From the very beginning, they involve organized sequences of actions that serve some purpose. For example, when Meryl turned toward Dr. Bryan's voice, this coordinated series of movements allowed her to locate the source of a sound.

They involve selective responses. For example, newborns do not look with equal attention at everything around them. Instead, they tend to look at sharp contrasts, such as a pair of eyes or the border between a person's hair and forehead.

They allow infants to detect relationships between actions and consequences. For example, a newborn can detect the connection between placing a thumb in the mouth and the good feelings it generates.

This chapter focuses on the capacities babies possess for interacting with the world during the first few months of life and how those capacities change and contribute to development throughout infancy. We begin by describing the early development of the brain, which provides the foundation for inborn capacities and their development. We continue by examining the various newborn states and newborn reflexes, followed by a discussion of the development of infants' learning capabilities, motor skills, sensory capacities, and perceptual abilities.

This chapter has two major themes. First, we once again focus on how heredity and the environment work jointly to guide the course of development. Early development provides a good place to examine the nature-nurture issue because infant skills and behaviors are relatively limited (and thus easy to assess) and because their initial state is relatively untouched by experience.

Second, throughout the chapter we emphasize how infants' initial skills, and the experiences they allow infants to have, provide the seeds for the development of the more complex and flexible skills seen by the end of the first year. The learning abilities, behavior systems, and sensory skills with which newborns enter the world are limited, but their very limitations are useful for guiding infants to experiences that foster the development of complex skills. For example, the hearing system of newborns is quite immature, but it seems to be specially tuned to pay attention to the human voice, an important factor in developing language skills.

Questions to Think About as You Read:

- How do infants' capacities foster interaction with the world, including other people?
- How do limitations on infants' abilities influence what they are able to perceive and learn?
- What practical implications do infants' early abilities and limitations have for parents?

**EARLY BRAIN DEVELOPMENT**

To understand newborns' abilities and limitations, it is helpful to know something about the early development of the brain. Research in this area is challenging because it is difficult to directly examine the development of infants' brains. The physical growth of the brain can be measured indirectly by studying the growth of infants' heads. Age-related changes in brain structure can be studied by examining the brains of babies who have died. Developmental changes in brain function can be tracked by electroencephalograms (EEGs) of normal infants and by brain scans of infants who need them for medical reasons. (Brain scans of normal infants are not routinely done for research because the available methods all involve risks such as radiation, and many of them require infants to be heavily sedated to keep them still.) Environmental effects on brain development can be estimated from experiments in which animals such as rats, kittens, and monkeys are placed in enriched or impoverished environments and from natural experiments involving children.
Part 2  Infancy

who have suffered early deprivation. All these methods have limitations, but together they provide an increasingly clear picture of early brain development.

**Brain Growth**

In accordance with the principle of cephalocaudal development discussed in Chapter 3, the head and brain are much closer to their adult size at birth than other parts of the body, and they continue to grow rapidly during infancy. At birth, an infant’s brain weighs 300 to 400 grams on average, which is about one-quarter of its adult weight (Morgan and Gibson, 1991). By the end of the first year, it has tripled in weight; it continues to grow, at a much slower rate, through adolescence. Head circumference is often used as a rough indicator of brain growth. Normal babies have an average head circumference of 34 centimeters (about 13.5 inches) at birth; by their first birthdays, this has increased to about 46 centimeters (just over 18 inches), on the way to an average adult head circumference of 52 centimeters (20.5 inches). Brain growth does not follow a smooth curve; instead, it occurs in spurts. Longitudinal studies of babies’ head circumference show growth spurts at 3 to 4 weeks, 7 to 8 weeks, 10 to 11 weeks, 3 to 4 months, and 7 to 8 months. Interestingly, the growth spurts at 3 to 4 and 7 to 8 months correspond to changes in various measures of brain functioning and to noticeable advances in cognitive abilities (Fischer and Rose, 1994).

**Changes in Structure and Function**

The amazing growth in brain size during infancy is associated with considerable structural and functional development. The various parts of the brain (see Figure 4.1) develop on somewhat different schedules. For example, much of the brainstem, which controls basic reflexes and other body functions, is fully functional at birth. Some parts of the brain are functioning at birth but show evidence of continued development and reorganization after birth. These include the thalamus, a part of the brainstem through which sensory information passes on the way to the cerebral cortex; the cerebellum, which is involved in motor control; and the hippocampus, which is involved in memory formation. The cerebral cortex, which controls many higher cognitive abilities, is not fully functional at birth and has the longest period of continued development after birth.

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**Figure 4.1**
CROSS SECTION OF THE HUMAN BRAIN
A newborn's brain has almost all the neurons, or nerve cells, it will ever have. As you learned in Chapter 3, most neurons in the cerebral cortex form by the seventh month of prenatal development (Rakic, 1995). However, neurons continue to form in the cerebellum for about the first 18 months of life (Johnson, 1997).

After birth, the cerebral cortex continues to develop in several ways (Johnson, 1998):

- Neurons increase in size and become more complex in structure.
- **Myelination**—the formation of sheaths of a fatty substance called myelin around nerve fibers—occurs. The myelin sheaths help to speed the conduction of electrical impulses in the brain. Myelination actually begins in lower regions of the brain in the seventh month of prenatal development; at birth, the brainstem already contains considerable myelin, but the cerebral cortex does not (Gibson, 1991). Myelination of higher brain regions begins soon after birth and is not complete until sometime in adolescence. In the cerebral cortex it occurs first in sensory areas, then in motor areas, and last in areas involved in higher mental functions.

  The number of synapses, or interconnections between neurons, increases rapidly, as shown in Figure 4.2. This happens at different ages for different parts of the cortex. For major visual and auditory areas, the increase in synapses peaks at three to four months after birth; for areas controlling higher cognitive functions, the peak occurs later in infancy. In fact, far more synapses are formed than will be needed; the excess synapses are eventually eliminated, beginning at about 1 year of age in the major visual and auditory areas and continuing into adolescence for some areas of the cerebral cortex (Huttenlocher, 1994).

- Connections between the cerebral cortex and other regions of the brain, especially the thalamus, the cerebellum, and the hippocampus, increase. At birth the lower brain regions seem to function independently, but as the cerebral cortex develops the various parts of the brain function more interdependently (Johnson, 1997).

  Areas of the cortex begin to take on specialized functions. At birth, an infant's cerebral cortex has very high plasticity, the capacity for different areas to take on new functions. Over time, regions of the cortex become increasingly specialized and gradually lose plasticity.

**Experience and Developmental Context**

The rapid development of the cerebral cortex in the first months after birth helps explain many changes in infant competencies, as you will see throughout this chapter. But this development, especially the increase in interconnections among neurons and the development of specialized functions, also depends on the experiences infants have (Johnson, 1998; Schore, 1994). At the same time that the developing nervous system is fostering and constraining infants' capacities, the development of the nervous system itself is being fostered.

**Myelination:**

Formation of myelin sheath around nerve fibers, which to speed conduction of electrical impulses.

**Plasticity:**

The capacity for different parts of the brain to take on new functions.

**Figure 4.2**

CEREBRAL CORTEX NEURONS, 1–15 MONTHS

and constrained by experiences. Developmental context, both inside and outside the brain, has a strong impact on the course and outcome of brain development.

At the most basic level, interactions with other areas of the brain, as well as input from the environment, play a significant role in the development of specialized functions in the cerebral cortex (Johnson, 1998). In animal studies, tissue transplanted from one area of the cortex to another early in development takes on the structure and function of the area to which it is transplanted, not the area from which it came. In addition, the amount of various types of sensory input received through the thalamus early in development determines the size of various specialized areas of the cortex. As we discuss later in the chapter, visual and auditory input are critical for the development of visual and auditory areas in the human brain.

External environmental factors also play a major role in brain development. Malnutrition in infancy, especially if it is severe and long-lasting, can cause severe and potentially permanent brain damage. Depending on when it occurs, it can reduce the number of neurons formed, the size and structure of neurons, the extent and speed of myelination, or the complexity of synapse formation (Morgan and Gibson, 1991). Fortunately, if malnourished infants receive early and prolonged nutritional supplementation, much of the damage can be reversed, resulting in normal cognitive development. This is especially true if nutritional supplementation is combined with an enriched environment that provides intellectual and social stimulation. However, children may not reach the level of functioning they would have achieved with adequate nutrition. For example, Korean orphans who had suffered malnutrition and were adopted into middle-class American homes before age 2 later scored in the normal range on intelligence tests, but had lower IQs than similar orphans adopted into similar homes who had not experienced malnutrition (Winick, Meyer, and Harris, 1975).

The structure of the cerebral cortex is also influenced by the amount and type of stimulation from the environment. Rats raised in cages containing toys—objects to explore and structures to climb on—develop larger brains and more dense connections between neurons than those raised in less stimulating environments (Diamond, 1991; Greenough, Black, and Wallace, 1987). Similar results have been obtained from studies of children who suffer early environmental deprivation, as discussed in Chapter 2. Environmental stimulation appears to play a role both in the formation of connections between neurons and in the later pruning of synapses; connections that are used strengthen over time, while those that are not used gradually disappear (Huttenlocher, 1994).

INFANT STATES

In the scene that opened this chapter, newborn Meryl started to become fussy during the physical exam, but then became alert and quiet while listening to Dr. Bryant’s voice and watching the orange ball. These two states are qualitatively different, as any observer can see. One frequently used classification system identifies six infant states: two kinds of sleep (quiet sleep and active sleep); two kinds of wakefulness (awake-and-quiet and awake-and-active); and two states of distress (fussing and crying) (Brazelton, 1973; Prechtl and Beintema, 1964).

States and the transitions between them are important in the study of infants’ capabilities, because babies respond to their environments very differently depending on their state. For example, a bell sounded next to a newborn may elicit an eye movement or head turn in the direction of the sound if the baby is in an awake-and-quiet state, but not if the baby is in an active-sleep or fussing state. During the first few months of life, infants gain increasing control over their states, and the states themselves become more stable and predictable.

Sleep States

Sleep states consume a great deal of a newborn’s time. The average newborn spends more than sixteen hours sleeping each day (Berg and Berg, 1987; Thoman and Whitney, 1989). Time spent sleeping decreases rapidly during infancy and childhood, and then declines