At the beginning of these experiments, I had sat myself down in the grass amongst the ducklings and, in order to make them follow me, had dragged myself, sitting, away from them. . . . The ducklings, in contrast to the greylag goslings, were most demanding charges, for, imagine a two-hour walk with such children—all the time squatting low and quacking without interruption! In the interests of science I submitted myself literally for hours on end to this ordeal.

—Lorenz, 1952, p. 42

The initial phase, that of protest, may begin immediately or may be delayed; it lasts from a few hours to a week or more. During it the young child appears acutely distressed at having lost his mother and seeks to recapture her by the full exercise of his limited resources. He will often cry loudly, shake his cot, throw himself about, and look eagerly towards any sight or sound which might prove to be his missing mother. . . . During the phase of despair, which succeeds protest, the child’s preoccupation with his missing mother is still evident, though his behavior suggests increasing hopelessness. The active physical movements diminish or come to an end, and he may cry monotonously or intermittently. He is withdrawn and inactive, makes no demands on people in the environment, and appears to be in a state of deep mourning.

—Bowlby, 1969, p. 27

Adenine-Thymine
Guanine-Cytosine
Adenine-Thymine
Cytosine-Guanine

—Genetic Code
Developmental psychologists have not taken Shakespeare’s advice, “Neither a borrower nor a lender be.” Some of the most fruitful ideas about development have been borrowed from other areas of psychology and even other sciences. Developmental psychology has borrowed heavily from biology for clues about where to look for connections between body and mind and behavior. In this chapter, we look at several biological perspectives on development that are heavily influencing developmental psychology—ethological theory (including evolutionary psychology), developmental neuroscience, and genetics.

We focus on ethology because of its long history of contributions to developmental psychology, especially infants’ attachment to their parents, but give careful attention to recent major contributions from the other two areas. Developmental neuroscience and genetics probably are the fastest-growing areas within developmental psychology currently and are changing the way developmentalists think about how nature and nurture co-construct development. Much of the progress is due to new tools for imaging the brain and analyzing genes, but also to new theoretical models that capture the complex interactions of various levels of biology, from cells to brain organization to behavior (and back again).

This chapter first describes ethology, including evolutionary psychology. Next is an account of developmental neuroscience, followed by genetics. The chapter ends with models that integrate genes, brain, and experience.

Ethology

**Ethology** is the study of the evolutionarily significant behaviors of a species in its natural surroundings. As a subdiscipline of zoology, it looks at the biological and evolutionary blueprints for animal behavior. Ethology places humans into a broad context: the animal world and our distant past. It is humbling to contemplate the fact that there are more species of insects in a square kilometer of Brazilian forest than there are species of primates in the world (Wilson, 1975). The English geneticist Haldane, when asked about the nature of God, is said to have remarked that he displays “an inordinate fondness for beetles” (as quoted in Hutchinson, 1959, p. 146). The human species is just one small part of the huge, evolving animal kingdom of approximately 3 million to 10 million species.

This section on ethology begins with a history followed by a general orientation. Then come sections on the main contributions of ethology.
to developmental psychology, mechanisms of development, the theory’s position on developmental issues, applications, an evaluation, and contemporary research.

History of the Theory

Whoever achieves understanding of the baboon will do more for metaphysics than Locke did, which is to say he will do more for philosophy in general, including the problem of knowledge.

—Charles Darwin

Ethology is linked to the German zoologists of the 1800s who studied innate behaviors scientifically. Darwin’s painstaking observations of fossils and variations in plant and animal life added an evolutionary perspective to the field. He, along with Alfred Wallace, concluded that nature ruthlessly selects certain characteristics because they lead to survival: “What a book a devil’s chaplain might write on the clumsy, wasteful, blundering, low, and horribly cruel works of nature” (Darwin, quoted in Shapley, Rapport, & Wright, 1965, p. 446). As a result of this selective force, species changed and sometimes differentiated into subspecies. Thus, many animals, including humans, are related through common ancestors. Darwin proposed that intelligence and other behaviors, as well as physical structures, were products of evolution. If they increased the chances of survival to the age of reproduction, they were retained; if they did not, they disappeared. Darwin’s claim of a common ancestry of humans and other primates was not received well in Victorian England: Montagu (1973) related an anecdote about a shocked wife of an English bishop. She said that she certainly hoped that the theory was false, but if it were true, that not many people would find out about it!

Darwin’s careful observing and cataloging of plants and animals was imitated by ethologists years later. Just as he carefully described animal and plant life, Darwin also described his own infants’ behavior, as in the following excerpt on fears:

Before the present one was 4 months old I had been accustomed to make close to him many strange and loud noises, which were all taken as excellent jokes, but at this period I one day made a loud snoring noise which I had never done before; he instantly looked grave and then burst out crying. . . . May we not suspect that the vague but very real fears of children, which are quite independent of experience, are the inherited effects of real dangers and abject superstitions during ancient savage times?

(1877, p. 289)
Ethology as a distinct discipline began in the 1930s with the European zoologists Konrad Lorenz and Niko Tinbergen. They developed, often in collaboration, many of the key concepts discussed in the next section. Their observations of species as diverse as ducklings, butterflies, and stickleback fish gave scientific meaning to the sometimes mystical term “instinct.” Many of Lorenz’s observations were of wild animals that wandered freely in and around his home. Lorenz and Tinbergen’s work was honored with the Nobel Prize in medicine or physiology in 1973, which they shared with another ethologist, Karl von Frisch.

Developmental psychology was receptive to ethology because developmentalists have a tradition of naturalistic observations of children and consideration of the biological basis of development. Many developmentalists continued to conduct natural observations of children even through psychology’s behaviorist years and welcomed ethology as a way to correct the extreme environmentalism of learning theory. The most important figure to bring ethology to the attention of developmental psychologists was John Bowlby. His turning from a Freudian to an ethological account of infant-caretaker social attachment in the 1950s in England laid the groundwork for subsequent research in this area in both Europe and North America. (His work is described later.)

The contemporary study of animal behavior has many subfields, such as comparative psychology, behavioral ecology, and evolutionary biology. In general, this work is more empirical and experimental and less observational, speculative, and theoretical than the earlier European classical ethological studies. The majority of the approaches favor a reductionist approach and study cells, neural connections, and hormones rather than the behaviors of the whole organism in its ecological niche.

Ethology was soon joined by sociobiology, defined by its main spokesman, E. O. Wilson, as the “study of the biological basis of all social behavior” (1975, p. 4). Although ethology and sociobiology overlap a great deal, sociobiology focuses on population genetics and kin selection. Because close relatives share most of one’s genes, people can pass on their genes not only by reproducing but also by furthering the survival of the genes of kin through altruistic behavior. Altruistic behavior may endanger oneself but benefit the species. Sociobiology minimally influenced developmental psychology, though there was some interest in such topics as reproductive patterns and parenting.

Evolutionary psychology, which arose after some of the criticisms of sociobiology as deterministic, reductionist, and socially conservative, has had more impact on developmental psychology. This field combines evolutionary biology, paleoanthropology, and cognitive psychology.
(Tooby & Cosmides, 2005). Evolutionary psychologists use primatology, archaeological data, cultural anthropology, neuroimaging, genetic analyses, and data on contemporary human universals to discover how the mind has been shaped by natural selection to solve problems of adaptation faced by our hunting-and-gathering ancestors.

A developmental perspective is important for all these approaches: “The gap between molecular biology and natural selection will be filled by developmental analysis of the nervous system, behavior, and psychology” (Gottlieb, 1979, p. 169). Today, a discipline called evolutionary developmental biology (or “evo-devo”) compares the developmental processes of various animals to determine how developmental processes evolved.

**General Orientation to the Theory**

Ethology is characterized by four basic concepts: (1) species-specific innate behavior, (2) an evolutionary perspective, (3) learning predispositions, and (4) ethological methodology.

**Species-Specific Innate Behavior**

Ethologists focus on behaviors that, like organs of the body, were considered primarily innate, adaptive, and essentially the same in all members of a species. Of course, any “innate” behavior is influenced by the environment, because it has to be developed within prenatal and postnatal environments. Ethologists consider a behavior primarily innate if it has these four characteristics (Cairns, 1979):

1. It is stereotyped in its form (that is, has an unvarying sequence of actions) across individuals in a species.
2. It is present without relevant previous experience that could have allowed it to be learned.
3. It is universal for the species (that is, found in all members).
4. It is relatively unchanged as a result of experience and learning after it is established.

For example, in certain songbirds, the same song appears in all members of the species at sexual maturity, even if they have never heard the song sung by other members of the species. As this example illustrates, some innate behaviors are not present at birth but appear later as a result of physical maturation. In contrast to primarily innate behaviors, learned behaviors vary in form from individual to individual, require relevant previous experience, usually vary in their occurrence among members of the species, and change as a result of subsequent experience.
Innate behaviors are termed *species-specific*, which means they occur among all members of the species or at least a particular subgroup, such as all the males or all the young. If another species also has the behavior, two inferences are possible. One is that the two species are related, perhaps having split into separate lines at some point in their evolution. Or, the behavior may have evolved independently in the two species, perhaps because they had similar physical environments and needs. For example, in many species, the young cling to the mother’s fur—a necessity for survival if infants must travel with their mothers as they move throughout an area in search of food or flee from predators. Also, the same behavior may have different meanings in the two species. An example is tail wagging in dogs and cats, thought to indicate contentment in dogs and conflict in cats.

Two types of innate behaviors are *reflexes* (wired-in responses to stimuli) and *fixed action patterns*. Examples of human infant reflexes are grasping a finger placed in the hand, spreading the toes when the bottom of the foot is stroked, and turning toward a nipple when it brushes the cheek. Any long-haired parent would agree that infants are particularly likely to grasp hair, especially during feeding. Ethologists speculate that this reflex originally served to facilitate clinging to the mother’s fur. Many such reflexes are quite strong. A premature baby can grasp a clothesline and support its own weight, for instance. This ability is later lost. More complex reflexes are coordinated swimming, crawling, and walking movements when the body’s weight is supported in newborns or young infants.

A fixed action pattern is a complex innate behavior that promotes the survival of the individual and thus the species. It is a “genetically programmed sequence of coordinated motor actions” (Hess, 1970, p. 7) that arises from specific inherited mechanisms in the central nervous system. Without being taught, squirrels bury nuts, birds perform courtship “dances,” spiders spin webs, and stickleback fish fight to protect their territory. Fixed action patterns can become very elaborate, as when the male bowerbird spends hours building a love nest decorated with flowers, fruit, shells, and colorful beetles to attract a mate. He adjusts a twig here, adds a flower there, and seemingly stops to admire his work from time to time. Fixed action patterns involving social behavior are of particular interest. The adaptive value of fixed action patterns lies in the fact that they often end in eating, mating, or avoiding predators.

A fixed action pattern is elicited by a *sign stimulus*—a particular stimulus whose presence automatically releases a particular fixed action pattern. Lorenz (1966) likened this process to a key opening a lock. For example, the red belly of a male stickleback fish venturing into another
A decoy that only vaguely resembles the stickleback in shape, but is red on its lower half, elicits this fixed action pattern, whereas an accurately shaped decoy without the red area usually does not (Tinbergen, 1951). Thus, the sign stimulus is specific, and sometimes it must be in a particular orientation or position. Tinbergen (1958) discovered this particular sign stimulus when he noticed that his sticklebacks in an aquarium near a window facing a street would become agitated at a certain time of the day. He eventually realized that a red mail truck passed by at that time, a stimulus that approximated the natural sign stimulus. A further example of the specificity of the sign stimulus is that a hen will not rescue a distressed, flailing chick she can see under a glass bell but cannot hear. However, she will rescue the chick immediately if she can hear the distress cries even if she cannot see it (Brückner, 1933). When people fish, they sometimes use lures that exaggerate the natural prey (the sign stimuli) of larger fish.

Innate reflexes and fixed action patterns enhance young infants’ survival by allowing them to seek food and hide from predators on their own or binding them to an adult caretaker by crying, grasping, sucking, or smiling. This fit between the organism’s needs and its innate behaviors is the product of a long evolutionary history. It is not always easy to infer the adaptive value of a characteristic, however. It was once claimed that flamingos are pink because that makes it difficult for predators to see them against the sunset (Thayer, 1909).

Despite the focus on innate behaviors, ethologists think that learning is important. Most behavior is viewed as an interweaving of innate and learned components. A raven innately knows how to build a nest, but through trial and error learns that broken glass and pieces of ice are less suitable than twigs for this purpose (Eibl-Eibesfeldt, 1975). An innate skill can easily be adapted to new situations, as when English titmice quickly learned how to use innate gnawing behaviors to open milk bottles.

Waddington (1957) proposed an influential model of how biological regulating mechanisms constrain the course of development while allowing for the modification of development by the environment. He presented development as a ball rolling down an “epigenetic landscape.” As the ball descends, this landscape becomes increasingly furrowed by valleys that greatly restrict the sideways movement of the ball. Slight perturbations from the developmental pathway can be corrected later through a “self-righting tendency,” and the ball returns to its earlier groove. Thus, the general course of development is set, but some variation is possible because of particular environmental events.
Evolutionary Perspective ▶ As Samuel Butler (1878) commented, “A hen is only an egg’s way of making another egg.” Evolution involves phylogenetic change, or change in a species over generations, in contrast to ontogenetic change, or developmental change in a single lifetime. Each species, including humans, is a solution to problems posed by the environment—an experiment in nature. These problems include how to avoid predators, how to obtain food, and how to reproduce.

The course of development within an individual follows a pattern that was acquired by the species because it facilitated survival. The young must adapt to their environment in order to reach the age at which they can reproduce and transmit their genes to the next generation. Just as certain physical characteristics, such as the upright stance and the hand with opposable fingers and thumb, facilitated making and using tools, so did certain behaviors, such as reflexes and fixed action patterns, facilitate survival through mating, food gathering, and caretaking. Social behaviors, such as interindividual communication and cooperation, encouraged group cohesion and thereby increased the chances of survival. New behaviors arose through natural genetic variations or mutations and, if they allowed the organism to survive long enough to reproduce, were genetically transmitted to the next generation. These successful behaviors gradually became more common in the whole population over many generations. Specifically, if genes are expressed in behavior (see later in this chapter) and if the behavior is adaptive, then it can be selected for during evolution.

Contemporary evolutionary theory has been changed dramatically by modern genetics. Theorists are increasingly aware of complex interactions of genes and environments. As explained later in this chapter, it is not just a matter of an environment simply triggering innate behaviors. Evolutionary models now also draw on population genetics to detect evolution by tracking changes over generations in the relative frequencies of various genes. One current notion, for example, is that sudden changes during evolution may have been more common than Darwin thought. Also, more attention is given now to the role of the environment, especially social environments. After all, species-specific behaviors have evolved within environments that are typical for that species. In a sense, “individuals inherit not only a species-typical genome but also a species-typical environment” (Bjorklund & Ellis, 2014, p. 230).

Humans have evolved few fixed action patterns. Rather, human plasticity has evolved as a successful strategy for enabling an organism to adapt to local conditions, including atypical environments. Plasticity refers to
the flexibility of the brain, the hormonal system, and the expression of genes. Plasticity starts to act even prenatally; chemical signals from the mother may prepare a fetus for a harsh and unpredictable environment. Specifically, prenatal exposure to high levels of stress hormones from the mother is associated with child behaviors such as high anxiety, fearfulness, aggression, and risk taking (Pluess & Belsky, 2011), which may be adaptive. However, infants typically delay significant changes in their developmental trajectory to match local conditions (e.g., a harsh or supportive environment) until they have had enough time to adequately process information about their environment (Frankenhuis & Panchanathan, 2011).

Note that both Piagetian and ethological approaches are concerned with how an organism adapts to its environment. Both identify biological predispositions toward learning, for example, the assimilation–accommodation process (Piaget) and specialized learning abilities (ethology).

Learning Predispositions

Ethologists see the biological control of behavior not only in largely innate behaviors acquired during evolution but also in predispositions toward certain kinds of learning. Species differ in which aspects of their behavior are modifiable, in what kinds of learning occur most easily, and in the mechanisms of learning. Sensitive, or critical, periods are specific time frames in which animals are biologically ready to learn from particular experiences. During this time, they are biologically pretuned to notice certain types of objects, sounds, or movements, and produce certain behaviors that are particularly susceptible to modification. After the end of the sensitive period, animals can acquire the behavior with great difficulty or even not at all.

An example of a sensitive period is Lorenz’s observation that, shortly after birth, certain birds (for example, geese) are most able to learn the distinctive characteristics of their mother and therefore their species. During this sensitive period, the young learn to follow a stimulus and come to prefer that stimulus—a phenomenon called imprinting. Imprinting increases the survival of the young because it ensures that they stay close to the parent and, therefore, near food and shelter and far from predators and other dangerous situations. The stimulus to be followed must meet certain criteria; for example, it makes a particular call note or type of movement. The criteria vary from species to species, but the mother always meets these criteria. In the wild, a row of ducklings scurrying after their mother is a common sight. However, as
Lorenz discovered, certain “unnatural” objects also meet the criteria. Young birds have become imprinted on flashing lights, electric trains, moving milk bottles, and a squatting, quacking Konrad Lorenz (see the excerpt at the beginning of this chapter). Horses and sheep have also become imprinted on humans.

In many species, imprinting has a long-term effect on sexual behavior. Lorenz (1931) discovered that jackdaws raised by humans will join a flock of jackdaws but return to their first love, a human, during the reproductive season. They try to attract the human with their species’ courting patterns.

Ethologists also have identified sensitive periods for behaviors such as learning bird songs, learning to distinguish males and females of the species, acquiring language, and forming a bond between a newborn and her mother. For example, mother goats form a bond with their young in the first five minutes after birth. If the young are removed right after birth for two hours, the mother attacks them upon their return. Waiting five minutes after birth before removal, however, leads to their acceptance later (Klopfer, 1971).

Developmental psychologists have drawn on the concept of a sensitive period to argue that early experience is particularly important for adult behavior, as suggested by Freud and others. Furthermore, all stage theories claim that at each stage the child is particularly sensitive to certain experiences, such as motor exploration in the sensorimotor period (Piaget), the meeting of one’s needs by other people in the stage of trust versus mistrust (Erikson), and the satisfaction or deprivation of anal drives during the anal stage (Freud). Most nonstage theories also use the concept of readiness—the idea that a child is most likely to learn from an experience if it comes at the optimal time. The child may not profit from being shown how to put objects to be remembered into categories when she is 3 years old but may have increased recall as a result of this experience at age 6. Moreover, sensitive periods are a central notion in prenatal development. A particular drug taken by a pregnant woman may have no effect or a devastating effect on the fetus, depending on its stage of development.

In addition to sensitive periods, a second way in which biology indirectly affects learning is through specific and general learning skills. Each species learns some things more easily than others. Digger wasps have excellent spatial memory. They can inspect up to 15 nests, decide how much food is needed by each nest, and retain this information for the entire day. Babies may be born biologically pretuned to learning language quickly. They rapidly acquire language early in life, show universal forms
of early utterances, and show babbling even if their parents are deaf and have no spoken language. Although a fear of snakes is not innate, infants as young as 7 months are predisposed to learn to associate snakes with fear and to respond quickly to the sight of a moving snake (DeLoache & LoBue, 2009). Moreover, 9-month-old infants are more attentive to evolutionarily fear-relevant sounds (e.g., hissing snake, crackling fire) than to modern fearful sounds (e.g., bomb exploding, tires screeching) or pleasant sounds (Erlich, Lipp, & Slaughter, 2013). Young infants also are experts in processing human faces. Early on, they can categorize female faces as attractive or unattractive (based on adults’ ratings of attractiveness) and even prefer the attractive faces (Langlois et al., 1987; Ramsey, Langlois, Hoss, Rubenstein, & Griffin, 2004), well before they possibly could have been taught about cultural norms regarding attractiveness.

In addition to these specific learning predispositions, human infants have evolved a tremendous general ability to learn. Humans are “specialists in nonspecialization” (Lorenz, 1959). We can construct novel solutions to problems in various types of environments and can learn from the consequences of our behavior. We also have hands that can perform many different actions and a language system that permits symbolic thought and verbal communication. The advantage of this flexibility is that we can adjust to a changing environment. The disadvantage of flexibility is that humans are born with few specific ready-made behaviors, such as running, that lead to survival.

As a result of humans’ biologically based general ability to learn, we have developed cultures to help us adapt. The culture is passed on to the next generation by imitation, instruction, and other forms of learning. Thus, even cultural adaptation has its biological origins.

Methodology

Ethologists rely on two general methods for studying behavior: naturalistic observation and laboratory experimentation. The insistence on observing organisms in their natural environments most clearly differentiates ethology from related disciplines such as evolutionary psychology and sociobiology. Ethologists’ particular version of naturalistic observation ranks as one of their main contributions to psychology.

Naturalistic Observation

Theories and methods are closely connected. Given the goal of understanding a behavior by seeing its function for adaptation, it is necessary to observe an animal in its typical environment. Giraffes’ long necks make sense when we see giraffes eating leaves from tall trees; we understand young gulls’ innate “freezing” rather than fleeing
in the face of danger by noting that their nests are built on narrow ledges or steep cliffs (Eibl-Eibesfeldt, 1975). In contrast, learning theorists (see Chapter 6) observed rats pressing bars and pigeons playing tennis in the laboratory—hardly typical species-specific behaviors. Interesting natural behaviors, such as defending a territory or building a nest, are not likely to occur in barren laboratory cages. From the viewpoint of ethologists, psychology has worked backward historically by performing laboratory research before obtaining a sufficient database of naturalistic observations.

Observations of animals in captivity are inadequate because their behavior may be abnormal due to their atypical environment. One cause of abnormal behavior in this setting is the absence of sign stimuli that would release fixed action patterns. Thus, behavior is often redirected. Animals in laboratories or poorly designed zoos may restlessly pace back and forth, constantly rock, and kill their young. Ironically, giving too much care to a captive animal may cause problems. Titmice in a zoo threw their young out of the nest soon after birth. The problem was that food was provided by the zoo. The young quickly became full, stopped gaping, and consequently were taken for dead by the parents. Young titmice in the wild never stop gaping unless they are sick or dead (Koenig, 1951). In humans, abnormal behavior—for example, rocking—has been observed in children in unnatural environments such as orphanages and hospitals.

Ethologists’ naturalistic observations focus on developing an ethogram—an extensive, detailed description of the behavior of a species in its natural environment. This inventory includes the animal’s behaviors, the characteristics of the setting, and the events immediately preceding and following each behavior. The ethogram spotlights adaptive behaviors, such as nesting and food gathering, and notes their frequency, stimulus context, function, and ontogenetic development. A complete description of the setting is particularly important, for it essentially defines the animal that inhabits it: “If we specify in detail the niche of a fish (its medium, its predators and prey, its nest, etc.), we have in a way described the fish” (Michaels & Carello, 1981, p. 14). Ethologists sometimes study human behavior by examining contemporary hunters and gatherers in order to understand the environment in which current human behaviors evolved. Finally, data about the frequency of behaviors is important for interpreting a behavior when it occurs. The problem of not having scientific data about frequency was noted long ago by Thorndike: “Dogs get lost hundreds of times and no one notices it or sends a scientific account of it to a magazine. But let one find its way
from Brooklyn to Yonkers and the fact immediately becomes a circulating anecdote” (1898, p. 4).

Interestingly, ethologists have detected previously unnoticed patterns of behavior by speeding up or slowing down their observational videos. For example, a slower rate revealed an unnoticed part of the flirting sequence—raising the eyebrows for only one-sixth of a second (Eibl-Eibesfeldt, 1975). A fast speed showed that people who eat alone look up and around after every few bites, as if scanning the horizon for enemies, as baboons and chimps do (Eibl-Eibesfeldt, 1975). This is much less obvious at a normal speed.

Once the function of a behavior is known from the ethogram, ethologists can understand the behavior further by comparing it with similar ones in other animals. For example, they may find mother–child attachment only in species in which the young are helpless, which suggests the reason for that behavior.

**Laboratory Studies**

For an ethologist, a behavior has both a phylogenetic cause and an immediate cause. Phylogenetically, a spider spins a web “because” that innate food-gathering behavior has allowed the species to survive. Immediate causes could include specific physiological events, particular inborn neurological pathways, the presence of a sign stimulus, or motor experience. Ethologists clarify these various causes of behavior suggested by the observational studies with controlled experiments, similar to those done by psychologists. For example, by systematically varying stimuli, they determine which attributes of a stimulus are critical for eliciting the response. They also examine the underlying physiological mechanisms. Although the laboratory experimental method is shared with experimental psychology, ethology maintains its distinctiveness by the content it chooses to study: behaviors tailored to the survival of the species.

One laboratory method associated with ethology is determining whether a behavior is primarily innate by preventing experiences that could teach the behavior. For example, an ethologist interested in the origin of nut-burying behavior raised squirrels in a cage with a bare floor and provided a diet of only liquid food. The squirrels had no exposure to other squirrels (who could serve as models), nuts, or earth (which could provide digging practice). Under these conditions, squirrels demonstrated nut-burying behaviors at the same age as do squirrels in the wild. When presented with a nut, they dug an imaginary hole in the concrete floor, pushed the nut into the “hole” with their snouts, covered it with invisible soil, and carefully patted down the “soil” to
finish the job (Eibl-Eibesfeldt, 1975). Thus, since they had no opportunity to learn this behavior, it must be an innate fixed action pattern of the species.

Contributions to Human Developmental Psychology

Ethologists are interested in the same categories of adaptive behaviors in humans as in other animals, for example, feeding, communication, parent–child interaction, and reproduction. The study of children has focused primarily on infant attachment but also has examined topics such as peer interaction and problem solving. A look at representative research in each of these areas will show ethology’s imprint on both the content and the methodology of developmental research.

Infant–Caretaker Attachment

Bowlby’s Theory

John Bowlby (1907–1990), a London psychoanalyst, is credited with bringing ethology to the attention of developmental psychologists. Because World War II had left many children as orphans, there were concerns about the effects of maternal deprivation. Bowlby’s observations of infants separated for a long time from their mothers (see the excerpt at the beginning of this chapter) led him to conclude that early social attachment between infant and caretaker is crucial for normal development. Infants show their attachment when they cry when a parent leaves, smile and babble when she returns, and seek her out when they are stressed.

Drawing on observations of mother–infant attachment in nonhuman primates, Bowlby (1969/1982) proposed that human attachment evolved because it promotes the survival of helpless infants by keeping them close to their mother and thus protected from predators or exposure to the elements. One newborn reflex related to attachment is grasping an object such as a finger or the hair when it contacts the infant’s palm, just as many mammalian infants stay with the mother by clinging to her hair. Another reflex is an embracing movement in response to a sudden loud sound or a loss of support. This reflex may have helped ancestral infants avoid falling when the mother suddenly ran from a predator.

Of course, human infants today do not depend on these reflexes for survival, because they need not physically attach themselves to their parent. Of more importance to human babies are signaling mechanisms such as crying, babbling, and smiling. These behaviors communicate infants’ needs and encourage adults to come to infants, since young
babies cannot go to adults. Just as following the imprinted object in
ducklings maintains proximity, signaling behaviors serve this purpose in
humans. Another ability found in young infants that may facilitate their
relationship with their parents is imitation of parents’ head movements
and tongue protrusions (Meltzoff & Moore, 1989). As infants mature,
other behaviors, such as crawling, walking, and talking, facilitate contact
between parent and child.

Research supports Bowlby’s notion that at least some signaling behav-
iors are innate (and possibly even fixed action patterns). Even infants
born blind or blind and deaf acquire a social smile at approximately
6 weeks, as do seeing and hearing infants. In fact, children blind and deaf
since birth reveal a wide range of normal behaviors, including laughing,
crying, babbling, and pouting, and typical facial expressions of fear,
anger, and sadness (Eibl-Eibesfeldt, 1975, 1989). It is highly unlikely
that adults teach these behaviors, because smiling and laughing involve
a complex sequence of coordinated movements or sounds. Even the
possibility that blind and deaf children might learn facial expressions by
touching the mother’s face and imitating her facial movements was ruled
out by a child deaf and blind since birth who was born with no arms.
Despite these handicaps, he showed normal facial expressions. Thus,
these behaviors have a strong innate component.

Bowlby proposed that early reflexes and signaling behaviors, along
with a bias toward looking at faces, leads to an attachment to adults in
general and then, usually around 6 to 9 months of age, to one or a few
specific adults. Separation from a specific adult may be an innate “cue
to danger” that elicits signaling behavior intended to restore proximity.

The infant and adult behaviors eventually become synchronized into
an “attachment behavioral system,” according to Bowlby. The appearance
and behavior of each member elicits certain behaviors in the other. Each
member of the system comes to expect that the other will respond to its
own behavior in certain ways. Infants’ expectations are part of their internal working models, discussed in Chapter 3—mental representations of
the attachment figures, the self, and the relationship. These models help
children interpret and evaluate new situations and then choose a behavior
such as playing or seeking the attachment figure for comfort. Between
the ages of about 9 and 18 months, an infant’s various individual behaviors, especially sucking, clinging, crying, smiling, and following, become incorporated into more complex, self-correcting “control systems.”

Bowlby used control-systems theory from engineering as a model
of how attachment forms an organizational system. Control systems are
goal directed and use feedback to regulate the system in order to achieve
the goal. A simple control system is a thermostat, which maintains a particular room temperature (the goal) by comparing the actual temperature (the feedback) with the desired temperature. With respect to behavioral systems, Bowlby proposed that genetic action causes the behavioral system to develop but that the developed system is flexible enough to adjust to changes in the environment, within prescribed limits. That is, when infants detect that the adult is too far away (feedback to the system), they correct this state by crying or crawling, which reestablishes contact and re-achieves equilibrium in the system. The limits of acceptable distance vary, depending on internal factors, such as hunger or illness, and external factors, such as the presence of an adult stranger or other cues of danger. The development of a secure attachment expands the distance acceptable by establishing the caretaker as a secure base from which the child can explore.

Bowlby’s theory of attachment includes many ideas from ethology. Species-specific reflexes and fixed action patterns, which are the products of evolution, ensure proximity to the mother. Sensitive periods and general and specific learning abilities biologically predispose infants and caretakers to develop a system of synchronized interactions. As in ethological theory, Bowlby observed children (though recent research on attachment stimulated by his theory often is conducted in a laboratory). His colleague, Mary Ainsworth, developed methods for assessing attachment (see below) and provided much of the empirical evidence for attachment theory.

The ethological account of attachment, with its focus on innate behaviors, obviously contrasts with learning theory’s (Chapter 6) focus on food or physical contact as reinforcement. Although it seems likely that pleasant interactions have a positive effect on the bond between child and adult, ethologists point out that attachment occurs even when the attachment object physically abuses the infant. Ethological accounts also differ from Freudian theory’s focus on the oral drive. Finally, ethology differs from both traditional learning and Freudian theory in stressing an infant’s effect on the parent as much as the parent’s effect on the infant.

Bowlby later (1980) incorporated into his theory some of the notions of information-processing theory (Chapter 7). He explained unsatisfactory early social relationships, abnormally strong repression, and thinking disorders in part by general principles of selective attention and selective forgetting. For example, if young children’s attachment behavior is continually aroused but not responded to, they eventually exclude from awareness the sights, thoughts, or feelings that normally would activate attachment behavior.
Bowlby continually applied his ideas about attachment to his clinical work. Interestingly, his final book (1991), a biography of Darwin, traced Darwin’s chronically poor health back to his failure to fully mourn his mother’s death when he was 8 years old.

**Adults’ Responsiveness to Infants**

Ethology contributed the important idea that adults, as well as infants, are biologically predisposed to develop attachment. A caretaker typically begins to form an emotional bond to a child in the first few hours or days of life, which encourages caretaking and thus enhances the infant’s survival. Babies elicit adult attachment behavior with signaling behaviors such as smiling, looking at the mother’s face, and babbling, or by their babyish appearance.

The words of a 1926 popular song were: “Baby face, you’ve got the cutest little baby face” (music by Harry Akst, lyrics by Benny Davis). An infant’s babyish appearance may elicit caretaking. The infants of many species, especially mammals, share certain physical characteristics depicted in Figure 5.1—a head that is large in relation to the body, a forehead that is large in relation to the rest of the face, limbs that are relatively short and heavy, large eyes at or below the midline of the head, and round, prominent cheeks—in a word, cuteness (Lorenz, 1943). This babyishness is exaggerated in baby dolls for children and in young animals in the Disney cartoon films. Interestingly, as Mickey Mouse became more lovable and well behaved over the years, his physical appearance became more babyish—a larger head with softer, more rounded features and larger eyes (Gould, 1980).

Infants’ smiles also may be powerful elicitors of adults’ attention. The adaptive significance of an infant’s smile may be to make a tired, busy mother of a young infant feel that those difficult first months are worthwhile (Robson, 1967).

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**FIGURE 5.1**

Characteristics of babyishness or cuteness common to several species.

The Developmental Course of Attachment

Very young infants are predisposed toward attachment. For example, they prefer looking at people's faces, and they vocalize in response to human voices. They also are biased toward looking at biological motion rather than random movements (Bardi, Regolin, & Simion, 2014). Early on, infants learn to discriminate their mother's odor from that of others. Two-week-old breast-fed infants turned toward a pad that had been worn in their mother's underarm area rather than a pad worn by another lactating female (Cernoch & Porter, 1985). Likewise, mothers quickly learn to recognize their infant's distinctive smell. Six hours after giving birth, and after only a single exposure to their babies, blindfolded mothers could pick out, by smell alone, their own baby from a set of three babies (Russell, Mendelson, & Peeke, 1983).

Attachment furthers infants' learning about their environment, because parents serve as a “secure base” for exploration in the first year or two of life. Children venture away to explore the next room but return from time to time for “emotional refueling” (Mahler, 1968). If, however, a parent’s responses to children’s signals are inappropriate (unpredictable, slow, abusive, or not matched to the child's needs), children feel insecure and are less likely to use the mother as a base for exploring a strange environment (Ainsworth, Blehar, Waters, & Walls, 1978). Because the appropriateness of the adult’s responses is more important than the total amount of interaction, infants become attached to parents who work full time, if they respond appropriately to the child’s signals.

Ainsworth (e.g., Ainsworth et al., 1978) devised the “Strange Situation” procedure, which lasts about 22 minutes, to assess babies’ patterns of attachment to their mothers. The infant, a parent, and a stranger in a laboratory setting proceed through a sequence of episodes, gradually moving from low stress (infant with parent) to high stress (infant alone with stranger). Based on their reactions to these events, children are classified into four categories. Securely attached infants (the majority of typical middle-class samples) cry when their mother leaves and greet her happily, for comforting, when she returns. Insecure–avoidant babies show little emotion when the mother leaves or returns. Insecure–resistant babies are difficult to comfort on the mother’s return and show either anger or desperate neediness toward her. Infants who do not fit into any of these categories (e.g., no consistent way of dealing with stress; contradictory behaviors) are called disorganized or disoriented (Main & Solomon, 1990). These infants sometimes have abusive parents.

A large literature (e.g., Cassidy & Shaver, 2008) shows that a dyad’s type of attachment depends on many factors, including parents’ sensitivity to
the child’s needs, stresses on the family, parental psychopathology, and child characteristics such as Down syndrome or a difficult temperament. Universally, secure attachment is the most common pattern, maternal sensitivity influences infant attachment patterns, and secure infant attachment leads to later social and cognitive competencies (Van IJzendoorn & Sagi-Schwartz, 2008). However, the percentage in each category shows some variability across countries. For example, in one study (Van IJzendoorn & Sagi, 1999), U.S. and Western European groups showed more avoidant infants than did groups from other regions. One reason for the great interest in attachment type is that the categories predict later social competence. In general, secure attachment predicts effective social functioning during childhood and adolescence, and even later, whereas insecure attachment is associated with various sorts of later psychopathology, as discussed in the chapter on psychoanalytic theory. The initial attachment pattern sets in motion particular styles of thinking, feeling, and relating to others that continue to influence the way children negotiate their environments throughout development. Also, work on young children at developmental risk, such as children with Down syndrome, cerebral palsy, or autism spectrum disorder, promises to broaden our understanding of the variety of social attachments and the complex interweaving of genetic and environmental forces (Vondra & Barnett, 1999). Today, attachment is seen as a lifelong process of forming affectionate bonds with various people, including romantic partners. In fact, assessments of adult attachment styles have been developed and related to various kinds of social relationships, including parenting (Frias, Shaver, & Mikulincer, 2015).

From a contemporary evolutionary perspective, attachment styles are different solutions to the problems in the environment faced by a child after birth. The particular style is an infant’s attempt to adapt to her parents’ behaviors and the resources available in the environment. For example, parents differ in their pattern of investment in their offspring in terms of time, effort, and resources. Infants increase their chances of survival if they can adapt to their particular caregiving condition (Bugental, Corpuz, & Beaulieu, 2015). If parents are heavily invested in their children and thus are sensitive and responsive, environmental risk decreases and children can explore more freely from their safe base. If, because of environmental pressures such as scarce food, parents are unable or unwilling to invest heavily in caring for their children, resistant or avoidant attachment may be more adaptive. In resistant attachment, clinging to the caregiver could elicit whatever meager resources are available. In avoidant attachment, a more independent infant can try to obtain resources from other adults.
Issues about the attachment categories include the following (Cassidy & Shaver, 2008): How stable over time is an infant’s attachment classification? Should attachment be measured as categories or as a continuum? How broad is the effect of the early attachment category on later social relationships and cognitive abilities? What is the child’s active contribution (for example, temperament) to the attachment relationship? How, if at all, do child-care arrangements affect type of attachment? What accounts for the variability in a child’s attachment behavior across situations? What specific effects does parental physical abuse of an infant have on attachment type?

Peer Interaction
Ethologists argue that children are innately predisposed toward interacting with other people in adaptive ways. Ethological studies of animals’ dominance hierarchies, aggression, play, altruistic behavior, and nonverbal communication have provided a powerful framework for observing and interpreting these behaviors in children in natural settings (Blurton-Jones, 1972; McGrew, 1972).

A basic feature of the organization of nonhuman primate groups is the dominance hierarchy—the ranking of members of the group according to their power, especially regarding access to resources such as food or mates (Hinde, 1974). This hierarchy indicates who can control whom. It is adaptive because, once established, it lessens conflicts within the group. These dominance hierarchies also construct the social environment into which an infant is born. For example, in rhesus monkeys, which form large and complex social groups, the matrilineal (mothers’) dominance hierarchies affect the rank of the infant. All members of the highest-ranking matriline, even infants, outrank lower matrilines. Thus, a newborn “inherits” the status of the mother and outranks even adults of lower-ranking matrilines. Dominance hierarchies even affect how mothers treat their infants. High-ranking mothers are more “laissez-faire” in their supervision of their young than are low-ranking mothers. The latter are more limited in the social situations from which they can rescue their infants, so they are reluctant to let them explore much (Sameroff & Suomi, 1996).

In humans, even 15-month-old infants can infer a social dominance hierarchy from a series of videos showing pairs of adults in which one person was dominant over the other (Mascaro & Csibra, 2014). These hierarchies can be seen in preschoolers’ groups (e.g., Hawley & Geldhof, 2012) and in adolescent groups, in which popular peers are looked at
more (Lansu, Cillessen, & Karremans, 2014). Within this structure, children learn how to use both prosocial and coercive behaviors to negotiate status and gain access to resources (Hawley, 2014). In particular, when children enter elementary school, they learn that they must express dominance in more subtle ways in order to obtain resources—what Hawley (1999) calls “competing with finesse.” Prosocial strategies, such as persuasion, cooperation, and helping, enable children to access resources such as toys or friends in ways that foster acceptance and maintain group harmony. Thus, aggression, or the threat of aggression, which usually is considered a negative behavior, actually may be a positive adaptation for a group and also provide opportunities to acquire the skills needed later during adulthood. Similarly, boys’ rough-and-tumble group play may enhance their ability to compete and permit them to evaluate each other’s relative strengths, which is one basis for dominance hierarchies. Such observations of children’s groups demonstrate several characteristics of ethological research. Researchers observe children’s adaptive behaviors, typically in natural settings, and compare them with that of other primates. In response to conflicts, such as a struggle over a toy, a child could, for example, submit, seek help, counterattack, give up the object or position, or make no response. The child who wins in these encounters is considered to be the more dominant. These categories of initiated conflict and response to the conflict are quite similar to those used to study dominance in nonhuman primate groups.

Individual differences in peer interaction might be explained in terms of social defense systems that have evolved for coping with negative peer behaviors and protecting oneself from interpersonal threat (Martin, Davies, & MacNeill, 2014). Children select a relevant strategy from a large repertoire of defense strategies for defusing threats from peers. A dominant child can threaten aggression. In contrast, a low-status child may run away, use subordination behaviors to deflect harm and social exclusion, or warily watch the dominant group members. These behaviors calm down the dominant members and avoid rejection from the group. The heightened arousal, need to be vigilant for potential violence, and frequent activation of the social defense system, may deplete the less dominant child’s resources that could have been devoted to other systems, such as exploring or caregiving. More secure, dominant members of the group do not have this high cost.

The ethological approach to children’s aggression clearly contrasts with social learning theory’s focus on how a behavior (for example, aggression) in individual children is affected by reinforcement, punishment, imitation, and self-efficacy. And, unlike Freud, ethologists focus
on interpersonal processes of aggression more than individual psychological processes. Finally, Vygotsky’s theory gives more attention to cultural contributions to aggression than does ethology.

Evolutionary psychology has addressed gender differences in social behaviors, especially mating strategies and parenting behaviors. Other behaviors for which evolutionary arguments have been made are male competition and violence; gender differences in play, risk taking, and the ability to inhibit behaviors; and parental investment in their children, with applications to child abuse.

Problem Solving

_I gather firewood_  
_As if I had been at it_  
_For a million years_

—William Charlesworth, *One Year of Haiku*, 1978

The human brain is designed to solve daily problems in the human-typical environment in which the species has evolved. This view of intelligence differs greatly from other approaches to studying this topic. The intelligence-testing approach views intelligence as a trait on which people differ and assesses it on tests administered by an adult, usually in an unfamiliar setting. Laboratory studies of problem solving (see information-processing theory in Chapter 7) examine children’s thinking about novel tasks, out of context, usually in a laboratory. Ethology lies closest to Vygotsky’s theory of cognition, among the various theories, in that both address the fit between children and their social environment.

Although even Darwin (1890) studied the “mental power” of earthworms, most of the research on cognition falls within the more recent evolutionary psychology framework. Evolutionary psychologists suggest that cognitive mechanisms may be the missing link between evolution and human behavior; that is, evolution may have led to changes in the brain, which changed thinking, which in turn changed behavior (Tooby & Cosmides, 2005). Complex cognitive skills must have evolved to solve problems such as finding a mate, hunting for food, recognizing group members, communicating with others, warding off enemies, raising offspring, and cooperating to obtain resources. People had to attend to, encode, process, store, and retrieve relevant information, such as remembering specific individuals and figuring out the costs and benefits of interacting with an individual, especially whether to risk one’s
life to help the person. In this way, evolution selects for the neurological mechanisms that underlie adaptive social and cognitive behaviors.

Tooby and Cosmides (2005), two main voices of evolutionary psychology, have identified Darwinian algorithms—evolved cognitive mechanisms specific to particular domains. The mind is like a Swiss army knife, with different tools for performing tasks well in different domains. Examples of these “core domains” are face recognition, language acquisition, certain characteristics of objects, and certain types of processing of social information. The brain consists of modules that process information in these domains with little effort. Infants are programmed to acquire and store certain sorts of information needed for solving certain sorts of problems. Their behaviors generated by Darwinian algorithms bear some relation to fixed action patterns but are more flexible, less tightly wired to particular stimuli.

It is important to note that these cognitive skills enhanced adaptation for our ancestral hunters and gatherers: “Our psyche is not built for the present. It resonates to the vibrations of 200,000 generations ago” (Thiessen, 1996, p. 159). We do not do much hunting and gathering these days. Thus, the cognitive skills underlying these activities may not lead to survival and reproductive fitness in today’s urban habitats. Still, we do have these ancestral ways of thinking that continue to influence our development and behavior in a world of shopping malls and computers, and the task of an evolutionary psychologist is to reveal how they are expressed in modern environments. One interesting hypothesis concerning the “modernization” of an ancestral cognitive module is that a module acquired to process information in one domain, such as the acoustical properties of the human voice, may be applied today to another domain, such as music. Music itself may not be essential for survival, but it may come from a module that is (Sperber, 1994).

One modification of the Tooby and Cosmides model is Geary’s (2005) model, in which modules within a domain are organized hierarchically. Lower-level modules process less complex information, which is integrated to form higher-level, more complex, and flexible modules. For example, infants have biases that orient them to important social stimuli and lead them to imitate others. Information obtained from these lower-level modules combines with more flexible higher-level social-cognitive mechanisms, to help children develop an understanding of themselves and other people, and thus adapt to various social and physical environments (Bjorklund & Ellis, 2014). Similarly, in concepts of the physical world, infants’ surprisingly sophisticated understanding of objects and the ability to use tools is integrated into more advanced and flexible understanding later.
Mechanisms of Development

Ethologists emphasize biological processes as mechanisms of development. Physical maturation, including hormonal changes, motor development, and increased efficiency of the nervous system, underlies the emergence of sensitive periods or of fixed action patterns at appropriate times. For example, nest-building behavior surfaces when a bird matures to the point where reproduction is possible. All of the biological mechanisms of behavior interact with experience, of course. In addition, innate general and specific learning abilities built into the nervous system allow the organism to profit from its experience.

Position on Developmental Issues

Human Nature

*Human nature is just one hodgepodge out of many conceivable.*

— *Wilson, 1978, p. 23*

Humans are social animals with certain species-specific characteristics. Human intelligence, language, social attachment, and perhaps even aggression and altruism are part of human nature because they serve or once served a purpose in the struggle of the species to survive. However, humans select from their evolutionary heritage the behaviors that best help them adapt to local circumstances—supportive or harsh caretaking, a resource-rich environment or poverty: “‘Human nature,’ then, is in part decided by the context within which we find ourselves (Hawley, 2014, p. 5).

Identifying the theory’s worldview highlights the differences among ethological theorists. Lorenz stressed the mechanistic, automatic, elicited nature of behaviors, such as reflexes and sign stimuli that elicit fixed action patterns. This stimulus–response model is based on early views of how the nervous system operates. In contrast, Bowlby and many modern ethology theorists are more organismic and draw on systems approaches. Humans spontaneously act to meet the demands of their environment by actively searching for the parent or playmates or by exploring. In Bowlby’s control-systems approach, an infant seeks to maintain a certain state, for example, an acceptable degree of proximity to the caretaker. Finally, the theory is contextual in its focus on links between a species’ evolutionary history and the present, and on the immediate physical and social setting, to which an organism must adapt.

Qualitative Versus Quantitative Development

Ethology allows for both qualitative and quantitative change. It is not a stage theory and
therefore does not posit large-scale qualitative changes in development. Qualitative change occurs when biological maturation reaches the point where a sign stimulus triggers a new fixed action pattern. In this way, a new behavior appears in a more or less discontinuous fashion. Qualitative change also occurs when a system is expressed in different behaviors as a child develops. One such instance is attachment, the desire for which is expressed at first by crying or smiling and later by crawling toward the mother or talking to her. The underlying attachment, however, may be changing quantitatively, usually toward increased organization and efficiency.

**Nature Versus Nurture**

Like Piaget, ethology was concerned with how an organism adapts to its environment. Both identified biological predispositions toward learning, for example, the assimilation–accommodation process (Piaget) and specialized learning abilities (ethology). Although ethologists focus on the biological basis of behavior, they are quite aware that heredity and environment are intertwined throughout the lifespan. Indeed, any evolved behavior requires some environmental input for its activation. A particular experience has more impact if it occurs during a relevant sensitive period rather than at another time. Moreover, a given genotype may be expressed differently in different environments. Also, one way to think about the importance of the environment is that it selects for or against genetic mutations that occur.

It is the fit between the genes and a particular environment that is adaptive, not just the genes themselves. The set of human genes evolved within a particular environment, so it is adaptive for the “expectable” environment into which most members of the species are born. This environment, typical for the species, provides the relevant experiences for expressing predispositions.

**What Develops**

The most important behaviors to develop are species-specific behaviors that are essential for survival. These include such behaviors as social attachment, dominance–submission, eating, mating, social cognition, and infant care. Both general abilities to learn or process information and specific behaviors such as fixed action patterns or domain-specific cognitive algorithms are applied to the environment at hand. The theory seeks to explain similarities in what behaviors are acquired and how they develop in all humans and in both humans and other animals. Like for Piaget, the focus has been on what is universal for a particular species. Biology constrains the range of possible differences between cultures or within a culture.
Applications

Ethological work on attachment has had the most impact on real-life topics such as orphanages, adoption, day care, prolonged separation from the mother, and early contact between mother and child. A popular current parenting approach, “attachment parenting,” encourages parents to keep their babies close and to respond promptly and appropriately when babies signal their needs. For a securely attached child, a parent serves as a safe base from which to explore the environment and establish independence. Parents should be sensitive to their children’s emotional needs during separation caused by hospitalization or other traumatic events.

Bowlby found pathological behaviors in children when they did not receive adequate attention from a caretaker early in life. A more recent project (Nelson, Zeanah, & Fox, 2007) has shown that early social deprivation in the institutional rearing of infants abandoned at birth in Bucharest, Romania, had serious negative effects on brain behavior and nearly all aspects of development. For example, almost half of the children appeared to suffer from one or several forms of psychopathology. However, subsequent adoption into normal families reversed some of these adverse effects, especially if adoption occurred early on. A variety of interventions for infants at risk for not developing secure attachment, as well as children and adolescents with attachment issues, have proven successful (Cassidy, Jones, & Shaver, 2013). Researchers also have applied attachment theory to policy concerning families with working parents, or a parent in the military or in prison (Cassidy et al., 2013).

Evaluation of the Theory

Strengths ► Both realized and potential contributions of ethology to developmental psychology are explored in three areas: theory, method, and content.

Theoretical Contributions ► Ethology broadens our perspective on what constitutes an explanation of development. We can fully understand children’s behavior only if we expand our vision to include a larger space (the larger social context) and a larger time span (the history of the species). Tinbergen (1973) identified four types of questions about the causes of behavior that developmentalists should try to answer about their topic of study. The questions are based in part on the time span involved, which varies from seconds to centuries. These “four whys” pertain to causes that are immediate, ontogenetic, functional, and phylogenetic.
Immediate causes are the external or internal events that occur directly before the behavior. They provide clues as to the causal mechanism. An infant smiles after viewing a human face or cries as a result of hunger pangs.

Ontogenetic causes encompass a longer time span—the genotype and the environment interact to produce changes in behavior over an individual’s lifetime. In this process, earlier events contribute to later events, as when a secure attachment may cascade to later positive relationships and social competence.

Functional causes involve the immediate adaptive value of a behavior. An ethologist asks, “What is this behavior trying to achieve?” Children behave in certain ways because they want to obtain food, protection, desired resources, and social support.

Phylogenetic causes lie in the earlier forms of the behavior as it was shaped over generations as a result of the food supply, types of predators, mating patterns, and so on. Thus, human social cognition may have evolved because of the need for hunting and gathering together.

Most developmental research has examined immediate causes or ontogenetic causes rather than functional or phylogenetic ones, but the latter two are needed as well for an adequate account of development. Knowing the function of a behavior helps the investigator relate a child’s behavior to its natural context. For example, the way that investigators think about children’s aggressive behavior changes if they discover that one of its functions is to increase the overall stability and cohesiveness of the group. The focus changes from a problem in the child to a feature of human groups. As for phylogenetic causes, among the theorists in this book, only the ethologists and Gibson (see Chapter 8) take an evolutionary perspective. Piaget was concerned with adaptation to the environment but paid little attention to evolutionary processes.

Few human behaviors today are a matter of life and death, such as avoiding predators, and children with mental disabilities, poor health, or physical disabilities are protected, so they may survive and reproduce. Thus, survival of the fittest is much less apparent as an evolutionary force. Developmentalists may find it most useful to draw on the concept of adaptation for understanding how a society may produce optimal adaptation (rather than biological survival). Optimal adaptation might include happiness, a feeling of competence at play, success at school, and efficient use of tools such as eating utensils, scissors, and computers.
Thinking about how a child’s behavior might be adaptive also can suggest new hypotheses about development. For example, behaviors that seem maladaptive actually may confer advantages in certain developmental niches. For instance, children with a strong tendency to approach novel but potentially dangerous situations tend to develop disruptive behaviors (e.g., Davies, Cicchetti, & Hentges, 2015). However, this risky behavior may be adaptive in adverse environments by making it more likely that children will find new, resource-rich, settings (Gatzke-Kopp 2011). Thus, ethology offers a more balanced perspective by considering both the costs and benefits of any developmental pathway, even when the behaviors are considered psychopathological (Martin et al., 2014).

**Methodological Contributions**

What can we learn from scientists who spend hours staring at crabs and birds? Regarding developmental psychology’s focus on laboratory research rather than naturalistic observation, Bronfenbrenner characterized the discipline as the “science of the strange behavior of children in strange situations with strange adults for the briefest possible periods of time” (1977, p. 513). Moreover, developmentalists rely too heavily on the questioning of children. As Charlesworth commented, “As soon as a research subject has the appropriate Piagetian operations and can talk, researchers stop observing and start asking. It’s less strenuous that way” (1988, p. 298).

Laboratory studies tell us what can happen during the attentional process. Ethological observation in natural settings tells us what in fact usually does happen and what function the behavior has. Ethology provides theoretically based observational methods that can fruitfully be combined with traditional developmental laboratory methods. As an illustration, consider what ethologically oriented observational studies might contribute to the understanding of the development of attention, typically examined in the laboratory. Lab research assesses infants’ preferences for attending to one of two stimuli placed in front of them or older children’s attention to physical attributes, such as shape, color, or size. A child looks preferentially at one object rather than another, sorts the objects, or tries to remember them. An ethologist, in contrast, would shift the focus of such research by asking the following questions: What types of objects or events do children look at or listen to at home and at school? Do children mainly look at people or nonsocial objects and events? What events distract young children? Does efficient attention lead to efficient problem solving or other adaptive behaviors? Does playful, exploratory attention resemble that observed in other primates, humans of other ages, and other cultures? Such observational studies would suggest new variables
to be examined in depth in the laboratory. In a similar way, ethological methods could be applied fruitfully to the other theories examined in this volume. We know little about when and how often children engage in problem solving (Piaget and information processing), displaced aggression (Freud), or collaborative learning (Vygotsky).

**Content Contributions**
Ethology has influenced developmental psychology by showing the importance of behaviors such as attachment and the structure of peer groups. A rich set of data about attachment provided a foundation for the neuroscience and genetic research on the long-term impact of poor early parenting described later in this chapter. Similarly, the information about human phylogenetic change from ethology and evolutionary psychology provided a backdrop for current developmentally oriented evolutionary approaches (e.g., Bjorklund & Ellis, 2014; Tomasello, 2014). More generally, observations of the social behavior of other primates, especially their apparent “mindreading” of their peers (e.g., Kaminski, Call, & Tomasello, 2008) has stimulated similar topics in children.

**Weaknesses**
The following are critical shortcomings in theoretical, methodological, and substantive areas that must be addressed by ethological theory if it is to fulfill its promise as a theory of development. Some of these shortcomings merely reflect a lack of developmental research in certain areas; others are more serious because they reflect the incompleteness of the theory itself.

**Theoretical Limitations**
Many of the ethological notions that are most useful to developmental psychology require further elaboration if they are to serve as specific explanations of development. For example, by what processes do sensitive periods begin, have their effect, and end? Are the effects of contact between mothers and their young infants due to biological, social, or cognitive variables or all these variables in interaction? What makes infants predisposed to attend to particular stimuli? The neuroscience and genetic approaches described later are beginning to identify the mechanisms that could answer these questions. Similarly, the cognitive foundation for adaptive behaviors is not well worked out. For example, by what cognitive processes do children detect and understand a dominance hierarchy in their peer group and their own place in it? How do children interpret social cues that could provide this information? The development of transitive reasoning ($A > B > C$...) may be necessary for perceiving a dominance hierarchy (Edelman & Omark, 1973).
More specificity also is needed for theory-based predictions: What specific aspects of a secure or insecure attachment predict specific future social competencies? As Thompson noted, “It is as important to determine what a secure attachment does not predict to, and why, as it is to understand its network of predictable consequences” (1998, p. 48). If the various attachment patterns are adaptive for different environmental situations, then the expected long-term outcomes of each attachment type are not so obvious.

Another problem concerns identifying the function of a behavior. The evolution of anatomical structures can be gleaned from fossils, but we have no fossils of human behavior. At best, we can examine other primates, contemporary hunter–gatherers, skulls, DNA, and archeological data such as diseases, housing, cultural artifacts, age distributions, and tools. We can speculate about how an upright stance, enlarged brain area, and increasingly sophisticated tools reflect changes in human behavior in our history. We can hypothesize what sorts of cognitive demands were made on early hunters and gatherers and the extent to which these demands are similar to or differ from those in modern human environments. What was adaptive generations ago may not be adaptive today, however. For example, a preference for fats and sugars was adaptive in our early history, but not now, and in fact leads to obesity and Type 2 diabetes. As another example, attention-deficit/hyperactivity disorder (ADHD) may consist of tendencies that were adaptive in early humans (Jensen et al., 1997). Rapid scanning, quick responses, and high motor activity work better for monitoring threats and escaping from enemies than for reading and concentrating on homework. Moreover, the function of a behavior may be far from obvious. “Morning sickness” and the food aversions associated with it during early pregnancy may protect the fetus from toxic foods at a time when it is most vulnerable (Profet, 1992). Food aversions are most common for foods high in toxins.

**Methodological Limitations** ▶ One obvious limitation to applying ethological methods to humans is that the most critical experiments are unethical. We cannot perform experiments such as preventing an infant from seeing a human smile for the first few weeks of life in order to see if the social smile is innate. In an early, misguided experiment, Frederick II (1194–1250) raised babies in silence and near isolation to find out if there is a “natural” human language. The babies, not surprisingly, died before the outcome was clear (Wallbank & Taylor, 1960). Instead of experiments, we must rely on naturally occurring atypical situations, such as infants born blind or deaf, institutionalized infants,
or infants of mothers who are hospitalized and thus absent for a long period.

A limitation to naturalistic observation is that it is not clear what constitutes a “natural environment” for children in a highly technological society. Should we study children running through a meadow, sitting in a classroom, or playing electronic games? Moreover, developing a comprehensive ethogram of human infants would be a time-intensive, expensive undertaking. As Charlesworth noted, “Unlike most tests, which throw out a small net with a small mesh, the present method throws out a big net with a small mesh and thereby catches many small fish. Herein, of course, lies a big problem of effort and cost. The net gets awfully heavy very quickly” (1979, p. 522). It also is not always clear what behaviors are relevant. An observer unfamiliar with Bowlby’s work might well record that the infant crawled to the door of the adjoining room but would probably not record the distance between the mother and the infant.

**Content Limitations**

Certain psychological phenomena that are not consistently reflected in spontaneous overt behavior may be difficult to study from the ethological perspective. Cognition is a good example. A researcher might be limited to studying overt behaviors, such as removing a physical barrier blocking a desired object. Since cognition and motivation become more complex with increasing age, ethological observations may in general be more informative in infants and toddlers than in older children.

**Contemporary Research**

The influences of ethological and evolutionary theory on developmental psychology can be seen most clearly in three contemporary topics—attachment, the evolution of human cognition in social groups, and adaptation during development.

**Attachment**

Research on attachment categories was presented earlier in this chapter, and work on internal working models appeared in the Freud section of this book. Most contemporary research on attachment focuses less on categories of attachment and more on psychological and biological processes involved in both child attachment and relevant parenting behaviors. The focus is on the process of forming a socioemotional relationship between parent and child, with attention given not only to parent effects on children but also how child factors, such as temperament, affect the parent (Laible, Thompson, & Froimson, 2015).
A typical model of the development of attachment is the following (Cassidy et al., 2013): Children develop an attachment behavioral system, which is an organized system of behaviors with the goal of establishing proximity with the parent in order to obtain protection. The parent’s state of mind regarding attachment contributes to both their caregiving behavior and their child’s attachment. The child’s attachment consists of two-way interactions between an internal working model and physiological processes. The child’s attachment then contributes to her developmental trajectory—either successful psychosocial functioning or psychopathology.

Much of the recent research identifies correlates between parenting quality and infant attachment, or between attachment categories and later child behaviors (e.g., empathy, compassion, altruism, internalizing or externalizing symptoms) and adulthood functioning (e.g., romantic relationships, parenting behaviors). Particularly of interest are the mechanisms underlying these links. Recent breakthroughs in genetics and neuroscience have provided additional levels of explanation of the process of attachment. For example, researchers have identified genotypes associated with the various attachment styles, particularly disorganized attachment (Spangler, Johann, Ronai, & Zimmermann, 2009). Contemporary neuroscience models of attachment generally propose that the brain systems underlying attachment involve sensitivity to threat in the environment and regulation of attachment-related behaviors and emotions (Gillath, 2015). Brain imaging is clarifying the child and parent neural correlates of attachment categories, such as underlying brain networks or brain volume. For example, mothers showed different brain responses when viewing their own 3- to 6-month-old infant’s face, compared to the face of another infant (Esposito, Valenzi, Islam, Mash, & Bornstein, 2015). Thus, today attachment is viewed as a process involving genetics, physiology, cognition, emotion, and behavior.

New directions in attachment research include the role of attachment style in constructing enduring patterns of response to stress, relations between attachment and health and immune function, school readiness, and culture (Cassidy, Jones, & Shaver, 2013; Rholes & Simpson, 2015). For example, insecure attachment during childhood and adulthood is related to altered stress responses, which affect the immune system and lead to poor health outcomes (Pietromonaco & Powers, 2015). Researchers also have added biological measures. Of particular interest is the role of the neurohormone oxytocin in promoting social bonding. For example, over the first three years of life, parents’ oxytocin levels predict their children’s oxytocin levels (Feldman, Gordon,
Influs, Gutbir, & Ebstein, 2013). The child’s social reciprocity with a friend was correlated with the child’s oxytocin levels, the mother’s oxytocin-related genes and hormones, and mother–child reciprocity. One important unanswered question concerns the mechanisms underlying the intergenerational transmission of attachment—how a child’s attachment category links to her adulthood attachment category, and how the latter, through the adult’s state of mind regarding attachment, affects her parenting behaviors and thus her child’s attachment. In other words, what are the relations between the caretaking system and the attachment system (Cassidy et al., 2013; Jones, Cassidy, & Shaver, 2015)? Another important question concerns whether the findings largely based on maternal behavior apply to fathers as well.

Evolution of Human Cognition in Social Groups

The five species of great apes (gorillas, orangutans, chimpanzees, bonobos, humans) share a common ancestor from approximately 15 million years ago, and the last three share a common ancestor from about 6 million years ago (Tomasello & Herrmann, 2010). What is unique about human cognition? The great apes have considerable genetic similarity: Chimpanzees and modern humans, for example, share approximately 95 percent to 99 percent of their genetic material, a proportion similar to that of lions and tigers or rats and mice (King & Wilson, 1975). The other great apes clearly have certain humanlike cognitive and social skills and, in fact, are surprisingly sophisticated cognitively (Call & Tomasello, 2008). They understand the physical world much like humans do. They can count, communicate, recognize themselves in a mirror, and understand object permanence. They also can deceive others of their species so that they are misled as to the location of food, engage in pretense, and predict others’ behavior on the basis of their emotional states and direction of locomotion. Chimpanzees have been observed pretending to pull an imaginary pull toy and even carefully disentangling the imaginary string (Hayes, 1951). They understand kinship and dominance relations, and they will select an appropriate ally, such as someone dominant over their opponent. Great apes even understand certain mental states. Chimpanzees, in a within-species competitive game, showed that they know whether their competitor knows or does not know something, though they did not understand false belief (Kaminski et al., 2008). Thus, “chimpanzees know what others know, but not what they believe” (p. 224).

Human thought is unique mainly in the ability to engage in joint attention and cooperative communication, and thus coordinate efforts and collaborate (Tomasello, 2014). These cognitive skills are possible because...
humans can think about others’ perspectives, reflect on their own thinking, and think about others’ thinking and one’s own in a recursive way (“He’s thinking that I’m thinking that . . . ”). That is, humans can represent others’ thinking (including false beliefs), interpret their perspectives, and monitor their own thoughts. These skills evolved when ancestral humans faced problems presented by attempts to collaborate and communicate with others. Specifically, early humans’ small social units required them to hunt collaboratively to acquire enough food. In order to collaborate, they had to be able to recognize others, communicate at least nonverbally, and form long-term social relationships. Collaboration also encouraged members to help each other so they would be available for future collaboration. Later, when societies became so large that members could not know all group members, humans came to rely on information about who belonged in their group. These ideas have generated research with children. Infants start helping others around 12 to 18 months (Warneken, 2015). By age 3½, they act prosocially toward their collaborative partners, and by age 5, both collaborating with others and belonging to the same group (even if the assignment to a group was arbitrary—a green group and a yellow group) led children to prefer, help, and trust their collaborative partners (Plötner, Over, Carpenter, & Tomasello, 2015). More generally, young children tend toward an in-group bias of liking, acting positively to, and feeling obligations to their own group, and a bias toward viewing out-groups negatively (Rhodes, 2013).

The economic necessity for larger groups with coordinated roles and perspectives, shared understanding that permitted communicating through language, and collective intentions, also led to the development of culture—norms and institutions (Tomasello, 2014). Humans’ social-cognitive skills permitted them to engage in cultural learning and pool their cognitive resources. Humans can work together to create new knowledge about objects, quantities, tools, and social relations that cannot be created by a single individual. Cultural artifacts, such as language and other social tools or systems of belief, were developed in each generation and taught to the next. Although young chimpanzees can communicate and learn how to use tools from adult chimpanzees around them, only humans show cultural transmission—an evolved biological mechanism that enables children to take advantage of the knowledge and skills acquired over generations by the species. Children grow up surrounded by the very best tools and symbols that the species has developed. A simple example, based on evidence from physical artifacts, is that during human evolution hammers changed from simple stones to stones tied to sticks to modern metal hammers and mechanical hammers.
Humans were able to improve the tool because they understood what the purpose of the tool was (that is, what people intended to do with the hammer); they could go beyond simple imitation of someone using a particular type of hammer.

As a result of this evolutionary heritage, young infants can develop the knowledge that other humans are like themselves, with intentional and mental properties. The mirror neuron system discussed in Chapter 6—brain activation that is similar to that of the person observed performing some behavior (e.g., Keysers, Thioux, & Gazzola, 2013)—may facilitate young children’s understanding of the psychological causes of another’s behavior. Tomasello refers to the “9-month social-cognitive revolution” in which infants begin to understand others as intentional beings. They see others as similarly motivated by goals and thus begin to share attention, as well as intentions, with other people, toward objects and events. Once this social cognitive skill evolved, humans could ‘imagine themselves ‘in the mental shoes’ of some other person, so that they can learn not just from the other but through the other” (Tomasello 1999, p. 6). In this way, infants understand why others are using a tool or symbol—what the person intends to do with it. With this understanding, children can engage in cultural learning and become full participants in various cultural rituals and games. Language obviously is particularly important, for example, to ensure that children engage in complex interactions with others that demand negotiation.

Adaptation During Development

Many species have adapted to their environments by evolving specific innate behaviors. In contrast, humans have adapted by evolving plasticity—flexibility in the hormonal system, the expression of genes (see later), and, especially, the brain. Thus, in humans, adaptation is a developmental phenomenon, as the young learn about their environment and adapt to their particular local conditions.

The young brain exhibits flexibility, but this decreases as brain regions becomes specialized to respond mainly to certain kinds of stimuli, such as faces or moving bodies. This plasticity is adaptive because it keeps the brain open to learning about the specific features of the child’s particular environment (Bjorklund, 2007; Bjorklund & Ellis, 2014; Bugental et al., 2015). Moreover, understanding the complex human social structure requires a big brain, which necessitates an extended infancy and childhood. This extended period for maturity is a risky strategy for the human species, because infants cannot obtain food or flee from enemies on their own. Moreover, it takes a lot of cognitive resources to constantly scan and evaluate environments.
Early childhood is a sensitive period during which children learn about positive (e.g., resources) and negative (e.g., violence) aspects of their environment and use this information to adapt by calibrating their developmental trajectory (Bugental et al., 2015). Specifically, they learn what physical and social resources are available in the environment, how predictable these resources are, how trustworthy other people are, whether close relationships are likely to last, and what threats exist. For example, early experience with “growing up in poverty, exposures to violence, harsh childrearing practices . . . shifts resource allocations toward more risky and aggressive behavior, earlier pubertal timing and sexual debut, enhanced early fertility, less stable pair bonding, more offspring, and less parental investment per child” (Bjorklund & Ellis, 2014, p. 237). In earlier evolutionary times, this strategy would have maximized people’s reproductive success (Bugental et al., 2015). It may be that the predictability of the environment is key. Having an unpredictable, rapidly changing environment (e.g., moving a lot, parents changing jobs frequently, divorce) from birth to age 5 is the best predictor of this fast-track developmental trajectory (Simpson, Griskevicius, Kuo, Sung, & Collins, 2012). Moreover, this early adaptive strategy of impulsivity and risk taking developed in uncertain environments affects later behaviors during adulthood; how adults respond to indicators of current resource scarcity (impulsive and risky decisions) depends on their childhood socioeconomic status not their current one (Griskevicius et al., 2013).

Adaptation during development is constrained by many factors, such as species-specific genes, the child’s developmental level (e.g., how much information about the environment can be processed), the nature of developmental mechanisms (e.g., small rather than large leaps in cognitive change), and characteristics of the environment (e.g., available resources). Thus, children inherit the ability to modify their own development so that it is maximally adaptive to local conditions, but within limits, and with the possibility of making wrong choices. Still, this imperfect evolutionary strategy may be the best balance between wired-in behaviors and total plasticity.

Bjorklund (Bjorklund, 2007; Bjorklund & Ellis, 2014) argues that although some of children’s behaviors were selected for and are developing because they will lead to an adapted adult, some may have evolved because they serve an adaptive function only at a particular time in childhood. Certain reflexes, such as the grasping reflex, are present in newborns but then disappear several months later after they have served their purpose of aiding survival during that particular period. Also, the
cognitive immaturity that goes along with brain plasticity during childhood allows time for play, which may provide a sense of mastery and self-efficacy that encourages children to try out new activities and roles. These activities and roles provide opportunities for learning new skills. Even behaviors that seem maladaptive actually may be adaptive. For example, toddlers’ limited working-memory capacity may be adaptive for language learning. The reason is that restricting how much language information can be processed simplifies the language corpus that is analyzed, and this in turn simplifies the process of acquiring language. Children first may acquire single syllables and then gradually deal with more information and increasingly complex information. If children could initially process more linguistic information, they might be overwhelmed by the amount of information and not be able to extract anything useful. In this case, less is more (Newport, 1991).

An example of immature, but advantageous, cognitive skills from the preschool period is children’s poor awareness of their cognitive performance, for example, their vastly overestimating how well they perform, even after feedback that they have performed poorly (see Chapter 7). Until approximately age 7, children unrealistically think of themselves as “one of the smartest kids in my class” (Stipek, 1984). This seemingly non-adaptive characteristic may in fact be quite adaptive. This Pollyanna attitude may encourage them to keep trying to do activities that are beyond their current ability level. In this way, they obtain valuable experiences that strengthen their skills. Because they do not expect to fail, they may not be afraid to try out a variety of new activities. This optimism and disregarding negative feedback also may be seen when children continue to use a good, new strategy that does not yet help them (Miller & Seier, 1994; see Chapter 7). This attitude keeps them using and thus strengthening the new strategy until it can help them. Another adaptive cognitive immaturity may be Piaget’s notion of egocentrism. Children’s bias toward perceiving and conceptualizing in terms of their own perspective obviously limits social understanding and interaction, but it may help them in other ways. Given that people tend to remember better when they relate the information to themselves (e.g., Pratkanis & Greenwald, 1985), egocentrism actually may help young children’s recall. Thus, although we tend to see young children’s apparent limitations as evidence that they are less advanced than older children and adults, they may be quite well adapted to the demands of their particular developmental period.

In sum, ethology and evolutionary psychology have made significant contributions to developmental psychology. They provide a larger
temporal context in which to view development. The focus on the function of molar behaviors complements the focus of most current biologically oriented developmental work on cells and the brain. We now turn to two main contemporary biological perspectives on development—developmental neuroscience and genetics.

Developmental Neuroscience

The human brain has evolved relatively recently:

If we compressed the 4.5 billion year history of the Earth into a 24-hour period, the first single-cell organisms would have emerged around 18 hours ago, the first simple nervous systems separating animals from plants would have emerged around 3.75 hours ago, the first brain would have emerged about 2 hours and 40 minutes ago, the first hominid brain would have emerged less than 2.5 minutes ago, and the current version of the human brain would have emerged less than 3 seconds ago.

(Cacioppo & Cacioppo, 2013, p. 667)

The boom in research exploring the human brain began in the 1990s, designated the “decade of the brain.” This exciting new work was stimulated by new technologies of brain imaging that generate maps of brain activity. Here are some of the more common techniques:

Several measure currents produced by electrical activity of brain neurons—for example, electroencephalography (EEG; sensor electrodes placed on the scalp) and magnetoencephalography (MEG). Others measure brain activity indirectly, by assessing blood flow and oxygenation as an indicator of increased neural activity—for example, functional magnetic resonance imaging (fMRI) and near-infrared spectroscopy (NIRS). MRI uses a magnetic field and pulses of radio wave energy. DTI (diffusion tensor imaging)—a variant of MRI that detects the movement of water—can be used to infer information about the pathways of brain white matter (brain tissue containing nerve fibers). PET (positron emission tomography) uses radioactive tracers in a dye injected into the bloodstream.

Each of these technologies has strengths and weaknesses for describing the structure and functioning (changes in activity) of the brain (see de Haan, 2015). For example, some tell us more about spatial patterns of brain activity, and others tell us more about the time course of this activity. Techniques vary in their spatial resolution and their temporal resolution of a moving image. Some (e.g., EEG) can be used with very young children but are limited because they do not probe deeply into the brain. PET cannot ethically be used with children because of the...
radioactive tracers. Moreover, there obviously are challenges with doing neuroimaging with squirmy young children, but researchers are developing creative ways to do this. Thus, the choice of a technique depends on the research question and the person’s age.

Neuroimaging methods reveal brain functioning when, for example, a picture or sound is presented. Thus, one could compare the patterns of brain activity in children of different ages or ability levels working on the same task, to infer developmental differences in cognitive processing. Or children of the same age might engage in different sorts of tasks thought to activate different cognitive skills, such as numerical and spatial reasoning. This approach provides information about the relations among brain regions (and among concepts). The patterns of brain activity associated with the two tasks might show both commonalities and domain-specific activity, thus addressing the issue of whether children’s thinking forms a general stage or domain-specific areas of knowledge.

Neuroimaging initially focused on identifying the particular region of the brain primarily associated with particular cognitive activities, emotions, or behaviors. More recently, models depict neural networks that may involve several regions of the brain. Also, measures have expanded beyond detecting brain activity to include anatomical measures, such as thickness of the cerebral cortex, that might show significant developmental changes.

In addition to providing information about the brain correlates of behavior, neuroimaging makes several contributions to assessment of abilities. Some imaging techniques can be used with infants, which is an important methodological contribution to developmental psychology, given that infants have few behaviors that can be used for assessment. Another methodological contribution is that imaging sometimes provides more sensitive assessments of social or cognitive skills that are not yet detected by behavioral measures. For example, after an eight-month exercise program, obese children showed brain changes in their fMRI’s consistent with improved executive function—a change that was not detected on standard behavioral assessments (Krafft et al., 2014).

A few words about brain anatomy and functioning can set the stage for a discussion of brain development by showing the enormity and complexity of the brain: “The brain is rather like a large, very wrinkled walnut” Karmiloff-Smith (2012, p. 3). If all the surface of the brain were laid out flat, it would be about the size of a football field. The fibers in white matter, laid into a line, would stretch 100,000 miles, enough to circle the earth four times. There are approximately 100 billion neurons in the brain. Each neuron might connect to approximately 1,000 neurons.
The cerebral cortex, which is critical for humans’ advanced cognition, language, and perception, accounts for 80 percent of the brain’s volume. For the purposes of this chapter, it is most important to know that the frontal lobes, at the front of the brain, involve activities of great interest to psychologists, such as thinking, intentionality, voluntary movement, personality, and attention. As for brain functioning, this occurs at various levels. At the cellular level, chemical substances such as neurotransmitters (e.g., dopamine and serotonin) transmit signals across a synapse (connection between neurons) to another nerve, muscle, or gland. At the brain level, activated neural networks across various regions collaborate to produce thought, feeling, or behavior. Finally, any one region of the brain carries out many functions, though it may be more responsible for particular functions.

The following section describes some of the main themes of brain development and its links with behavior. It provides an overview, rather than a detailed technical account, in order to focus on models of developmental neuroscience. These themes are derived mainly from several recent key sources in this area (e.g., Johnson & de Haan, 2015; Stiles, Brown, Haist, & Jernigan, 2015).

**Brain Development**

1. **Early anatomical changes** Important structural changes in the brain occur in the first few weeks and months of life: For example, the rapid increase in myelin (insulation around the nerve fibers) increases the speed and efficiency of the transmission of neural signals and thus enhances information processing (see Chapter 7). As discussed in the neo-Piagetian section of Chapter 2, being able to think about, and manipulate, larger amounts of information is necessary for moving to the next cognitive level. Although this anatomical change is most rapid in the first few years of life, the efficiency of information processing continues to improve until late adolescence or early adulthood.

2. **Strengthening or pruning of connections between neurons** A major task for the brain, especially in the first two years of life, is to form connections between neurons as a result of environmental stimulation. These neural networks, which typically involve numerous neurons, become increasingly refined through late adolescence and continue to change throughout the lifespan. Infants have many more neurons and synapses than end up actually being used. This is one reason why the human infant brain has so much plasticity for adapting to local conditions. Neural pathways that are not used are pruned away—a
sort of “neural Darwinism” (Edelman, 1987)—while others strengthen. The complex relations between biology and experience can be seen in this biologically driven overproduction of synapses early in development, coupled with the pruning away of certain ones because they are not stimulated by experience. An example is infants’ perception of phonemes. Infants are born with the ability to discriminate the sounds of all human languages, but the particular subset of these phonemes that they still can discriminate by late infancy depends on the language or languages to which they were exposed during early infancy. Through pruning, they lose the ability to discriminate the phonemes of languages that they do not hear.

The brain seems to have major periods of growth and then pruning during the toddler years and adolescence. These periods of rapid neural growth might indicate that some developmental change is qualitative, especially if it involves brain reorganization, thus addressing the issue of qualitative versus quantitative development.

Increased specialization At first, most areas of the cerebral cortex are capable of performing a variety of functions. However, the cortex becomes increasingly lateralized, with the left hemisphere typically becoming more dominant. Moreover, with increasing age, brain regions and networks become more specialized, committed to particular activities. In general, a particular task elicits a larger, more diffuse area of brain activity in children than in adults. That is, the engagement of neural networks becomes more specific during development. The outcome is that brain plasticity decreases as brain regions commit to particular tasks. This can be seen, for example, in the fact that late second-language learners do not achieve the level of proficiency of earlier second-language learners. Late second-language learners may even process the second language differently from native speakers. These findings suggest that the brain organization associated with the first language has to be used to learn the second language later. Similarly, the greater ease of discriminating faces from one’s own race than faces from other races, when babies primarily have seen faces of their own race, is reflected in different patterns of brain activity when comparing two same-race versus two different-race faces, showing brain specialization for same-race faces (Vizioli, Rousselet, & Caldara, 2010). The experienced brain cannot go back to its less differentiated past.

Effects of environmental stimulation Normal brain development is dependent on environmental stimulation. Without the stimulation that a typical human environment would have, for which the brain evolved, the brain develops differently. Most children, because
they are physically normal and are raised in an environment typical for the species, have more or less the same sorts of experiences at about the same time. Thus, the pruning proceeds along similar lines for most children. However, what about atypical situations, such as children who are deaf or blind and thus do not receive auditory or visual stimulation? In deaf children, certain areas of the brain that normally would be devoted to auditory processing if the brain received both auditory and visual stimulation instead gradually become devoted to visual processing (Neville, 1995). Conversely, in blind children, areas normally devoted to visual processing when receiving both auditory and visual stimulation instead are devoted over time to auditory processing. Thus, when an area of the brain does not receive its normally expected input, it can be used for other purposes. The brain is preset to rapidly guide children along certain developmental paths, but it is also flexible enough to deal with atypical circumstances. Thus, cognitive neuroscience research is about brain plasticity as much as brain determinism of behavior.

The social environment is as important as the physical environment. For example, infants of mothers experiencing high stress due to social isolation have an altered development of brain inhibitory systems (Huggenberger, Suter, Blumenthal, & Schachinger, 2013). The mothers’ mental–emotional state likely decreased their verbal and nonverbal interaction with their infants, which prevented typical pathways from developing and instead set in motion other pathways. Recall also the atypical developmental timetable or pathways set in motion by adverse or unpredictable local conditions, described earlier in this chapter.

5 **Constraints on brain development** These constraints are genetic, environmental, and developmental (the current developmental level of the child). Genetic constraints that impact the structure and function of the brain are discussed in the genetics section of this chapter. The environment sets limits on ways that the brain might develop; it presents options, but not all possible options. Developmental constraints, such as the current organization of the brain system, influence subsequent brain development.

6 **Brain areas develop at different rates** Subcortical brain areas, associated with emotion and sensitivity to reward (e.g., the amygdala and striatum) mature rather quickly. In contrast, prefrontal areas (the front part of the frontal lobes), which support higher-level cognition, especially control over one’s thoughts and behaviors, develop more gradually over a longer period of time, continuing even through early adulthood. Thus, young adolescents have an imbalance between
early maturing subcortical structures that increasingly draw them into risky, rewarding behaviors, and later maturing structures for cognitive and emotional control that could put the brakes on these behaviors. This asynchrony presents an interesting theoretical model to explain normal young adolescents’ tendencies to engage in risky behaviors, followed by decreases in risk taking in later adolescence as prefrontal areas continue to develop (e.g., Steinberg, 2011). Given these neural findings, along with the significant social and hormonal changes during adolescence, it is not surprising that adolescence seems to be a time of increased vulnerability for psychopathology (Powers & Casey, 2015).

Lifespan changes Brain changes, including strengthening and weakening of synapses, continue throughout the lifespan. The brain is always a work in progress. During aging, the brain does, for example, becomes smaller and there is a reduction in neurotransmitters. However, certain experiences, such as exercise, can cause changes in the brain that improve brain functioning during the aging years. Contrary to prior belief, recent research shows that new neurons are created throughout our lifetimes, even during old age. This finding questions some of the theories of aging that focus on cognitive loss.

From these themes, the most important point may be that neuroscience research shows the impact of environmental influences on the brain as much as brain influences on behavior. The next section describes contributions of neuroscience to developmental theoretical issues, including interactions of nature and nurture.

Theoretical Issues
What can a neuroscience perspective contribute to our theoretical understanding of development? A main contribution is that neuroscience increases our understanding of how nature and nurture collaborate in complex ways to drive development. The research findings reported above show how environmental inputs to a plastic, yet constrained, brain start a journey down a particular developmental path. Moreover, as described later in this chapter, the brain often is the mediator between genes and behavior, as genes affect behavior and behavior affects gene expression.

Neuroscience findings bolster theories emphasizing the evolution of humans within social groups (e.g., Tomasello, 2014) and identifying the importance of early social experience. A main function of the brain is to recognize and interpret social information. Even in infancy, “babies’ brains are adapted to tap into the richest source of new information in their early environment: other human beings” (Johnson, 2013, p. 8). As
Grossmann (2015, p. 1266) notes, “Humans are such intensely social creatures that already as young children they outperform their closest living primate relatives (the great apes) in terms of their social-cognitive skills, while showing very similar skills as great apes when dealing with the physical world.” For example, even a rather subtle emotional response such as empathy can be tracked in terms of its changes in brain activity during childhood. These changes, measured by EEG, indicate a gradual decrease with age in emotional arousal and an increase in cognitive evaluation of the situation (Cheng, Chen, & Decety, 2014). More generally, there seems to be a network of specific brain areas focused on the processing of social information that is somewhat independent from other forms of cognition.

Developing brains are sensitive to both positive and negative social environments. On the positive side, neuroimaging documents competent mothering. For example, competent mothering of children at age 12 predicted brain changes (seen in MRIs) thought to indicate positive development at age 16 (Whittle et al., 2014). On the negative side, stresses from maltreatment (Bruce et al., 2013), low socioeconomic status (Muscatell et al., 2012), and institutionalized rearing (Mehta et al., 2010) are associated with brain functioning in children and adolescents that differs from that of children reared in more typical environments. Even mild stressors affect brain activity. In one study (Graham, Fisher, & Pfeifer, 2013), mothers’ reports of higher conflict between parents was associated with infants’ greater neural responses to very angry speech, compared to neutral speech, across several brain regions known to be involved in emotion and reactions to stress.

Some neuroscience models have addressed explicitly the continual interplay of biological and environmental influences and the causes of diverse developmental pathways. As described in Chapter 2, neuroconstructivism posits slight initial brain constraints or biases such that, for a particular task and situation, some neural pathways are more easily activated or more easily connect to certain outputs. Examples are infants’ biases toward looking at faces or analyzing language sounds. Infants seek out these stimuli, which further strengthens and specializes these pathways. Thus, infants may be slightly biased to look at particular types of stimuli, but the small biases become further amplified through specialized activity. The outcome is specialization of brain pathways, because the infant does not use the other pathways that initially could have been used. Slight individual differences in brain structure or function initially also could cascade into larger differences later that are considered neurodevelopmental disorders.
As for other theoretical issues, neuroscience can address the issue of quantitative versus qualitative development. Imaging reveals qualitative changes in the changing organization of neural networks during development and quantitative change in the strength of activation of each neural network. Neuroscience findings also can inform the issue of the extent to which cognition is general versus domain specific. The increasing specialization of areas of the brain during development suggests that cognition becomes more domain specific during development.

Another contribution to theorizing is that cognitive neuroscience research can test some of the claims of theories presented in this book. For example, the fact that cognitive tasks activate both cognitive-control and motor areas of the brain (Diamond, 2000) suggests close connections between action and thought. This could be taken as support for Piaget’s claim that motor actions play a key role in cognitive development. Relevant to Piaget’s claims about stages, if engaging in two tasks believed to tap the same knowledge system in fact activate the same neural networks, this would suggest that the two cognitive skills involved are part of the same cognitive structure rather than two domain-specific ones. Also relevant to Piaget, seeing how different neural networks interact at various ages can provide clues to age differences in cognitive organization. Another issue relevant to Piaget is whether the unexpected competence of infants described in Chapter 2 indicates the same level of knowledge as that of older children at the age when Piaget thought they develop that concept. The fact that EEG and NIRS measures of infants’ face and eye gaze processing, joint attention, and understanding of human action detect precursors of later networks for social cognition (Grossmann & Johnson, 2014) could suggest that social understanding at these two ages is related but not identical.

A final example is that the observed heightened self-consciousness of adolescents, described by Piaget and Erikson, has been supported by fMRI measures. When research participants thought that a peer was actively watching them, adolescents showed higher physiological arousal compared to other ages, as well as engagement of brain regions thought to be involved in the processing of socioaffective information (Somerville et al., 2013).

Applications
The neuroscience approach has led to a number of interesting applications. An important one is the insights into atypical development due to brain injury, atypical environments, or neurodevelopmental disorders.
This information about brain functioning in such children both clarifies typical development and suggests interventions for children developing atypically. For example, 3- and 4-year-old children with autism spectrum disorder (ASD) showed an atypical pattern of brain activity when viewing photos of an unfamiliar woman with a neutral or a fearful expression (Dawson, Webb, Carver, Panagiotides, & McPartland, 2004). Given that the ability to accurately identify emotional states in other people is critical for using emotions to explain behavior, children with ASD clearly are disadvantaged in this way. One goal is to detect brain patterns during infancy that predict the later development of ASD so that interventions can begin early.

Another important application has been to legal issues, an area called “neurolaw.” Evidence about adolescents’ asynchronous brain development, with emotions running ahead of the development of inhibition, contributed to the Supreme Court decision to end sentences of life without parole for crimes committed by minors. The reasoning was that adolescents’ neurobiological immaturity makes them less responsible for their actions than are adults. Still another application is called “educational neuroscience.” The idea is to use information about children’s brain development to design instruction.

Summary

Neuroscience findings and theoretical models have generated a great deal of excitement in developmental psychology for three reasons. First, neuroscience provides additional levels of analysis for understanding development. This information about the biological processes involved in behavior has become increasingly important as developmental theorizing has moved more and more to a focus on development as a changing system, with interacting levels from cells to society (see Chapter 9). The brain is one important part of this organized, interactive system. Second, neuroscience has revealed the importance of experience and learning, as much as the brain, when explaining behavior. In this way, neuroscience strengthens the long history of developmental research on the influences of the environment. One sees brain plasticity throughout life in the strengthening or weakening of synapses and the formation of new neurons and new synapses as the contexts of development change. Development involves continual interplay among brain development, behavior, and environmental resources. Third, neuroscience findings serve as a bridge to clarify the relations between genes and the environment. As described in the next section,
the brain often is the mediator between the expression of genes into thinking, feeling, and behavior, and between environmental conditions and the expression of genes. Still, it should be noted that some developmentalists are concerned that the focus of developmental psychology has shifted so much toward neuroscience perspectives that the field is out of balance empirically and theoretically as well as in resources such as grant funding, employment, and university investment in research.

Genetics

Genetics has had a presence in developmental psychology for decades, particularly in discussions of the nature–nurture issue—how genetic predispositions come together with environmental factors to contribute to behavioral outcomes. However, recently the conversation has shifted. Historically, behavioral geneticists could ask “How much of the variation in this trait (e.g., IQ) is due to genetic differences among individuals in this population and how much is due to environmental differences?” The question was about sources of individual differences in a group. Researchers often looked at how the known degree of genetic relatedness in the group correlated with similarities in a trait. Thus, they studied families, twins, and adopted children. For example, studies have compared adult identical twins, separated early in life, to estimate the relative contributions of genetic and environmental influences. This approach continues today and is clarifying some of the nuances of heritability. For example, the siblings of individuals with schizophrenia have impaired functioning in several areas of cognition compared to normal control families, even when these siblings do not develop schizophrenia (Barch, Cohen, & Csernansky, 2014).

A newer approach in developmental psychology draws on molecular genetics to ask a different question. It asks how the meshing of genes and environment in an individual causes a trait. What is the causal pathway from genes to cells to tissues to organs to behaviors, and vice versa? This question could not have been studied before technologies for assessing genetic makeup were developed. Geneticists’ drive to map the genome, in the Human Genome Project, basically completed in 2003, provided techniques to determine the order of DNA building blocks in an individual’s genetic code (see the beginning of this chapter). Psychologists then used these techniques to try to map the gene–environment connections throughout development. That is, they correlated genetic variations with
variations in behavior. In part because genetic analyses now are accessible and cost effective, research in this area has boomed in psychology.

Molecular genetics has generated a great deal of excitement in developmental psychology because it provides the genetic component for new theoretical models of the developmental unfolding of brain and behavior as influenced by genes and the environment together. This contemporary approach involves Gene X Environment interactions (G X E) and epigenetics (when the environment causes chemical changes affecting regulation of the genes). We now look at each of these.

Models of Gene X Environment Interactions

Mapping the human genome did not lead to the dramatic breakthrough in understanding physical and mental illness that geneticists expected. A likely reason is that genes are only part of the equation for human physiology and behavior. Genes are simply potentials that may or may not be expressed in particular environments, so in a sense we need to map the human environment as well as the human genome. G X E interactions show that the environment moderates the association between a particular gene variant and an outcome. For example, the known association between a particular gene variant and depression might be strongest in people who experience stressful major life events. Thus, genes may or may not be expressed, depending on a child’s developmental contexts. Similarly, a person’s genotype moderates the effect of an environmental factor on outcomes, such as traits, behaviors, mental health, and cognition. For example, highly stressful life events might be more likely to lead to depression if a person has a particular pattern of genes. Thus, due to the contributions of the environment, a given genotype (genetic makeup) can result in different phenotypes (outcomes—traits, behaviors, etc.) in different children, and a given phenotype can reflect different genotypes in different children.

To understand G X E interactions, it first is necessary to review a few basic genetic concepts. Humans have 23 pairs of chromosomes in each cell, and each chromosome is composed of thousands of genes. Genes are short segments along a long chemical spiraling chain of two strands of DNA (see Figure 5.2). The basic chemical building blocks of each gene’s DNA provide an information code (for example, the code at the beginning of this chapter) for making proteins. These proteins contribute to the development and regulation of the organism. This code involves particular sequences of these chemical building blocks. An allele is one of two or more possible versions of a gene; these are called
genetic polymorphisms—variants of a particular DNA sequence. Polymorphisms most commonly involve different versions of a single base pair (one of the four pairs of the genetic code presented at the beginning of this chapter) but instead can involve long stretches of DNA. A single gene may have many polymorphic regions and polymorphisms. An individual has two alleles for a gene pair—one from each parent. The two alleles in a gene pair can be the same or different versions, which affects which phenotype (e.g., eye color, blood type) a person has. This is a main source of genetic variation among individuals that could affect how much an environmental event or substance (e.g., an environmental toxin) affects them.

It is exceedingly complex to study G X E interactions because the genetic landscape is huge: A person’s genome has 20,000 to 25,000 genes, which sounds like a lot, but is barely more than the number for the miniscule roundworm, and much less than the 32,000 for an ear of corn (Schnable et al., 2009). The genome has more than 3 billion bits of information. Thus, the search for the genes relevant to the behavior or trait of interest may seem like a search for a needle in a haystack. Still, the search takes place with the knowledge that the genomes of any two humans are more than 99 percent the same. Importantly, this one percent of variation can provide valuable clues to the nature–nurture issue.

Genes can be analyzed from a small amount of blood or saliva. One analytic technique is to examine variations across individuals in a very small region of a gene that, based on prior research, is a prime suspect for the outcome of interest. This is called the candidate gene approach. The initial results were exciting, but subsequently they were not replicated for the most part, perhaps because the gene–outcome link depends on the environment, as shown in the G X E findings above. Subsequently, researchers turned to a newer technique, called “Genome
Wide Association Studies” (GWAS), which examines much of the whole genome of a very large number of individuals (usually thousands) to detect genetic variations that are correlated with a particular mental or physical disorder. Particular genetic patterns tend to co-occur with schizophrenia, autism spectrum disorder, substance-use disorders, and bipolar disorder (e.g., Horga, Kaur, & Peterson, 2014). Typically the genetic pattern identified involves numerous genes, because few if any outcomes of interest to psychologists are due to a single gene. In fact, mental disorders likely are influenced by thousands of genetic polymorphisms (Hindorff et al., 2009). One finding of great surprise to geneticists is that about 98 percent of genetic variations are not even in the coding portions of genes but somehow help regulate genes’ functioning. Little is known about how these noncoding variants (formerly considered “junk” DNA) influence outcomes. Another complication to tracking gene–behavior links is the discovery that what a gene can do can depend on nearby genes; genes can interact, such that one gene can suppress another one.

In general, the amount of variation in outcomes associated with genetic variations from these analyses has been disappointingly small. Thus, geneticists have moved to larger and larger samples to capture small correlations between genetic polymorphisms and behavior. Again, one reason that geneticists have found only small direct effects may be that the association is large only in particular environments, which reflects a G X E interaction. That is, the correlation may vary from one environment to another, for example, under conditions of parental support versus neglect. Thus, G X E interactions show that mapping the genome is not enough. At this point, psychologists have studied G X E interactions for a variety of outcomes (e.g., depression, drug abuse, psychopathology) in a variety of environments (e.g., high stress or trauma, neglectful parenting, poor nutrition, and low physical activity).

In Chapter 1, the discussion of the issue of how nature and nurture interact to direct development included examples of G X E interactions. A study was described (Brody et al., 2009) in which improving parenting skills provided a protective factor for adolescent boys who had a genetic predisposition for engaging in high-risk behaviors, such that the predisposition was less likely to be expressed. Thus, good parenting is like an insurance policy. If children do happen to be genetically predisposed to certain disorders that could be expressed under adverse circumstances, then the effects of good parenting and social supports may provide a buffer against gene expression and the resulting negative outcomes. Such findings are exciting to developmental psychologists,
because they show that when children have both high-risk genes and a high-risk environment it is possible to create an environmental buffer to genetic tendencies. Complicating the choice of interventions, however, is the fact that the effects of an experience, such as a psychological intervention, depend partly on a person’s genetic makeup.

The overall model of G X E interactions is that having, or not having, particular adverse experiences can “turn on” or “turn off” genes that predispose children to psychological or health problems later. This model obviously is of great interest to developmentalists, who want to know how genes are expressed during development in particular environments, which may differ from one developmental point to another. To understand how the environment can be a trigger or a silencer for relevant genes, it helps to liken a person’s DNA to a large, organized library:

Asking what DNA does is like asking what a book in this library does. Books sit on a shelf waiting to be read. Once read, the information in those books can have limitless consequences and can perhaps even lead to the reading of more books, but that refers to the book’s potential. Likewise, DNA sits in our cells and waits to be read. The reading or so-called “expression” of DNA can, like the books in our library, have limitless consequences. However, without the active process that triggers “expression,” this potential may never be realized.

(Champagne, 2009, p. 27)

Just as certain books are blocked and others are easily reached, both the environment and regions that regulate DNA can block DNA or make it accessible, thus affecting how easily DNA is expressed. The environment provides, or does not provide, the trigger. Ineffective parenting, high stress, or poor nutrition are examples of triggers. In this way, experience affects the expression of genes. The result is that each cell turns on only a fraction of its genes. Developmental psychology takes center stage in this work because turning on particular genes is timed to particular phases of development, as seen, for example, in puberty changes in adolescence. Similarly, whether a particular experience is a trigger often depends on the child’s age and developmental history (for example, poor prenatal nutrition or lack of cuddling during infancy).

A fuller picture of the pathway between a genetic liability and an outcome comes from a recent study (Davies et al., 2015) illustrating the G X E approach. It shows that genetic variation affects the sensitivity of low-socioeconomic, predominantly minority toddlers to particular experiences, specifically, mothers’ unresponsive caretaking. For children with a genetic pattern known to put them at risk for poor self-regulation, this
poor parenting was linked to an increase in disruptive behaviors two years later. Children in the sample without that genotype did not show these disruptive behaviors. Thus, a given environmental variable, unresponsive mothering, may negatively impact only children with a particular genetic makeup; some children are more vulnerable than others to adverse family situations. The likely pathway was that prolonged unresponsive caretaking triggered the expression of the high-susceptibility genetic variant, which caused decreased dopamine activity in brain circuits involved in reward seeking. This in turn led to an uninhibited temperament, with sensation seeking and risk taking, which escalated into disruptive behaviors.

**Epigenetic Models**

One groundbreaking and startling finding is that one way that environments can affect gene expression (a G X E interaction) is through epigenetics—the modification of gene activity without actually changing the gene. These chemical changes to or near the genes affect which genes are turned on and which are turned off, and this change can continue into the future. In effect, these chemical tags serve as enhancers and repressors that reprogram the gene’s activity. It is as if little red or green flags are attached to certain gene regions (see Figure 5.2). Epigenetic changes can be caused by poor prenatal nutrition, parental maltreatment, extreme stress, social isolation, and exposure to pollutants, as well as many other events. Various outcomes have been observed, including depression, schizophrenia, abnormal responses to stress, and decreased learning and memory. Every individual has numerous epigenetic changes during development.

The actual mechanism of epigenetics sometimes involves attaching certain chemical compounds to segments of DNA in genes, thereby affecting access to them and governing the gene’s activity by suppressing or enhancing it. That is, the compound “turns on” or silences the gene. For example, in one study (Romens, McDonald, Svaren, & Pollak, 2015), high stress from parents’ physical maltreatment of their children (ages 11 to 14) caused an epigenetic change affecting a gene involved in stress regulation. The disrupted hormonal system for regulating stress led to “cascades of downstream changes in biology and behavior” (p. 303) known to lead to later health and psychological problems. It often is the combination of genetic risk and environmental risk that can push children into a maladaptive developmental pathway. What is particularly important about epigenetics is that it potentially can be a permanent change that continues to affect development in the future.
Developmental science is at the heart of epigenetics because genes are expressed during development as experiences accumulate. At any developmental point, our epigenome (all our epigenetic changes) is the sum of the environmental signals it has received thus far. Thus, for example, the epigenetic effects of child maltreatment can accumulate and only at some point trigger a genetic region. Also, new experiences later in life can cause new epigenetic changes. Epigenetics is a lifelong process, and each change in our epigenetic makeup affects how we react to future environmental events. Also, developmental timing is everything. A particular environmental event might cause an epigenetic change in one developmental period but not another. Complicating the picture of environmental influences on gene activity even further, to some extent children create their own environments. For example, children with a genetically predisposed temperament to engage with adults may then evoke cognitively stimulating experiences from their environments, which then enriches their environment and affects what epigenetic changes might occur.

One of the most surprising findings is that epigenetic changes sometimes are passed on to future generations. For instance, maternal abuse and neglect can cause epigenetic changes resulting in abnormal reactivity to stress, which continues into the next generation (Champagne et al., 2006). This finding helps explain the observed cycle of abuse and its negative effects across generations. The impact of environmental effects on the next generation seems to contradict classical genetics principles taught in high school—that experience does not alter genes. However, it is not the genes themselves that are modified; rather, it is the “cellular memory” of the altered gene expression profile that somehow is transmitted.

It still is uncertain how abnormal gene regulation conditions are passed on. It may involve the transmission of the chemically changed context of the gene that altered its expression; the epigenetic signature is passed on. Or, the transmission may occur prenatally, affecting the development of the fetus. Suggesting prenatal processes, the newborns of depressed mothers also have the chemical changes associated with this gene expression in the blood of their umbilical cords (Oberlander et al., 2008).

Finally, an important, and intriguing, index of environmental influences on the genome is the length of telomeres—the tail-like regions protecting the ends of chromosomes. Telomeres are thought to be a molecular clock for biological aging in that eroded (and thus shortened) telomeres can indicate that factors such as smoking, obesity, or chronic stress have caused physiological wear and tear on the body.
(e.g., the cardiovascular system) and thus physical aging. Short telomeres are associated with chronic diseases of aging and early death. In a longitudinal study, children who experienced two or more forms of violence—domestic violence, bullying, or physical maltreatment by an adult—showed significant telomere erosion between ages 5 and 10, even after controlling for socioeconomic status (Shalev et al., 2013). Similar effects were shown in young adults, with high levels of stress at age 17 associated with nonsupportive parenting and predicting shorter telomere length five years later (Brody, Yu, Beach, & Philibert, 2015). Specifically, chronic activation of the body’s stress response damages the body.

Theoretical Issues

In a sense, epigenetic findings even destroy the dichotomy between nature and nurture, because nurture changes the regulation of genes. In light of G X E interactions and epigenetics, perhaps the most accurate way to think about nature and nurture is that humans inherit resources for development rather than specific gene-based characteristics (Lickliter & Honeycutt, 2015). The meeting of genetic and environmental processes is exceedingly complex—more complex than ever imagined. An individual is constructed over the lifespan from a dynamic developmental system consisting of various levels from genes to environments, with causality in both directions. Moreover, genetics research shows the importance of the timing of a particular experience, consistent with ethologists’ notion of sensitive periods. For example, the study described above on depression was conducted on adolescents because that is a time when a number of major psychiatric disorders appear, suggesting that adolescence may be a time of particular vulnerability to epigenetic changes. The fact that epigenetic effects can be cumulative and permanent provides an explanation for how adverse early experiences can cause problems years later.

One important theoretical advance is the differential susceptibility hypothesis, the theory that some children are especially affected by environments—both positive and negative ones—whereas other children are much less affected (Ellis, Boyce, Belsky, Bakermans-Kranenburg, & Van IJzendoorn, 2011). Some children are like dandelions, who seem to be rather impervious to environmental input and can grow in a variety of environmental circumstances; others are like orchids, highly reactive and very influenced by both harsh and highly nurturing environments. This concept may help solve certain mysteries from research on environmental influences. For example, some children
show remarkable resilience in a childhood of poverty, abuse, and high stress and manage to stay on a positive developmental pathway. These children may have genetic polymorphisms making them less susceptible to environmental influences.

G X E and epigenetics research provide another level of explanation to the other theories in this book. Each theory identifies particular types of experience important for development, which potentially could affect gene expression. For instance, Piaget focused on active interaction with one’s physical world, Freud and ethologists emphasized early mothering and attachment, Erikson emphasized culture-based socialization, and Vygotsky thought early language interactions were important. The genetic approach suggests pathways between these experiential histories and psychological outcomes, namely, pathways involving turning genes off or on and perhaps permanently altering the regulation of genes. Epigenetics research also spotlights the physiological and behavioral route between the environmental triggering of a gene and the positive or negative behavioral outcome.

Genetics research also adds to our understanding, in each theory, of individual differences in children’s responses to events and environments. Polymorphisms affect the impact of the experiences and environmental influences emphasized by various theories. For example, different children may respond differently to disequilibrium (Piaget’s theory) or guidance in the zone of proximal development (sociocultural theory) or aggressive models (social learning theory, Chapter 6).

Genetics research points to the need for theories to identify specific critical aspects of experience. For instance, in a longitudinal study (Murphy, Slavich, Rohleder, & Miller, 2013), adolescent females at risk for developing major depression showed more epigenetic markers for depression at testing sessions only when one specific type of rejection, “targeted rejection” (intentional rejection of a person), recently had occurred. This effect was especially strong for females who perceived themselves as high in social status in their peer group. This suggested that targeted rejection set in motion a neurohormonal chain of events that led to the inflammation of body systems, which is the body’s protective response to damage or harmful stimuli, including stress. Chronic inflammation is a change associated with mental and physical illnesses. These findings suggest new hypotheses about possible different effects of different kinds of environmental stressors. The study also suggests that perceptions of the environment (accurate or inaccurate), not just the environments themselves, influence the impact of environments on susceptibility genes.
Cultural developmental theories (Chapter 4) suggest the importance of attending to human diversity in G X E and epigenetics research. Human cultures differ in their DNA profiles. It matters who is studied. Most genetic research has been conducted on people of European descent, but various genetic polymorphisms occur at different frequencies in different populations. The NIH 1000 Genomes Project is an international public–private consortium attempting to build a detailed catalog of the main genetic variations between populations in Europe, Africa, and East Asia. The goal is to identify the contribution of genetic variation to illness. A main step is to show which genes indicate the most variability in their responses to particular aspects of the environment. However, cultural theories would argue that attending to genetic diversity is only part of the story. Cultural diversity also may contribute to G X E and epigenetic outcomes. For example, what constitutes a supportive parental environment or what kinds of events are stressful may show cultural differences.

The focus of genetics research on mental and physical diseases has prompted developmentalists to construct new models of links between experience, psychological development, and health. The impact of stress on health, and on telomere length as an indicator of overall health, for example, was described earlier. The growing awareness of connections among genes, the environment, and health can be seen in a current NIH initiative aimed at understanding effects of different environments on genes. The Environmental Genome Project identifies “susceptibility genes,” which have polymorphisms that make individuals particularly sensitive or insensitive to radiation and natural and human-made chemicals, including environmental pollutants.

Some of the current theoretical controversies in genetics are quite relevant to development. One concerns the extent to which epigenetic changes and the resulting bodily changes can be reversed. Another concerns the fact that much of the genetic variation among people now appears to come from outside of the coding genes, the basis for the mapped human genome. Another controversy has to do with the fact that most of the research thus far has focused on negative outcomes, such as mental disorders or atypical development. Are the identified genetic and epigenetic processes the same for normal development, including positive developments or traits such as language acquisition, prosocial behavior, and musical talent? Is there a critical difference between typical environments and very enriched environments?

Several important questions about development likely will be addressed in future research. Are there sensitive periods for specific
environments measured in G X E interactions? In fact, it has been suggested that researchers should be developing G X E X D (Development) models (Hyde, 2015). Early childhood and adolescence are good candidates for sensitive periods because of significant neural, behavioral, and environmental changes at those times. For example, peer relations (e.g., affiliation and support versus rejection) may be a particularly strong mediator of gene-brain-behavior links during adolescence. Another question concerns the range of environmental triggers in children’s lives. Much of the genetic-oriented work thus far has looked at mothering, which, though important, is only one of many important environmental influences, particularly fathers.

Applications
These genetic and epigenetic breakthroughs have important applications. Having more information about their children’s genetic makeup, or their own, and the probability of susceptibility genes being expressed, can help people make decisions related to physical and mental health (e.g., susceptibility to depression, recommendations about lifestyle, such as exercise). Eventually, newborn screening involving whole-genome analysis may be routine. One goal of knowing the genetic composition and environmental stressors of various racial, ethnic, and socioeconomic groups is to help tailor interventions to these groups in an attempt to eliminate health disparities. This is similar to “personalized medicine” in the medical field. An intervention that reduces stress on children or improves parenting early on can deter the expression of susceptibility genes into negative outcomes. Along with these applications, however, come a host of ethical and legal issues. Do you want to know your genetic makeup, given that it may alert you to dangers that might never materialize? Would information about your child’s genetic makeup affect how you treat him or her? Should doctors tell patients about a genetic risk for a disorder with no known preventive treatment, such as early dementia?

Summary
G X E and epigenetic research provides complex new developmental models of genetic and environmental influences. In fact, such research has documented the importance of the environment as much as that of genes. Genes mediate the impact of the environment, and the environment affects the expression of genes. Sometimes, through epigenetics, experience even chemically alters gene regulation in ways that are transmitted to the next generation in some cases. Children differ in their
particular genetic vulnerabilities and even in how sensitive they are to the environment in general. Environments vary in their degree of support for positive developmental pathways despite genetic vulnerabilities.

**Integrated, Multilevel Biological Theoretical Perspectives**

The various biological approaches in this chapter have developed models of the pathways between biological processes and behavior, making it clear that genes, brain, and experience form a complex system in which each influences, either directly or indirectly, each of the others. This system is particularly complex because their interactions are developmentally sensitive. For example, a particular environmental event might cause an epigenetic change during early infancy but not if it occurs later. Also adding to the complexity is the fact that interactions occur at multiple levels, from cells to society. The following examples of these complex models give a flavor of this interrelated system.

Because the brain often is the pathway through which genes are expressed and thus influence behavior, a new field called developmental neurogenetics has emerged recently (Hyde, 2015). This approach develops models in which genetic polymorphisms are associated with particular neural variability. In other words, the goal is to determine which genetic polymorphisms predict particular variations in brain neurochemistry, architecture, or functioning, which in turn result in variations in behavior. This approach typically uses the imaging techniques discussed earlier to assess brain outcomes. An example of a neurogenetic finding is that a particular genetic variant increases amygdala reactivity during adolescents’ response to stress (i.e., angry faces) (Battaglia et al., 2012). Specifically, such a pattern typically indicates a gene (or genes) sending signals to the brain that affect the pathways of neurotransmitters. Another example is that genetic polymorphisms that affect dopamine production in certain brain areas are associated with low inhibition of behavior, for instance, sensation seeking and impulsivity (Caylak, 2012). One variation of this approach that can advance our understanding of development is to study these correlations in specific subgroups of people. For example, one might describe the neural and genetic profiles of individuals who are resilient despite their developmental history of harsh, and thus risky, environments (Hyde, 2015).

The developmental aspect of neurogenetics is that the gene-brain-behavior associations often change as a function of age, not only during
brain development but also throughout the lifespan as individuals engage in new experiences. A main question is the mechanisms by which these connections occur. The end result of correlating genetic, neural, and behavioral variability is a probabilistic model of development. For example, a model might present the probability of a child developing depression in a particular environment (e.g., high social support vs. maltreatment), based on information about the child’s genetic vulnerabilities and particular brain structure and functioning. Development is central because, for example, an initial genetic variant with very small effects can cascade (see Chapter 1), as one thing leads to another, into large effects on behavior over time.

Neurogenetics is beginning to be applied to models of the development of psychopathology (Hyde, 2015). There are known correlations between particular brain patterns and particular psychopathologies. A neurogenetics model would link such correlations to particular genetic polymorphisms. In other words, the goal is to link genetic variation to brain variation to behavior variation, including pathological behaviors. Because brain chemistry and functioning are a phenotype that is at a level closer to the genotype than are the more distant behaviors used to classify different kinds of psychopathology, gene-brain links may be easier to identify than gene-behavior links.

A recent model (Hyde, 2015) expands developmental neurogenetics by adding measures of environmental variability. Thus, this model adds G X E interactions to neurogenetics, such that associations of brain variability with both genetic and environmental variability are included. Genes, brain, and behavior are all in an environmental context, and the brain is a mechanism linking G X E interactions to development. For example, a strong brain reaction to stress might occur with a particular genetic variant in a child developing in a harsh, stressful environment but not in a child developing in a more supportive environment.

Another model that nicely ties together the perspectives of this chapter addresses the relations between the body’s response to stress and later outcomes. Experiencing chronic violence during childhood, such as mistreatment by adults, bullying, or domestic violence, often has adverse effects inside a child’s body that put the child’s physical, psychological, and cognitive health at risk later, even decades later. The main mechanism appears to be the stress response, which can lead to the epigenetic, telomere, and inflammatory changes described earlier. These changes are associated with increased risk for health problems such as heart disease, stroke, immune diseases, dementia, and metabolic diseases (Moffitt et al., 2013). Moreover, altered brain functioning, as seen in
neuroimaging, is expressed in behavioral and learning problems, as well as in depression and anxiety. The hormone cortisol, part of the stress response, appears to be particularly important (e.g., Wadsworth, 2015). Some models of the stress response emphasize environmental conditions such as poverty and racial discrimination. For instance, preadolescent African-American preadolescents in the rural South who developed psychosocial competence despite the developmental risks posed by their family’s low socioeconomic status, paid a price in harmful physiological changes in response to the high stress, evident by age 19 (Brody et al., 2013). Moreover, the negative effects of family instability and maternal unresponsiveness during the preschool years result in lower cognitive functioning by age 4 (Suor, Sturge-Apple, Davies, Cicchetti, & Manning, 2015). Finally, maternal prenatal stress can affect development during infancy and later. Mothers who experience chronic stress during pregnancy have newborns with elevated levels of cortisol in their bodies (Pluess & Belsky, 2011).

Ethology and evolutionary psychology also are part of the study of this complex system, as reflected for example in new fields, such as neuroethology and evolutionary cognitive neuroscience. Regarding connections between genetics and evolution, genetic variation and plasticity in gene expression (as seen in epigenetics) contribute to the survival of the species during evolution; when the environment changes, some genetic polymorphisms may be better adapted than others to the new environment. The growing evidence of both plasticity in gene expression and brain plasticity (in the effects of the environment and behavior on brain networks) shows that humans are uniquely equipped to adapt to changing environments. Altered gene regulation and neural connections can, for instance, help us adapt to harsh social or physical environments. For example, dangerous and unpredictable environments tend to lead to a chronic stress response, which is negative from a health perspective, but by encouraging constant vigilance may help children survive, adapt, and develop within that environment (Wadsworth, 2015). In one study, children with stressful childhoods showed improved detection, learning, and memory on tasks involving stimuli of importance to them, such as those having to do with dangers (Frankenhuis & de Weerth, 2013). These systems have evolved and, in turn, potentially change the course of evolution through, for example, the transmission of epigenetic changes across generations. In fact, some of any individual’s inherited epigenetic makeup may have been created by conditions hundreds of years ago and transmitted through subsequent generations.
Another way to think about relations between genetics and ethology is that, given that the environments in which humans develop cause epigenetic changes that affect whether a gene is expressed, some genetically possible behaviors never are expressed and thus cannot enter into the process of natural selection by increasing or decreasing survival. Thus, evolution involves not only genetic changes, but also epigenetic changes.

What can we conclude, regarding theory, from this account of neuroscience and genetics? The predominant contemporary theoretical model of gene-environment connections is that there is a dynamic interplay at various levels, including genetic, epigenetic, neuronal, hormonal, emotional, cognitive, behavioral, and environmental levels (e.g., Lickliter & Honeycutt, 2015). In this developmental system (see also Chapter 9), each level affects and is affected by each of the other levels: “All adaptations, regardless of when they appear, have their roots in earlier experiences, shaped by the bidirectional interaction between all levels of an organism and its environment (both macroenvironments, such as the family and one’s culture, and microenvironments, such as neurotransmitters and chemicals affecting the functioning of DNA molecules)” (Bjorklund & Ellis, 2014, p. 247). Note that genes do not hold a privileged controlling position but are just one component that must interact with other components in the system to function. Moreover, the nature of this system changes from one developmental point to another, and early events can cascade through later development. We already knew that development is exceedingly complex; neuroscience and genetics, along with contemporary ethological and evolutionary psychology perspectives, are providing additional mechanisms to explain this complexity.

SUMMARY
The biological terrain of development has many players—ethology, evolutionary psychology, developmental neuroscience, genetics, epigenetics, and many more. Each of these perspectives has made important contributions to developmental theorizing. Each approach has revealed both biological and environmental influences on development, and has proposed models of how they interact. Environmental influences “get under the skin” and become biologically embedded to impact development, as when chronic stress in adverse environments can trigger susceptibility genes, cause epigenetic changes, and modify brain functioning. These new findings basically destroy the nature–nurture dichotomy.

Ethology, along with other evolutionary perspectives, is one of zoology’s main contributions to developmental psychology. Thousands of
hours spent observing animals, especially nonhuman primates, have helped us understand human behavior and its development. Each species, including humans, has a set of innate behaviors, specific to that species. These behaviors have evolved phylogenetically because they have increased that species’ chances of surviving in its particular environment. Some of the most important behaviors are social, such as imprinting and dominance behaviors. Of particular interest are fixed-action patterns elicited by sign stimuli. Even learned behaviors have a strong genetic component, because each species has particular learning predispositions in the form of sensitive periods or general and specific learning abilities. Ethologists study behaviors by conducting both observations in natural settings and experimental studies in laboratories.

The ethological point of view has most influenced developmental psychology by stimulating work on attachment. Very young infants and adults are pre-tuned to respond to each other. Current attachment research examines long-term effects of each pattern of attachment, adult attachment styles, correlates between parenting quality and infant attachment, links between attachment quality and an infant’s stress response, and biological processes involved in developing attachment. Observation of dominance hierarchies in primates and other animals has led to similar studies of human peer groups, especially in preschool settings. Investigators also have asked what cognitive skills might have evolved in natural settings. With respect to developmental issues, ethologists see humans as a species that has evolved in order to survive within a particular environmental niche. Behavior changes both quantitatively and qualitatively as innate and environmental factors interact during development. The result is an organism that can operate efficiently within its environment.

Ethology has several strengths to offer the current field of developmental psychology. With respect to theory, it provides a broad evolutionary perspective on behavior that has encouraged investigators to look at the function of children’s behaviors. Ethologists advocate more observational studies of children in natural settings in order to determine the function of particular behaviors. A final contribution is the identification of several content areas as particularly important in development, such as dominance hierarchies, attachment, and cognition. Ethology has certain weaknesses, however, that limit its usefulness for developmental psychology. Its theoretical notions, such as sensitive periods, have not yet reached an explanatory level. With respect to methodology, the observational method poses many challenges. Finally, ethologists find it difficult to study certain aspects of development, such
as language and abstract thought in older children. Main examples of contemporary ethological and evolutionary research on development are attachment, the evolution of human cognition in social groups, and adaptation during development.

Ethology and evolutionary psychology are a fruitful source of working hypotheses about what behaviors are important and why they are acquired. An ethological attitude opens the investigator’s eyes to a broad context that spans space and time and various levels of analysis. In particular, ethologically based observations in the early phases of a research project can give the “big picture” of the behavior that will later be studied in a controlled laboratory setting.

Neuroscience perspectives have produced models of brain development, as cause of and effect of, children engaged in their environments. Anatomical changes, such as increased myelination, make new learning possible. An initial overproduction of neurons in early infancy is modified by experience. Humans have a lifetime of strengthening certain neural pathways, developing new pathways, and pruning away unused pathways. An initially highly plastic brain becomes less plastic as specialization of brain areas and pathways gradually occurs during development. Brain areas develop at different rates, resulting in important asynchronies at certain developmental points, as seen in adolescents’ difficulties controlling their risk-taking behaviors. Finally, brain development takes place over the lifespan, subject to constraints from genes, the environment, and development. Neuroscience has revealed important mechanisms related to the nature–nurture issue and has provided evidence for both qualitative and quantitative development. In applications, neuroscience has improved our understanding of developmental disorders, such as autism, and has informed the design of educational programs.

The human genome is an amazingly complex blueprint for development. Just as a blueprint may never become a house, a genome may never be fully translated into behaviors. Genes may be expressed similarly in most environments, expressed more in some environments than others, or not expressed at all in certain environments. The two main approaches are Gene X Environment models and epigenetics. G X E interactions show that a person’s genotype moderates the effect of an environmental factor on outcomes, such as traits, behaviors, mental health, and cognition. For example, highly stressful life events might be more likely to lead to depression if a person has a particular pattern of genes. Similarly, the environment moderates the association between a particular gene polymorphism and an outcome. Positive, close relationships, especially with
parents, can buffer the negative effects of certain genes. Epigenetics provides the molecular mechanism by which G X E interactions affect cell biology and consequently behavior. Through epigenetics, certain aspects of the environment affect whether a genetic predisposition is expressed in behavior, which can result in permanent changes in gene regulation. Moreover, epigenetic changes can be transmitted to the next generation. G X E interactions and epigenetics during the course of development influence degrees of risk for developing a problem, given vulnerable gene polymorphisms. Bringing together neuroscience and genetics, recent models have correlated genetic variations and specific patterns of brain activity. Such information clarifies how the brain is a mediator between genes and behavior. Variations in environments also should be added to these models.

Current models of the dynamic interplay among genes, brain, behavior, and the environment favor a systems approach, to capture the complexity and co-influences of these components. Development emerges from these interactions among multiple levels of influence.

**SUGGESTED READINGS**

The following readings survey evolutionary, including ethological, research on humans and animals:


Lorenz delights us with this account of his life with animals:


Cognitive developmental neuroscience:


Genetics:

NIH has worked with several scientific organizations to create websites with genetics tutorials for scientists and students in the social sciences.
As of this writing, the following one with the National Coalition for Health Profession Education in Genetics is especially useful: http://www.nchpeg.org/bssr/

