone now agrees that a laboring wor should never be alone. However, family members may not know what to do, professionals focus more on the medical than the psychological aspects of bi so some women do not get the emotional support they need. To meet this n more women now have a **doula,** a woman trained to support the laboring wo by timing contractions, doing massage, providing ice chips, or doing whatever might be helpful.

Often doulas begin their work before active labor, and then, as the momer birth approaches, they work beside the midwives or doctors. Many studies l

**Pressure Point** Many U.S. couples, like this one, benefit from a doula's gentle touch, strong pressure, and sensitive understanding —all of which make doula births less likely to include medical intervention.

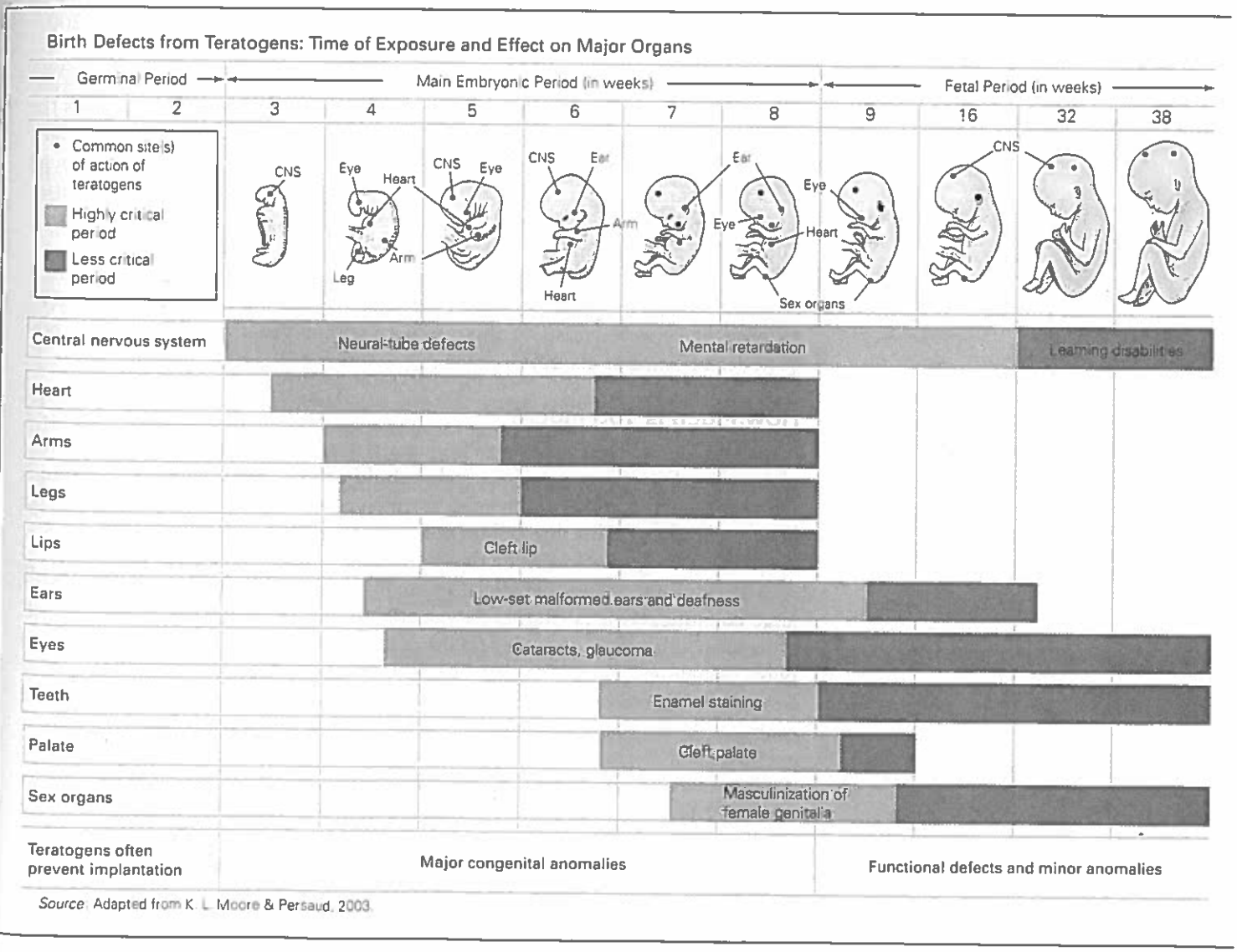
episodes showed otherwise: (1) On an Australian military base, an increase in babies born blind was linked to a rubella (German measles) epidemic on the same base seven months earlier (Gregg, 1941, reprinted in Persaud et al., 1985), and (2) a sudden rise in British newborns with deformed limbs was traced to maternal use of thalidomide, a new drug for nausea that was widely prescribed in Europe in the late 1950s (Schardein, 1976). Thus began *teratology*, a science of risk analysis. Although all teratogens increase the *risk* of harm, none *always* cause damage. The impact of teratogens depends on the interplay of many factors, both destructive and protective, an example of the dynamic-systems perspective described in Chapter 1.

## The Critical Time

One crucial factor is *timing*—the age of the developing organism when it is exposed to the teratogen (Sadler, 2009). Some teratogens cause damage only during a *critical period* (see Chapter 1) (see Figure 4.6). Obstetricians recommend that *before* pregnancy occurs, women should avoid drugs (especially alcohol), supplement a balanced diet with extra folic acid and iron, and update their immunizations. Indeed, preconception health is at least as important as health during pregnancy.

**FIGURE 4.6**

**Critical Periods in Human Development** The most serious damage from teratogens (green bars) is likely to occur early in prenatal development. However, significant damage (purple bars) to many vital parts of the body, including the brain, eyes, and genitals, can occur during the last months of pregnancy as well.




*Source:* Adapted from K. L. Moore & Persaud, 2003.

## >> Problems and Solutions

The early days of life place the developing person on the path toward health and success—or not. Fortunately, resilience is apparent from the beginning; healthy newborns are the norm, not the exception. However, if something is amiss, it is often part of a cascade that may become overwhelming.

### Harmful Substances

**teratogens** Agents and conditions, including viruses, drugs, and chemicals, that can impair prenatal development and result in birth defects or even death.

Such a cascade begins before the woman realizes she is pregnant, as many toxins, illnesses, and experiences can harm a new pregnancy. Every week, scientists discover an unexpected **teratogen,** defined as anything—drugs, viruses, pollutants, malnutrition, stress, and more—that increases the risk of prenatal abnormalities. But do not be alarmed. Many abnormalities can be avoided, many potential teratogens do no harm, and much damage can be remedied. Thus, prenatal development is not a dangerous period to be feared as much as a natural process to be protected.

**behavioral teratogens** Agents and conditions that can harm the prenatal brain, impairing the future child's intellectual and emotional functioning.

Some teratogens cause no physical defects but affect the brain, making a child hyperactive, antisocial, or learning-disabled. These are **behavioral teratogens.** About 20 percent of all children have difficulties that *could* be connected to behavioral teratogens, although the link is not straightforward: The cascade is murky. One of my students described her little brother as follows:

> I was nine years old when my mother announced she was pregnant. I was the one who was most excited. . . . My mother was a heavy smoker, Colt 45 beer drinker. . . . I asked, "Why are you doing it?" She said, "I don't know."
>
> During this time I was in the fifth grade and we saw a film about birth defects. My biggest fear was that my mother was going to give birth to a fetal alcohol syndrome (FAS) infant. . . . My baby brother was born right on schedule. The doctors claimed a healthy newborn. . . . Once I heard healthy, I thought everything was going to be fine. I was wrong, then again I was just a child. . . . My baby brother never showed any interest in toys . . . he just cannot get the right words out of his mouth . . . he has no common sense . . .
>
> *[J., personal communication]*

My student asks, "Why hurt those who cannot defend themselves?" As you remember from Chapter 1, one case proves nothing, and as you just read, teratogens often cascade with murky connections. J. blames her mother for smoking and drinking beer, although genes, postnatal experiences, and lack of preventive information and services may be part of the cascade as well. Nonetheless, J. is right to wonder why her mother took a chance.

Behavioral teratogens can be subtle, and their effects may last a lifetime. That is one conclusion from research on pregnant women exposed to flu in 1918. Some miscarried; some babies were stillborn. Most survivors seemed unharmed and lived long lives—but not as long as the average baby born a year earlier. By middle age, the flu-exposed babies averaged less education, more unemployment, and lower income than their peers (Almond, 2006).

### Risk Analysis

Life entails risks. *Risk analysis* discerns which chances are worth taking and how risks are minimized. To pick an easy example: Crossing the street is a risk, yet it would be worse to avoid all street crossing. Knowing this, we cross carefully, looking both ways.

Sixty years ago, no one applied risk analysis to prenatal development. It was assumed that the placenta screened out all harmful substances. Then two tragic

tion, impaired spatial reasoning, and slow learning (Niccols, 2007; Streissguth & Connor, 2001).

However, some pregnant women drink alcohol in moderation with no evident harm to the fetus. If occasional drinking during pregnancy always caused FAS, almost everyone born in Europe before 1980 would be affected. As for FAE, hyperactivity and slow learning are so common that FAE cannot be blamed for every case. Currently, pregnant women are advised to avoid all alcohol, but women in the United Kingdom receive conflicting advice about drinking a glass of wine a day or two a week (Raymond et al., 2009), and French women are told to abstain but many do not seem to have heard that message (Toutain, 2010). Total abstinence requires that all women who might become pregnant avoid a legal substance that most adults use routinely. Wise? Probably. Necessary?

### Innate Vulnerability

Genes influence the effects of teratogens. When a woman carrying dizygotic twins drinks alcohol, for example, the twins' blood alcohol levels are equal; yet one twin may be more severely affected than the other because their alleles for the enzyme that metabolizes alcohol differ. Genetic vulnerability is suspected for many birth defects (Sadler et al., 2010). (Remember differential sensitivity.)

One particular chromosome, the Y, may be crucial. Male fetuses are more likely to be spontaneously aborted and, if born, more likely to have been affected by teratogens than female fetuses. Are those extra genes on the second X chromosome protective, or does the Y chromosome carry genes that increase vulnerability? Scientists do not know.

Genes are important in another way, in that the mother's genes affect the prenatal environment she provides. One maternal allele results in low levels of folic acid during pregnancy, which can produce *neural-tube defects*—either *spina bifida*, in which the tail of the spine is not enclosed properly (in healthy embryos, enclosure occurs at about week 7), or *anencephaly*, when part of the brain is missing. Neural-tube defects are more common in certain ethnic groups (Irish, English, and Egyptian) than in others (most Asian and African groups) because that maternal allele is rare among Asians and Africans (Mills et al., 1995).

A U.S. law required that, beginning in 1998, folic acid be added to packaged cereal. That initiative is credited with reducing neural-tube defects by 26 percent (MMWR, September 13, 2002). But some women rarely eat cereal and do not take vitamins. In 2010, in the Appalachian region of the United States (parts of West Virginia, Tennessee, and Kentucky), about 1 newborn in 1000 had a neural-tube defect.

**Swing High and Low** Adopted by loving parents but born with fetal alcohol syndrome, Philip, shown here at age 11, sometimes threatens to kill his family members. His parents sent him to this residential ranch in Eureka, Montana, a temporary home (nonprofit, tuition $3,500 a month) for children like him. This moment during recess is a happy one; it is not known whether he learned to control his fury.

**Especially for Nutritionists** Is it beneficial that most breakfast cereals are fortified with vitamins and minerals? (see response, page 111)

## Applying the Research

Risk analysis cannot precisely predict the results of teratogenic exposure in individual cases. However, much is known about destructive and damaging teratogens and what individuals, family members, and society can do to reduce the risks. Table 4.4 on pages 110–111 lists some teratogens and their possible effects, as well as preventive measures.

Remember that the effects of teratogens vary. Many fetuses are exposed with no evident harm. The opposite occurs as well: About 20 percent of all serious defects occur for reasons unknown. Women are advised to maintain good nutrition and avoid teratogens, especially drugs and chemicals (pesticides, cleaning fluids, and many cosmetics contain teratogenic chemicals). Some medications are necessary (e.g., for women who have epilepsy, diabetes, severe depression) and should continue, but caution should begin *before* pregnancy is confirmed (Haas et al., 2011).

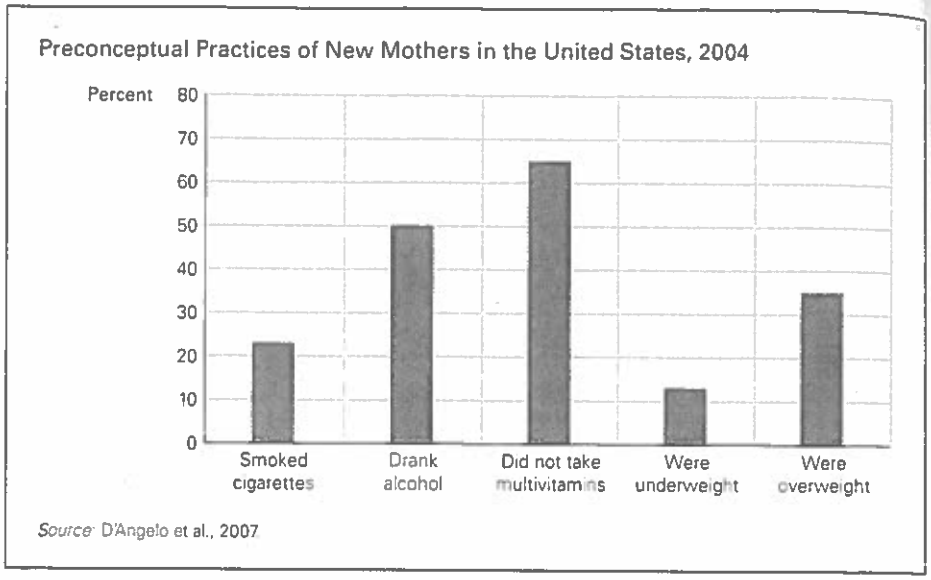



**FIGURE 4.7**

**No One is Perfect** Blaming pregnant women is easy, but almost no one avoids all drugs and stresses, sleeps and eats well, weighs just the right amount, exercises at least an hour each day, and completely avoids fried or salty foods. If you are the exception, could you keep it up for a year, while gaining 35 pounds; sometimes feeling nauseous; coping with stares and the questions of friends, relatives, and strangers; and going to the doctor every few weeks?

Unfortunately, almost half the births in the United States are unplanned, often to women who are not in the best of health before conception (D'Angelo et al., 2007) (see Figure 4.7).

The first days and weeks after conception (the germinal and embryonic periods) are critical for body formation, but health during the entire fetal period affects the brain. Some teratogens that cause preterm birth or low birthweight are particularly harmful in the second half of pregnancy. Indeed, one study found that, although smoking cigarettes throughout prenatal development can be lethal for the fetus, smokers who quit in the first weeks of pregnancy had no higher risks of birth complications than did women who never smoked (McCowan et al., 2009).

Timing may be important in another way. When pregnancy occurs soon after a previous pregnancy, risk increases. For example, second-born children may be twice as likely to be autistic if they are born within a year of the first-born child (Cheslack-Postava et al., 2011).

## How Much Is Too Much?

**threshold effect** In prenatal development, when a teratogen is relatively harmless in small doses but becomes harmful once exposure reaches a certain level (the threshold).

A second factor affecting the harm from any teratogen is the dose and/or frequency of exposure. Some teratogens have a **threshold effect;** they are virtually harmless until exposure reaches a certain level, at which point they "cross the threshold" and become damaging. This threshold is not a fixed boundary: dose, timing, frequency, and other teratogens affect when the threshold is crossed (O'Leary et al., 2010).

A few substances are beneficial in small amounts but fiercely teratogenic in large quantities. One is vitamin A, essential for healthy development but a cause of abnormalities if the dose is 50,000 units per day or higher (obtained only in pills) (Naudé et al., 2007). Experts are reluctant to specify thresholds, partly because the presence of one teratogen may intensify the effects of another. For example, the threshold for alcohol, tobacco, and marijuana is lower when all three are combined.

**fetal alcohol syndrome (FAS)** A cluster of birth defects, including abnormal facial characteristics, slow physical growth, and retarded mental development, that may occur in the fetus of a woman who drinks alcohol while pregnant.

Thresholds are controversial. It is known that high doses of psychoactive drugs are harmful, but it is not known if small amounts are teratogenic as well. Consider alcohol. Early in pregnancy, an embryo exposed to heavy drinking can develop **fetal alcohol syndrome (FAS),** which distorts the facial features (especially the eyes, ears, and upper lip). Later in pregnancy, alcohol is a behaviorial teratogen, the cause of *fetal alcohol effects (FAE),* leading to hyperactivity, poor concentra-

declared safe during pregnancy (prescribed for 40 percent) and drugs with proven risks to fetuses (prescribed for 2 percent) (Andrade et al., 2004). Perhaps these doctors did not know their patients were pregnant and perhaps these women did not take the medications, but even a few pills early in pregnancy may be harmful.

Another problem is that not every doctor takes the time to understand the woman's life patterns, some of which may be harmful. For example, one Maryland study found that almost one-third of pregnant women were not asked and counseled about their alcohol use (Cheng et al., 2011). Those who were over age 35 and college-educated were least likely to be counseled, perhaps because their doctors assumed they knew the dangers, but in this study at least, they were also most likely to drink during pregnancy.

**>> Response for Nutritionists** (from page 109) Useful, yes; optimal, no. Some essential vitamins are missing (too expensive), and individual needs differ, depending on age, sex, health, genes, and eating habits. The reduction in neural-tube defects is good, but many women don't eat cereal or take vitamin supplements before becoming pregnant.

| Teratogens | Effects of Exposure | To Prevent Harm |
|---|---|---|
| **Medicinal Drugs** | | |
| Lithium | Can cause heart abnormalities. | Avoid all medicines, whether prescription or over-the-counter, unless essential and approved by a medical professional who understands recent research. |
| Tetracycline | Can harm the teeth. | |
| Retinoic acid | Can cause limb deformities. | |
| Streptomycin | Can cause deafness. | |
| ACE inhibitors | Can harm digestive organs. | |
| Phenobarbital | Can affect brain development. | |
| Thalidomide | Halts ear and limb formation. | |
| **Psychoactive Drugs** | | |
| Caffeine | Normal use poses no problem. | Avoid excessive use. Limit beverages containing caffeine (coffee, tea, cola, cocoa). |
| Alcohol | May cause fetal alcohol syndrome (FAS) or fetal alcohol effects (FAE). | Stop or severely limit alcohol consumption during pregnancy; binge drinking is dangerous. |
| Tobacco | Decreases birthweight. May harm lungs, heart, urinary tract. | Stop smoking. If not, severely limit consumption. |
| Marijuana | Heavy exposure may affect the central nervous system; may hinder fetal growth. | Avoid or strictly limit use of marijuana. |
| Heroin | Slows fetal growth, starts preterm labor; addicted newborns require treatment to prevent convulsions. | Stop before pregnancy; if already pregnant, gradual methadone withdrawal is better than sudden abstinence. |
| Cocaine | May cause slow fetal growth, preterm birth, slow learning in infancy and childhood. | Stop before pregnancy; children may need special medical and educational attention |
| Inhaled solvents (glue or aerosol) | May cause abnormally small head, crossed eyes, and other indications of brain damage. | Stop sniffing before pregnancy; serious damage occurs during first weeks after conception. |
| Antipsychotic drugs (e.g., Haldol, Risperdal) | May cause movement abnormalities or withdrawal symptoms in newborns. | Caution needed. Sudden stopping is harmful; such drugs may make the woman a better prospective mother. |

*Note:* This table includes only relatively common teratogens. As the text makes clear, many individual factors interact to determine harm. Some of these generalities will change with new research. Pregnant women should consult with their physicians.

*Sources:* Briggs et al., 2008; R. D. Mann & Andrews, 2007; Sadler, 2009; U.S. Food and Drug Administration, 2011.

Sadly, the cascade of teratogens is most likely to begin with women who are already vulnerable. For example, cigarette smokers are more often drinkers (as was J.'s mother); those whose jobs involve chemicals and pesticides are more often malnourished (Ahmed & Jaakkola, 2007; Hougaard & Hansen, 2007).

## Advice From Doctors

While prenatal care can be helpful to women who need to know how to protect the developing person, even doctors are not always as careful as they could or should be. According to a massive study of 152,000 new mothers in eight health maintenance organizations (HMOs) in the United States, doctors wrote an average of three prescriptions per pregnant woman, including drugs that had not been

**TABLE 4.4 Teratogens: Effects of Exposure and Prevention of Damage**

| Teratogens | Effects of Exposure | To Prevent Harm |
|---|---|---|
| **Diseases** | | |
| Rubella (German measles) | In embryonic period, causes blindness and deafness; in fetal period, brain damage. | Immunization before pregnancy. |
| Toxoplasmosis | Causes brain damage, loss of vision, mental retardation. | Avoid eating undercooked meat and handling cat feces, garden dirt. |
| Measles, chicken pox, influenza | May impair brain functioning. | Immunization before pregnancy; avoid infections during pregnancy (wash hands). |
| Syphilis | Baby born with syphilis; may damage brain and bones; eventual death. | Get early prenatal diagnosis and treatment with antibiotics. |
| HIV/AIDS | Baby may catch the virus during birth. If so, drugs may prevent illness and death. | Prenatal drugs and cesarean birth limit HIV transmission. |
| Other sexual infections, such as gonorrhea | Not harmful prenatally but may cause blindness and infections after vaginal birth. | Get early diagnosis and treatment; if necessary, cesarean section, treatment of newborn. |
| Infections, including infections of urinary tract, gums, teeth | May cause premature labor, which increases vulnerability to brain damage. | Get infection treated, preferably before pregnancy. |
| **Pollutants** | | |
| Lead, mercury, PCBs, dioxin, pesticides, cleaning compounds | May cause spontaneous abortion, preterm labor, and brain damage. | Most substances are harmless in small doses. Avoid unwashed fruits, toxic chemicals, fish from polluted waters. |
| **Radiation** | | |
| Massive or repeated exposure to radiation, as in medical X-rays | Early in pregnancy, may cause small head (microcephaly), retardation; late, may damage brain. | Get ultrasounds, not X-rays; reassignment suggested for women who work directly with radiation |
| **Social/Behavioral** | | |
| Very high stress | Early in pregnancy, may cause cleft lip or cleft palate, spontaneous abortion. Later may cause preterm labor. | Adequate relaxation, rest, and sleep; reduce hours of employment; get help with housework and child care. |
| Malnutrition | When severe, interferes with conception, implantation, fetal development, and birthweight. | Consume balanced diet,extra folic acid, and iron; women with normal weight, gain 25–35 lbs (10–15 kg) during pregnancy. |
| Excessive, exhausting exercise | Can affect fetal development when it interferes with woman's sleep or digestion. | Maintain regular, moderate exercise. |

Immigrants average lower SES than the native-born, and low-SES babies are often small. But, paradoxically, newborns born in the United States to immigrants are generally healthier in every way, including in birthweight, than are newborns of American-born women of the same ethnicity. Thus, although Hispanic Americans born in Mexico or South America average lower SES than Hispanics born in the United States, their pregnancies and newborns have fewer problems because their husbands, their mothers, and their culture keep them healthy.

## Consequences of Low Birthweight

You have already read that life itself is uncertain for the smallest newborns. Ranking worse than most developed nations—and similar to Poland and Malaysia—the U.S. infant mortality rate (death in the first year) is about 7 per 1000, primarily because of low birthweight. When compared with newborns conceived at the same time but born later, very-low-birthweight infants are later to smile, to hold a bottle, to walk, and to communicate.

As months go by, cognitive difficulties as well as visual and hearing impairments emerge. Survivors who were high-risk newborns become infants and children who cry more, pay attention less, disobey, and experience language delays (Aarnoudse-Moens et al., 2009; Spinillo et al., 2009). Longitudinal research studies find that, compared with the average child in middle childhood, formerly SGA children have smaller brain volume, and those who were preterm have lower IQs (van Soelen et al., 2010). Even in adulthood, risks persist: Adults who were LBW are more likely to have heart disease and diabetes.

Longitudinal data provide both hope and caution. Remember that risk analysis gives odds, not certainties—averages that are not true in every case. Some ELBW infants, by age 4, are normal in brain development and overall (Claas et al., 2011; Spittle et al., 2009).

## Comparing Nations

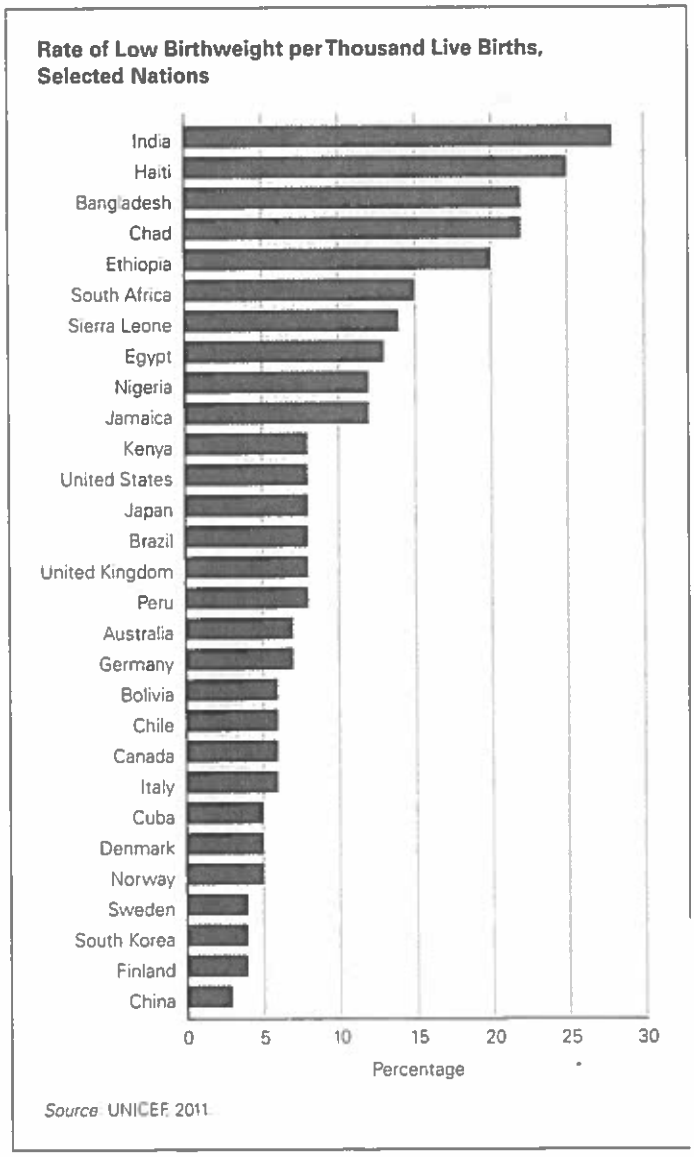
In some northern European nations, only 4 percent of newborns weigh under 2,500 grams; in several South Asian nations, more than 20 percent do. Worldwide, far fewer low-birthweight babies are born than 20 years ago, and neonatal deaths have been reduced by one-third as a result (Rajaratnam et al., 2010). Some nations, China and Chile among them, have shown dramatic improvement. In 1970, about half of Chinese newborns were LBW; recent estimates put that number at 3 percent (UNICEF, 2011). By contrast, in other nations, notably in sub-Saharan Africa, the LBW rate is steady or rising because global warming, AIDS, food shortages, wars, and other problems affect pregnancy.

Another nation with a rising LBW rate is the United States, where the rate fell steadily throughout most of the twentieth century, reaching a low of 7.0 percent in 1990. But then it rose again, with the 2008 rate at 8.2 percent—higher than that of virtually every other developed nation (see Figure 4.8 for a sampling).

Many scientists have developed hypotheses to explain the rising U.S. rates. One logical possibility is assisted reproduction, since ART often leads to low-birthweight twins and triplets (and other multiples). However, LBW rates are rising even for naturally

**FIGURE 4.8**

**Getting Better** Some public health experts consider the rate of low birthweight to be indicative of national health, since both are affected by the same causes. If that is true, the world is getting healthier, since the estimated LBW world average was 28 percent in 1980 but is now 15 percent. When all nations are included, 47 report LBW at 6 per 1000 or lower, which suggests that many nations (including the United States and United Kingdom) could improve.



## Low Birthweight

Some newborns are small and immature. With modern hospital care, tiny infants usually survive, but it would be better for everyone—mother, father, baby, and society—if all newborns were in the womb for at least 35 weeks and weighed more than 2,500 grams (5½ pounds). (Usually, this text gives pounds before grams, but hospitals worldwide report birthweight using the metric system, so grams precede pounds and ounces here.)

**low birthweight (LBW)** A body weight at birth of less than 5½ pounds (2,500 grams).

**very low birthweight (VLBW)** A body weight at birth of less than 3 pounds, 5 ounces (1,500 grams).

**extremely low birthweight (ELBW)** A body weight at birth of less than 2 pounds, 3 ounces (1,000 grams).

**Low birthweight (LBW)** is defined by the World Health Organization as under 2,500 grams. LBW babies are further grouped into **very low birthweight (VLBW),** under 1,500 grams (3 pounds, 5 ounces), and **extremely low birthweight (ELBW),** under 1,000 grams (2 pounds, 3 ounces).

### Maternal Behavior and Low Birthweight

Remember that fetal weight normally more than doubles in the last trimester of pregnancy, with 900 grams (about 2 pounds) of that gain occurring in the final three weeks. Thus, a baby born **preterm** (three or more weeks early; no longer called *premature*) is usually, but not always, LBW. Preterm birth correlates with many of the teratogens already mentioned, an example of the cascade that leads to newborns with evident problems. When the environment of the womb is harmful, the hormones of the fetus may begin birth early.

**preterm** A birth that occurs 3 or more weeks before the full 38 weeks of the typical pregnancy—that is, at 35 or fewer weeks after conception.

Early birth is only one cause of low birthweight. Some fetuses gain weight slowly throughout pregnancy and are *small-for-dates,* or **small for gestational age (SGA).** A full-term baby weighing only 2,500 grams and a 30-week-old fetus weighing only 1,000 grams are both SGA, even though the first is not quite low birthweight. Maternal or fetal illness might cause SGA, but maternal drug use is a more common cause. Every psychoactive drug slows fetal growth, with tobacco implicated in 25 percent of all low-birthweight births worldwide.

**small for gestational age** (SGA) A term for a baby whose birthweight is significantly lower than expected, given the time since conception. For example, a 5-pound (2,265-gram) newborn is considered SGA if born on time but not SGA if born two months early. (Also called *small-for-dates.*)

Another common reason for slow fetal growth is maternal malnutrition. Women who begin pregnancy underweight, who eat poorly during pregnancy, or who gain less than 3 pounds (1.3 kilograms) per month in the last six months are more likely to have an underweight infant. Malnutrition (not age) is the primary reason teenagers often have small babies. Unfortunately, many of the risk factors just mentioned—underweight, undereating, underage, and smoking—tend to occur together.

### What About the Father?

The causes just mentioned of low birthweight focus on the pregnant woman: If she takes drugs or is undernourished, her fetus suffers. However, the more we learn about birth problems, the more important fathers—and grandmothers, neighbors, and communities—are discovered to be. As an editorial in a journal for obstetricians explains: "Fathers' attitudes regarding the pregnancy, fathers' behaviors during the prenatal period, and the relationship between fathers and mothers . . . may indirectly influence risk for adverse birth outcomes" (Misra et al., 2010, p. 99).

As already explained in Chapter 1, each person is embedded in an ecosystem of other people who influence every action. Since the future mother's behavior impacts the fetus, everyone who affects her also affects the future baby. For instance, one correlate of low birthweight is whether the pregnancy was intended (Shah et al., 2011). Obviously, a mother's intentions are in her mind, not her body. Just as obviously, her intentions are affected by the father, and his intentions as well as hers affect her diet, drug abstinence, prenatal care, and so on.

Not only fathers, but the entire social network and culture are crucial influences (Lewallen, 2011). This is most apparent in what has been called the *Hispanic paradox.* In general, low socioeconomic status (SES) correlates with low birthweight.

**>> Response for Social Workers** (from page 112) Testing and then treatment are useful at any time because women who know they are HIV-positive are more likely to get treatment, reduce the risk of transmission, or avoid pregnancy. If pregnancy does occur, early diagnosis is best. Getting tested after birth is too late for the baby.