After Malcolm was born, the members of his family took charge of most of what happened to him—where he lay, what he saw, and what he heard. But within six months this situation had changed. Malcolm was now able to do many things for himself. He could turn over, sit up, grasp objects and put them in his mouth; he was even starting to crawl. By the time he was 1, he had acquired many other skills, including taking his first steps and saying a few words.

Developmental psychologists view such dramatic changes in behavior as the joint outcome of genetic control and learning. In examining the interaction of learning and genetic control, developmentalists ask questions such as: When do infants start learning? What limitations are there on the things they can learn? Does the way infants learn change as they grow older? The answers to these questions are not just of scientific interest; they are also of practical interest to parents. In the following sections we look at how learning abilities develop during infancy.

Habituation and Dishabituation

One of the first signs that babies are able to retain information about their environments is habituation, the decrease in attention that occurs when the same stimulus is presented repeatedly. For example, when the pediatrician first spoke to Meryl, she ceased her other behaviors and attended to his voice. This reaction, called an orienting response, includes physiological changes casual observers wouldn’t notice, such as a change in heart rate and a slight dilation of the pupils. Researchers have found that when the same stimulus is presented over and over, the orienting response disappears and the baby resumes other activities. The novelty of the stimulus apparently wears off. We know that such a decline in responding is due to learning and not fatigue, because presentation of a new stimulus again elicits the orienting response. The response to a new stimulus after decreased interest in an old stimulus is called dishabituation.

Habituation and dishabituation require infants to do two things. First, they must learn enough about the first stimulus to realize it is the same from one presentation to another. Second, they must make some kind of comparison between the first and second stimuli and recognize the second one as new. Infants’ tendency to become habituated has turned out to be useful to researchers interested in early perceptual and memory development. (For details on the use of habituation as a research technique, see A Closer Look on page 132.) Research using habituation provides insight into what kinds of stimuli babies can distinguish, how many repetitions are required for a memory to form, and how long a memory will endure once it has been formed.

Associative Learning

Over the last seventy years, psychologists have spent a great deal of time studying associative learning—how infants learn that certain events tend to go together or be associated with each other. Two kinds of associative learning they have explored extensively are classical conditioning and instrumental conditioning.

Classical Conditioning

Classical conditioning is a learning process in which a new stimulus comes to elicit an established reflex response through association with an old stimulus. The Russian psychologist Ivan Pavlov (1849–1936) caused dogs to salivate by giving them food, at the same time ringing a bell. Eventually, the sound of the bell alone caused the dogs to salivate. Pavlov thus conditioned the dogs to salivate in response to a stimulus that would not normally produce that reaction.

From the 1930s through the 1950s many researchers (e.g., Wickens and Wickens; 1940) tried classical conditioning with newborns and infants under 3 months of age.
A CLOSER LOOK

TECHNIQUES FOR STUDYING EARLY INFANT DEVELOPMENT

Developmental psychologists who study infants' earliest abilities and responses to the world share a basic problem: young infants can't talk and don't understand language. This means they can't tell researchers what they are seeing, hearing, feeling, or thinking; and they can't follow researchers' instructions or answer questions. As a result, experimenters have had to be creative in finding indirect ways to measure what infants sense, perceive, and remember.

In this chapter you will read about studies using a variety of techniques developed to address this problem. Techniques mentioned include:

- **Eye movements**—Video recorders and computers can produce a detailed record of infants' eye movements as they look at a stimulus, such as a face. This record indicates something about how infants explore their environment and what features they find most interesting. One limitation: knowing where babies look doesn't tell us what they see—exactly what they are paying attention to or how they organize the information they take in, for example.

- **Preferential looking**—This method uses babies' visual preferences to measure when they can detect the difference between two stimuli. It involves placing two stimuli in front of an infant (e.g., a gray card and a card with black and white stripes), and measuring how long the infant looks at each one. One limitation: if a baby shows no preference between two stimuli, it doesn't necessarily mean he or she can't tell the difference between them—it's possible the two are equally attractive (or unattractive) to the baby.

- **Habituation/dishabituation**—Another way of measuring whether infants can discriminate between two stimuli, this method is based on some of their most basic learning abilities. A stimulus (e.g., a photo of a woman) is presented repeatedly until the baby shows signs of having lost interest in it by decreased looking or listening. A new stimulus [e.g., a photo of a different woman or of a man] is then presented; renewed interest from the baby suggests that he or she has noticed that it is different from the previous stimulus. This method can also indicate when infants believe two stimuli are the same despite superficial differences [e.g., if they habituate to a series of photos of different women, then show dishabituation in response to a photo of a man]. One limitation: when dishabituation does not occur, it does not necessarily mean the baby can't distinguish between two stimuli; it may simply mean he or she has lost interest in the experiment and is not paying attention.

- **Instrumental conditioning**—Instrumental conditioning has been used to determine what infants find reinforcing; for example, newborns have been conditioned to suck at various rates to hear a particular sound or see a particular image. It has also been used to ensure a consistent response to a stimulus of interest. For instance, infants can be conditioned to turn their heads to see an interesting mechanical toy whenever they hear a tone; the infants' hearing abilities can then be tested by varying the pitch or volume of the tone. One limitation: a lack of response may reflect fatigue, inattention, or individual differences in what is reinforcing, rather than a lack of the ability being tested.

- **Evoked potentials**—When a baby detects a new visual or auditory stimulus, a characteristic pattern of electrical activity appears in the brain. This provides a more direct measurement of a baby's ability to distinguish between two stimuli, using brain waves measured by an electroencephalogram (EEG). One limitation: a change in the brain's electrical activity doesn't necessarily mean the baby can make meaningful use of the information detected.

Although they failed to convincingly demonstrate classical conditioning, many of these studies did demonstrate changes in behavior produced by experience, and thus some kind of learning. More recent studies of classical conditioning in newborns have met with greater success. One has even shown some retention of a conditioned eyelink blink over a ten-day period within the first month of life (Lipsitt, 1990). However, the difficulty of demonstrating classical conditioning in newborns suggests that it is not a very likely explanation for early changes in behavior. Along with a variety of other abilities, the disposition toward classical conditioning does not become well established until around 3 months of age, probably reflecting maturation of the infant's brain.

Classical conditioning by itself cannot explain the emergence of new behavior. The response to be conditioned must be one that already occurs when the unconditioned stimulus is present. Classical conditioning simply causes an old response to be elicited in a new situation. A famous example of classical conditioning of an infant is Watson's work with
11-month-old Albert, mentioned in Chapter 1. Watson (1928) conditioned Albert to fear a white rat (the conditioned stimulus) by pairing the rat with a sudden loud noise (the unconditioned stimulus). Albert already possessed a fear reaction; all Watson did was make the initially neutral rat into an effective elicitor of fear. Classical conditioning may play a role in certain aspects of early emotional development, but it cannot account for the crucial acquisition of new behaviors and skills.

**Instrumental Conditioning**

When Mikey said “beh” while pointing at a piece of bread, his father immediately showered him with praise and encouragement for saying a new word. Frank’s positive reaction to Mikey’s efforts at speech is a form of reinforcement because it increases the likelihood that Mikey will say “beh” again in a similar situation.

Positive reinforcement and negative reinforcement are important to the type of learning called instrumental or operant conditioning, in which behaviors are influenced by their consequences. If those consequences are pleasant, such as a hug from a parent, the child is positively reinforced and is likely to do the same thing again. Similarly, when a behavior—crying, for example—is followed by the removal of an unpleasant stimulus, such as a wet diaper, that behavior is said to be negatively reinforced and is more likely to occur again. Both positive and negative reinforcement increase the likelihood of a particular behavior. In contrast, punishment, the presentation of an unpleasant stimulus, such as a spanking, after a behavior, is intended to decrease the likelihood of the behavior.

It is much easier to instrumentally condition newborns than to classically condition them. This suggests that human infants come prepared to notice and respond to contingencies, the relationships between actions and their consequences. In older children and adults, it is generally voluntary behaviors that are instrumentally conditioned. In newborns, researchers condition behaviors with a reflexive component. Examples are sucking on a nipple (related to the sucking reflex) and turning the head from side to side (related to the rooting reflex). The relative ease of instrumental conditioning of young infants has made it a useful research technique (see A Closer Look on page 132).

As mentioned in Chapter 2, sucking rates of 3-day-old infants have been instrumentally conditioned. Newborns automatically suck in a burst-pause pattern, a succession of rapid sucks followed by a pause. DeCasper and Fifer (1980) measured the average interval between babies’ bursts of sucking on a nipple. Then they rewarded half of the babies every

---

**Reinforcement:**

An event following a behavior that increases the likelihood the behavior will be repeated.

**Positive reinforcement:**

The presentation of a pleasant stimulus following a behavior so as to increase the likelihood the behavior will be repeated.

**Negative reinforcement:**

The removal of an unpleasant stimulus following a behavior so as to increase the likelihood the behavior will be repeated.

**Instrumental or operant conditioning:**

Learning in which behaviors are influenced by their consequences.

**Punishment:**

The presentation of an unpleasant stimulus following a behavior so as to decrease the likelihood the behavior will be repeated.

**Contingencies:**

The relationships between events and their consequences.
time the interval between their sucking bursts was longer than average, and rewarded the other half every time their interval was shorter than average. The reinforcement they used was simply the sound of the child’s mother speaking. As expected, the sucking rate of the first group of babies decreased, while that of the second group increased. This experiment demonstrates not only instrumental conditioning, but also the fact that a human voice can be reinforcing for an infant only 3 days old.

Instrumental conditioning is of particular interest to psychologists because it provides a means of acquiring new behaviors. When Mikey says something that vaguely resembles the word bread, his father reinforces him with smiles and attention. Mikey may respond by saying "beh" again. Over time, Frank may become more selective in his reinforcement. He may require that Mikey say something closer to the real word before giving him praise. If Mikey were to utter the sound "breh," for instance, his father might grin and exclaim, "Atta boy!" In time, Mikey will say the word bread. Reinforcing gradually closer approximations of some target behavior is an example of a process called shaping.

Systematic shaping can result in quite remarkable feats, even in very young infants. As mentioned in Chapter 2, Papoušek (1967) conditioned babies only a few weeks old to perform complex sequences of behavior. When the infants turned their heads in one direction, they were rewarded with a taste of sugar solution. Soon they were turning their heads repeatedly in that direction. Next the babies were rewarded only after two head turns, and again they learned the pattern. Eventually they were required to perform even longer chains of responses, such as two head turns to the right, then two to the left.

Imitative Learning

Imagine how difficult it would be for Mikey to learn to talk if shaping were the only learning technique available to him. His parents would have to wait until he happened to make a sound that remotely resembled an English word. Then they would have to reinforce him immediately and continue reinforcing him every time he came closer to the correct pattern. This laborious process would have to be repeated for every word Mikey learned. Fortunately, infants are also capable of imitative learning, in which new behaviors are learned by copying others’ actions. This process helps explain why Mikey will learn new words so rapidly in his early years.

Imitation is a powerful mechanism for learning and a much faster way of acquiring new skills than shaping. But to imitate a new behavior, children must be able to reproduce
the behavior and remember it for future use. For example, when Mikey imitates a word his father says, he must first translate the sounds he hears into a set of movements of his own lips and tongue and then store some memory of these movements for future use.

Piaget (1962) argued that these abilities develop gradually during a child's first two years. In general agreement with Piaget's view, Ina Uzgiris observed a four-step sequence in the development of imitation (Uzgiris, 1972; Uzgiris and Hunt, 1975):

- Before 6 months, infants can match the behaviors of others based on similarity of perceptual consequences, such as sound. Imitation at this step is limited to behaviors the infant has already produced spontaneously. For example, if a baby makes a cooing sound and an adult imitates it, the baby will often repeat the sound.
- Beginning at about 6 months, babies try to imitate behaviors they see or hear but have never tried before. Frequently they fail altogether or manage only a partial imitation. For example, during this time babies begin to imitate characteristics of the language they hear, which makes their babbling sound more like speech.
- Around 12 months, babies become much better at imitating unfamiliar behaviors. Their imitation of language leads to some intelligible words, and other kinds of imitation become increasingly common, often coupled with frequent checking for assurance that the imitation is right.
- By about 18 months, children's imitations, even of novel behaviors, become very accurate and require little checking for accuracy. Children this age become adept at imitating actions even when they cannot directly monitor their own success, as when they imitate the facial expressions of others (Abravanel and Gingold, 1985).

Many issues about the development of imitation are still unsettled. One is how the baby's early imitative abilities change into the much more elaborate ones of later infancy and toddlerhood. Piaget argued that the answer resides in the development of the child's underlying cognitive capacities, particularly their capacity for mental representation.

Some researchers have found evidence of apparent imitation much earlier than Piaget or Uzgiris expected. For example, Andrew Meltzoff and M. Keith Moore (1977) had adults display facial expressions to infants only 12 to 21 days old. The expressions included sticking out the tongue and opening the mouth wide. The babies often seemed to imitate the adults. Some researchers have replicated this finding; others have been unable to do so (Harris, 1983; Slater, 1989).

One criticism of the Meltzoff and Moore study is that the infant behaviors they observed may not have been true imitation. Some activities you might try with an infant under 4 months old are suggested by Sandra W. Jacobson (1979). Suppose that, rather than sticking your tongue out, you make a circle with your thumb and fingers and push a pencil through it in the baby's direction. Don't be surprised if the baby responds by sticking out his or her tongue. Many actions may elicit this response. As another experiment, try interlocking your fingers in front of the baby's face. The baby will not be able to duplicate this gesture, because it is not something he or she can already do spontaneously. Imitation as a means of learning new behaviors must await further development. In fact, more than a year must pass before the baby will be able to imitate new behaviors quickly and without error. This speed and accuracy are what give imitation its special importance as a learning mechanism.

The Concept of Preparedness

A baby's inability to imitate interlocking fingers stresses something important about infant learning. Some things are relatively easy for young infants to learn; others are difficult. Heredity seems to have endowed infants with a predisposition to acquire some behaviors but not others. The genetic predisposition to learn certain behaviors is called preparedness (Seligman, 1970).

Many developmentalists argue that some of a baby's early social behaviors are prepared responses. Examples are smiling back when an adult smiles and cooing when an adult speaks. These responses are easy for young babies; they seem biologically inclined to learn to perform them in social contexts. Other easily learned behaviors emerge in later
infancy. For example, in their second six months babies readily babble the sounds of the language spoken around them. Think how complex a process it is to distinguish and reproduce speech sounds. Evolution must have prepared human babies to acquire this skill quite early. Thus, the concept of preparedness provides one way to think about the limitations on infant learning. Babies learn most easily those behaviors they are prepared to learn; they learn other behaviors more slowly or not at all.

An important aspect of preparedness is a predisposition to analyze the connection between certain behaviors and their consequences. For example, humans are prepared to analyze the connection between the taste and smell of what they eat and any subsequent feelings of nausea (Garcia and Koelling, 1966). For this reason you readily develop an aversion to foods you eat just before getting sick to your stomach, but you don’t acquire a similar aversion to the people you’re with or the color of the shirt you’re wearing. Your brain is programmed to focus on the food-nausea connection, probably because learning to avoid food that produced illness has survival value. Babies, too, are prepared to learn certain contingencies between their own actions and the consequences produced. Instrumental conditioning of infants is often very easy when the association to be learned is one they’re prepared to discover.

---

**INFANT MOTOR SKILLS**

When Mikey was born, Christine knew from experience that she had to keep his fingernails trimmed. If his nails were allowed to grow too long, he could easily scratch his face as he moved his arms and hands around in the poorly coordinated manner of newborns. By the time Mikey was a year old, his motor skills had improved dramatically. Now he could sit unsupported, crawl rapidly wherever he wished, pull himself up into a standing position, and take a few tentative steps while hanging on to furniture. His movements were much more deliberate and coordinated than the random flailing of his arms and legs when he was a newborn. He could reach for and grasp an object, pick it up for inspection, and move it from hand to hand.

Figure 4.4 summarizes major milestones in motor development during the first two years, giving the average age for each. Keep in mind that normally developing children vary considerably in the ages at which they reach these milestones.

**Motor Skills and Physical Growth**

Infant motor skills develop in the context of dramatic physical growth. During the first year after birth, the average baby triples in weight and grows ten inches in length. Bones, which are soft and pliable at birth, become harder and more rigid. Muscle mass and strength increase. Body proportions change. At birth, the head is large relative to the rest of the body, and the trunk is long relative to the arms and legs. By the end of the first year, the head and trunk are not as out of proportion as in newborns. Just as during the prenatal period, different parts of the body grow at different times and rates.

Rapid physical growth provides a challenge for the development of motor skills; infants must learn to control the movements of bodies that are changing in size. For example, babies must learn to reach for objects with arms that are constantly growing longer. In the discussion that follows we focus mainly on the initial acquisition of motor skills, but keep in mind that the motor system must recalibrate to adapt to physical changes throughout development.

**Some Principles of Motor Skill Development**

We will look at four major principles involved in the development of motor skills:

- Differentiation
- Cephalocaudal development
- Proximodistal development
- The joint role of maturation and experience
Figure 4.4
MILESTONES IN MOTOR DEVELOPMENT
Normal children vary considerably in the ages at which they achieve major motor milestones. (Source: Frankenbourg and Dodds, 1967.)

Differentiation, a concept introduced in Chapter 3, applies to the development of motor skills as well as to prenatal development of cells and body structures. A newborn's global, poorly defined motor skills develop into a set of precise skills, each adapted to a specific function. Consider infants' reactions when an adult's hand covers their mouth and nose (Bühler, 1930). Newborns react reflexively with the whole body; arms and legs go into random motion, the body twists, the infant wails. Such a global reaction may result in the withdrawal of the hand, making it adaptive. Some weeks later babies will respond to the same situation with more arm movements, mostly directed toward the center of the body, thus increasing the chances of inadvertently batting away the hand. But not until age 6 months do infants precisely push the hand away using a directed swipe, perhaps with only one arm. A month or two later, babies may even block the hand from covering the nose and mouth by using a specific anticipatory movement.

The concepts of cephalocaudal and proximodistal development were also introduced in Chapter 3. Cephalocaudal development means that control over motor skills tends to progress from the head downward to lower parts of the body. For instance, refined sucking and eye movements emerge before refined walking movements. Proximodistal development means that control over motor skills tends to progress from the center of the body out to the extremities. For example, babies show refined control of head movements before arm movements, and of arm movements before hand movements. These patterns seem to be caused by different rates of development in the brain areas and muscles involved in the various skills.
However, the development of motor skills is influenced by both maturation and experience. In the early 1900s, there was great interest in charting the course of motor skill development, which was viewed as an inevitable sequence of milestones governed by maturation of the central nervous system. Contemporary developmentalists have modified this view. They argue that motor development is best understood as a dynamic system in which a number of factors—brain development, physical growth, sensory and perceptual abilities, specific motor skills, and motivation—interact in constantly changing ways (Bertenthal and Clifton, 1998). Brain development and physical growth establish only general behavioral tendencies. Experience is essential for these general tendencies to unfold and become refined, and to support and guide the developing organization of the central nervous system. This view is supported not only by evidence that practice influences the rate of motor skill development, but also by the fact that there are individual differences in how babies accomplish the same task (Thelen, 1995).

The Development of Specific Motor Skills

Rather than discussing all the motor skills that emerge during infancy, we focus here on a few representative skills: controlled eye movements, reaching and grasping, and walking.

**Controlled Eye Movements**

Your eye movements are so automatic that you probably don’t think of them as a motor skill. However, controlled eye movements are one of the earliest motor skills to develop, and they help to support further development. Without them, young infants could look only at whatever happened to be in their line of sight. They could not study the different parts of an object one after another, follow people visually as they moved about, or keep their eyes fixed on something despite movements of their own heads and bodies. If infants could not control their eye movements, their ability to learn about the world would be severely limited.

Even newborns show some controlled eye movements. When they have nothing to look at, they move their eyes more often and farther than normal, as if searching for something to see (Salapatek and Kessen, 1966). As the weeks pass, babies become more effective at controlling where they look. For instance, when 1-month-olds look at a person’s face, they tend to focus on border areas of high contrast. If a new stimulus appears off to one side, the baby may move his or her eyes to look at the new object. This tendency is more pronounced, and the eye shifts are more accurate, by the time the child is 2 months old (Aslin and Salapatek, 1975). Control over eye movements continues to improve until at least 7 years of age (Zaporozhets, 1965).

During the first months of life, babies also become increasingly skilled at visually tracking moving objects. Newborns show **saccadic eye movements**, the rapid, jerky eye movements that adults use to shift their gaze to a new object. For at least the first month of life babies typically use a series of saccadic eye movements to shift their gaze when adults would make the shift with one saccadic movement. Similarly, they use saccadic eye movements to track a moving object, rather than the smooth, continuous **pursuit eye movements** that an older infant or adult would use. At 2 months of age, smooth pursuit eye movements are common, but they can usually be applied only to slowly moving objects (Dayton and Jones, 1964). This is probably why adults tend to move their heads slowly from side to side when talking to very young infants, who cannot follow rapid side-to-side or up-and-down motions. The ability to follow more rapidly moving objects develops between 2 and 4 months of age (Aslin, 1981).

Visual tracking skills are also needed in situations in which infants themselves are in motion. To keep their eyes fixed on stationary objects while they are being carried around, babies must move either their eyes or their entire heads to compensate for their own movement through space. Even in the first months of life, infants make compensatory eye movements when they feel their bodies being moved (Evitar, Evitar, and Naray, 1974). By 16 weeks, infants’ compensatory head movements have developed almost to adult levels, but their ability to keep their eyes on target is still far below adult standards (Daniel and Lee, 1990).
Reaching and Grasping

Reaching and grasping are examples of behaviors that appear early in an infant’s life, decline or disappear with development, and then reappear in more advanced forms (Bower, 1974). Newborns respond to an object within their gaze by producing an increased rate of arm movements in the general direction of the object, though they seldom actually make contact with the object (Bertenthal and Clifton, 1998). These and other early spontaneous arm movements are generally referred to as *prereaching*. Between 1 and 4 months, infants show a decline in prereaching. Intentional reaching emerges around 4 months and gradually becomes more refined. By age 15 months, children commonly reach for things smoothly and accurately.

Until recently it was believed that the earliest accurate intentional reaching was visually guided (Piaget, 1952; White, Castle, and Held, 1964). Visually guided intentional reaching requires that infants simultaneously see the object they are reaching for and their own hand so that they can adjust their hand movements appropriately. It was assumed that early experience with visually guided reaching later allowed children to reach for objects without visually monitoring their hands. We now know that extensive experience with visually guided reaching is not essential for intentional, nonvisually guided reaching to occur. At about 15 weeks of age, the same time that visually guided reaching begins, babies will reach for glowing objects in the dark, where they can’t see their hands. They will also reach in the dark for objects that make an interesting sound (Clifton et al., 1993). Apparently, they can make a successful reach by combining visual or auditory information about objects with sensations about the location of their own hands in space.

This does not mean that reaching is a simple result of brain development. Esther Thelen and her colleagues (Thelen et al., 1993), who have studied early reaching in detail, conclude that reaching is refined through active exploration of the environment and the pursuit of particular goals (i.e., wanting particular objects). Physical maturation makes intentional reaching possible, but intentional efforts, practice, and experience transform it into a refined motor skill.

Effective reaching depends on an object being within arm’s length, or on moving the rest of the body to put the object within reaching distance. This means that reaching must be integrated into a more complex system of body movements. Young infants reach more for nearby objects than for distant ones (Gordon and Yonas, 1976). Five-month-olds who can sit up will lean and try to reach objects that are beyond arm’s length, whereas babies who have not yet developed the leaning skill do not try to reach in this situation (Yonas and Hartman, 1993). Similarly, a study of 8- to 10-month-olds found that they simply reach for objects that are within arm’s length, but they simultaneously lean and reach for objects that

**Prereaching:**

Early spontaneous arm movements, sometimes made in response to an object.

*Babies gradually become more accurate and coordinated in their attempts to reach for and grasp objects as reflexes are replaced by voluntary actions.*
are beyond this distance (McKenzie et al., 1993). By 8 months, reaching and leaning have become part of an integrated system. Babies this age do not try to reach first, fail to get the object they want, and then lean to get it; instead, they lean and reach simultaneously if an object is not close at hand.

The development of grasping follows a course similar to the development of reaching. It begins with a reflexive behavior that declines and is replaced by a voluntary one. Grasping skill develops gradually and follows a predictable pattern. From the beginning of voluntary grasping, infants adjust their grasp somewhat to the size, shape, and texture of objects, but with maturation and experience, their grasping becomes increasingly refined (Bertenthal and Clifton, 1998). By 3 to 4 months of age, babies can pick up objects voluntarily, but they generally use a whole-hand grasp, making it hard to pick up things that don’t fit in the hand. Until about 6 months of age they have trouble letting go of objects voluntarily. By 8 months, infants can use the thumb in opposition to the fingers, but the fingers act in unison. Not until around 1 year of age are infants finally able to oppose thumb and forefinger, allowing them to grasp very small things easily.

Walking
By 7 months of age Malcolm had learned to slide along the floor on his stomach, propelled by his legs. His family was suddenly faced with all the challenges of a baby who could go almost anywhere he wanted. Nothing was safe any longer. Infants this age acquire different methods of getting around. Some push themselves by their legs; others pull their bodies along with their arms; still others sit upright and scoot across the floor on their bottoms. Later, many babies learn to creep on their hands and knees. Before their first birthday they can usually hoist themselves into a standing position and “cruise”—that is, walk along while holding onto things. Most babies take their first solo steps shortly after the age of 1, although the age at which walking begins varies greatly. The age at which a baby starts walking and the pattern of development of prior abilities, such as crawling, are unrelated to later intelligence. Thus, parents should not be concerned about early walkers who never crawled or, unless the delay is extreme, about late walkers.

The movements involved in walking are apparent in the stepping reflex, which is present at birth and starts to decline at around 2 months. As in the case of grasping, some developmentalists argue that the decline of the reflex is related to the development of connections in the brain that allow babies to control reflexive activity. It may also be that as babies get heavier they don’t have the leg strength to make stepping movements. Thelen (1986) showed that the stepping reflex can still be elicited in 7-month-olds if they are supported over a treadmill. This indicates that the reflex’s disappearance involves more than just the development of the ability to stop the behavior.

Thelen argues that walking depends on the ability to integrate many systems, including balance. Studies of balance in infants show that even 5-month-olds begin to make appropriate movements to remain upright when sitting, although not always successfully (Bertenthal and Clifton, 1998). After further refinement, this balancing system will later be necessary for walking.

Thelen (1981) has also illustrated the role of early rhythmic, repetitive movements in the transition from the stepping reflex to real walking. As infants develop, their random and often jerky movements give way to smoother, more controlled ones. For example, all normal infants show stereotypic leg movements, such as kicking like a frog, when they are excited. These movements, mentioned in our story about Malcolm, appear around 1 month of age and peak at 5 to 6 months. Stereotypic leg movements are not reflexes, since a wide variety of stimuli can elicit them, but they are not really voluntary actions either. Infants lying on their backs begin to kick repetitively when they reach a certain level of excitement. Interestingly, infants do not learn to control their leg movements until after the rhythmic, repetitive patterns have appeared (Rovee-Collier and Gekoski, 1979). Thus, these rhythmic patterns seem to be an important way station between reflexes and learned motor behaviors.

The onset of walking depends partly on maturation of the muscles and nervous system and partly on practice. To investigate the role of practice, researchers have studied babies
in various cultures who have differing opportunities to walk. Many years ago Wayne and M. C. Dennis (1940) studied Hopi Indian babies who spent much of their first year bound to cradleboards. The babies were unbound from the boards to have their clothes changed, but otherwise they had little chance to move their legs. Toward the end of their first year, the Hopi infants were given the same freedom of movement that babies in a control group had had since birth. Surprisingly, babies in both groups learned to walk at about the same age. This and other early studies suggested that physical maturation exerted a greater influence over the onset of walking than practice did.

More recent studies have led to refinement of this conclusion. The Hopi babies were given complete freedom of movement toward the end of their first year. If their movement had continued to be restricted, their walking might well have been delayed. Consider the Ache people of Paraguay, who live in a rain forest that presents numerous dangers. Ache mothers carry their babies around for much of the day and keep young children within arm’s reach for several years. The children do not walk well until 2 years of age (Kaplan and Dove, 1987). Apparently, prolonged restriction of movement can delay the development of walking.

Conversely, certain practices can speed up the development of walking to some degree. For example, the Kipsigis people of Kenya begin to teach their babies to sit up, stand, and walk between their second and third month (Super, 1976). Kipsigis children start walking about three weeks earlier on average than American children do, although they aren’t advanced in acquiring motor skills for which they haven’t received any training. This suggests that practice specific to walking can make a difference in getting children to take their first steps.

Some insights into the nature of this practice come from some interesting experiments in which researchers regularly exercised the stepping reflex in groups of babies (André-Thomas and Dargassies, 1952; Zelazo, 1983). The stepping reflex did not decline as rapidly in these babies as it usually does, and the babies walked somewhat sooner than infants whose stepping reflex was not exercised. Both findings are consistent with the theory that reflexes are the raw materials out of which more advanced skills are built. But even with all their early practice, the experimental babies did not walk a great deal sooner than others. Maturation still plays a major role in the onset of walking. We do not recommend that parents exercise the stepping reflex in their infants. The time spent in this effort could be better used interacting with the baby in other ways.

**SENSING AND PERCEIVING THE WORLD**

When John and DeeDee brought Malcolm home from the hospital, the whole family, talking and smiling, crowded around to see him. How did the newborn perceive all this commotion? Could he see distinct faces peering into his? Could he hear different voices and tell speech from laughter? Could he smell soap on Momma Jo’s hands as she touched his cheek?

**Sensory Systems in the Newborn**

For years people have wondered how newborns like Malcolm experience the world. Since they respond reflexively to a variety of stimuli, their sensory systems must be working to some extent. But exactly what do babies experience when they see, hear, taste, smell, and touch things around them? And what causes them to direct their senses to one thing or another?

**Vision**

The pictures on page 142 illustrate how a mother’s face may look to 1-, 2-, and 3-month-old infants. These computer-created pictures are based on estimates of babies’ average visual acuity, the fineness of detail they are able to see. Even an adult with perfect eyesight has somewhat limited visual acuity. You can demonstrate this to yourself by looking at any

**Visual acuity:**

The degree to which one can see fineness of detail.
Determining How Clearly Babies See. How do researchers determine an infant’s visual acuity when babies cannot say what they see? One method is to use a preferential looking technique developed decades ago by R. L. Fantz (1958) based on young infants’ tendency to look at sharp contrasts between dark and light. If a solid gray card and a card with broad black and white stripes are placed in front of young infants, even newborns look longer at the striped card with its contrasting features. If the stripes are made progressively narrower and closer together, eventually babies no longer show a preference for the striped card. Presumably this is the point at which the limits of the infants’ visual acuity make the striped card look like the gray card.

Studies using preferential looking and a variety of other behavioral measures of visual acuity produce very similar results. Translating these results into the ratios used to describe adult acuity, Martin Banks and Phil Salapatek (1983) estimated that at 2 weeks of age a baby’s acuity is about 20/300: the child sees at 20 feet what an adult with normal vision can see at 300 feet. Five months later, a baby’s visual acuity has usually improved to about 20/100.

Infant visual acuity has also been studied by examining visual evoked potentials, the characteristic pattern of electrical activity that occurs in a baby’s brain in response to a new visual stimulus. This makes it possible to tell when a baby can detect the difference between two stimuli with differing fineness of detail. Studies measuring brain activity tend to give somewhat higher estimates of infants’ visual acuity than those based on behavioral measures, but they show the same general pattern of development (Atkinson and Braddick, 1989).

The reasons for young infants’ limited acuity are not yet well understood. Researchers once thought that the lenses of infants’ eyes did not adjust their focus in response to an object’s distance. More recent studies show that infants’ eyes do focus in response to distance from an object, though this adjustment does not reach an adult level until 4 months of age (Banks, 1980). Interestingly, for younger babies the limitations on visual acuity probably limit adjustment of focus, not the other way around (Banks and Salapatek, 1983). Low acuity reduces the ability to detect when adjustment is needed because it keeps the baby from seeing fine detail.

Young babies’ limited visual acuity does seem to be due to some other deficiency in the eyes themselves (Banks and Crowell, 1993). The optical quality of an infant’s eyes is quite good and allows a sharp image to be focused on the retina, the light-sensitive surface at the back of the eye. The limitation on acuity probably lies somewhere in the system that changes this image into neural signals, transmits them to the brain, and then...
mature at birth.

What causes infants’ visual acuity to improve gradually with age? Does this happen automatically with maturation? Although the visual system may be genetically predisposed to make the connections among brain cells that ultimately produce high visual acuity, appropriate visual experience also seems necessary to foster this development. Studies of cats, whose visual systems are very much like humans, show that visual experience with patterned stimuli is needed to produce the developments that lead to normal acuity. If kittens are raised in the dark, or see only diffused light, they do not develop normal acuity. This result has been related to the development of acuity in infants with visual defects (Held, 1978). (Applying Research Findings on page 144 provides more information on the role of visual experience in the development of vision.)

Can Infants See Colors? Determining whether young infants see colors is difficult because of the need to distinguish between color (determined by the wavelength of light) and brightness (determined by the light’s intensity). When you see the difference between a red car and a blue car in a color movie, you are doing so on the basis of color. When you see a difference between the same two cars in a black-and-white movie, you are doing so on the basis of brightness. Thus, when babies who are shown two different colors look longer at one than the other, researchers have to make sure that this visual preference is based on color, not relative brightness.

By using two different colors of the same intensity, researchers have been able to show that babies cannot reliably discriminate on the basis of color alone until 7 to 8 weeks of age (Kellman and Banks, 1998). By 3 to 4 months, babies are thought to possess all of an adult’s color vision abilities (Bornstein, 1978).

Hearing

It has long been known that pregnant women often feel their babies move seconds after a loud noise (Forbes and Forbes, 1927). Studies measuring fetal heart rate have shown this sensitivity to sound in fetuses 26 to 28 weeks old (Kisilevsky, Muir, and Low, 1992). In fact, hearing prior to birth is sufficiently well developed that newborns in one study showed signs of recognizing the sound characteristics of a passage from Dr. Seuss’s The Cat in the Hat that their mothers had read out loud twice a day for six weeks prior to their scheduled delivery (DeCasper and Spence, 1986).

To measure the sensitivity of a baby’s hearing, researchers monitor eye blinks, changes in heart rate, and changes in the brain’s electrical activity as sounds are presented. They have found that for young infants to hear a noise, it must be ten to twenty decibels louder than it has to be for adults to hear it (Sinnott, Pisoni, and Ashlin, 1984). (Loud voices are about twenty decibels louder than average speaking voices.) A child’s sensitivity to sound gradually improves with age, but it takes twelve to thirteen years to become equal to an adult’s (Maurer and Maurer, 1988). A baby’s ability to detect the direction of a sound is also present very early and improves with age. By 18 months this skill reaches an adult level of accuracy (Morrongiello and Rocca, 1990).

Another topic of interest to researchers who study the development of babies’ hearing is the infants’ ability to discriminate among sounds. How different must two sounds be for a baby to notice the difference between them? One approach to answering this question is to take advantage of infants’ tendency to become habituated to repeated stimuli.
EARLY TREATMENT OF HEARING AND VISION IMPAIRMENTS

Many babies are born each year with impaired hearing or vision caused by either genetic defects or factors in the prenatal environment. About one in a thousand are born with severe loss of hearing (Downs, 1986), and serious visual impairments occur at a similar rate. Today doctors try to treat sensory disorders in infancy because later treatment does not work as well.

One reason treatment after infancy is often unsuccessful is that there appear to be critical periods when sensory input is needed for the development of vision and hearing (Ruben and Nelson, 1993). When baby animals are completely deprived of certain sensory stimulation, they do not develop a normally functioning sensory system, even if they later receive normal sensory input. Similarly, abnormal sensory input, such as blurred vision or unclear sounds, can also cause sensory development to go awry.

There are several possible explanations for these developmental patterns. The parts of the nervous system that aren’t being stimulated may simply atrophy, or these parts may be recruited for other nervous system uses. It is also possible that children learn to ignore degraded sensory data; such as images from a poorly focused eye, and find it hard to redirect attention if normal sensory stimulation is later restored.

Virtually all experts agree that enhanced auditory stimulation should begin as early as possible in hearing-impaired babies to try to prevent abnormal development of basic auditory connections in the brain (Shannon, 1989). Infants with up to a 110-decibel hearing loss can benefit from receiving enhanced auditory stimulation via powerful hearing aids (Brookroyd et al., 1986). (To a person with a 110-decibel hearing loss, noise that sounds very loud to someone with normal hearing is just barely detectable.) Hearing aids are used even if the baby shows no signs of hearing the amplified sounds, because some children develop responsiveness to sound later.

Early stimulation is equally important to many aspects of vision. As already mentioned, early stimulation is important to the development of binocular depth perception. Lack of appropriate early visual stimulation can also cause a condition called amblyopia, or poor vision, usually in just one eye, that cannot be corrected with glasses. Amblyopia can be caused by abnormalities in a baby’s eye that are not corrected early, such as cloudiness of the lens, a severely drooping eyelid, or extreme refractive errors (errors in the way light is focused on the retina). Many of these problems can be corrected in infancy with surgery or glasses. However, if they are left uncorrected until later, normal vision can no longer be restored (King, 1993).

Amblyopia is frequently caused by strabismus, or misalignment of the eyes. Because information from the two eyes doesn’t correspond, input from one of them is suppressed in the nervous system. This suppression seems to prevent the eye from developing normal acuity. The treatment for this problem is to place a patch over the good eye to force the other eye to develop normally (Ruben and Nelson, 1993). This treatment must be monitored carefully or amblyopia can also arise in the patched eye due to insufficient stimulation. When properly carried out, however, and begun early enough, this treatment usually leads to normal vision in both eyes.

For developmentalists, it is fascinating to see how important early experience is to maintaining and refining sensory systems, even though their basic structure is specified by genes. Appropriate early experience may in fact be critical to the normal development of a wide range of other human capabilities on which the impact of early experience is harder to measure.

In habituation studies of hearing, researchers repeatedly present one sound until the baby apparently loses interest in it. Then they change the sound. If the baby responds with renewed attention, they conclude that he or she has detected the change. Using this method, investigators have found that 6-month-olds can distinguish between sounds that differ in loudness by as little as ten decibels (Aslin, Pisoni, and Jusczyk, 1983). By the time they are 5 to 8 months old, babies are also quite good at detecting small changes in pitch (Olsho et al., 1982). Infants are sensitive to a broad range of pitches and hear high frequencies better than lower frequencies. This may be one reason why adults in many cultures use high-pitched voices when talking to infants.

Young infants discriminate among speech sounds even better than among pitches. Peter Fimas and his colleagues (Fimas, Singelton, and Jusczyk, 1971) found that
discriminate among sounds that fall between /ba/ and /pa/ in the same way adults do. When a computer-generated continuum of sounds between /ba/ and /pa/ is presented to adults, they do not hear it as a large number of different sounds. Instead, they perceive all the sounds as either /ba/ or /pa/, with the dividing line between them falling at a consistent point in the continuum. Perceiving stimuli that actually vary along a continuum as belonging instead to distinct categories is called categorical perception (Liberman et al., 1957). Infants display categorical perception when listening to sounds between /ba/ and /pa/, making a distinction at the same point in the continuum as adults do. Babies show categorical perception for other speech sounds as well, suggesting that the basic sensory system needed to learn language is probably genetically given, even though speech perception changes with development and depends partly on experience (Eimas, 1985).

**Smell and Taste**

Young infants are very sensitive to odors. They respond to various odors placed on cotton swabs and held beneath their noses with facial expressions and body movements similar to those of adults. For instance, infants respond positively to the odor of a banana, somewhat negatively to fishy odors, and very negatively to the odor of rotten eggs (Steiner, 1979). Babies can also make fine discriminations among odors, as shown in habituation studies involving very similar smells. In one such study, newborns discriminated between a perfume used by their mothers and another perfume (Schleidt and Genzel, 1990). In another study, they actually discriminated between the smell of their own mothers’ nursing pads and those of other women (MacFarlane, 1975).

As for taste, researchers have found that even young infants can discriminate among sweet, bitter, and salty tastes (Ganchrow, Steiner, and Daher, 1983). Newborns can also discriminate between the sweetness of a fairly weak sugar solution and the taste of plain water (Engen, Lipsitt, and Peck, 1974). The fact that young infants can discriminate among tastes does not necessarily mean that their sensory system for taste is fully mature. From studying the tongues of premature and full-term babies, researchers know that receptors for taste—the taste buds—are present throughout the mouth prior to birth, and that they become more localized on the tongue around the normal time of delivery. Although the taste buds are relatively mature at birth, the nervous system initially processes taste information in an inefficient way, as in its processing of visual information. Nervous system development related to taste is quite rapid, however, and the initial immaturity does not last long.

**Organization of Infant Sensory Behavior**

Newborns use their sensory capacities in an organized way. When awake and alert, babies visually scan their environment rather than simply staring straight ahead. If they hear a sound, they direct their gaze toward it. If no sound attracts them, they scan with their eyes until they find an edge (a border of light-dark contrast). Having found an edge, they scan the zone of the edge for some time, passing back and forth over it.

As babies grow older, this pattern of visual scanning changes. For example, they begin to look at the internal features of a stimulus rather than its borders. Their sensory behavior remains organized, however. The organization of sensory behavior guarantees that infants will attend to and learn a great deal about people, since people are a rich source of the kinds of auditory and visual stimulation that attract babies’ attention.

**Development of Perceptual Abilities**

**Perception** is the process by which the brain interprets information from the senses, giving it order and meaning. The fact that Malcolm can see lines and colors (sensory capabilities) does not mean that he interprets them as you and I do (a perceptual skill). For instance, when Malcolm looks at the faces of his family clustered around him, can he tell that some
are closer than others? Or when Dee Dee turns her back to him, does Malcolm know he is still viewing the same head as before, just from a different angle? These questions focus on visual perception in infants.

**Depth and Distance Perception**

When can a baby estimate how far away something is? Eleanor Gibson and Richard Walk (1960) provided a partial answer through a clever experiment using an apparatus called the *visual cliff*, shown in Figure 4.5. To construct the visual cliff, a sheet of thick glass, lighted from below to reduce reflection, is placed over a checkerboard platform with a dropoff in the middle. On the shallow side of the dropoff, the checkerboard surface is directly below the glass; on the deep side, it is several feet below. Gibson and Walk observed whether 6- to 7-month-olds, who had started to crawl, would cross the visual cliff. They found that the babies preferred the shallow side and that this preference increased with age. Babies who can crawl can also apparently perceive depth.

Joseph Campos and his colleagues (Campos et al., 1978) tested even younger babies for depth perception using Gibson and Walk’s apparatus. They placed the infants facedown on each side while measuring their physiological responses, such as heart rate. Babies only 2 months old could distinguish a difference between the sides. However, fear of the deep side was only apparent in babies who could crawl. Thus, direct experience with edges, drops, and distances probably contributes to a fear of heights in humans (Campos, Bertenthal, and Kermoian, 1992).

Psychologists have long been interested in how people are able to perceive depth. The images projected onto the retina are in two dimensions, but our brains register them as three-dimensional rather than flat. Visual cues that enable depth perception can be divided into three types: *kinetic cues*, *binocular cues*, and *pictorial cues* (Yonas and Granrud, 1985). Developmentalists are interested in when children begin to use each of these types of cues and when they ultimately organize them to obtain an adultlike perception of depth.

**Kinetic depth cues.** The first visual depth cues infants become able to use are *kinetic depth cues*, in which information about depth and distance is carried in the motion of objects. Kinetic depth cues are monocular, meaning that only one eye is needed to perceive them. One such cue is the apparent expansion in size of approaching objects. Albert Yonas and his colleagues have shown that 3-month-old babies consistently blink and often move their heads backward in response to a rapidly expanding shape projected on a screen in front of them. They respond this way more frequently to shapes that appear to be...
make this distinction between apparently dangerous and nondangerous approaching objects, though they do blink more often in response to shapes that are expanding than to shapes that are contracting (Yonas and Granrud, 1985).

Another kinetic depth cue, called accretion-deletion, is produced by the gradual disappearance and reappearance of surfaces behind a moving object. For example, if a person walks between you and a patterned curtain, one way you are able to tell the person is in front of the curtain is that portions of the pattern are temporarily blocked from view as the person walks past. The portions that are blocked are constantly changing, going out of sight behind the person (deletion) and then coming back into view (accretion). Infants are able to use accretion-deletion to distinguish edges and shapes by the time they are about 3 months old (Kaufmann-Hayoz, Kaufmann, and Stucki, 1986). However, they do not consistently use accretion-deletion to judge depth until 5 to 7 months of age; this finding comes from studies in which infants reached for sets of dots that appeared to be moving in front of a background of other dots on a video screen (Granrud et al., 1985).

**Binocular depth cues.** The second type of depth cues to become useful to infants is **binocular depth cues**, which result from the fact that visual information reaches the brain from two eyes rather than one. One binocular depth cue is **convergence**, which occurs when the eyes turn inward to focus on a nearby object. In Figure 4.6 diagram A shows two eyes pointing toward a distant object. Notice that the center of each eye is facing almost straight ahead. Now look at diagram B, which shows two eyes focused on an object that is close to them. You can see that each eye must point inward to accomplish this. The closer an object is, the more the eyes must angle inward. Your brain uses this degree of convergence to help estimate distance.

Richard Aslin (1977) measured infants' degree of convergence as they watched objects that were moved closer and farther away. He found that 1-month-old babies converged and diverged their eyes in the appropriate directions, but that they were not good at locating the precise angle for a given distance. In contrast, 2- to 3-month-old babies were fairly accurate in the angles at which they converged their eyes. By age 5 months, infants are able to use convergence as an effective cue for determining distance when they reach for something (Von Hofsten, 1977).

Another binocular depth cue, called **retinal disparity**, arises because the eyes are set apart from each other and receive slightly different images of the world. Combining the information from the two images allows the brain to interpret the scene as three-dimensional, just as combining two slightly different images produces a three-dimensional image in a Viewmaster or an old-fashioned stereoscope. Infants show signs of sensitivity to retinal disparity by age 3 months (Atkinson and Braddick, 1989), and by 5 months retinal disparity becomes an efficient depth cue for detecting an approaching object and for guiding reaching (Gordon and Yonas, 1976; Granrud, 1986).

**Figure 4.6**

**INFORMATION DISTANCE FROM CONVERGENCE**

(A) When you object, the straight line joining a nearer object rotates.
Strabismus: A condition in which the eyes are misaligned and do not function together.

Pictorial depth cues: Visual cues that can be used to depict depth and distance in two-dimensional pictures.

A sensitive period exists during which experience has the greatest influence on the development of the ability to use binocular depth cues. Evidence for this comes from studying children born with their eyes misaligned. These children are often called crossed-eyed or walled-eyed, but the medical term for their condition is strabismus. Children with strabismus get little practice coordinating their eyes in a normal way. If the condition is not corrected, these children do not receive the visual experience needed to produce connections among neurons that respond to binocular information. The result is deficient binocular depth perception. Fortunately, surgeons can correct the condition by adjusting the length of the eye muscles. Richard Aslin and Martin Banks (1978) discovered that the timing of this operation affected the later quality of binocular depth perception. People who had the operation in early infancy had binocular vision comparable to that of people born without strabismus. However, when the surgery was performed after 1 year of age, sensitivity to binocular information declined substantially. Apparently, the first year of life is a sensitive period for the development of binocular depth perception.

The example of children with strabismus shows that the development of binocular depth perception requires both maturation of an appropriate system in the brain and appropriate visual experience. In children with uncorrected strabismus, appropriate connections within the brain are never made because the children lack the visual experience needed to guide this developmental process. Moreover, not only does visual experience shape brain development, but the reverse is also true. Infants who are born without the brain cells that respond to binocular information later develop strabismus despite having normal eye muscles. This happens because their visual system does not tell them when their eyes are properly aligned (Atkinson and Braddick, 1989). Brain development and visual experience influence each other in a circular way.

Pictorial depth cues. The last depth cues infants become able to use are pictorial depth cues, which are the cues used to depict depth in two-dimensional pictures. Like kinetic depth cues, they are monocular. In contrast to the kinetic cues, they are static cues, meaning they do not depend on motion for their effectiveness.

One pictorial depth cue is linear perspective—the fact that parallel lines seem to converge as they extend away from the viewer. Because of linear perspective, a picture of a rectangular window viewed from an angle will be trapezoidal in shape, not rectangular. When people look at a window that is actually shaped like a trapezoid (see Figure 4.7), their perception of it depends on whether they look at it with one eye or two. Viewed with two eyes, it appears as what it is—an abnormal window in the shape of a trapezoid.

Figure 4.7 TRAPEZOIDAL WINDOW

When adults look at a window frame shaped like a trapezoid with both eyes open, they see it as a trapezoid. When they look at it with one eye closed, it appears rectangular and slanted because of linear perspective. Infants become sensitive to linear perspective by 7 months.
Viewed with only one eye, it appears to be a normal rectangular window that is slanting away from the viewer (Ames, 1951). This depth effect occurs because one-eyed viewers use linear perspective to interpret what they see.

Yonas and his colleagues investigated when babies begin to use linear perspective as a depth cue by letting infants look at a trapezoidal window with a patch over one eye (Yonas, Cleaves, and Pettersen, 1978). They found that 5-month-olds reached equally often toward each end of the window, but 7-month-olds reached more often toward the long end of the window—the end that would appear closer if they were using linear perspective as a depth cue. This finding suggests that infants begin to use this cue sometime between 5 and 7 months of age.

Yonas and his colleagues have studied the onset of sensitivity to a number of other monocular depth cues. One is interposition—when objects appear to overlap, the one that is partly covered is perceived as farther away (see Figure 4.8). Another is shading, the difference in shadows produced by protrusions and depressions in a surface. Babies become sensitive to these depth cues between 5 and 7 months of age, the same age at which they become sensitive to linear perspective (Yonas and Owsley, 1987). The simultaneous onset of sensitivity to several monocular depth cues suggests that brain maturation plays a significant role in their development.

**Size and Shape Constancy**

As Christine walks toward Mikey to lift him out of his crib, her image on his retina grows larger. Does Mikey think his mother is getting bigger? When she hands Mikey a bottle and he tips it up to drink, does he think that the bottle changes shape as he views it from different angles?

Thirteen-month-old Mikey makes neither of these mistakes because he possesses perceptual skills called size and shape constancy. **Size constancy** is the perception of an object as constant in size, even though its image on the retina grows larger or smaller as the object is viewed from different distances. Similarly, **shape constancy** is the perception of an object as constant in shape, even though its image on the retina changes shape when the object is viewed from different angles. Both these processes are crucial to perceiving the world as relatively stable.

Several studies indicate that size constancy is present even in newborns. In one study, newborns were repeatedly shown either a large or a small cube at various distances, so that actual size stayed the same, but the size of the retinal image varied. Then they were shown a large cube and a small cube placed at different distances so that the retinal image of both cubes was the same size. They consistently looked longer at the cube that was different in actual size from the one they had seen before (Slater, Mattock, and Brown, 1990). In another study, Carl Granrud (1987) demonstrated that newborns habituated more quickly to a series of objects of the same physical size placed at varying distances than to a series of objects that varied in physical size. Both studies suggest that the babies recognized that actual size remained constant even when retinal image size changed.

There is also evidence of shape constancy in newborns. Slater (1989) conducted a study in which newborns were shown either squares or trapezoids displayed at varying angles, as shown in Figure 4.9. (The retinal image of some of the squares would be trapezoidal, and the retinal image of some of the trapezoids would be square.) The babies were then shown a square and a trapezoid together, both presented at an angle they had not previously seen. Even though they had not seen either specific stimulus before, the babies showed a preference for looking at the shape that was new to them—the babies who had been shown squares preferred the trapezoid, and the babies who had been shown trapezoids preferred the square. A study using a similar procedure found clear evidence of shape constancy in 3-month-olds (Caron, Caron, and Carlson, 1979).

As with less complex visual skills, newborns may have tendencies toward shape and size constancy that become more efficient and stable by 3 to 5 months. In any case, perceiving objects as relatively stable and unchanging is an important step toward an organized perception of the physical world. Understanding that the world consists of particular objects and people begins with the perception of constancies.
Perception of Faces

Face recognition is a complex perceptual task that develops in a series of steps reflecting the influence of both brain development and experience (Johnson, 1998). Newborns show a tendency to track a moving facelike pattern farther than a scrambled or blank face, a preference that declines sharply between 4 and 6 weeks of age. However, newborns do not look longer at static human faces than at other equally complex figures, showing instead a preference for abstract high-contrast patterns. It is not until 2 to 3 months of age that babies show a preference for looking at static facelike patterns.

Recognition of specific faces also develops in a series of steps. There is some evidence that in the first week of life babies can recognize their mothers' faces (Pascalis et al., 1995). By 3 months of age infants can recognize photographs of their mothers and prefer pictures of them to pictures of strangers (Barrera and Maurer, 1981). By 5 months infants can remember the faces of strangers (Olson and Sherman, 1983), a task that requires very subtle distinctions.

At first glance, these findings seem somewhat confusing. If newborns show a preference for tracking moving faces and quickly become able to recognize their mothers' faces, why does it take several months for more general face perception skills to develop? The answer seems to be that newborns and older infants are using different visual information and different neurological processes to respond to faces.

True face recognition depends on attention to internal facial features, such as eyes, nose, and mouth. Newborns rely heavily on outline shape in perceiving objects—and presumably also faces. They can discriminate simple shapes, such as
1978). As we discussed earlier, when 1-month-olds look at faces, they tend to look at the outer edges, whereas 2-month-olds scan within the face and spend time looking at internal features (Maurer and Salapatek, 1976; see Figure 4.10). Very young infants appear to use such general features as shape of the head and hair, rather than internal facial features, to recognize their mothers' faces.

Infants' early recognition of their mothers' faces seems to be based on a general visual pattern recognition ability that does not involve the cerebral cortex (Johnson, 1997). Likewise, their visual tracking of moving faces involves activity in lower regions of the brain, similar in some ways to newborn chicks' built-in tendency to follow adult chickens. In contrast, mature face perception depends on activity in specific areas of the cerebral cortex, which become functional in the first few months of life. The development of these areas depends in part on experience looking at faces, and infants' early tendency to track moving faces helps to provide that experience.

**FIRST ADAPTATIONS IN CONTEXT**

Newborns come into the world prepared in many ways for the developmental tasks they face. Their biology prepares them with built-in ways to respond to their environment, in the form of reflexes. They are prepared to detect contingencies—connections between their actions and changes in the environment. They have a variety of sensory capacities, and they are preadapted to select and attend to certain kinds of stimuli, such as light-dark contrasts and the sound of a human voice. These capacities serve them well as they explore the properties of objects and deepen their understanding of the physical world. Their preadaptations also provide them with a basis for social interaction by directing their attention to human faces and voices.

In turn, the environment provides infants with experiences that help to shape the development of their brains, their motor skills, their perceptual abilities, and the specific behaviors they learn. Other people, particularly caregivers, are the most complex, contingently responsive objects in the infant's world. Infants are biased to attend to and direct behavior toward others, who likewise are disposed to respond to an infant's behavior. Over time, the interactions thus set in motion form a foundation for the development of social relationships.
During the first year of life, a major task that babies face is learning how to control their environment. By learning the connections between their own behaviors and subsequent reinforcements, infants gradually discover the things they can do to get what they want. In the process, the helpless newborn who merely responds reflexively to stimuli is transformed into an agent who actively controls many aspects of his or her world.

Chapter Summary

Introduction
Newborns come preadapted to the tasks of learning about their environments and forming social relationships. Their built-in capacities include:

1. reflexes,
2. learning ability, and
3. basic sensory and perceptual skills.

The major themes of the chapter are:

- Heredity and the environment work jointly to guide the course of development.
- Infants’ initial skills provide the seeds for development of more complex and flexible skills by the end of the first year.

Early Brain Development
In the first year of life a baby’s brain grows rapidly and changes in structure and function.
Lower areas of the brain are more mature than the cerebral cortex at birth. After birth the cerebral cortex continues to develop in several ways:

1. Neurons increase in size and complexity.
2. Myelination occurs.
3. The number of synapses increases rapidly.
4. Connections between the cerebral cortex and other regions of the brain increase.
5. Areas of the cortex take on specialized functions.

Brain development helps explain many changes in infant competencies, but development of the brain itself is also shaped by infants’ experiences.

Infant States
Developmentalists divide the infant’s rest-activity cycle into six states: quiet sleep, active sleep, awake-and-quiet, awake-and-active, fussing, and crying. The state an infant is in determines how the environment is perceived and acted upon.

Time spent in a sleep state and the pattern of sleep change during infancy, influenced by both brain maturation and cultural practices.

Newborn reflexes include:

- some with clear survival value, such as the rooting and sucking reflexes;
- some that may once have had survival value, such as the Moro and grasping reflexes; and
- some that later become part of complex voluntary actions, such as the grasping and stepping reflexes.

Infant Learning
One of the first signs that infants can retain information about their environments is habituation to a repeatedly presented stimulus and dishabituation in response to a new stimulus.

In associative learning, infants learn that certain events tend to go together.

One kind of associative learning is classical conditioning. It is difficult to classically condition newborns, but the process becomes easier after about 3 months of age. Classical conditioning cannot explain the emergence of new behaviors.

Another form of associative learning is instrumental or operant conditioning. Even newborns can be instrumentally conditioned.

Imitative learning is a way of rapidly acquiring new behaviors. The ability to imitate others quickly and without error develops gradually over the first 18 months of life.

Babies have a genetic predisposition, or preparedness, to acquire certain behaviors. Preparedness includes a pre-