CHAPTER

5

Physical Development:
The Brain, Body, Motor Skills, and Sexual Development

"My, my, she is already walking! What a smart little girl!"

"Look at you go. Oops, fall down, go boom!"

"Get your rest, little guy, it will help you grow big and strong."

"He's growing like a weed—and his arms are too long!"

"Only 11 and she's got her period. What's the world coming to?"

"All that girl thinks about is boys."

HAVE YOU EVER HEARD adults make these kinds of statements about developing children and adolescents? Few aspects of development are more interesting to the casual observer than the rapid transformation of a seemingly dependent and immobile little baby into a running, jumping bundle of energy who grows and changes at what may seem to be an astounding pace, and who may one day surpass the physical stature of his or her parents. Those physical changes that many find so fascinating are the subject of this chapter.

We will begin by focusing on the changes that occur in the body, the brain, and motor skills throughout childhood. Then we will consider the impact of puberty—both the dramatic physical changes that adolescents experience and their social and psychological impacts. Finally, we will end the chapter by discussing the factors that influence physical growth and development throughout the first 20 years of life.

Having experienced most (if not all) of the changes covered in this chapter, you may assume that you know quite a bit about physical development. Yet students often discover that there is much they *don't* know. To check your own knowledge, take a minute to decide whether the following statements are true or false:

1. Babies who walk early are inclined to be especially bright.
2. The average 2-year-old is already about half of his or her adult height.

3. Half the nerve cells in the average baby's brain die over the first few years of life.
4. Most children walk when they are ready, and no amount of encouragement will enable a 6-month-old to walk alone.
5. A person's hormones have little effect on human growth and development until puberty.
6. Emotional trauma can seriously impair the physical growth of young children, even those who are adequately nourished, free from illness, and not physically abused.

Jot down your responses and we will see how you did on this "pretest" as we discuss these issues throughout the chapter. (If you would like immediate feedback, the correct answers appear at the bottom of the page.)

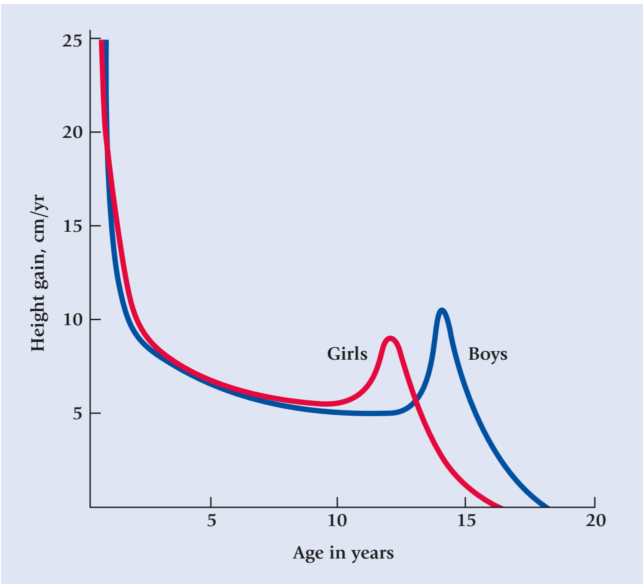
An Overview of Maturation and Growth

Adults are often amazed at how quickly children grow. Even tiny babies don't remain tiny for long: in the first few months of life, they gain nearly an ounce each day and an inch each month. Yet the dramatic increases in height and weight that we see are accompanied by a number of important *internal* developments in the muscles, bones, and central nervous system that will largely determine the physical feats that children are capable of performing at different ages. In this section of the chapter, we will briefly chart the course of physical development from birth through adolescence and see that there is a clear relationship between the external aspects of growth that are so noticeable and the internal changes that are much harder to detect.

Changes in Height and Weight

Babies grow very rapidly during the first 2 years, often doubling their birth weight by 4 to 6 months of age and tripling it (to about 21 to 22 pounds) by the end of the 1st year. Growth is very uneven in infancy. One study found that babies may remain the same length for days or weeks at a time before showing spurts of more than a centimeter in a single day (Lampl, Veldhuis, & Johnson, 1992). By age 2, toddlers are already half their eventual adult height and have quadrupled their birth weight to 27 to 30 pounds. If children continued to grow at this rapid pace until age 18, they would stand at about 12 feet 3 inches and weigh several tons!

From age 2 until puberty, children gain about 2 to 3 inches in height and 6 to 7 pounds in weight each year. During middle childhood (ages 6 to 11), children may seem to grow very little; over an entire year, gains of 2 inches and 6 pounds are hard to detect on a child who stands 4 to 4½ feet tall and weighs 60 to 80 pounds (Eichorn, 1979). But as shown in ▮ Figure 5.1, physical growth and development are once again obvious at puberty, when adolescents enter a 2- to 3-year growth spurt, during which they may post an annual gain of 10 to 15 pounds and 2 to 4 inches in height. After this large growth spurt, there are typically small increases in height until full adult stature is attained in the mid- to late teens (Tanner, 1990).



▮ **Figure 5.1** Gain in height per year by males and females from birth through adolescence. At about age 10½, girls begin their growth spurt. Boys follow some 2½ years later and grow faster than girls once their growth begins. *Based on a figure in* Archives of the Diseases in Childhood, 41, *by J. M. Tanner, R. H. Whithouse, and A. Takaishi, 1966, pp. 454–471.*

Answers to pretest: 1. F; 2. T; 3. T; 4. T; 5. F; 6. T

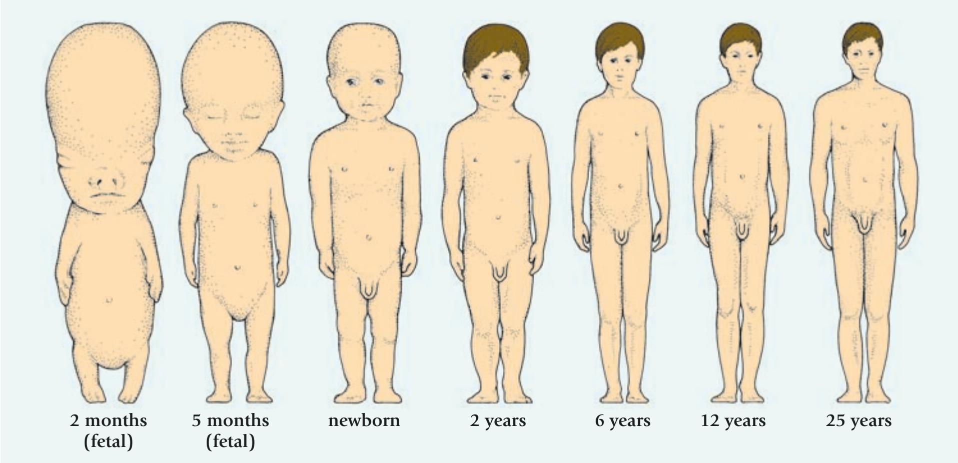


Figure 5.2 Proportions of the human body from the fetal period through adulthood. The head represents 50 percent of body length at 2 months after conception but only 12 to 13 percent of adult stature. In contrast, the legs constitute about 12 to 13 percent of the total length of a 2-month-old fetus, but 50 percent of the height of a 25-year-old adult.

Changes in Body Proportions

To a casual observer, newborns may appear to be "all head"—and for good reason. The newborn's head is already 70 percent of its eventual adult size and represents one-quarter of total body length, the same fraction as the legs.

As a child grows, body shape rapidly changes (see Figure 5.2). Development proceeds in a **cephalocaudal** (head downward) direction. The trunk grows fastest during the 1st year. At 1 year of age, a child's head now accounts for only 20 percent of total body length. From the child's 1st birthday until the adolescent growth spurt, the legs grow rapidly, accounting for more than 60 percent of the increase in height (Eichorn, 1979). During adolescence the trunk once again becomes the fastest-growing segment of the body, although the legs are also growing rapidly at this time. When we reach our eventual adult stature, our legs will account for 50 percent of total height and our heads only 12 percent.

cephalocaudal development
a sequence of physical maturation and growth that proceeds from the head (cephalic region) to the tail (or caudal region).

proximodistal development
a sequence of physical maturation and growth that proceeds from the center of the body (the proximal region) to the extremities (distal regions).

While children grow upward, they are also growing outward in a **proximodistal** (center outward) direction (Kohler & Rigby, 2003). During prenatal development, for example, the chest and internal organs form first, followed by the arms and legs, and then the hands and feet. Throughout infancy and childhood, the arms and legs continue to grow faster than the hands and feet. However, this center-outward growth pattern reverses just before puberty, when the hands and feet begin to grow rapidly and become the first body parts to reach adult proportions, followed by the arms and legs and, finally, the trunk. One reason teenagers often appear so clumsy or awkward is that their hands and feet (and later their arms and legs) may suddenly seem much too large for the rest of their bodies (Tanner, 1990).

Body proportions change rapidly over the first few years as chubby toddlers become long-legged children.

Skeletal Development

The skeletal structures that form during the prenatal period are initially soft cartilage that will gradually ossify (harden) into bony material. At birth, most of the infant's bones are soft, pliable, and difficult to break. One reason that newborns cannot sit up or balance themselves when pulled to a standing position is that their bones are too small and too flexible.

The neonate's skull consists of several soft bones that can be compressed to allow the child to pass through the cervix and the birth canal, making childbirth easier for the mother and the baby. These skull bones are separated by six soft

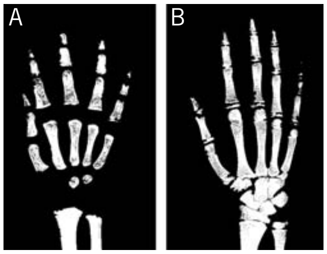


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Figure 5.3 X-rays showing the amount of skeletal development seen in (A) the hand of an average male infant at 12 months or an average female infant at 10 months and (B) the hand of an average 13-year-old male or an average 10½-year-old female.

skeletal age
a measure of physical maturation based on the child's level of skeletal development.

spots, or *fontanelles,* that are gradually filled in by minerals to form a single skull by age 2, with pliable points at the seams where skull bones join. These seams, or *sutures,* allow the skull to expand as the brain grows larger.

Other parts of the body—namely, the ankles, feet, wrists and hands—develop more (rather than fewer) bones as the child matures. In Figure 5.3, we see that the wrist and hand bones of a 1-year-old are both fewer and less interconnected than the corresponding skeletal equipment of an adolescent.

One method of estimating a child's level of physical maturation is to X-ray his or her wrist and hand (as in Figure 5.3). The X-ray shows the number of bones and the extent of their ossification, which is then interpretable as a **skeletal age.** Using this technique, researchers have found that girls mature faster than boys. At birth, girls are only 4 to 6 weeks ahead of boys in their level of skeletal development; but by age 12, the gender difference has widened to 2 full years (Tanner, 1990).

Not all parts of the skeleton grow and harden at the same rate. The skull and hands mature first, whereas the leg bones continue to develop until the mid- to late teens. For all practical purposes, skeletal development is complete by age 18, although the widths (or thicknesses) of the skull, leg bones, and hands increase slightly throughout life (Tanner, 1990).

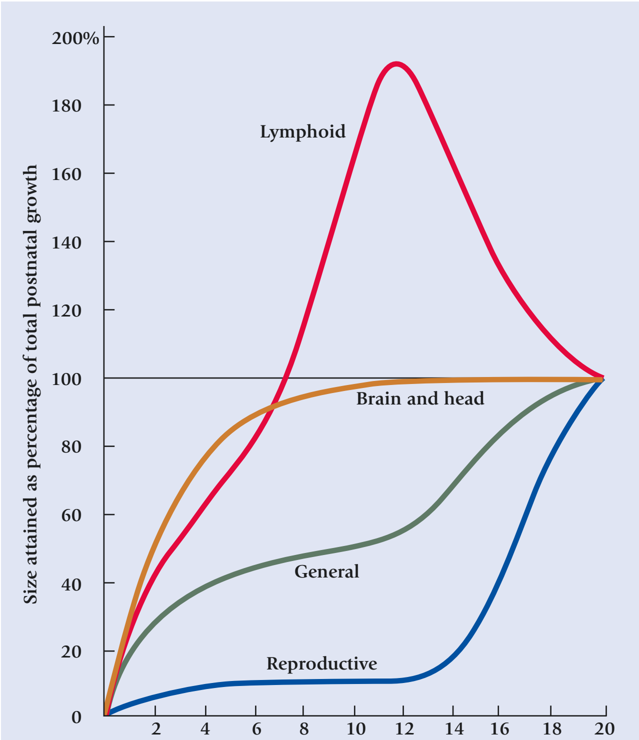

Figure 5.4 Growth curves for different body systems. Each curve plots the size of a group of organs or body parts as a percentage of their size at age 20 (which is the 100 percent level on the vertical scale). The "general" curve describes changes in the body's size as well as the growth of respiratory and digestive organs and musculature. The brain and head grow more rapidly than the body in general, and the reproductive organs are the slowest to reach adult size. (The lymph nodes and other parts of the lymphoid system, which function as part of the immune system, also grow rapidly and actually exceed adult size during late childhood and adolescence.) *From* Growth at Adolescence, *2nd ed., by J. M. Tanner, 1962. Oxford, England: Blackwell. Copyright © 1962 by Blackwell Scientific Publications, Inc. Reprinted by permission of Blackwell Science, Ltd.*

Muscular Development

Newborns are born with all the muscle fibers they will ever have (Tanner, 1990). At birth, muscle tissue is 35 percent water, and it accounts for no more than 18 to 24 percent of a baby's body weight (Marshall, 1977). However, muscle fibers soon begin to grow as the cellular fluid in muscle tissue is bolstered by the addition of protein and salts.

Muscular development proceeds in cephalocaudal and proximodistal directions, with muscles in the head and neck maturing before those in the trunk and limbs. Like many other aspects of physical development, the maturation of muscle tissue occurs very gradually over childhood and then accelerates during early adolescence. One consequence of this muscular growth spurt is that members of both sexes become noticeably stronger, although increases in both muscle mass and physical strength (as measured in tests of large-muscle activity) are more dramatic for boys than for girls (Malina, 1990). By the mid-20s, skeletal muscle accounts for 40 percent of the body weight of an average male, compared with 24 percent for the average female.

Variations in Physical Development

To this point, we have been discussing sequences of physical growth that all humans display. However, physical development is a very uneven process in which different bodily systems display unique growth patterns. As we see in Figure 5.4, the brain and head actually grow much faster and are quicker to reach adult proportions than the rest of the body, whereas the genitals and other reproductive organs grow very slowly throughout childhood and develop rapidly in adolescence. Notice also that growth of the lymph tissues—which make up part of the immune system and help children fight off infections—actually overshoots adult levels late in childhood, before declining rapidly in adolescence.

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Figure 5.5 There are large individual variations in the timing of the adolescent growth spurt, as we see in comparing the stature of these two boys of the same age.

Individual Variations

Not only is the development of body systems an uneven or asynchronous process, but there are sizable individual variations in the rates at which children grow (Kohler & Rigby, 2003). Look carefully at Figure 5.5. These two boys are the same age, although one has already reached puberty and looks much older. As we will see later in the chapter, two grade-school friends might begin the pubertal transition from child to adult as much as 5 years apart!

Cultural Variations

Finally, there are meaningful cultural and subcultural variations in physical growth and development. In general, people from Asia, South America, and Africa tend to be smaller than those from North America, Northern Europe, and Australia. In addition, there are cultural differences in the *rate* of physical growth. Asian American and African American children, for example, tend to mature faster than European American and European children (Berkey et al., 1994; Herman-Giddens et al., 1997).

What accounts for these variations in growth? Current thinking is that asynchronies in the maturation of different body systems are built into our species' heredity—that is, the common maturational program that all humans share (Tanner, 1990). And later in the chapter, we will see that heredity, in concert with such environmental factors as the food people eat, the diseases they may encounter, and even the emotional climate in which they live, can produce significant variations in the rates at which they grow and the statures they attain (Kohler & Rigby, 2003).

Development of the Brain

The brain grows at an astounding rate early in life, increasing from 25 percent of its eventual adult weight at birth to 75 percent of adult weight by age 2. Indeed, the last 3 prenatal months and the first 2 years after birth have been termed the period of the **brain growth spurt** because more than half of one's adult brain weight is gained at this time (Glaser, 2000). Between the 7th prenatal month and a child's 1st birthday, the brain increases in weight by about 1.7 grams a day, or more than a milligram per minute.

brain growth spurt
the period between the 7th prenatal month and 2 years of age when more than half of the child's eventual brain weight is gained.

However, an increase in brain weight is a general index that tells us very little about how or when various parts of the brain mature and affect other aspects of development. Let's take a closer look at the internal organization and development of the brain.

Neural Development and Plasticity

synapse
the connective space (juncture) between one nerve cell (neuron) and another.

neurons
nerve cells that receive and transmit neural impulses.

The human brain and nervous system consist of more than a trillion highly specialized cells that work together to transmit electrical and chemical signals across many trillions of **synapses,** or connective spaces between the cells. **Neurons** are the basic unit of the brain and nervous system—the cells that receive and transmit neural impulses.

Neurons are produced in the neural tube of the developing embryo. From there, they migrate along pathways laid down by a network of *guiding cells* to form the major parts of the brain. The vast majority of the neurons a person will ever have—some 100 to 200 billion of them—have already formed by the end of the second trimester of pregnancy, before the brain growth spurt has even begun (Kolb & Fantie, 1989; Rakic, 1991). Until recently, it was thought that no new neurons were produced after a baby was born. However, scientists have established that formation of new neurons in the hippocampus (an area of the brain important to learning and memory) occurs throughout life (Kemperman & Gage, 1999).

What, then, accounts for the brain growth spurt? One major contributor is the development of a second type of nerve cell, called **glia,** which nourish the neurons and eventually encase them in insulating sheaths of a waxy substance called *myelin*. Glia are far more numerous than neurons are, and they continue to form throughout life (Tanner, 1990).

glia
nerve cells that nourish neurons and encase them in insulating sheaths of myelin.

Neural Development: Cell Differentiation and Synaptogenesis

Influenced by the sites to which they migrate, neurons assume specialized functions—as cells of the visual or auditory areas of the brain, for example. If a neuron that would normally migrate to the visual area of the brain is instead transplanted to the area that controls hearing, it will change to become an auditory neuron instead of a visual neuron (Johnson, 1998, 2005). So individual neurons have the potential to serve any neural function, and the function each serves depends on where it ends up.

Meanwhile, the process of **synaptogenesis**—the formation of synaptic connections among neurons—proceeds rapidly during the brain growth spurt. This brings us to an intriguing fact about the developing nervous system: the average infant has far more neurons and neural connections than adults do (Elkind, 2001). The reason is that neurons that successfully interconnect with other neurons crowd out those that don't, so that about half the neurons produced early in life also die early (Elkind, 2001; Janowsky & Finlay, 1986). Meanwhile, surviving neurons form hundreds of synapses, many of which will disappear if the neuron is not properly stimulated (Huttenlocher, 1994). If we likened the developing brain to a house under construction, we might imagine a builder who merrily constructs many more rooms and hallways than he or she needs and later goes back and knocks about half of them out!

synaptogenesis
formation of connections (synapses) among neurons.

What is happening here reflects the remarkable **plasticity** of the young infant's brain—the fact that its cells are highly responsive to the effects of experience (Stiles, 2000). As William Greenough and his colleagues (1987) explain, the brain has evolved so that it produces an excess of neurons and synapses in preparation for receiving any and all kinds of sensory and motor stimulation that a human being could conceivably experience. Of course, no human being has this broad a range of experiences, so much of one's neural circuitry remains unused. Presumably, then, neurons and synapses that are most often stimulated continue to function. Other surviving neurons that are stimulated less often lose their synapses (a process called *synaptic pruning*) and stand in reserve to compensate for brain injuries or to support new skills (Elkind, 2001; Huttenlocher, 1994). Note the implication: the development of the brain early in life is not due entirely to the unfolding of a maturational program, but is instead the result of both a biological program and early experience (Greenough, Black, & Wallace, 1987; Johnson, 1998, 2005).

plasticity
capacity for change; a developmental state that has the potential to be shaped by experience.

Neural Plasticity: The Role of Experience

How do we know that early experience plays such a dramatic role in the development of the brain and central nervous system? The first clue came from research by

Austin Riesen and his colleagues (Riesen, 1947; Riesen et al., 1951). Riesen's subjects were infant chimpanzees that were reared in the dark for periods ranging up to 16 months. His results were striking. Dark-reared chimps experienced atrophy of the retina and the neurons that make up the optic nerve. This atrophy was reversible if the animal's visual deprivation did not exceed 7 months, but it was irreversible and often led to total blindness if the deprivation lasted longer than a year. So neurons that are not properly stimulated will degenerate (Elkind, 2001; Rapoport et al., 2001).

Might we then foster the neural development of an immature, malleable brain by exposing participants to enriched environments that provide a wide variety of stimulation? Absolutely. Animals raised with lots of companions and many toys to play with have brains that are heavier and display more extensive networks of neural connections than those of litter-mates raised under standard laboratory conditions (Greenough & Black, 1992; Rosenzweig, 1984). What's more, the brains of animals raised in stimulating environments lose some of their complexity if the animals are moved to less stimulating quarters (Thompson, 1993).

In one human study, head circumference, a rough indicator of brain size, was assessed in 221 children at a gestational age of 18 weeks, again at birth, and finally at 9 years of age. The head circumferences of children from high-socioeconomic-status (SES) homes, and those whose mothers had earned college degrees, were significantly larger than the head circumferences of children from low-SES homes and whose mothers had no degrees (Gale et al., 2004). So, even though genes may provide rough guidelines as to how the brain should be configured, early experience largely determines the brain's specific architecture (Rapoport et al., 2001).

Brain Differentiation and Growth

Not all parts of the brain develop at the same rate. At birth, the most highly developed areas are the lower (subcortical) brain centers, which control states of consciousness, inborn reflexes, and vital biological functions such as digestion, respiration, and elimination. Surrounding these structures are the *cerebrum* and *cerebral cortex,* the areas most directly implicated in voluntary bodily movements, perception, and higher intellectual activities such as learning, thinking, and language. The first areas of the cerebrum to mature are the *primary motor areas* (which control simple motor activities such as waving the arms) and the *primary sensory areas* (which control sensory processes such as vision, hearing, smelling, and tasting). Thus, one reason human neonates are reflexive, "sensory-motor" beings is that only the sensory and motor areas of the cortex are functioning well at birth. By 6 months of age, the primary motor areas of the cerebral cortex have developed to the point that they now direct most of the infant's movements. Inborn responses such as the palmar grasp and the Babinski reflex should have disappeared by now, thus indicating that the higher cortical centers are assuming proper control over the more primitive subcortical areas of the brain.

Myelinization

As brain cells proliferate and grow, some of the glia begin to produce a waxy substance called *myelin,* which forms a sheath around individual neurons. This myelin sheath acts as an insulator to speed up the transmission of neural impulses, allowing the brain to communicate more efficiently with different parts of the body.

myelinization
the process by which neurons are enclosed in waxy myelin sheaths that will facilitate the transmission of neural impulses.

Myelinization follows a definite chronological sequence that is consistent with the maturation of the rest of the nervous system. At birth or shortly thereafter, the pathways between the sense organs and the brain are reasonably well myelinated.

As a result, the neonate's sensory equipment is in good working order. As neural pathways between the brain and the skeletal muscles myelinate (in a cephalocaudal and proximodistal pattern), the child becomes capable of increasingly complex motor activities such as lifting its head and chest, reaching with its arms and hands, rolling over, sitting, standing, and eventually walking and running. Although myelinization proceeds very rapidly over the first few years of life (Herschkowitz, 2000), some areas of the brain are not completely myelinated until the mid- to late teens or early adulthood (Fischer & Rose, 1995; Kennedy et al., 2002; Rapoport et al., 2001; Sowell et al., 1999). For example, the *reticular formation* and the *frontal cortex*—parts of the brain that allow us to concentrate on a subject for lengthy periods—are not fully myelinated at puberty (Tanner, 1990). This may be one reason that the attention spans of infants, toddlers, and school-age children are much shorter than those of adolescents and adults.

In addition, as myelinization enhances the efficiency between the more primitive, emotive subcortical areas of the brain and the more regulatory prefrontal cortical areas of the brain, an infant or child's ability to process and respond to socially important emotional input—such as the expressions of fear or disapproval on a parent's face—may improve. As well, a child's ability to monitor his or her own emotional reactions increases (Herba & Phillips, 2004). For example, in a rush to grab the next present, a 3- or 4-year-old may quickly discard a disappointing birthday gift, such as clothing, whereas a 6-year-old may pause and give a polite "thank you" to Grandma, thus managing to mask disappointment and delay the gratification of exploring the next, more desirable gift. A teenager may display an even more complex inhibition pattern—smiling politely when a gift of unfashionable clothing is received from Grandma, and scowling and protesting when a similar fashion faux pas is passed along from Mom (who should know better).

cerebrum
the highest brain center; includes both hemispheres of the brain and the fibers that connect them.

corpus callosum
the bundle of neural fibers that connects the two hemispheres of the brain and transmits information from one hemisphere to the other.

cerebral cortex
the outer layer of the brain's cerebrum that is involved in voluntary body movements, perception, and higher intellectual functions such as learning, thinking, and speaking.

Cerebral Lateralization

The highest brain center, the **cerebrum,** consists of two halves (or *hemispheres*) connected by a band of fibers called the **corpus callosum.** Each of the hemispheres is covered by a **cerebral cortex**—an outer layer of gray matter that controls sensory and motor processes, perception, and intellectual functioning. Although identical in appearance, the left and right cerebral hemispheres serve different functions and control different areas of the body. The left cerebral hemisphere controls the right side of the body; and, as illustrated in Figure 5.6, it contains centers for speech,

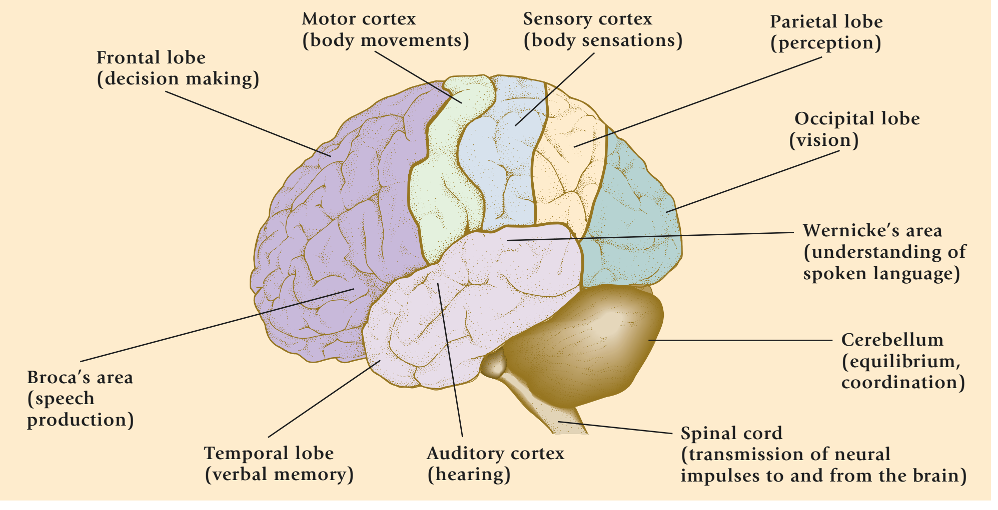

Figure 5.6 Lateral view of the left cerebral cortex and some of the functions that it controls. Although the cerebellum and spinal cord are not part of the cerebral cortex, they serve important functions of their own.

hearing, verbal memory, decision making, language processing, and expression of positive emotions. The right cerebral hemisphere, on the other hand, controls the left side of the body and contains centers for processing visual-spatial information, nonlinguistic sounds such as music, tactile (touch) sensations, and expressing negative emotions (Fox et al., 1995). Thus, the brain is a *lateralized* organ. **Cerebral lateralization** also involves a preference for using one hand or one side of the body more than the other. About 90 percent of adults rely on their right hands (or left hemispheres) to write, eat, and perform other motor functions, whereas these same activities are under the control of the right hemisphere among most people who are left-handed. However, the fact that the brain is a lateralized organ does not mean that each hemisphere is totally independent of the other; the corpus callosum, which connects the hemispheres, plays an important role in integrating their respective functions.

cerebral lateralization
the specialization of brain functions in the left and the right cerebral hemispheres.

When do the two cerebral hemispheres begin to become lateralized? Brain lateralization may originate during the prenatal period and be well under way at birth (Kinsbourne, 1989). For example, about two-thirds of all fetuses end up positioned in the womb with their right ears facing outward, and it is thought that this gives them a right ear advantage and illustrates the left hemisphere's specialization in language processing (Previc, 1991). From the first day of life, speech sounds stimulate more electrical activity in the left side of the cerebral cortex than in the right (Molfese, 1977). In addition, most newborns turn to the right rather than to the left when they lie on their backs, and these same babies later tend to reach for objects with their right hands (Kinsbourne, 1989). So it seems that the two cerebral hemispheres may be biologically programmed to assume different functions and have already begun to differentiate by the time a baby is born (Kinsbourne, 1989; Witelson, 1987).

However, the brain is not completely specialized at birth; throughout childhood we come to rely more and more on one particular hemisphere or the other to serve particular functions. Consider, for example, that even though left- or right-handedness is apparent early and is reasonably well established by age 2, lateral preferences become stronger with age. In one experiment, preschoolers and adolescents were asked to pick up a crayon, kick a ball, look into a small, opaque bottle, and place an ear to a box to hear a sound. Only 32 percent of the preschoolers, but more than half of the adolescents, showed a consistent lateral preference by relying exclusively on one side of the body to perform all four tasks (Coren, Porac, & Duncan, 1981).

Because the immature brain is not completely specialized, young children often show a remarkable ability to bounce back from traumatic brain injuries as neural circuits that might otherwise have been lost assume the functions of those that have died (Kolb & Fantie, 1989; Rakic, 1991). Although adolescents and adults who suffer brain damage often regain a substantial portion of the functions they have lost, especially with proper therapy, their recoveries are rarely as rapid or as complete as those of younger children (Kolb & Fantie, 1989). So the remarkable recuperative power of the human brain (that is, its plasticity) is greatest early in life, before cerebral lateralization is complete.

Development of the Brain During Adolescence

Through the ages, adults have noticed that when children reach the teenage years, they suddenly begin to ask hypothetical, "what if" questions and to ponder weighty abstractions such as truth and justice. Are these changes in thinking tied to late developments in the brain?

Many researchers now believe that they are (Case, 1992; Somsen et al., 1997). For example, myelinization of the higher brain centers, which continues well into adolescence, not only may increase adolescents' attention spans but also explains why they process information much faster than grade-school children (Kail, 1991; Rapoport et al., 2001). Furthermore, we now know that the brain retains at least some of its plasticity well beyond puberty (Nelson & Bloom, 1997) and that reorganizations of the neural circuitry of the *prefrontal cortex,* which is involved in such higher-level cognitive activities as strategic planning, continues until at least age 20 (Spreen, Risser, & Edgell, 1995; Stuss, 1992). In addition, brain volume increases through early to midadolescence and then decreases during late adolescence, suggesting that some pubertal reorganizations may involve synaptic pruning (Kennedy et al., 2002; Rapoport et al., 2001). So, even though changes in the brain during adolescence are less dramatic than those earlier in life, it is likely that some of the cognitive advances that teenagers display become possible only after their brains undergo a process of reorganization and specialization (Barry et al., 2002, 2005).

CONCEPT CHECK 5.1 Overview of Physical Development and Brain Development

Check your understanding of general trends in maturation and growth and the development of the brain by answering the following questions. Answers to objective questions appear in the Appendix.

Multiple Choice: Select the best alternative for each question.

______ 1. The fact that a newborn's head is 70 percent of its adult size and a full half of its body length is best explained by which concept of development?
a. The skeletal age trend
b. The cephalocaudal trend
c. The proximodistal trend
d. The fontenelle trend

______ 2. Which of the following body parts actually *overshoots* adult levels in childhood and then declines to adult levels later in adolescence?
a. The head and brain
b. The muscular system
c. The lymphoid system
d. The skeletal system

______ 3. The basic unit of the brain and nervous system are the cells that receive and transmit neural impulses. These cells are called
a. glia cells.
b. neurons.
c. myelin.
d. synapses.

______ 4. Scientists believe that the human brain has evolved so that the infant brain can be highly responsive to the effects of experience. The brain is thought to produce an excess of neurons and synapses so that it can be responsive to many different kinds of sensory and motor stimulation. This responsiveness also results in synaptic and neural degeneration when the neurons that are not stimulated do not continue to function. This aspect of brain development is termed
a. plasticity.
b. myelinization.
c. cerebral cortexification.
d. cerebral lateralization.

______ 5. Gretchen is having a baby. She learned that brain lateralization may occur during the prenatal period and be well under way at birth. This understanding led her to fully expect the positioning of her fetus when it was examined with ultrasound. Like two-thirds of all fetuses, her fetus was positioned in her womb
a. with its left ear facing outward.
b. with its right ear facing outward.
c. with its ears facing upward.
d. with its ears facing downward.

True or False: Indicate whether each of the following statements is true or false.

6. (T)(F) At birth, an infant's bones are very stiff and brittle and easy to break.
7. (T)(F) Individual neurons have the potential to serve any neural function, depending on where their migration delivers them.
8. (T)(F) Very few neurons produced early in life die; instead, they are adapted for different functions in the nervous system.
9. (T)(F) Although the brain is lateralized at birth, lateral preferences continue to become stronger across age through adolescence.

Short Answer: Briefly answer the following question.

10. Explain the ways in which the development of the brain and nervous system help us to understand why babies are reflexive, "sensory-motor" beings at birth.

Motor Development

One of the more dramatic developments of the 1st year of life is the remarkable progress that infants make in controlling their movements and perfecting motor skills. Writers have sometimes described newborns as "helpless babes"—a characterization that largely stems from the neonate's inability to move about on her own. Clearly, human infants are disadvantaged when compared with the young of some other species, who can follow their mothers to food (and then feed themselves) very soon after birth.

However, babies do not remain immobile for long. By the end of the 1st month, the brain and neck muscles have matured enough to permit most infants to reach the first milestone in locomotor development: lifting their chins while lying flat on their stomachs. Soon thereafter, children lift their chests as well, reach for objects, roll over, and sit up if someone supports them. Investigators who have charted motor development over the first 2 years find that motor skills evolve in a definite sequence, which appears in Table 5.1. Although the ages at which these skills first appear vary considerably from child to child, infants who are quick to proceed through this motor sequence are not necessarily any brighter or otherwise advantaged, compared with those whose rates of motor development are average or slightly below average. Thus, even though the age norms in Table 5.1 are a useful standard for gauging an infant's progress as he or she begins to sit, stand, and take those first tentative steps, a child's rate of motor development really tells us very little about future developmental outcomes.

Basic Trends in Locomotor Development

The two fundamental "laws" that describe muscular development and myelinization also hold true for motor development during the first few years. Motor development proceeds in a *cephalocaudal* (head downward) direction, with activities involving the

TABLE 5.1 Age Norms (in Months) for Important Motor Developments (Based on European American, Latino, and African American Children in the United States)

Skill	Month when 50% of infants have mastered the skill	Month when 90% of infants have mastered the skill
Lifts head 90° while lying on stomach	2.2	3.2
Rolls over	2.8	4.7
Sits propped up	2.9	4.2
Sits without support	5.5	7.8
Stands holding on	5.8	10.0
Crawls	7.0	9.0
Walks holding on	9.2	12.7
Plays pat-a-cake	9.3	15.0
Stands alone momentarily	9.8	13.0
Stands well alone	11.5	13.9
Walks well	12.1	14.3
Builds tower of two cubes	13.8	19.0
Walks up steps	17.0	22.0
Kicks ball forward	20.0	24.0

Sources: Bayley, 1993; Frankenburg et al., 1992.

head, neck, and upper extremities preceding those involving the legs and lower extremities. At the same time, development is *proximodistal* (center outward), with activities involving the trunk and shoulders appearing before those involving the hands and fingers. The kicking movements displayed by infants during the first few months present a problem for the cephalocaudal perspective and are usually dismissed as unintentional movements generated by the central nervous system (Lamb & Yang, 2000). However, Galloway and Thelen (2004) present evidence that contradicts the "cephalocaudal rule." First they point to evidence demonstrating that infants alter the pattern of their leg movements when rewarded. For example, infants change from alternating leg kicks to simultaneous kicks (Thelen, 1994), as well as from flexed leg movements to extended leg movements (Angulo-Kinzler, 2001; Angulo-Kinzler, Ulrich, & Thelen, 2002). They note that even Piaget (1952) noticed that his son repeated leg kicks that shook a toy. Finally, Galloway and Thelen (2004) presented six infants with toys at both foot and hand level. The infants first made contact with the toy at around 12 weeks and did so by lifting a leg to touch the toy. First contact with hands was made at around 16 weeks, much later than the intentional foot contact. Extended contact with their feet also preceded extended contact with their hands. Galloway and Thelen suggest that the structure of the hip joint may contribute to infants' early ability to control their legs because the hip joint is more stable and constrained than the shoulder joint. Therefore, the amount of motion to be controlled is much smaller for the hip joint than for the shoulder joint. Control of the shoulder joint may call for much more experience, practice, and activity to master. Infants thus are able to coordinate hip movement earlier than shoulder movement, contradicting the cephalocaudal rule of thumb.

How do we explain the sequencing and timing of early motor development? Let's briefly consider three possibilities: the *maturational viewpoint,* the *experiential* (or practice) *hypothesis,* and a newer *dynamical systems theory* that views motor development (and the whole of development) as a product of a complex transaction among the child's physical capabilities, goals, and the experiences he has had (Kenrick, 2001; Thelen, 1995).

The Maturational Viewpoint

The maturational viewpoint (Shirley, 1933) describes motor development as the unfolding of a genetically programmed sequence of events in which the nerves and muscles mature in a *downward* and *outward* direction. As a result, children gradually gain more control over the lower and peripheral parts of their bodies, displaying motor skills in the sequence shown in Table 5.1.

One clue that maturation plays a prominent role in motor development comes from cross-cultural research. Despite their very different early experiences, infants from around the world progress through roughly the same sequence of motor milestones. In addition, early studies in which one identical twin was allowed to practice motor skills (such as climbing stairs or stacking blocks) while the co-twin was denied these experiences suggested that practice had little effect on motor development: when finally allowed to perform, the unpracticed twin soon matched the skills of the co-twin who had had many opportunities to practice (Gesell & Thompson, 1929; McGraw, 1935). Taken together, these findings seemed to imply that maturation underlies motor development and that practice merely allows a child to perfect those skills that maturation has made possible.

The Experiential (or Practice) Hypothesis

Although no one denies that maturation contributes to motor development, proponents of the experiential viewpoint believe that opportunities to practice motor skills are also important. Consider what Wayne Dennis (1960) found when he studied two groups of institutionalized orphans in Iran who had spent most of their first


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Toddler aptly describes 1–2 year olds who often lose their balance when trying to walk.

2 years lying flat on their backs in their cribs. These infants were never placed in a sitting position, were rarely played with, and were even fed in their cribs with their bottles propped on pillows. Was their motor development affected by these depriving early experiences? Indeed it was! None of the 1- to 2-year-olds could walk, and less than half of them could even sit unaided. In fact, only 15 percent of the 3- to 4-year-olds could walk well alone! So Dennis concluded that maturation is *necessary but not sufficient* for the development of motor skills. In other words, infants who are physically capable of sitting, crawling, or walking will not be very proficient at these activities unless they have opportunities to practice them.

Not only does a lack of practice inhibit motor development but cross-cultural research illustrates that a variety of enriching experiences can even accelerate the process. Cross-cultural studies tell us that the ages at which infants attain major motor milestones are heavily influenced by parenting practices. The Kipsigis of Kenya, for example, work to promote motor skills. By their 8th week, infants are already practicing their "walking" as parents grasp them by the armpits and propel them forward. Also, throughout their first few months, infants are seated in shallow holes, dug so that the sides support their backs and maintain an upright posture. Given these experiences, it is perhaps not surprising that Kipsigi infants sit unassisted about 5 weeks earlier and walk unaided about a month earlier than Western infants do.

Similarly, Brian Hopkins (1991) has compared the motor development of white infants in England with that of black infants whose families emigrated to England from Jamaica. As in several other comparisons between black and white infants, the black infants displayed such important motor skills as sitting, crawling, and walking at earlier ages. Do these findings reflect genetic differences between blacks and whites? Probably not, because black babies were likely to acquire motor skills early *only* if their mothers had followed traditional Jamaican routines for handling infants and nurturing motor development. These routines include massaging infants, stretching their limbs, and holding them by the arms while gently shaking them up and down. Jamaican mothers expect early motor development, work to promote it, and get it.

Dovetailing nicely with the cross-cultural work are experiments conducted by Philip Zelazo and his associates (1972, 1993) with North American infants. Zelazo found that 2- to 8-week-old babies who were regularly held in an upright posture and encouraged to practice their stepping reflex showed a strengthening of this response (which usually disappears early in life). They also walked at an earlier age than did infants in a control group who did not receive this training.

Why might having one's limbs stretched or being held (or sat) in an upright posture hasten motor development? Esther Thelen's (1986; Thelen & Fisher, 1982) view is that babies who are often placed in an upright position develop strength in the neck, trunk, and legs (an acceleration of muscular growth), which, in turn, promotes the early development of such motor skills as standing and walking. So it seems that both maturation and experience are important contributors to motor development. Maturation does place some limits on the age at which the child will first be capable of

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According to dynamical systems theory, new motor skills emerge as curious infants reorganize their existing capabilities in order to achieve important objectives.

dynamical systems theory
a theory that views motor skills as active reorganizations of previously mastered capabilities that are undertaken to find more effective ways of exploring the environment or satisfying other objectives.

sitting, standing, and walking. Yet experiences such as upright posturing and various forms of practice may influence the age at which important maturational capabilities are achieved and translated into action.

Motor Skills as Dynamic, Goal-Directed Systems

Although they would certainly agree that both maturation and experience contribute to motor development, proponents of an exciting new perspective—**dynamical systems theory**—differ from earlier theorists. They do not view motor skills as genetically programmed responses that simply "unfold" as dictated by maturation and opportunities to practice. Instead, they view each new skill as a *construction* that emerges as infants *actively* reorganize existing motor capabilities into new and more complex action systems. At first, these new motor configurations are likely to be tentative, inefficient, and uncoordinated. New walkers, for example, spend a fair amount of time on their backsides and are not called "toddlers" for nothing. But over a period of time, these new motor patterns are modified and refined until all components mesh and become smooth, coordinated actions such as bouncing, crawling, walking, running, and jumping (Thelen, 1995; Whitall & Getchell, 1995).

But why would infants work so hard to acquire new motor skills? Unlike earlier theories that did not address this issue, the dynamical systems theory offers a straightforward answer: Infants hope to acquire and perfect new motor skills that will help them to get to interesting objects they hope to explore or to accomplish other goals they may have in mind (Thelen, 1995). Consider what Eugene Goldfield (1989) learned in studying infants' emerging ability to crawl. Goldfield found that 7- to 8-month-old infants began to crawl on their hands and knees only after they (1) regularly turned and raised their heads toward interesting sights and sounds in the environment, (2) had developed a distinct hand/arm preference when reaching for such stimuli, and (3) had begun to thrust (kick) with the leg opposite to the outstretched arm. Apparently, visual orientation motivates the infant to approach interesting stimuli she can't reach, reaching steers the body in the right direction, and kicking with the opposite leg propels the body forward. So, far from being a preprogrammed skill that simply unfolds according to a maturational plan, crawling (and virtually all other motor skills) actually represents an active and intricate *reorganization* of *several existing capabilities* that is undertaken by a curious, active infant who has a particular *goal* in mind.

Why, then, do all infants proceed through the same general sequence of locomotor milestones? Partly because of their human maturational programming, which sets the stage for various accomplishments, and partly because each successive motor skill must necessarily build on specific component activities that have developed earlier. How does experience fit in? According to the dynamical systems theory, a real world of interesting objects and events provides infants with many reasons to want to reach out or to sit up, crawl, walk, and run—that is, with *purposes* and *motives* that might be served by actively reorganizing their existing skills into new and more complex action systems (Adolph, Vereijken, & Denny, 1998). Of course, no two infants have exactly the same set of experiences (or goals), which may help explain why each infant coordinates the component activities of an emerging motor skill in a slightly different way (Thelen et al., 1993).

In sum, the development of motor skills is far more interesting and complex than earlier theories had assumed. Though maturation plays a very important role, the basic motor skills of the first 2 years do not simply unfold as part of nature's grand plan. Rather, they emerge largely because goal-driven infants are constantly recombining actions they can perform into new and more complex action systems that will help them achieve their objectives.

Fine Motor Development

Two other aspects of motor development play especially important roles in helping infants to explore and adapt to their surroundings: *voluntary reaching* and *manipulatory* (or hand) *skills*.

Development of Voluntary Reaching

An infant's ability to reach out and manipulate objects changes dramatically over the 1st year. Recall that newborns come equipped with a grasping reflex. They are also inclined to reach for things, although these primitive thrusts (or *prereaches*) are little more than uncoordinated swipes at objects in the visual field. Prereaching is truly a hit-or-miss proposition (Bower, 1982). By 2 months of age, infants' reaching and grasping skills may even seem to deteriorate: the reflexive palmar grasp disappears and prereaching occurs much less often (Bower, 1982). However, these apparent regressions set the stage for the appearance of *voluntary* reaching. Babies 3 months of age and older display this new competency as they extend their arms and make in-flight corrections, gradually improving in accuracy until they can reliably grasp their objectives (Hofsten, 1984; Thelen et al., 1993). However, infants clearly differ in how they reach for objects. Some infants will flap their arms at first and must learn to dampen their enthusiasm, whereas others start off reaching tentatively and will soon learn that they must supply more power to grasp their objectives (Thelen et al., 1993). So, here again, we see that reaching is a motor skill that does not simply "unfold"; instead, babies reach in different ways and take their own unique pathways to refining this important skill.

Development of Manipulatory Skills

Once an infant is able to sit well and to reach inward, across his body, at about 4 to 5 months, he begins to grasp interesting objects with *both* hands and his exploratory activities forever change. Rather than merely batting or palming objects, he is now apt to transfer them from hand to hand or to hold them with one hand and finger them with the other (Rochat, 1989; Rochat & Goubet, 1995). Indeed, this fingering activity may be the primary method by which 4- to 6-month-olds gain information about objects, for their unimanual (one-handed) grasping skills are poorly developed: the reflexive palmar grasp has already disappeared by this age, and the **ulnar grasp** that replaces it is itself a rather clumsy, clawlike grip that permits little tactile exploration of objects by touch.

ulnar grasp
an early manipulatory skill in which an infant grasps objects by pressing the fingers against the palm.

During the latter half of the 1st year, fingering skills improve and infants become much more proficient at tailoring all their exploratory activities to the properties of the objects they are investigating (Palmer, 1989). Now, wheeled toys are likely to be scooted rather than banged, spongy objects are squeezed rather than scooted, and so on. The next major step in the growth of hand skills occurs near the end of the 1st year as infants use their thumbs and forefingers to lift and explore objects (Halverson, 1931). This **pincer grasp** transforms the child from a little fumbler into a skillful manipulator who may soon begin to capture crawling bugs and to turn knobs and dials, thereby discovering that he or she can use his newly acquired hand skills to produce any number of interesting results.

pincer grasp
a grasp in which the thumb is used in opposition to the fingers, enabling an infant to become more dexterous at lifting and fondling objects.

Bruce Plotkin / The Image Works

The pincer grasp is a crucial motor milestone that underlies the development of many coordinated manual activities.

Throughout the 2nd year, infants become much more proficient with their hands. At 16 months of age, they can scribble with a crayon; and by the end of the 2nd year, they can copy a simple horizontal or vertical line and even build towers of five or more blocks. What is happening is quite consistent with the dynamical systems theory: infants are gaining control over simple movements and then integrating these skills into increasingly complex, coordinated systems (Fentress & McLeod, 1986). Despite this ability, even 2- to 3-year-olds are not very good at catching and throwing a ball, cutting food with utensils, or drawing within the lines of their coloring books. These skills will emerge later in childhood as the muscles mature and children become more proficient at using visual information to help them coordinate their actions.

Psychological Implications of Early Motor Development

Life changes dramatically for both parents and infants once a baby is able to reach out and grasp interesting objects, especially after he or she can crawl or walk to explore these treasures. Suddenly, parents find they have to child-proof their homes, limit access to certain areas, or else run the risk of experiencing a seemingly endless string of disasters including torn books, overturned vases, unraveled rolls of toilet paper, and irritated pets whose tails the little explorer has pulled. Placing limits on explorations often precipitates conflicts and a "testing of the wills" between infants and their parents (Biringen et al., 1995). Nevertheless, parents are often thrilled by their infant's emerging motor skills, which not only provide clear evidence that development is proceeding normally, but also permit such pleasurable forms of social interaction as pat-a-cake, chase, and hide-and-seek.

As infants swing back and forth they experience changes in optical flow, leading to a better understanding of distance relationships.

Aside from the entertainment value it provides, an infant's increasing control over bodily movements has other important cognitive and social consequences. Mobile infants may feel much bolder, for example, about meeting people and seeking challenges if they know that they can retreat to their caregivers for comfort should they feel insecure (Ainsworth, 1979). Achieving various motor milestones may also foster perceptual development. For example, crawlers (as well as noncrawlers who are made mobile with the aid of special walkers) are better able to search for and find hidden objects than infants of the same age who are not mobile (Kermoian & Campos, 1988). The self-produced movement of crawling and walking also makes infants more aware of *optic flow,* the perceived movement of objects in the visual field as well as the perceived movements of the foreground and background in which the objects are imbedded. The relative movements of the observer or the objects being observed influence such perceptions. For example, an infant who is seated in a mechanical swing may watch the family dog grow larger and then smaller in a rhythmic manner. However, if the swing winds down and the infant is stationary, the synchronized optic flow of the dog ceases. Now that the swing has stopped its anxiety-producing movement, the dog may wish to investigate the infant. As the dog approaches the stationary infant and swing, the dog appears to grow bigger. The pattern of optic flow generated by the dog moving toward the infant is quite different from the pattern generated by the motion of the infant seated in the activated mechanical swing. The infant will experience yet a third pattern of optical flow if, while the parents are preoccupied, big brother releases her from the swing and allows her to approach the dog unsupervised. The dog expands to fill the field completely—unless the dog's previous experience with big brother's infancy was traumatic. Then the crawling infant will perceive the dog as constant in size, as the background and foreground change (the dog maintains a safe distance, as it leads the infant all over the house).

So, optic flow and an infant's gradual understanding of it help the child to orient himself in space, improve his posture, and cause him to crawl or walk more efficiently (Higgins, Campos, & Kermoian, 1996). Also, crawling and walking both contribute to an understanding of distance relationships and a healthy fear of heights (Adolph, Eppler, & Gibson, 1993; Campos, Bertenthal, & Kermoian, 1992). Experienced crawlers and experienced walkers are better able to use landmarks to find their way than infants who have just begun to crawl or to walk—that is, locomotion influences spatial memory (Clearfield, 2004). So, once again, we see that human development is a holistic enterprise: changes in motor skills have clear implications for other aspects of development.

Beyond Infancy: Motor Development in Childhood and Adolescence

The term *toddler* aptly describes most 1- to 2-year-olds, who often fall down or trip over stationary objects when they try to get somewhere in a hurry. But as children mature, their locomotor skills increase by leaps and bounds. By age 3, children can walk or run in a straight line and leap off the floor with both feet, although they can only clear very small (8- to 10-inch) objects in a single bound and cannot easily turn or stop quickly while running. Four-year-olds can skip, hop on one foot, catch a large ball with both hands, and run much farther and faster than they could 1 year earlier (Corbin, 1973). By age 5, children are becoming rather graceful: like adults, they pump their arms when they run and their balance has improved to the point that some of them can learn to ride a bicycle. Despite (or perhaps because of) the rapid progress they are making, young children often overestimate the physical feats they can perform, and the bolder or less inhibited ones are likely to be somewhat accident prone, ending up with bruises, burns, cuts, scrapes, and an assortment of other injuries (Schwebel & Plumert, 1999).

With each passing year, school-age children can run a little faster, jump a little higher, and throw a ball a little farther (Herkowitz, 1978; Keough & Sugden, 1985). The reasons that children are improving at these large-muscle activities is that they are growing larger and stronger, and are also fine-tuning their motor skills. Young children throw only with the arm, whereas adolescents are usually able to coordinate shoulder, arm, and leg movements to put the force of their bodies behind their throws. So, older children and adolescents can throw farther than younger children can, not solely because they are bigger and stronger, but because they also use more refined and efficient techniques of movement (Gallahue, 1989).

At the same time, eye–hand coordination and control of the small muscles are improving rapidly, so children can make more sophisticated use of their hands. Three-year-olds find it difficult to button their shirts, tie their shoes, or copy simple designs. By age 5, children can accomplish all of these feats and can even cut a straight line with scissors or copy letters and numbers with a crayon. By age 8 or 9, they can use household tools such as screwdrivers and have become skilled performers at games such as jacks and Nintendo that require hand–eye coordination. Finally, older children display quicker reaction times than younger children (Williams et al., 1999), which helps explain why they usually beat younger playmates at "action" games such as dodgeball or Ping-Pong.

Boys and girls are nearly equal in physical abilities until puberty, when boys continue to improve on tests of large-muscle activities, whereas girls' skills level off or decline (Thomas & French, 1985). These sex differences are, in part, attributable to biology: adolescent boys have more muscle and less fat than adolescent girls and might be expected to outperform them on tests of physical strength (Tanner, 1990). Yet biological developments do not account for all the difference in large-muscle performance between boys and girls (Smoll & Schutz, 1990), nor do they adequately explain the declining performance of many girls, who continue to grow taller and heavier between ages 12 and 17. The apparent physical decline of adolescent girls may be a product of gender-role socialization: with their widening hips and developing breasts, girls are often encouraged to become less tomboyish and more interested in traditionally feminine (and less athletic) activities (Blakemore, Berenbaum, & Liben, 2008; Herkowitz, 1978).

There is clearly an element of truth to this notion in that female athletes show no apparent decline in large-muscle performance over time. Furthermore, as gender roles have changed in the past few decades, female athletes have been steadily improving their performances, and the male/female gap in physical performance has narrowed dramatically (Dyer, 1977; Whipp & Ward, 1992). So it seems that adolescent girls would almost certainly continue to improve on tests of large-muscle activity should

physically active play
moderate to vigorous play activities such as running, jumping, climbing, play fighting, or game playing that raise a child's metabolic rate far above resting levels.

FOCUS ON RESEARCH Sports Participation and Self-Esteem Among Adolescent Females


Smiley N. Pool/Dallas Morning News/Corbis

Recently, developmentalists have begun to consider the benefits of **physically active play,** speculating that it serves as a mechanism for building muscle strength and endurance and possibly for reducing levels of fat in children's growing bodies (Pellegrini & Smith, 1998). Physically active play typically peaks in early to middle childhood and declines thereafter. This reduction in vigorous physical activity is much more apparent for girls than for boys, which undoubtedly helps explain the decline in large-muscle strength often seen among girls during the adolescent years.

Interestingly, over the past 40 years, our society has become much more supportive of one kind of physical activity for girls—participation in competitive and noncompetitive sports. Title IX, a federal law passed in 1972 that bans discrimination on the basis of gender in federally funded institutions, has resulted in dramatic increases in funding for female athletic programs at the college level. High school programs for female athletes have expanded greatly over the same period, and even private corporations such as Nike have entered the playing field with an ad campaign featuring young girls pleading, "If you let me play sports . . . ," and then citing various health and social benefits that can result from sports participation. One of the benefits to which the ads allude is an enhanced sense of self-worth (or self-esteem) among female athletes.

Is there any basis for the latter claim? To find out, Erin Richman and David Shaffer (2000) constructed an elaborate questionnaire to measure both the depth and breadth of female freshman college students' participation in formal and informal sporting activities during their high school years. These researchers also asked their participants to complete instruments designed to assess their current (1) levels of self-esteem, (2) feelings of physical competence, (3) body images, and (4) possession of such desirable "masculine" attributes as assertiveness and a healthy sense of competition.

The results provided some support for the claims made in the Nike ad campaign. First, there was a clear relation between girls' participation in sports during high school and their later self-esteem: girls who had earlier participated to a greater extent in sports enjoyed higher levels of general self-worth as college students. Further analysis revealed that the apparently beneficial effect of earlier sporting activities on girls' college self-esteem reflected the findings that (1) sports participation was associated with increases in perceived physical competencies, development of a more favorable body image, and acquisition of desirable masculine attributes (such as assertiveness); and (2) all these developments, in turn, were positively correlated with (and apparently fostered) participants' college self-esteem.

In sum, it appears that girls' participation in sporting activities during the adolescent years may well contribute to an enhanced sense of self-worth—but this was true only to the extent that sporting activities fostered physical competencies, more favorable body images, and such desirable personal attributes as assertiveness (see also Ackerman, 2002; Lehman & Joerner, 2005; Malcom, 2003; Shakib, 2003). These findings imply that gym classes and formal team sports might be more beneficial to a larger number of girls if educators and coaches were to emphasize and devise ways to measure and illustrate the physical gains and psychological benefits of formal and informal sporting activities, while concentrating less on the outcomes of competitive sports and/or the physical deficiencies of the less athletically competent girls under their tutelage.

they choose to remain physically active. And as we see in the Focus on Research feature, they may experience important psychological benefits as well by remaining physically active throughout the teenage years.

Puberty: The Physical Transition from Child to Adult

adolescent growth spurt
the rapid increase in physical growth that marks the beginning of adolescence.

puberty
the point at which a person reaches sexual maturity and is physically capable of fathering or conceiving a child.

The onset of adolescence is heralded by two significant changes in physical development. First, children change dramatically in size and shape as they enter the **adolescent growth spurt** (Pinyerd & Zipf, 2005). Second, they also reach **puberty** (from the Latin word *pubertas,* meaning "to grow hairy"), the point in life when an individual reaches sexual maturity (Mustanski et al., 2004) and becomes capable of producing a child (Pinyerd & Zipf, 2005).

The Adolescent Growth Spurt

The term *growth spurt* describes the rapid acceleration in height and weight that marks the beginning of adolescence (a growth rate that is faster than any growth rate since the children were infants) (Pinyerd & Zipf, 2005). Girls typically enter the growth spurt by age 10.5, reach a peak growth rate by age 12 (about 1.3 years before menarche), and return to a slower rate of growth by age 13 to 13.5 (Pinyerd & Zipf, 2005; Tanner, 1990). Most girls gain only about 2.5 centimeters in height after menarche (Grumbach & Styne, 2003). Boys lag behind girls by 2 to 3 years: they typically begin their growth spurt by age 13, peak at age 14 (midpuberty), and return to a more gradual rate of growth by age 16. Because girls mature much earlier than boys, it is not at all uncommon for females to be the tallest two or three students in a middle school classroom. By the end of the growth spurt, boys have increased 28 to 31 centimeters in height and girls 27.5 to 29 centimeters (Abbassi, 1998).

In addition to growing taller and heavier, the body assumes an adultlike appearance during the adolescent growth spurt. Perhaps the most noticeable changes are the appearance of breasts and a widening of the hips for girls, and a broadening of the shoulders for boys. Facial features also assume adult proportions as the forehead protrudes, the nose and jaw become more prominent, and the lips enlarge.

Sexual Maturation

Maturation of the reproductive system occurs at roughly the same time as the adolescent growth spurt and follows a predictable sequence for girls and boys.

Sexual Development in Girls

For most girls, sexual maturation begins at about age 9 to 11 as fatty tissue accumulates around their nipples, forming small "breast buds" (Herman-Giddens et al., 1997; Pinyerd & Zipf, 2005). Full breast development, which takes about 3 to 4 years, finishes around age 14 (Pinyerd & Zipf, 2005). Usually pubic hair begins to appear a little later, although as many as one-third of all girls develop some pubic hair before their breasts begin to develop (Tanner, 1990).

As a girl enters her growth spurt, the breasts grow rapidly and the sex organs begin to mature. Internally, the vagina becomes larger, and the walls of the uterus develop a powerful set of muscles that may one day be used to accommodate a fetus during pregnancy and to push it through the cervix and vagina during the birth process. Externally, the mons pubis (the soft tissue covering the pubic bone), the labia (the fleshy lips surrounding the vaginal opening), and the clitoris all increase in size and become more sensitive to touch (Tanner, 1990).

menarche
the first occurrence of menstruation.

At about age 12, the average girl in Western societies reaches **menarche**—the time of her first menstruation (Pinyerd & Zipf, 2005). Though it is generally assumed that a girl becomes fertile at menarche, young girls often menstruate without ovulating and *may* remain unable to reproduce for 12 to 18 months after menarche (Pinyerd & Zipf, 2005; Tanner, 1978). Anovulatory menstrual cycles (menstruation without ovulation) are often associated with irregular and painful periods. After 1 to 2 years, cycles become ovulatory, more regular, and less painful (Pinyerd & Zipf, 2005). In the year following menarche, female sexual development concludes as the breasts complete their development and axillary (underarm) hair appears (Pinyerd & Zipf, 2005). Hair also appears on the arms, legs, and, to a lesser degree, on the face (Pinyerd & Zipf, 2005).

Sexual Development in Boys

For boys, sexual maturation begins at about 10 to 13 (9.5 to 13.5) with an enlargement of the testes (Pinyerd & Zipf, 2005). The growth of the testes is often accompanied or soon followed by the appearance of unpigmented pubic hair (Pinyerd & Zipf, 2005). As the testes grow, the scrotum also grows; it thins and darkens, and descends to its pendulous adult position (Pinyerd & Zipf, 2005). Meanwhile, the penis lengthens and widens. At about age 13 to 14.5, sperm production begins (Pinyerd & Zipf, 2005). By the time the penis is fully developed at age 14.5 to 15, most boys will have reached puberty and are now capable of fathering a child (Tanner, 1990).

Somewhat later, boys begin to sprout facial hair, first at the corners of the upper lip, then on the sides of the face, and finally on the chin and jawline (Mustanski et al., 2004; Pinyerd & Zipf, 2005). Body hair also grows on the arms and legs, although signs of a hairy chest may not appear until the late teens or early 20s, if at all. Another hallmark of male sexual maturity is a lowering of the voice as the larynx grows and the vocal cords lengthen. In fact, many men may laugh (years later) about hearing their voices "cracking" up and down between a squeaky soprano and a deep baritone, sometimes within a single sentence.

Individual Differences in Physical and Sexual Maturation

So far, we have been describing developmental norms, or the average ages when adolescent changes take place. There are many individual differences in the timing of physical and sexual maturation. An early-maturing girl who develops breast buds at age 8, starts her growth spurt at age 9.5, and reaches menarche at age 10.5 may nearly complete her growth and pubertal development before the late-developing girls in her class have even begun. Individual differences among boys are at least as great: some boys reach sexual maturity by age 12.5 and are as tall as they will ever be by age 13, whereas others begin growing later and do not reach puberty until their late teens. This perfectly normal biological variation may be observed in any middle school classroom, where one will find a wide assortment of bodies, ranging from those that are very childlike to those that are quite adultlike.

George Doyle & Ciaran Griffin/Photos.com

In early adolescence, girls are maturing more rapidly than boys.

Secular Trends—Are We Maturing Earlier?

About 25 years ago, women in one family were surprised when a sixth-grader began to menstruate shortly after her 12th birthday. The inevitable comparisons soon began, as the girl learned that neither of her great-grandmothers had reached this milestone until age 15 and that her grandmother had been nearly 14 and her mother 13. At this point, the girl casually replied, "Big deal! Lots of girls in my class have got their periods."

As it turns out, this young woman was simply telling it like it is. In 1900, when her great-grandmother was born, the average age of first menstruation was 14 to 15. By 1950, most girls were reaching menarche between 13½ and 14, and recent norms have dropped even further, to age 12.5 (Tanner, 1990). Today, the definition of "early"

secular trend
a trend in industrialized societies toward earlier maturation and greater body size now than in the past.

puberty remains puberty begun before 8 years of age for girls and 9 years of age for boys (Saenger, 2003). This **secular trend** toward earlier maturation started more than 100 years ago in the industrialized nations of the world, where it has now leveled off, and it has begun happening in the more prosperous nonindustrialized countries as well (Coleman & Coleman, 2002). In addition, people in industrialized nations have been growing taller and heavier over the past century. What explains these secular trends? Better nutrition and advances in medical care seem to be most responsible (Tanner, 1990). Today's children are more likely than their parents or grandparents to reach their genetic potentials for maturation and growth because they are better fed and less likely to experience growth-retarding illnesses. Even within our own relatively affluent society, poorly nourished adolescents mature later than well-nourished ones. Girls who

CONCEPT CHECK 5.2 Motor Development and Puberty

Check your understanding of motor development and developmental changes associated with puberty by answering the following questions. Answers to objective questions appear in the Appendix.

True or False: Indicate whether each of the following statements is true or false.

1. (T)(F) Infants who proceed through stages of motor development more quickly than the average are likely to be more intelligent later in childhood than infants who are average or behind average.
2. (T)(F) Infants who are mobile (can crawl or walk easily) are less fearful about meeting strangers because they know they can easily escape to their caregivers if they should begin to feel insecure in the new situation.
3. (T)(F) Generally, girls reach sexual maturity earlier than boys.
4. (T)(F) Girls become capable of having children as soon as they have their first menstruation.
5. (T)(F) The *secular trend* refers to the fact that children today are reaching sexual maturity at later ages than their grandparents and great-grandparents.

Multiple Choice: Select the best alternative for each question.

______ 6. Zach has a young son, about 6 months old. Zach believes that helping his son practice motor skills will help his son achieve motor skills alone earlier than if he did not help his son practice. Consequently, when Zach plays with his son he helps his son practice sitting and walking and encourages his son's efforts. Zach's viewpoints about motor development are most closely aligned with which scientific view of motor development?
  a. The maturational viewpoint
  b. The experiential viewpoint
  c. The developmental sequence viewpoint
  d. The dynamical systems viewpoint

______ 7. In a study of orphaned children who were confined to their cribs during their first 2 years of life, Dennis found that
  a. maturation determined the age at which young toddlers could sit, crawl, and walk, regardless of their experiences.
  b. experience determined the age at which young toddlers could sit, crawl, and walk, regardless of their maturational age.
  c. maturation was necessary but not sufficient for the development of such motor skills as sitting, walking, and crawling.
  d. experience was the determining factor, regardless of age, of when young toddlers could sit, crawl, and walk.

______ 8. Boys and girls are nearly equal in physical abilities until puberty, when
  a. girls continue to improve on tests of large-muscle activities, whereas boys' skills level off or decline.
  b. boys continue to improve on tests of large-muscle activities, whereas girls' skills level off or decline.
  c. boys and girls continue to improve on tests of large-muscle activities.
  d. boys' and girls' skills level off or decline.

______ 9. Which of the following is *not* one of the changes associated with the adolescent growth spurt?
  a. Girls and boys grow taller and heavier.
  b. Girls and boys assume adult facial features as their foreheads protrude, and their noses and jaws become more prominent.
  c. Girls and boys experience a widening of their hips.
  d. Girls develop breasts and boys experience a broadening of their shoulders.

Short Answer: Briefly answer the following question.

10. Explain the ways in which participation in sports may improve the self-esteem of young girls.

are tall and overweight as children tend to mature early (Graber et al., 1994), whereas many dancers, gymnasts, and other girls who engage regularly in strenuous physical activity may begin menstruating very late or stop menstruating after they have begun (Hopwood et al., 1990). Here, then, are strong clues that nature and nurture interact to influence the timing of pubertal events.

Causes and Correlates of Physical Development

Although we have now charted the course of physical development from birth through adolescence, we've touched only briefly on the factors that influence growth. What *really* causes children to grow in the first place? And why do their bodies change so dramatically at adolescence, when growth accelerates? As we will see in the pages that follow, physical development results from a complex and continuous interplay between the forces of nature and nurture.

Biological Mechanisms

Clearly, biological factors play a major role in the growth process. Although children do not all grow at the same rate, we have seen that the *sequencing* of both physical maturation and motor development is reasonably consistent from child to child. Apparently, these regular maturational sequences that all humans share are species-specific attributes—products of our common genetic heritage.

Effects of Individual Genotypes

Aside from our common genetic ties to the human race, we have each inherited a unique combination of genes that influence our physical growth and development. For example, family studies clearly indicate that height is a heritable attribute: identical twins are much more similar in height than fraternal twins, whether the measurements are taken during the 1st year of life, at 4 years of age, or in early adulthood (Tanner, 1990). Rate of maturation is also genetically influenced (Kaprio et al., 1995; Mustanski et al., 2004). Similar genetic influences hold for milestones in skeletal growth and even for the appearance of teeth in infants.

How does genotype influence growth? We are not completely certain, although it appears that our genes regulate the production of hormones, which have major effects on physical growth and development.

Hormonal Influences: The Endocrinology of Growth

Hormones begin to influence development long before a child is born. As we learned in Chapter 3, a male fetus assumes a malelike appearance because (1) a gene on his Y chromosome triggers the development of testes, which (2) secrete a male hormone (testosterone) that is necessary for the development of a male reproductive system.

The most critical of the *endocrine* (hormone-secreting) glands is the **pituitary,** a "master gland" located at the base of the brain that triggers the release of hormones from all other endocrine glands. In addition to regulating the endocrine system, the pituitary produces a **growth hormone (GH)** that stimulates the rapid growth and development of body cells. Growth hormone is released in small amounts several times a day. And GH is essential for normal growth and development as well. What, then, triggers the adolescent growth spurt and other pubertal changes?

Research (reviewed in Tanner, 1990) has clarified the endocrinology of adolescence far beyond what we knew only 20 to 25 years ago. Long before any noticeable physical changes occur, pituitary secretions stimulate a girl's ovaries to produce more

pituitary
a "master gland" located at the base of the brain that regulates the endocrine glands and produces growth hormone.

growth hormone (GH)
the pituitary hormone that stimulates the rapid growth and development of body cells; primarily responsible for the adolescent growth spurt.

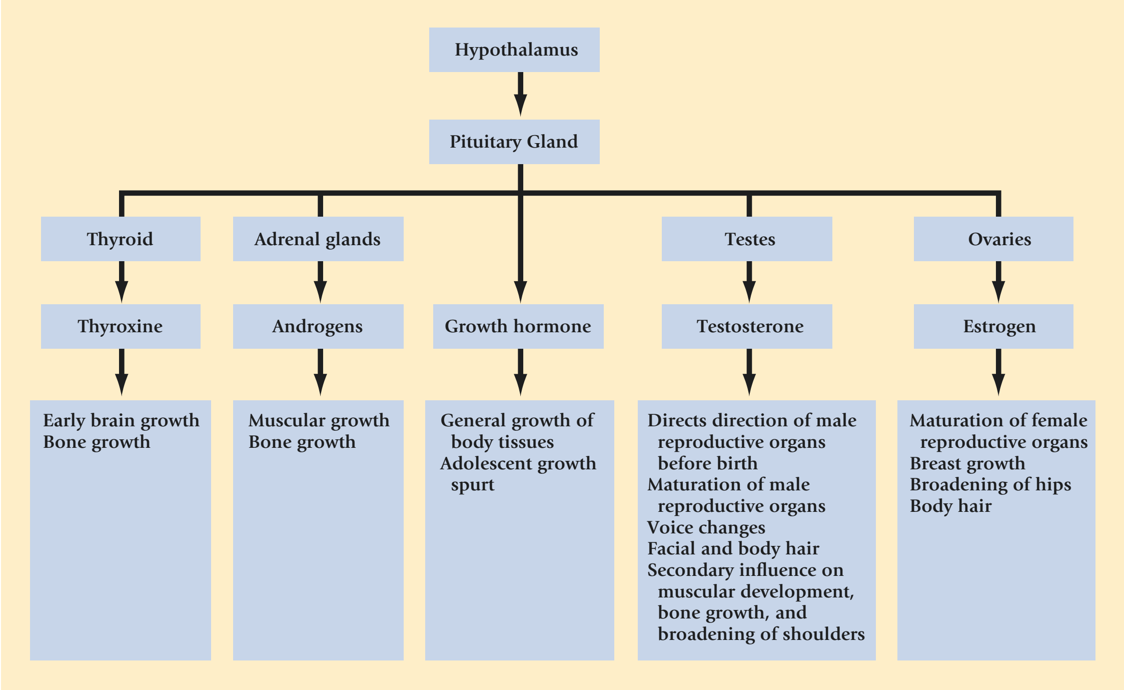

Figure 5.7 Hormonal influences on physical development.

estrogen
female sex hormone, produced by the ovaries, that is responsible for female sexual maturation.

testosterone
male sex hormone, produced by the testes, that is responsible for male sexual maturation.

estrogen and a boy's testes to produce more **testosterone.** Once these sex hormones reach a critical level, the hypothalamus (a part of the brain) instructs the pituitary to secrete more GH. This increase in GH seems to be wholly responsible for the adolescent growth spurt in girls and is primarily responsible for boys' growth spurt. As for sexual maturation, the female hormone estrogen triggers the growth of a girl's breasts, uterus, vagina, pubic and underarm hair, and the widening of her hips. In boys, testosterone is responsible for growth of the penis and prostate, voice changes, and the development of facial and body hair. And although GH may be the primary contributor to the male growth spurt, testosterone exerts its own independent effects on the growth of a boy's muscles, the broadening of his shoulders, and the extension of his backbone. So it seems that adolescent boys experience larger growth spurts than adolescent girls simply because testosterone promotes muscular and bone growth in ways that estrogen does not. Finally, androgen secreted by *adrenal glands* plays a secondary role in promoting the maturation of muscles and bones in both sexes (Tanner, 1990).

What causes the pituitary to activate the endocrine glands and precipitate the dramatic physical changes of adolescence? No one can say for sure. So, we have learned a great deal about *how* hormones affect human growth and development (see Figure 5.7 for a brief review). However, the events responsible for the timing and regulation of these hormonal influences remain unclear.

Environmental Influences

Three kinds of environmental influence can have a major effect on physical growth and development: nutrition, illnesses, and the quality of care that children receive.

Nutrition

Diet is perhaps the most important environmental influence on human growth and development. As you might expect, children who are inadequately nourished grow very slowly, if at all.

Problems of Undernutrition. If undernutrition is neither prolonged nor especially severe, children usually recover from any growth deficits by growing much faster than normal once their diet becomes adequate. James Tanner (1990) views this **catch-up growth** as a basic principle of physical development. Presumably, children who have experienced short-term growth deficits because of malnutrition grow very rapidly in order to regain (or catch up to) their genetically programmed growth trajectory.

catch-up growth
a period of accelerated growth in which children who have experienced growth deficits grow very rapidly to "catch up to" the growth trajectory that they are genetically programmed to follow.

However, prolonged undernutrition has a more serious impact, especially during the first 5 years of life: brain growth may be seriously retarded and the child may remain relatively small in stature (Barrett & Frank, 1987; Tanner, 1990). These findings make sense when we recall that the first 5 years is a period when the brain normally gains about 65 percent of its eventual adult weight and the body grows to nearly two-thirds of its adult height.

In many of the developing countries of Africa, Asia, and Latin America, as many as 85 percent of all children under age 5 experience some form of undernutrition (Barrett & Frank, 1987). When children are severely undernourished, they are likely to suffer from either of two nutritional diseases—*marasmus* or *kwashiorkor*—each of which has a slightly different cause.

marasmus
a growth-retarding disease affecting infants who receive insufficient protein and too few calories.

Marasmus affects babies who get insufficient protein and too few calories, as can easily occur if a mother is malnourished and does not have the resources to provide her child with a nutritious commercial substitute for mother's milk. A victim of marasmus becomes very frail and wrinkled in appearance as growth stops and the body tissues begin to waste away. Even if these children survive, they remain small in stature and often suffer impaired social and intellectual development (Barrett & Frank, 1987).

kwashiorkor
a growth-retarding disease affecting children who receive enough calories but little if any protein.

Kwashiorkor affects children who get enough calories but little if any protein. As the disease progresses, the child's hair thins, the face, legs, and abdomen swell with water, and severe skin lesions may develop. In many poor countries of the world, one of the few high-quality sources of protein readily available to children is mother's milk. So breast-fed infants do not ordinarily suffer from marasmus unless their mothers are severely malnourished; however, they may develop kwashiorkor when they are weaned from the breast and denied their primary source of protein.

In Western industrialized countries, the preschool children who do experience protein/calorie deficiencies are rarely so malnourished as to develop marasmus or kwashiorkor. However, **vitamin and mineral deficiencies** affect large numbers of children in the United States, particularly African American and Hispanic children from lower socioeconomic backgrounds (Pollitt, 1994). Especially common among infants and toddlers are iron and zinc deficiencies that occur because rapid growth early in life requires more of these minerals than a young child's diet normally provides. Thus, children whose diets are deficient in zinc grow very slowly (Pollitt et al., 1996).

vitamin and mineral deficiency
a form of malnutrition in which the diet provides sufficient protein and calories but is lacking in one or more substances that promote normal growth.

Prolonged iron deficiency causes **iron deficiency anemia,** a condition that not only makes children inattentive and listless, thereby restricting their opportunities for social interaction, but also retards their growth rates and is associated with poor performances on tests of motor skills and intellectual development.

iron deficiency anemia
a listlessness caused by too little iron in the diet that makes children inattentive and may retard physical and intellectual development.

Problems of Overnutrition. Dietary excess (eating too much) is yet another form of poor nutrition that is increasing in Western societies and can have several long-term consequences (Galuska et al., 1996). The most immediate effect of overnutrition is that children may become obese and face added risk of diabetes, high blood pressure, and heart, liver, or kidney disease. **Obese** children may also find it difficult to make friends with age-mates, who are apt to tease them about their size and shape. Indeed, obese children are often among the least popular students in grade-school classrooms (Sigelman, Miller, & Whitworth, 1986; Staffieri, 1967).

obese
a medical term describing individuals who are at least 20 percent above the ideal weight for their height, age, and sex.

Obese grade-school children and adolescents are much more likely than their thinner peers to be obese in later adolescence and adulthood (Cowley, 2001). Heredity definitely contributes to these trends (Stunkard et al., 1990). Yet, a genetic predisposition

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This child's swollen stomach and otherwise emaciated appearance are symptoms of kwashiorkor. Without adequate protein in the diet, children with kwashiorkor are more susceptible to many diseases and may die from illnesses that well-nourished children can easily overcome.

does not guarantee obesity. Highest levels of obesity are found among children who eat a high-fat diet and who do not get sufficient exercise to burn the calories they've consumed (Cowley, 2001; Fischer & Birch, 1995).

Bad eating habits that can lead to obesity are often established early in life (Birch, 1990). Some parents use food to reinforce desirable behaviors (for example, "Clean your room and you can have some ice cream"), or they bribe their children to eat foods they do not want ("No dessert until you eat your peas") (Olvera-Ezzell, Power, & Cousins, 1990; Smith, 1997). Unfortunately, children may attach a special significance to eating that extends far beyond its role in reducing hunger if they are encouraged to view food as a reward. Moreover, use of high-fat desserts or snacks as a reward may convince young children that the healthier foods they are being "bribed" to eat must really be yucky stuff after all (Birch, Marlin, & Rotter, 1984).

In addition to their poor eating habits, obese children are less active than normal-weight peers. Of course, their inactivity may both contribute to obesity (obese children burn fewer calories) and be a consequence of their overweight condition. One strong clue that activity restriction contributes to obesity is that the amount of time children spend in the sedentary activity of watching television is one of the best predictors of future obesity (Cowley, 2001). Television may also promote poor eating habits: not only do children tend to snack while passively watching TV, but the foods they see advertised are mostly high-calorie products containing lots of fat and sugar and few beneficial nutrients (Tinsley, 1992).

Illnesses

Among children who are adequately nourished, common childhood illnesses such as measles, chicken pox, or even pneumonia have little if any effect on physical growth and development. Major illnesses that keep a child in bed for weeks may temporarily retard growth, but after recovering, the child will ordinarily show a growth spurt (catch-up growth) that makes up for the progress lost while he or she was sick (Tanner, 1990).

Yet, diseases are likely to permanently stunt the growth of children who are moderately to severely undernourished. A poor diet weakens the immune system, so that childhood diseases strike an undernourished child sooner and harder (Pollitt et al., 1996). Not only does malnutrition increase one's susceptibility to disease, but diseases contribute to malnutrition by suppressing a child's appetite and limiting the body's ability to absorb and utilize nutrients (Pollitt, 1994). In developing countries where gastrointestinal infections and upper respiratory illnesses are common, young school-age children who have been relatively disease-free are already 1 to 2 inches taller and 3 to 5 pounds heavier on average than their more "sickly" peers (Martorell, 1980; Roland, Cole, & Whitehead, 1977), and are outperforming them on a variety of cognitive tests as well (Pollitt, 1994).

Emotional Stress and Lack of Affection

Finally, otherwise healthy children who experience too much stress and too little affection are likely to lag far behind their age-mates in physical growth and motor development. This *failure-to-thrive* syndrome may characterize as many as 6 percent of preschool children in the United States and up to 5 percent of all patients admitted to pediatric hospitals (Lozoff, 1989).

nonorganic failure to thrive
an infant growth disorder, caused by lack of attention and affection, that causes growth to slow dramatically or stop.

Nonorganic failure to thrive is a growth disorder that appears early, usually by 18 months of age. Babies who display it stop growing and appear to be wasting away, in much the same way that malnourished infants with marasmus do. These infants do not have an obvious illness, and no other biological cause for their condition is apparent.

Affected babies often have trouble feeding and, in many cases, their growth retardation is undoubtedly attributable to poor nutrition (Brockington, 1996; Lozoff, 1989). Of course, a major question is, why would an otherwise healthy baby have trouble feeding?

One clue comes from these babies' behaviors around caregivers. They are generally apathetic and withdrawn, will often watch their caregivers closely, but are unlikely to smile or cuddle when they are picked up. Why? Because their caregivers are typically cool and aloof, impatient with them, and sometimes even physically abusive (Brockington, 1996). So even though caregivers may offer enough food for those babies to thrive, their impatience and hostility causes babies to withdraw and to become aloof to the point of feeding poorly and displaying few, if any, positive social responses.

deprivation dwarfism
a childhood growth disorder that is triggered by emotional deprivation and characterized by decreased production of GH, slow growth, and small stature.

Deprivation dwarfism is a second growth-related disorder that stems from emotional deprivation and a lack of affection. It appears later, usually between 2 and 15 years of age, and is characterized by small stature and dramatically reduced rates of growth, even though children who display this disorder do not look especially malnourished and usually receive adequate nutrition and physical care. What seems to be lacking in their lives is a positive involvement with another person, namely with their primary caregivers, who themselves are likely to be depressed by an unhappy marriage, economic hardships, or some other personal problem (Brockington, 1996; Roithmaier et al., 1988). It appears that deprivation dwarfs grow very slowly because their emotional deprivation depresses the endocrine system and inhibits the production of growth hormone. Indeed, when these children are removed from their homes and begin to receive attention and affection, secretion of GH quickly resumes, and they display catch-up growth, even when they eat the same diet on which they formerly failed to thrive (Brockington, 1996; Gardner, 1972).

The prognoses for children affected by nonorganic failure to thrive and deprivation dwarfism are very good if the caregiving problems responsible for these disorders are corrected by individual or family therapy, or if the affected child is placed with caring foster parents (Brockington, 1996). However, if nonorganic failure to thrive is not identified and corrected in the first 2 years, or if the emotional neglect that underlies deprivation dwarfism persists for several years, affected children may remain smaller than normal and display long-term emotional problems and intellectual deficiencies as well (Drotar, 1992; Lozoff, 1989).

CONCEPT CHECK 5.3 Psychological Impacts of Puberty and Causes of Growth and Development

Check your understanding of the psychological impacts of puberty as well as the causes and correlates of growth and development by answering the following questions. Answers appear in the Appendix.

True or False: Indicate whether the following statement is true or false.

1. (T)(F) "Rites of passage" are rituals observed in many nonindustrialized countries that are used to mark the child's puberty and transition from child to adolescent.

Matching: Match the following nutritional deficits with their definitions.

2. kwashiorkor
3. marasmus
4. iron deficiency anemia
5. overnutrition

a. a wasting away of body tissues caused by insufficient protein and calories
b. a disease marked by a swollen abdomen and severe skin lesions caused by insufficient protein
c. a disease associated with diabetes, high blood pressure, and heart or kidney disease
d. a disease that makes children listless and inattentive, retards their growth, and causes them to score poorly on tests of intelligence

In sum, failure to thrive provides yet another indication that children require love and responsive caregiving if they are to develop normally. Fortunately, there is hope for preventing these deprivation-related disorders if parents whose children are at risk can be identified early, which they often can be. Even before giving birth, women whose children may fail to thrive are more likely than other mothers to feel unloved by their parents, to reject their own mothers as models, and to say their own childhoods were unhappy. Within days of giving birth, these mothers are already having more problems feeding and soothing their babies than are other mothers (Lozoff, 1989). Clearly, these families need help and would almost certainly benefit from early interventions that teach parents how to be more sensitive and responsive caregivers.

Applying Developmental Themes to Physical Development

Before we close our discussion of physical development, let's take a brief look at how our developmental themes are reflected in the various aspects of physical development, including the development of the brain and body, the development of motor skills, and puberty. Recall that our developmental themes include the active child, the interplay of nature and nurture in development, qualitative and quantitative developmental changes, and the holistic nature of development.

Our first theme is that of the active child, or how the child participates in his or her own development both intentionally and through unconscious implications of his or her nature. One dramatic piece of evidence that the child is active in development is the fact that the child's early experiences direct the synaptic pruning that occurs in the first few years of life. Children who are reared in stimulating environments may develop dramatically different brain organizations than those who are reared in impoverished environments. We saw an example of this in the orphans who were left lying on their backs in cribs for the first 2 years of life and, as a result, were severely handicapped in their motor development when finally freed from this restriction. Further support for this active role in development came from Riesen's work with dark-reared chimpanzees, which revealed that atrophy of the neurons that make up the optic nerve led to blindness if the young chimps were unable to see for longer than 7 months, suggesting that the active use of these neurons was necessary for normal visual development. Turning to the development of motor skills, dynamical systems theory clearly sees the child as active in the development of motor skills early in life, as the infants use goals and objectives to actively reorganize existing motor capabilities into new and more complex action systems. And, finally, we saw evidence that the adolescent's activity can even affect the timing of puberty. Adolescent females who are engaging in extremely strenuous physical activity and those who are afflicted with anorexia may begin menstruating very late or stop after they have begun.

The interactions of nature and nurture in their effects on physical development expand the influence of the active child to include the environment in which the child is reared. For example, both heredity and environmental factors such as the food people eat, the diseases they may contract, and even the emotional climate of their lives can produce significant variations in the rates at which they grow and the statures they eventually attain. We saw that the early development of the brain is the result of both a biological program and early experiences. The effects on the timing of puberty also illustrate the interactions of nature and nurture on physical development. Both genetic influences (as demonstrated by twin and family studies) and environmental influences (such as the cessation of pubertal development seen in girls who are involved in extremely strenuous physical activity) interact to influence the timing of pubertal events.

Physical development across childhood and adolescence is marked by both qualitative and quantitative changes. We saw that babies may remain the same length for days or weeks at a time before showing spurts of more than a centimeter in a single day, a dramatic qualitative change. Quantitative changes mark the period of physical development during middle childhood (ages 6 to 11) when children may seem to grow very little. This is because their rate of growth is slow and steady throughout these years. Another qualitative change concerns the body's physical proportions. Across childhood, body shape changes from infancy to childhood, and then dramatically during the adolescent growth spurt and puberty, when the child takes on adult proportions. Qualitative physical changes also influence cognitive abilities (which is also an example of the holistic nature of development). We saw that researchers believe that the cognitive advances of adolescent experience occur only after a qualitative change in brain development including reorganizations and specializations. And of course the adolescent growth spurt and the physical changes of puberty are a clear example of a qualitative change in physical development.

Finally, looking at the holistic nature of development, we saw many examples of the effects physical development can have on social, intellectual, and psychological aspects of development in this chapter. Indeed, these effects are the reason a chapter on physical development is included in a developmental psychology textbook! Some examples include the fact that individual differences in the rates at which children grow have strong consequences for their social and personality development. One area where such differences are seen is in the changes in the structures of the brain during adolescence, including myelinization of the higher brain centers and reorganizations of the neural circuitry of the prefrontal cortex that are responsible for the dramatic changes in the types of thought that occupy adolescents as compared to younger children. Looking at motor skill development, we saw that the dynamical systems theory sees early motor development as a holistic enterprise, involving the infants' cognitive goals and objectives, leading to the reorganization of simple motor skills into more complex motor systems. We saw that experienced crawlers and walkers are better able to use landmarks to guide their adventures than are infants who have just begun to crawl or walk. This suggests that locomotion influences spatial memory, another example of how various aspects of development work together in a holistic manner. Turning to the physical changes of adolescence, we saw that physically active girls and teenagers experience important psychological benefits such as increased self-esteem. Furthermore, the many social and psychological implications of maturing early or late, for both girls and boys (but in opposite directions), are more evidence of how physical development is linked to other aspects of development in a holistic manner.

SUMMARY

An Overview of Maturation and Growth

- The body is constantly changing between infancy and adulthood.
  - Height and weight increase rapidly during the first 2 years.
  - Growth becomes more gradual across middle childhood.
  - In early adolescence there is a rapid growth spurt when height and weight again increase rapidly.
- The shape of the body and body proportions also change because various body parts grow at different rates.
- Physical development follows a **cephalocaudal** (head downward) and a **proximodistal** (center outward) direction: structures in the upper and central regions of the body mature before those in the lower and peripheral regions.
- Skeletal and muscular development parallel the changes occurring in height and weight.
  - Bones become longer and thicker and gradually harden, completing their growth and development by the late teens.
  - **Skeletal age** is a measure of physical maturation.
  - Muscles increase in density and size, particularly during the growth spurt of early adolescence.
- Physical growth is quite uneven, or asynchronous.
  - The brain, the reproductive system, and the lymph tissues mature at different rates.

- There are sizable individual and cultural variations in physical growth and development.

Development of the Brain

- A **brain growth spurt** occurs during the last 3 months of the prenatal period and the first 2 years of life.
  - **Neurons** form **synapses** with other neurons.
  - **Glia** form to nourish the neurons and encase them in myelin—a waxy material that speeds the transmission of neural impulses.
- Many more neurons and synapses are formed than are needed.
  - Those that are used often will survive.
  - Neurons that are stimulated less often either die or lose their synapses and stand in reserve to compensate for brain injuries.
  - Up until puberty, the brain shows a great deal of **plasticity**, which allows it to change in response to experience and to recover from many injuries.
- The highest brain center, or **cerebrum**, consists of two hemispheres connected by the **corpus callosum**.
  - Each hemisphere is covered by a **cerebral cortex**.
  - The brain may be **lateralized** at birth so that the two hemispheres assume different functions.
  - Children come to rely increasingly on one particular hemisphere or the other to perform each function.
- **Myelinization** and reorganization of the neural circuitry of the cerebral cortex continue throughout adolescence.

Motor Development

- Like the physical structures of the body, motor development proceeds in a cephalocaudal and proximodistal direction.
- Motor skills evolve in a definite sequence.
  - Infants gain control over their heads, necks, and upper arms before they become proficient with their legs, feet, and hands.
- Motor skills that infants display do not unfold according to a maturational timetable; experience is important as well.
  - Institutionalized children who have few opportunities to practice motor skills have retarded motor development.
  - Cross-cultural research shows that motor development can be accelerated.
- According to **dynamical systems theory,** each new motor skill represents an active and intricate reorganization of several existing capabilities that infants undertake to achieve important objectives.
- Fine motor skills improve dramatically in the 1st year.
  - Prereaching is replaced by voluntary reaching.
  - The clawlike **ulnar grasp** is replaced by the **pincer grasp.**
  - Reaching and grasping skills transform infants into skillful manipulators.
- Emerging motor skills often thrill parents and allow new forms of play.
- Emerging motor skills support other aspects of perceptual, cognitive, and social development.
- With each passing year, children's motor skills improve.
  - Boys become notably stronger than girls early in adolescence because of their greater muscular development and the fact that girls are less inclined to remain physically active.

Puberty: The Physical Transition from Child to Adult

- At about age 10½ for females and age 13 for males, the **adolescent growth spurt** begins.
  - Adolescents grow taller and heavier.
  - Adolescents' bodies and faces assume a more adult-like appearance.
- Sexual maturation
  - begins about the same time as the adolescent growth spurt and
  - follows a predictable sequence.
- For girls, **puberty** includes
  - the onset of breast and pubic-hair development,
  - a widening of the hips, enlarging of the uterus and vagina,
  - **menarche** (first menstruation), and
  - completion of breast and pubic-hair growth.
- For boys, puberty includes
  - development of the testes and scrotum,
  - the emergence of pubic hair,
  - the growth of the penis and the ability to ejaculate,
  - the appearance of facial hair, and
  - a lowering of the voice.
- There are great individual differences in the timing of sexual maturation.
- The **secular trend** refers to the fact that people in industrialized societies are reaching sexual maturity earlier than in the past.
  - People are also growing taller and heavier than people in the past.
  - The secular trend is due to improved nutrition and health care.

Causes and Correlates of Physical Development

- Physical development results from a complex interplay between biological and environmental forces.
  - Individual genotypes set limits for stature, shape, and tempo of growth.
  - Growth is heavily influenced by hormones released by the endocrine glands as regulated by the **pituitary**.

- **Growth hormone** (**GH**) regulates growth throughout childhood.
- At adolescence, other endocrine glands secrete hormones.
- **Estrogen** from the ovaries triggers sexual development in girls.
- **Testosterone** from the testes instigates sexual development in boys.

- Adequate nutrition, in the form of total calories, protein, and vitamins and minerals, is necessary for children to reach their growth potentials.
  - **Marasmus, kwashiorkor**, and **iron deficiency anemia** are three growth-retarding diseases that stem from undernutrition.
  - In industrialized countries, **obesity** is a nutritional problem, with many physical and psychological consequences.
- Chronic infectious diseases can combine with poor nutrition to stunt physical and intellectual growth.
  - **Nonorganic failure to thrive** and **deprivation dwarfism** illustrate that affection and sensitive, responsive caregiving are important to ensure normal growth.

CHAPTER 5 PRACTICE QUIZ

Multiple Choice: Check your understanding of physical development by selecting the best choice for each question. Answers appear in the Appendix.

1. Which of the following statements about physical development is *false*?
   a. Babies who walk early are inclined to be especially bright.
   b. The average 2-year-old is already about half of his or her adult height.
   c. Half the nerve cells (neurons) in the average baby's brain die (and are not replaced) over the first few years of life.
2. Which of the following statements about physical development is *true*?
   a. Most babies can walk alone, with sufficient encouragement and practice, by the time they are 6 months old.
   b. Hormones have little effect on human growth and development *until* puberty.
   c. Emotional trauma can seriously impair the growth of young children, even those who are adequately nourished, free from illness, and not physically abused.
3. Physical development occurs in a head-downward direction across prenatal, child, and adolescent development. The name of this principle is the __________ principle.
   a. proximodistal
   b. cephalocaudal
   c. ossification
   d. vertical
4. Which body system actually *exceeds* adult size during child and adolescent development?
   a. Brain and head
   b. General growth
   c. Lymphoid
   d. Reproductive
5. The __________ brain cells are the most numerous, produce myelin, and continue to form throughout life.
   a. glia
   b. cerebral
   c. neurons
   d. synapse
6. The bundle of neural fibers that connects the two hemispheres of the brain and transmit information from one hemisphere to the other is called the
   a. cerebrum.
   b. cerebral cortex.
   c. lateralization.
   d. corpus collosum.
7. The __________ views motor development as a complex transaction among the child's physical capabilities and goals and the experiences she has.
   a. maturational viewpoint
   b. experiential viewpoint
   c. dynamical systems theory
   d. transactional theory

KEY TERMS

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