BENJAMIN BENSCHNEIDER/THE SEATTLE TIMES

Electric Excitement Milo's delight at his mother's facial expressions is visible, not just in his eyes and mouth but also in the neurons of the outer layer of his cortex. Electrodes map his brain activation region by region and moment by moment. Every month of life up to age 2 shows increased electrical excitement.

Brain Development

Lifelong, no body part is more important than the brain. No transplant or artificial organ can replace it. Brain maturation is the crucial factor in viability of the fetus (as you saw in Chapter 2), and decades later death is defined by lack of normal neurological activity (as you will see in the Epilogue). Accordingly, you will read more about the brain in almost every chapter. We start here with the basics.

BASIC BRAIN STRUCTURES The newborn's brain has billions of **neurons**, as brain cells are called. About 70 percent of neurons are in the **cortex**, the brain's six outer layers (see Figure 3.2); it is sometimes called the *neocortex* (Kolb & Whishaw, 2008).

Every brain area specializes in particular functions. For instance, seeing is located in the visual cortex, and hearing is located in the auditory cortex. This does not mean that only one part of the cortex is activated at a time: Most tasks require activation of many areas of the brain, each of which plays a particular role in coordination with the others.

Within and between brain areas, neurons are connected to other neurons by intricate networks of nerve fibers called **axons** and **dendrites** (see Figure 3.3). Each neuron has a single axon and numerous dendrites, with the latter spreading out like the branches of a tree. The axon of one neuron meets—but does not touch—the dendrites of other neurons at intersections called **synapses,** which are critical communication links within the brain.

To be more specific, a neuron communicates by sending electrical impulses through its axon. Along the way, the electrical signal is turned into a chemical signal, or **neurotransmitter,** and sent across the synapse, to be picked up by the dendrites of another neuron. The dendrites bring the message to the cell body of their neuron, where it is translated back into an electrical signal and conveyed via the axon to other neurons. This process is much slower in infancy than later on, for reasons explained in Chapter 5.

During the first months and years, rapid growth and refinement occur in axons, dendrites, and synapses, especially in the cortex. Dendrite growth is the major reason that brain weight triples in the first two years (Johnson, 2005).

The particulars of brain structure and growth depend on both genes and experience. For example, one part of the brain is dedicated to faces. In newborns, this area is activated by anything that looks like a face (e.g., a simple drawing with two dots for eyes). Very young humans seem to attend to monkey faces, dog faces, and even doll faces as avidly as to human faces. But experience refines perception, and soon infants become discriminating observers, focusing on people.

By 6 months, using both the visual cortex and the face region, infants immediately recognize the faces of their caregivers (even in a photograph) and closely examine the facial expressions of strangers. They no longer stare intently at monkey faces or simple drawings (Johnson, 2005).

Throughout life, that face area of the brain allows acute perception of tiny details. That is why you can recognize your best friends from high school even if you have not seen them for a decade, or why a glance at a face in a crowd makes you think "I know that person from somewhere," perhaps wracking your brain (the non–face areas) to remember where and when you met that individual.

neuron
One of billions of nerve cells in the central nervous system, especially in the brain.

cortex
The outer layers of the brain in humans and other mammals. Most thinking, feeling, and sensing involve the cortex. (Sometimes called the *neocortex.*)

axon
A fiber that extends from a neuron and transmits electrochemical impulses from that neuron to the dendrites of other neurons.

dendrite
A fiber that extends from a neuron and receives electrochemical impulses transmitted from other neurons via their axons.

synapse
The intersection between the axon of one neuron and the dendrites of other neurons.

neurotransmitter
A brain chemical that carries information from the axon of a sending neuron to the dendrites of a receiving neuron.

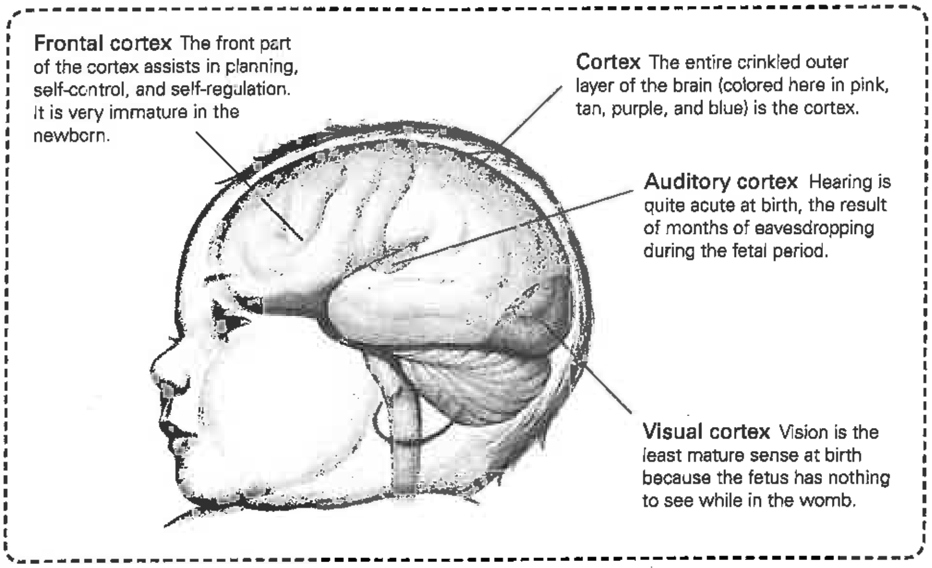

FIGURE 3.2 The Developing Cortex The infant's cortex consists of four to six thin layers of tissue that cover the brain. It contains virtually all the neurons that make conscious thought possible. Some areas of the cortex, such as those devoted to the basic senses, mature relatively early. Others, such as the frontal cortex, mature quite late.

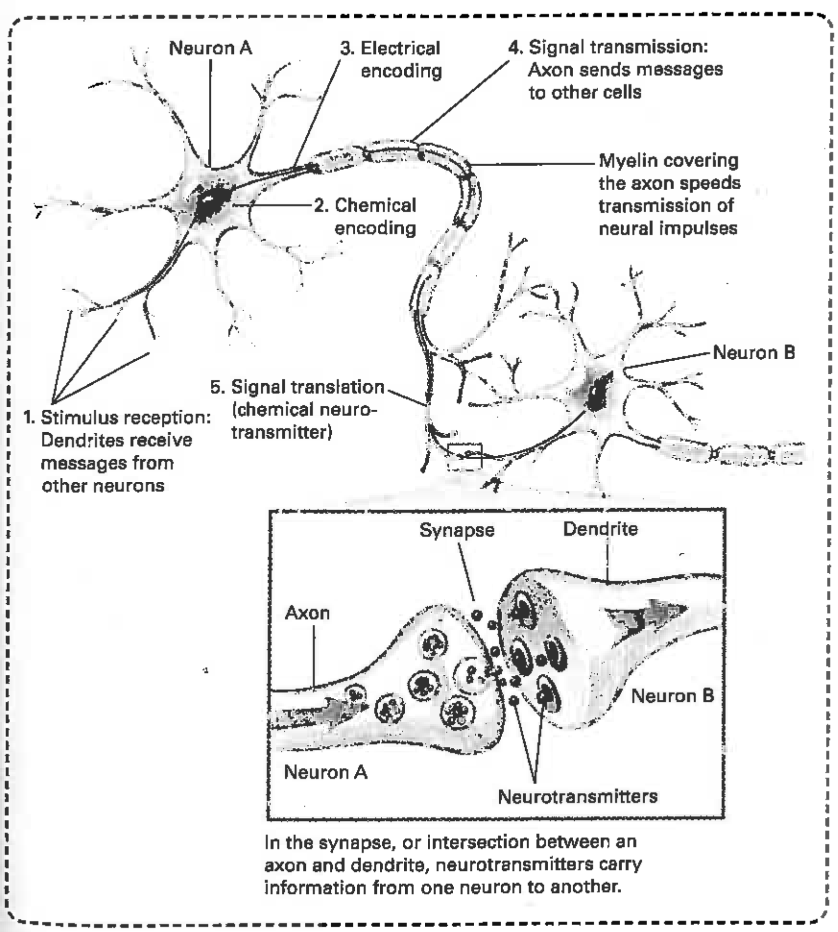

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FIGURE 3.3 How Two Neurons Communicate The link between one neuron and another is shown in the simplified diagram at left. The infant brain actually contains billions of neurons, each with one axon and many dendrites. Every electrochemical message to or from the brain causes thousands of neurons to fire simultaneously, each transmitting the message across the synapse to neighboring neurons. The electron micrograph directly above shows several neurons, greatly magnified, with their tangled but highly organized and well-coordinated sets of dendrites and axons.

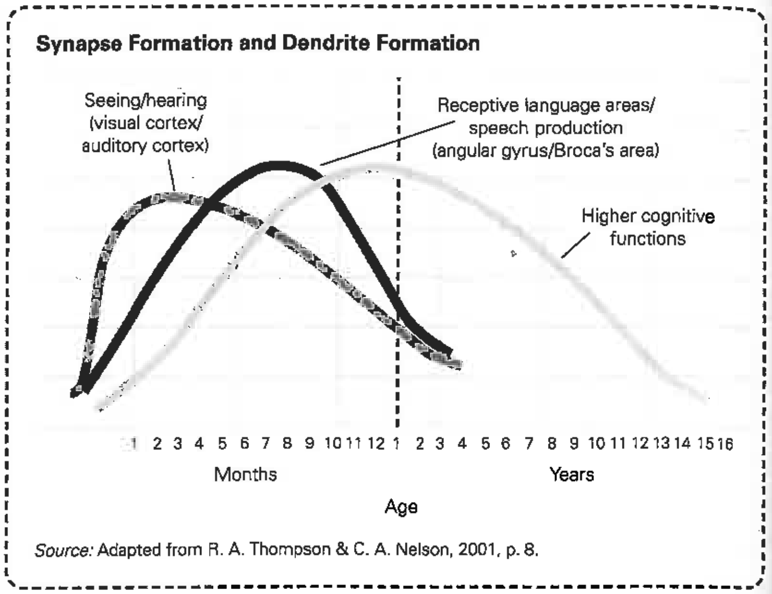


FIGURE 3.4 Brain Growth in Response to Experience These curves show the rapid rate of synapse formation for three functions of the brain (senses, language, and planning). After the initial increase, the underused neurons are gradually pruned, or inactivated, as no functioning dendrites are formed from them.

Neurons and synapses *proliferate* (increase rapidly in number) before birth. This increase continues at a fast pace after birth, but soon an opposite phenomenon occurs: the elimination, or *pruning*, of unnecessary connections (C. A. Nelson et al., 2006). Unused dendrites, axons, synapses (and probably neurons) shrink and die because no experience has activated them to send or receive messages (see Figure 3.4). Pruning occurs lifelong, but it is most intense before age 2. As one expert says:

> At birth, the brain is a thicket of branching extensions that connect neurons and allow them to talk to one another. Early in life, experience works on this tangle like a bonsai master, pruning away connections that don't play a part in working neuronal circuits and reinforcing those that do.
>
> *[G. Miller, 2003, p. 78]*

Paradoxically, this loss of dendrites increases brain power (L. S. Scott et al., 2007). In fact, fragile X syndrome (mentioned in Chapter 2) involves "a persistent failure of normal synapse pruning," which results in axons and dendrites that are too dense and too long and make it impossible to think normally (Irwin et al., 2002, p. 194).

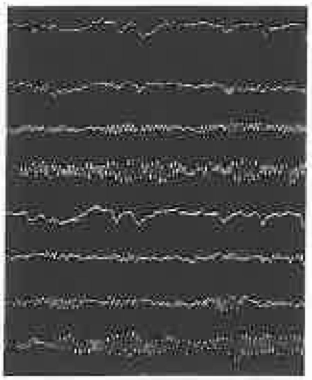
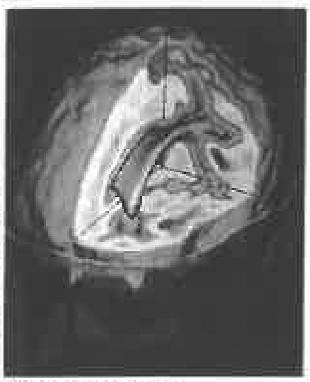
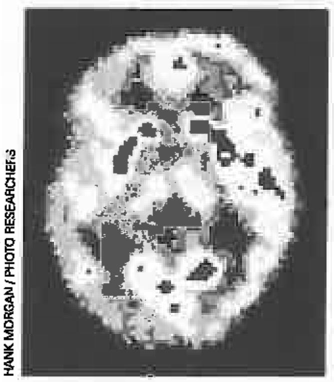
TIMETABLE OF BRAIN MATURATION Each part of the brain develops on a schedule. Proliferation and then pruning occur first in the visual and auditory cortexes, before age 1. For this reason, remediation of blindness or deafness (such as cataract removal or cochlear implants) should occur in the first months of life, to prevent atrophy of those brain regions (Leonard, 2003). If a deaf infant's deficit is recognized at birth and repaired, language comprehension and expression will be more advanced than those of a child whose deafness was noticed later (Kennedy et al., 2006).

prefrontal cortex
The area of the cortex at the front of the brain that specializes in anticipation, planning, and impulse control.

The last part of the brain to mature is the **prefrontal cortex,** the area for anticipation, planning, and impulse control. It is virtually undeveloped in early infancy and gradually becomes more efficient over the years of childhood and adolescence (Luciana, 2003). Thus, telling an infant to stop crying and go to sleep is pointless because the infant cannot decide to comply; such self-control requires brain capacity that is not yet present.

STIMULATION AND BRAIN DEVELOPMENT Is it necessary for brain circuits to be activated in infancy? Yes, but this happens naturally. Most parents provide all the stimulation that is needed, caressing the newborn, talking to the preverbal infant, and

TABLE 3.1 Some Techniques Used by Neuroscientists to Understand Brain Function

	Technique	Use	Limitations
 SPL / PHOTO RESEARCHERS — EEG, normal brain	EEG (electroencephalogram)	Measures electrical activity in the outer layers of the brain, where the cortex is.	Especially in infancy, much brain activity of interest occurs below the cortex.
 © 2001 UNIVERSITY OF WASHINGTON, INSTITUTE FOR LEARNING AND BRAIN SCIENCES — ERP when listening	ERP (event-related potential)	Notes the amplitude and frequency of electrical activity (as shown by brain waves) in specific parts of the cortex in reaction to various stimuli.	Reaction within the cortex signifies perception, but interpretation of the amplitude and timing of brain waves is not straightforward.
 VOLKER STEGER / PETER ARNOLD — fMRI when talking	fMRI (functional magnetic resonance imaging)	Measures changes in blood flow anywhere in the brain (not just the outer layers).	Signifies brain activity, but infants are notoriously active, which can make fMRIs useless.
 HANK MORGAN / PHOTO RESEARCHERS — PET scan of sleep	PET (positron emission tomography)	Also (like fMRI) reveals activity in various parts of the brain. Locations can be pinpointed with precision, but PET requires injection of radioactive dye to light up the active parts of the brain.	Many parents and researchers hesitate to inject radioactive dye into an infant's brain unless a serious abnormality is suspected.

For both practical and ethical reasons, these techniques have not been used with large, representative samples of normal infants. One of the challenges of neuroscience is to develop methods that are harmless, easy to use, and comprehensive for the study of normal children. A more immediate challenge is to depict the data in ways that are easy to interpret.

showing affection toward a small person. No special toys are required, because infant brains are adaptive (C. A. Nelson et al., 2007). They show plasticity in that they grow in the way that their experiences allow.

This does not mean that infant brains are impervious to harm. Early in life, brains notice what occurs and adapt their neurons and dendrites. That much is known, but thousands of scientists are using various techniques to try to understand precisely how areas of the brain function in the early months (see Table 3.1).

Some causes of brain damage are known. An impatient caregiver may shake a baby, sharply and quickly, to make him or her stop crying. Shaken babies become quiet because of ruptured blood vessels in the brain. This results in broken neural connections, the mark of **shaken baby syndrome.** In the United States, more than one in five of all children hospitalized for maltreatment have suffered this kind of brain damage, according to sensitive brain scans (Rovi et al., 2004).

shaken baby syndrome
A life-threatening injury that occurs when an infant is forcefully shaken back and forth, a motion that ruptures blood vessels in the brain and breaks neural connections.

Even without such evident damage, the brains of terrified babies produce a flood of cortisol and other stress hormones that may disrupt normal reactions lifelong, causing a person to be hypervigilant (always alert) or emotionally flat (never happy, sad, or angry). Furthermore, depriving a baby of normal social contact can also impair the brain, as the following explains.

A VIEW FROM SCIENCE

The Effect of Social Deprivation on Brain Growth

What effect does early stimulation—or lack of it—have on the brain's development? To explore that question, Marion Diamond, William Greenough, and their colleagues raised some rats in a social playground—large cages with other rats and many stimulating objects. Some of their litter mates (who were from the same gene pool) were raised alone, in small, barren cages. Autopsies on rats from both groups found that the brains of the "enriched" rats were larger and heavier and had more dendrites than the brains of the "deprived" rats (Diamond et al., 1988; Greenough & Volkmar, 1973).

Using many other species of animals, researchers have confirmed that early experiences do affect brain growth. Isolation and sensory deprivation harm the developing brain, and a complex social environment enhances neurological growth (Curtis & Nelson, 2003). Note that this experimental deprivation was extreme: Every animal raised in the wild has many social and environmental experiences.

Such experiments are unthinkable with humans, but a chilling natural experiment began in Romania in the 1980s, when dictator Nicolae Ceausesçu forbade birth control and outlawed abortions except for mothers who already had five or more children. Parents were paid for every birth but received no financial support for raising their children.

As a result of these policies, unwanted births and infant mortality rose; illegal abortions became the leading cause of death for women age 15–45 (Verona, 2003). More than 100,000 children were abandoned to crowded institutions, forced to endure "severe and pervasive restriction of human interactions, play, conversation, and experiences" (Rutter & O'Connor, 2004, p. 91).

AP/WIDE WORLD PHOTOS

A Fortunate Pair Elaine Himelfarb (shown in the background), of San Diego, California, is shown here in Bucharest to adopt 22-month-old Maria.

Ceausesçu was ousted and killed in 1989. In the following years, North American and western European couples adopted thousands of the institutionalized Romanian children. They hoped that "lots of love and good food would change the skinny, floppy waif they found in the orphanage into the child of their dreams" (D. E. Johnson, 2000, p. 154).

All the Romanian adoptees experienced catch-up growth, becoming taller and gaining weight until they reached the norms for their age (Rutter & O'Connor, 2004). However, many showed signs of emotional damage. They were too friendly to strangers, or too angry without reason, or too frightened of normal events (Chisholm, 1998).

By age 11, most of those who had been adopted before they were 6 months old seemed normal, but those adopted when they were older than a year averaged 15 points below normal on IQ tests. Their deficits were especially evident in abilities controlled by the prefrontal cortex, including social interaction and impulse control (C. A. Nelson, 2007).

Further research in Romania has found that infants develop best in their own families, second best in foster families, and much worse in institutions (C. A. Nelson et al., 2007). This is confirmed by recent data on a group of Romanian children who had lived in institutions until about age 2 (Romania no longer permits international adoptions). These institutionalized 2-year-olds were then randomly assigned to foster homes in Romania or to ongoing institutional care. By age 4, the fostered children were smarter (by about 10 IQ points) than those who had remained institutionalized, although their IQ scores were still below those of children who had been cared for by their parents since birth (C. A. Nelson et al., 2007).

Developmentalists are convinced that infants in frightening homes or impersonal institutions are at risk for lifelong brain damage (Maclean, 2003). Many governments ignore this danger. More than a million children in central and eastern Europe live in institutions. Some of these institutions provide excellent physical care but nonetheless harm infants because their caregiving staff do not respond to the babies as individuals (St. Petersburg–U.S.A. Orphanage Research Team, 2008).

Fewer infants are institutionalized in North America. However, another problem occurs: Authorities should, but do not, "move children into permanent homes more quickly or remove them from abusive homes sooner" (C. A. Nelson, 2007, p. 17).

It is apparent that all infants need love and stimulation to become the persons their genes enable them to be. Head-sparing, plasticity, and catch-up growth compensate for the many limitations, imperfections, and lapses of human parenting, but they cannot overcome prolonged early deprivation. Impairment increases the longer stress or isolation goes on.

SLEEP PATTERNS One consequence of brain maturation is the ability to sleep for several uninterrupted hours. Newborns cannot do this. In the early months, parents need to adjust their schedules to accommodate their babies, since the reverse is impossible. Normally, newborns sleep about 17 hours a day, in one- to three-hour segments. Spending so much time sleeping helps them use most of their energy for the doubling of birthweight, as described earlier.

ESPECIALLY FOR Social Workers An infertile couple in their late 30s asks for your help in adopting a child from eastern Europe. They particularly want an older child. How do you respond? (see response, page 95) →

Newborns' sleep is primarily *active sleep,* as opposed to *quiet sleep.* That means they are often dozing, able to awaken if someone rouses them, but also able to go back to sleep quickly if they wake up, cry, and are comforted. In such sleep (but not in quiet sleep, with slow brain waves and slow breathing), infants wake themselves up if their oxygen level falls (H. L. Richardson et al., 2006). They then breathe rapidly, protecting themselves from *anoxia* (lack of oxygen).

A curious aspect of early sleep patterns is that newborns have a high proportion of **REM (rapid eye movement) sleep,** with flickering eyes and rapid brain waves. When adults are awakened during REM sleep, they report that they had been dreaming; presumably infants would say the same thing if they could talk. The content of infant dreams is not known, but experts agree that dreaming helps consolidate memories and that infant sleep patterns generally are adaptive.

REM (rapid eye movement) sleep A stage of sleep characterized by flickering eyes behind closed lids, dreaming, and rapid brain waves.

Over the first months, the proportion of time spent in each type of sleep changes. REM sleep declines, as does "transitional sleep," the dozing, half-awake stage. At 3 or 4 months, quiet sleep (also called *slow-wave sleep*) increases markedly (Salzarulo & Fagioli, 1999).

The various states of waking and sleeping become more evident with age, as brain maturation allows a more definite cycle, with longer periods of sleeping, eating, and playing at a stretch. Thus, although many newborns rarely seem sound asleep or wide awake, by 3 months most babies have periods of alertness (when they are neither hungry nor sleepy) and periods of deep sleep (when household noises do not wake them). By 12 months, infants take naps, usually two a day, and then sleep longer at night.

Sleeping Beauty At 3 months, most babies—like this infant in Mongolia—can sleep soundly amid noisy human activity.

KEY Points

- Weight and height increase markedly in the first two years; the norms are three times the birthweight by age 1 and 12 inches (30 centimeters) taller than birth height by age 2.
- Brain development is rapid during infancy, particularly development of the axons, dendrites, and synapses within the cortex.
- Experience shapes the infant brain, as pruning eliminates unused connections.
- Early sleep patterns originate from brain impulses and are adaptive.

Moving and Perceiving

Brain development cannot be directly observed. Various brain scans highlight neurological activity in special cases, but for most infants, brain maturation is invisible. However, brain growth is evident in the progression of many skills involved in movement and awareness of the surrounding environment.

Motor Skills

Motor skills are the abilities needed to move and control the body (Adolph & Berger, 2006). Just as the motor of a car is the crucial part that allows it to go, the motor skills of people and other animals allow them to move their bodies. To make the car actually travel, a driver, gas, and various connections to the motor are needed; in the human body, the brain directs movement, and nutrition is needed to fuel the muscles.

REFLEXES Normal newborns are active. They curl their toes, grasp with their fingers, screw up their faces, and so on. Even at birth, these movement abilities indicate brain functioning. This is evident in the Apgar scale and many other tests of newborn functioning, such as the *Brazelton Neonatal Behavioral Assessment Scale*, which elicits reflexes and assesses newborns' senses and reactions to discern how well the brain is functioning.

reflex
An unlearned, involuntary action or movement emitted in response to a particular stimulus. A reflex is an automatic response that is built into the nervous system and occurs without conscious thought.

Strictly speaking, the first movements are not *skills* but **reflexes,** involuntary responses to a particular stimulus. The reflexes that are part of the Apgar and Brazelton scales (and other measures of an infant's health) are particularly significant if the infant is preterm or if brain damage is suspected, as is often indicated by the absence of reflexes. Reflexes are also useful to demonstrate to parents that their tiny baby is already a capable young person (Lawhon & Hedlund, 2008).

Newborns normally have dozens of reflexes, 18 of which are mentioned in *italics* below. There are three sets of reflexes that are critical for survival:

- Reflexes that maintain oxygen supply. The *breathing reflex* begins in normal newborns even before the umbilical cord, with its supply of oxygen, is cut. Additional reflexes that maintain oxygen are reflexive *hiccups* and *sneezes,* as well as *thrashing* (moving the arms and legs about) to escape something that covers the face.
- Reflexes that maintain constant body temperature. When infants are cold, they *cry, shiver,* and *tuck in their legs* close to their bodies, thereby helping to keep themselves warm. When they are hot, they try to *push away* blankets and then stay still.
- Reflexes that facilitate feeding. The *sucking reflex* causes newborns to suck anything that touches their lips—fingers, toes, blankets, and rattles, as well as natural and artificial nipples of various textures and shapes. The *rooting reflex* causes babies to turn their mouths toward anything that brushes against their cheeks—a reflexive search for a nipple—and start to suck. *Swallowing* is another important reflex that aids feeding, as are *crying* when the stomach is empty and *spitting up* when too much has been swallowed too quickly.

Never Underestimate the Power of a Reflex For developmentalists, newborn reflexes are mechanisms for survival, indicators of brain maturation, and vestiges of evolutionary history. For parents, they are mostly delightful and sometimes amazing. Both of these viewpoints are demonstrated by three star performers: A 1-day-old girl stepping eagerly forward on legs too tiny to support her body, a newborn boy grasping so tightly that his legs dangle in space, and another newborn boy sucking on the doctor's finger.


JENNIE WOODCOCK; REFLECTIONS PHOTOLIBRARY / CORBIS


PETIT FORMAT / PHOTO RESEARCHERS, INC


ASTIER / BSIP / SCIENCE SOURCE / PHOTO RESEARCHERS, INC.

Other reflexes are not necessary for survival but are important signs of normal brain and body functioning. Among them are the following:

- *Babinski reflex*. When infants' feet are stroked, their toes fan upward.
- *Stepping reflex*. When infants are held upright with their feet touching a flat surface, they move their legs as if to walk.
- *Swimming reflex*. When they are laid horizontally on their stomachs, infants stretch out their arms and legs.
- *Palmar grasping reflex*. When something touches infants' palms, they grip it tightly.
- *Moro reflex*. When someone startles them, perhaps by banging on the table they are lying on, infants fling their arms outward and then bring them together on their chests, as if to hold on to something, while crying with wide-open eyes.

Cultural differences *may* originate from temperamental differences in the strength of various reflexes. For instance, some researchers report that reflexive thrashing and crying when a cloth covers the face are typical for European infants but not Chinese ones, who often will simply turn their heads to escape the cloth. In general, Chinese infants are less active than European babies in their reflexive responses; it is not known whether the difference is primarily genetic or environmental. Some alleles are more common among Chinese infants, but prenatal care, birth practices, diet, and early postnatal care differ as well (Kagan & Snidman, 2004).

RESPONSE FOR Social Workers (from page 93) Tell them that such a child would require extra time and commitment. Ask whether both are prepared to meet with other parents of international adoptees; to obtain professional help (for speech, nutrition, physical development, and/or family therapy); and to help the child with schoolwork, play dates, and so on. You might ask them to adopt a special-needs child from their own area, to become foster parents, or to volunteer at least 10 hours a week at a day-care center. Their response would indicate their willingness to help a real—not imagined—child. Then you might help them adopt the child they want. ●

GROSS MOTOR SKILLS Deliberate, coordinated actions that produce large movements, usually involving several parts of the body, are called **gross motor skills.** These emerge from reflexes.

gross motor skills
Physical abilities involving large body movements, such as walking and jumping. (The word *gross* here means "big.")

Crawling is one example. As babies gain muscle strength, they start to wiggle, attempting to move forward by pushing their shoulders and upper bodies against whatever surface they are lying on. Usually by 5 months or so, they use their arms, and then legs, to inch forward on their bellies. Between 8 and 10 months, most infants can lift their midsections and crawl (or *creep*, as the British call it) on "all fours," coordinating their hands, elbows, knees, and feet in a smooth, balanced manner (Adolph et al., 1998).

Sitting is another gross motor skill that develops gradually, as muscles mature to steady the top half of the body. By 3 months, most infants have enough muscle control to be lap-sitters if the lap's owner provides back support. By 6 months, they can usually sit unsupported. If an 8-month-old cannot sit, it is a sign that something is seriously amiss with the child's brain as well as body.

RICK GOMEZ/MASTERFILE

Bossa Nova Baby? This boy in Brazil demonstrates his joy at acquiring the gross motor skill of walking, which quickly becomes dancing whenever music plays.

Walking progresses from reflexive, hesitant, adult-supported stepping to a smooth, coordinated gait. Most infants can walk while holding on at 9 months, can stand alone at 10 months, and can walk independently at 12 months.

Once maturation of the muscles and brain allows it, infants become passionate walkers, logging long hours of practice on foot.

> Walking infants practice keeping balance in upright stance and locomotion for more than 6 accumulated hours per day. They average between 500 and 1,500 walking steps per hour so that by the end of each day, they have taken 9,000 walking steps and traveled the length of 29 football fields.
>
> *[Adolph et al., 2003, p. 494]*

They take all these steps on many surfaces, with bare feet or wearing socks, slippers, or shoes. They do not want to be held or pushed in their strollers.

fine motor skills
Physical abilities involving small body movements, especially of the hands and fingers, such as drawing and picking up a coin. (The word *fine* here means "small.")

FINE MOTOR SKILLS Small body movements are called **fine motor skills.** Finger movements are fine motor skills, enabling humans to write, draw, type, tie, and so on. Movements of the tongue, jaw, lips, and toes are fine movements, too. Mouth skills precede finger skills by many months, and skillful grabbing with the feet sometimes precedes grabbing with the hands (Adolph & Berger, 2005). However, hand skills are most praised. (Skill at spitting, chewing, or flexing the toes is rarely noted or valued.)

ELIZABETH CREWS/THE IMAGE WORKS

What Next? This 7-month-old is focused on grabbing, but her reach seems off-target, her overalls seem restrictive, and she is too young to crawl; she may soon be crying in frustration as the ball rolls out of reach. But there are other signs that her motor skills are advanced, so she may be on the verge of a major new achievement.

Regarding finger skills, newborns have a strong reflexive grasp but lack control. During their first 2 months, babies excitedly wave their arms at objects dangling in front of them. By 3 months of age, they can usually touch something within reach, but limited eye–hand coordination prevents them from grabbing, holding on, and letting go. When babies were fitted with "sticky mittens" that allowed them to capture objects earlier than they normally could, their reaching and grabbing were speeded up; this is further evidence that experience affects motor skills (Heathcock et al., 2008).

By 4 months, infants usually grab, but their timing is off: They are likely to close their hands too early or too late. Finally, by 6 months, with a concentrated, deliberate stare, most babies can reach for and grasp any object of the right size. They can hold a bottle, shake a rattle, and yank a sister's braids. Once this maneuver is possible, they practice it: "From 6 to 9 months, reaching appears as a quite compulsive behavior for small objects presented within arm's reach" (Atkinson & Braddick, 2003, p. 58).

Toward the end of the first year and throughout the second, finger skills improve. Babies master the *pincer movement* (using thumb and forefinger to pick up tiny objects) and feed themselves, first with hands, then fingers, then utensils. By about age 2, thinking may precede grabbing (Atkinson & Braddick, 2003). A toddler may decide against grabbing Mommy's earrings or Daddy's glasses . . . but the parents shouldn't count on it.

OBSERVATION QUIZ
Which of these skills has the greatest variation in age of acquisition? Why? (see answer, page 98) →

ETHNIC VARIATIONS All healthy infants develop skills in the same sequence, but the timing varies. Table 3.2 shows age norms for gross motor skills, based on a large, multiethnic sample of U.S. infants. When infants are grouped by ethnicity, the average African American is ahead of the Latino, who is ahead of the European American—but individual differences often outweigh ethnic differences.

TABLE 3.2 AT ABOUT THIS TIME: Age Norms (in Months) for Gross Motor Skills

Skill	When 50% of All Babies Master the Skill	When 95% of All Babies Master the Skill
Sit, head steady	3 months	4 months
Sit, unsupported	6	7
Pull to stand (holding on)	9	10
Stand alone	12	14
Walk well	13	15
Walk backward	15	17
Run	18	20
Jump up	26	29

Note: As the text explains, age norms are approximate and are affected by culture and cohort. These are U.S. norms, mostly for European American children. Mastering skills a few weeks earlier or later is not an indication of health or intelligence. Mastering them very late, however, is a cause for concern.
Source: Coovadia & Wittenberg, 2004; based primarily on Denver II (Frankenburg et al., 1992).

What accounts for this variation? It is at least partly genetic. Monozygotic twins walk on the same day more often than dizygotic twins do. Striking individual differences are apparent in infant strategies, effort, and concentration, again suggesting something inborn in motor-skill achievements (Thelen & Corbetta, 2002).

Cultural patterns of child rearing are also influential, as is apparent from the opening of this chapter. Early reflexes are less likely to fade if culture and conditions allow extensive practice. This has been demonstrated with legs (the stepping reflex), hands (the grasping reflex), and crawling (the swimming reflex). Thus, motor skills are an example of a complex and dynamic system in which practice counts, as discussed in Chapter 1 (Thelen & Corbetta, 2002).

Some cultures promote more practice than others. For example, Jamaican caregivers (such as Mrs. Todd) provide rhythmic and stretching exercises for their infants as part of daily care; their infants are among the youngest walkers (Adolph & Berger, 2005).

Other cultures discourage or even prevent infants from crawling or walking. The people of Bali, Indonesia, never let their infants crawl, for babies are considered divine and crawling is for animals (M. Diener, 2000). In colonial America, "standing stools" were designed for babies to strengthen their walking muscles without crawling (Calvert, 2003). Infants were tightly swaddled and tied in their cradles day and night to prevent movement, because

> parents and physicians alike viewed crawling on all fours, not as a natural stage of human development, but as a bad habit that, if not thwarted, would remain the baby's primary form of locomotion for the rest of its life. . . . As the common form of locomotion for most animals, crawling raised too many fears and negative associations.
>
> *[Calvert, 2003, p. 65]*

Safe and Secure Like this Algonquin baby in Quebec, many American Indian infants spend happy hours each day on a cradle board. The discovery in the 1950s that Native American children walk at about the same age as European American children suggested that maturation, not practice, led to motor skills. Later research found that Native American infants undergo exercise sessions each day, an indication that practice is important, too.

By contrast, the Beng people of the Ivory Coast are proud when their babies crawl but do not let them walk until they are at least 1 year old. Although the Beng do not recognize the connection, one reason for this prohibition may be birth control: Beng mothers do not resume sexual relations until their baby begins walking (Gottlieb, 2000).

Sensation and Perception

The motor skills just described reflect brain development. The senses we now describe typically *precede* intellectual and motor development, making it possible. Newborns have open eyes, sensitive ears, and responsive noses, tongues, and skin, all of which are used to perceive and then understand their experiences.

Since all of a newborn's senses function, why do newborns seem to perceive very little? They might look at their mother's face and then look away, staring longer at a light. They might hear a loud noise and startle, crying and moving their limbs. The reason for such imperceptive reactions is that perception requires experience. Let us clarify the difference between sensation and perception.

Sensation occurs when a sensory system detects a stimulus, as when the inner ear reverberates with sound or the retina and pupil of the eye intercept light. Thus, sensations begin when an outer organ (eye, ear, skin, tongue, or nose) meets something that can be seen, heard, touched, tasted, or smelled.

Perception occurs when the brain processes a sensation. Perception results when a message from one of the sensing organs reaches the brain, and then past experiences and neurological connections suggest that a particular sensation merits processing. Without experience, newborns stare at lights, startle at noises, and consider every face the same. By 6 months, they are far more discerning.

sensation
The response of a sensory system (eyes, ears, skin, tongue, nose) when it detects a stimulus.

perception
The mental processing of sensory information when the brain interprets a sensation.

HEARING The sense of hearing develops during the last trimester of pregnancy and is already quite acute at birth; it is the most advanced of the newborn's senses (Saffran et al., 2006). Certain sounds trigger reflexes in newborns, even without conscious perception. Sudden noises startle them, making them cry; rhythmic sounds, such as a lullaby or a heartbeat, soothe them and put them to sleep.

A newborn's hearing can be checked with advanced equipment. This practice is standard at most hospitals in North America and Europe, since early remediation is


AP PHOTO / THE PLAIN DEALER, DAVID I. ANDERSEN

Before Leaving the Hospital As mandated by a 2004 Ohio law, 1-day-old Henry has his hearing tested via vibrations of the inner ear in response to various tones. The computer interprets the data and signals any need for more tests—as is the case for about 1 baby in 100. Normal newborns hear quite well; Henry's hearing was fine.

needed for those infants (less than 1 percent) who would benefit (Calevo et al., 2007). Normally, even in the first days of life, infants turn their heads toward the source of a sound. It takes some learning before they can accurately pinpoint where the sound came from, but they already sense and begin to perceive what they hear (Saffran et al., 2006).

Young infants are particularly attentive to the human voice, developing rapid comprehension of the rhythm, segmentation, and cadence of spoken words long before comprehension of their meaning. As time goes on, sensitive hearing combines with the developing brain to distinguish patterns of sounds and syllables.

Infants become accustomed to the rules of their language, such as which syllable is usually stressed (various English dialects have different rules), whether changing voice tone is significant (as in Chinese), whether certain sound combinations are repeated, and so on. All this is based on very careful listening to human speech, even speech not directed toward them or speech that is uttered in a language they do not yet understand.

SEEING Vision is the least mature sense at birth. Newborns focus only on objects between 4 and 30 inches (10 and 75 centimeters) away (Bornstein et al., 2005). If an object in front of them moves, they might not track (follow) it with their eyes. Instead, they lose sight of it, even though it is just a few inches to the left or right.

Soon experience combines with brain maturation to improve visual ability. By 3 months, infants might look intently at a human face and, tentatively and fleetingly, smile when they realize that those eyes, nose, and mouth are, indeed, a face. They can also track a slowly moving object, such as a rattle, in front of them.

Over time, visual scanning becomes more efficient. For example, 3-month-olds look closely at the parts of a face—the eyes and mouth—that contain the most information. They much prefer photos of real faces over photos of faces with the eyes blanked out. Even better from the infants' perspective are faces that move: Parents typically bob their heads, open their mouths wide, and raise their eyebrows to get their infants to smile. The reason for such parental foolishness is that infants reward it with evident delight.

binocular vision
The ability to focus the two eyes in a coordinated manner in order to see one image.

Binocular vision is the ability to coordinate the two eyes to see one image. Because using both eyes together is impossible in the womb, many newborns temporarily seem wall-eyed or cross-eyed. At about 3 months, binocular vision appears, and infants focus both eyes on one thing (Atkinson & Braddick, 2003). This is seen with tracking: Moving an object slowly in front of an infant reveals that both eyes follow it from one side to another. Such evidence of binocular vision is absent in newborns but usually present by 4 months.

Is sensation essential for the visual cortex to develop? Yes, according to a series of classic experiments (Hubel & Wiesel, 2005). Kittens' eyes were sutured shut for several weeks, and then the stitches were removed. The anatomy of their eyes was normal, but some of the neural pathways of the visual cortex had atrophied. Their vision was diminished for life. When adult cats experienced the same temporary blindness, no visual impairment occurred.

Worse were the effects on one eye when it was blindfolded and the other eye was not. In that situation, no neural connections could build to that eye. The kitten's other eye was normal, but without both eyes, binocular vision never became activated in the brain. When the blinded eye was opened, it became obvious that the other eye had taken over the entire visual cortex (unlike when both eyes were blindfolded, and the visual cortex was unused and therefore underdeveloped). Because

ANSWER TO OBSERVATION QUIZ
(from page 96) Jumping up, with a three-month age range for acquisition. The reason is that the older an infant is, the more impact culture has. ●

binocular vision is essential for depth perception, those cats could not safely leap from one surface to another. Instead, they sometimes fell to the floor.

Such experiments would never be done with humans, and current guidelines for ethical research now forbid similar studies in cats. However, when human adults who were blind from birth become able to see, their lack of early visual experience is evident (Sacks, 1995). Typically, they do not perceive tiny visual details in the same way as a person who could see from birth, and their spatial navigation is impaired because vision aids the early development of many gross motor skills.

SMELLING, TASTING, AND TOUCHING As with vision and hearing, the senses of smell, taste, and touch function at birth and rapidly adapt to the social world. For example, one study found that a taste of sugar is a good pain reliever for newborns (Gradin et al., 2002), but another study found that it had no effect on 4-week-olds—unless the sugar was accompanied by a reassuring look from a caregiver (Zeifman et al., 1996).

Learning About a Lime As with every other normal infant, Jacqueline's curiosity leads to taste and then to a slow reaction, from puzzlement to tongue-out disgust. Jacqueline's responses demonstrate that the sense of taste is acute in infancy and that quick brain reactions are still to come.

Similar adaptation occurs for the other senses. Breast-fed babies can differentiate the smell as well as the taste of their own mother's milk.

Touch seems especially sensitive in the early months. The ability to be comforted by touch is one of the important "skills" tested in the Brazelton Neonatal Behavioral Assessment Scale. Although almost all newborns respond to massage and cuddling, over time they perceive whose touch it is and what it communicates. For instance, 12-month-olds respond differently to their mother's touch, depending on whether the touch is tense or relaxed (Hertenstein & Campos, 2001).

As babies learn to recognize their caregiver's smell and handling, they relax only when cradled by that caregiver, even when their eyes are closed. This discrimination is familiar to every adult, who might regard a pat from a loved one as reassuring but the same gesture from a stranger as intrusive, perhaps even insulting and hostile.

THE SENSES AND SOCIAL PERCEPTIONS Infants perceive the most important experiences with all their senses. Breast milk, for instance, is a mild sedative, so the newborn literally feels happier at the mother's breast, connecting pleasure with taste, touch, smell, and sight.

The entire package of the **five** senses furthers two goals: social interaction (to respond to familiar caregivers) and comfort (to be soothed amid the disturbances of infant life). Infants similarly adapt their awareness of pain and motion to aid their socialization and comfort.

ESPECIALLY FOR Parents of Grown Children Suppose you realize that you seldom talked to your children until they talked to you and that you often put them in cribs and playpens. Did you limit their brain growth and their sensory capacity? (see response, page 100) →