2

The Substrate for Learning

Unconditioned Behavior

Did you know that

- learning is constrained by the organism's unconditioned or unlearned behavior? Therefore, understanding the structure of unconditioned behavior is necessary for the study of learning.
- the simplest units of unconditioned behavior are reflexes and modal action pattens? These are responses to specific eliciting stimuli that occur in a similar fashion in all members of a species.
- although seemingly simple, reflexes and modal action patterns can result in well-coordinated, complex social behavior?
- modal action patterns do not occur in isolation but are organized in systems of behavior that evolved to accomplish important biological goals, such as feeding, reproduction, and defense against injury?
- behavior systems consist of a series of response modes and response modules? These include general search, focal search, and consummatory behavior.
- the response modes of a behavior system are organized in space and time and determine how behavior is modified by conditioning procedures?

Learning enables organisms to benefit from experience. Through learning, behavior can be changed in ways that make the individual more effective in

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interacting with its environment. Animals can forage more effectively by learning where and when food is likely to be available (Stephens et al., 2007). They can defend themselves more successfully by learning when and where they are likely to encounter a predator (e.g., Hollis, 1999). And they can be more effective in their sexual responses and produce more offspring by learning when and where they are likely to encounter a potential sexual partner (Domjan & Gutiérrez, 2019).

SHAPING AND HETEROGENEOUS SUBSTRATES OF BEHAVIOR

In all instances of learning, the behavior of an organism is modified or shaped by its prior experience. B. F. Skinner introduced the term **shaping** in reference to a particular type of conditioning procedure in which new forms of behavior are produced by reinforcing successive approximations to the behavior. We describe shaping in greater detail in Chapter 6. For our present purposes, it is sufficient to point out that through shaping, an organism's behavior can be gradually changed to enable it to perform new responses. A child's uncoordinated arm and leg movements, for example, can be gradually shaped to enable him to swim rapidly across a pool.

Skinner chose the term *shaping* by analogy with the way in which a sculptor gradually changes and molds a lump of clay into a recognizable object (Skinner, 1953). A sculptor interested in making a statue of a swan, for example, starts with an unformed lump of clay. She then cuts away pieces of clay here and there and molds what remains in special ways. As this process continues, a recognizable swan gradually emerges. In an analogous fashion, learning can change or shape an organism's behavior, with the result that the individual comes to respond in new ways.

The analogy with molding a block of clay into a swan captures some of the aspects of how behavior is changed through learning. However, the analogy has a serious shortcoming. Clay is a homogeneous substance that can be molded in any direction with equal ease. Behavior is not like that. Behavior cannot be changed in any direction with equal ease. Changes in behavior occur in the context of genetically programmed predispositions that make certain changes easier to produce than others. For example, it is much easier to train animals to approach and manipulate food-related stimuli (Hearst & Jenkins, 1974) than it is to train them to release or withdraw from stimuli related to food (Breland & Breland, 1961; Timberlake et al., 1982).

Learning procedures do not shape new behavior in the way that a sculptor shapes clay into a new object. A more apt analogy for the behavioral substrate of learning is provided by wood rather than clay (Rachlin, 1976). Unlike clay, wood has a heterogeneous or uneven consistency. It is grainy and has knots. Cutting with the grain is easier and results in a smoother line than cutting against the grain and cutting around knots is easier than cutting through them. Because of this heterogeneity, if you are carving a statue out of wood, you have to pay close attention to how the statue is oriented in relation to the grain and

the knots in the wood. Analogously, learning psychologists must pay close attention to how the new skills they are trying to teach fit with the organism's preexisting behavioral tendencies. Chapter 2 is devoted to a description of these preexisting behavioral tendencies.

All instances of learning reflect an interaction between the training procedures used and the individual's preexisting behavior. Changes brought about by learning are not applied to a homogeneously modifiable substrate. Rather, learning is superimposed on a heterogeneous preexisting behavioral structure. Therefore, understanding how learning occurs and is expressed in observable performance requires an appreciation of the heterogeneous behavioral substrate that organisms bring to a learning situation.

The dependence of learning on unlearned aspects of behavior has been emphasized in some areas of learning more than others. The interaction between conditioned and unconditioned aspects of behavior has been the focus of attention in studies of Pavlovian conditioning and avoidance learning (see Chapters 4 and 12). However, as we will see, unlearned or unconditioned behavioral tendencies are important in many other forms of learning as well.

THE CONCEPT OF THE REFLEX

The smallest unit of unconditioned behavior is the **reflex**, a unit of elicited behavior involving a specific environmental event and its corresponding specific elicited response. The concept of a reflex was formulated by the French philosopher René Descartes (1596–1650). Descartes made numerous contributions to Western philosophy, including ideas about behavior that are familiar to most of us today but were innovative in the 17th century when he introduced them. Like other philosophers of his time, Descartes believed that important aspects of human behavior were voluntary. However, he was also impressed with the seemingly automatic and involuntary nature of some actions and proposed the concept of the reflex to characterize involuntary behavior.

Descartes based his concept of the reflex on animated statues that he saw in public parks in France. Sophisticated animated characters, such as those created by Disney Studios, were not available in Descartes's time. But some of the parks Descartes frequented had statues whose limbs would move when someone walked by. Through a series of levers and linkages, the limbs and joints of the statue were connected to steppingstones along the walkway near the statue. Whenever someone stepped on one of these stones, the pressure on the steppingstone was transferred to the statue, causing its arm or leg to move.

The moving statues appeared lifelike, and it seemed to Descartes that some aspects of human and animal behavior were similar to the behavior of these statues. Descartes pointed out that animals and people also perform certain actions in response to particular environmental stimuli. For example, we quickly withdraw our finger when we touch a hot stove, we "instinctively" flinch when we hear a sudden noise, and we extend our arm when we lose our footing. When a specific behavior or action pattern occurs reliably upon

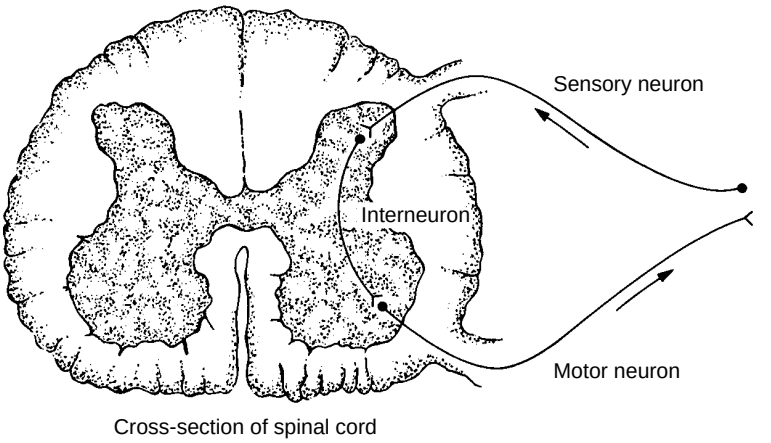
presentation of a particular stimulus (its eliciting stimulus), this is known as **elicited behavior**.

The movements of the statues Descartes saw were elicited by the stimulus or force applied to the associated stepping stones. Thus, the movements were reflections of the eliciting stimulus. Descartes coined the term reflex to capture this idea of behavior being a reflection of an eliciting stimulus. The entire unit from stimulus input to response output was termed the **reflex arc** (see Figure 2.1).

Reflexes are involved in many aspects of behavior important for sustaining critical life functions. Respiratory reflexes provide us with sufficient air intake. The suckling reflex provides a newborn's first contact with milk. Chewing, swallowing, and digestive reflexes are important in obtaining nutrients throughout life. Postural reflexes enable us to maintain stable body positions, and withdrawal reflexes protect us from focal sources of injury.

For about 250 years after Descartes, investigators of reflexes were primarily concerned with physiological questions. Scientists studied the neural circuitry of the reflex arc, the mechanisms of neural conduction, and the role of reflexes in various physiological systems. These investigations continued at an accelerated pace in the 20th century. While many refinements to the reflex concept were introduced, the key idea was that much of behavior could ultimately be understood in reflex terms. In addition, the concept of elicited behavior was extended to more complex forms of behavior. Much of this work was done in the newly emerging field of **ethology**, which is a specialty in biology concerned with the evolution and development of functional units of behavior (Baerends, 1988).

FIGURE 2.1. Neural Organization of the Reflex Arc



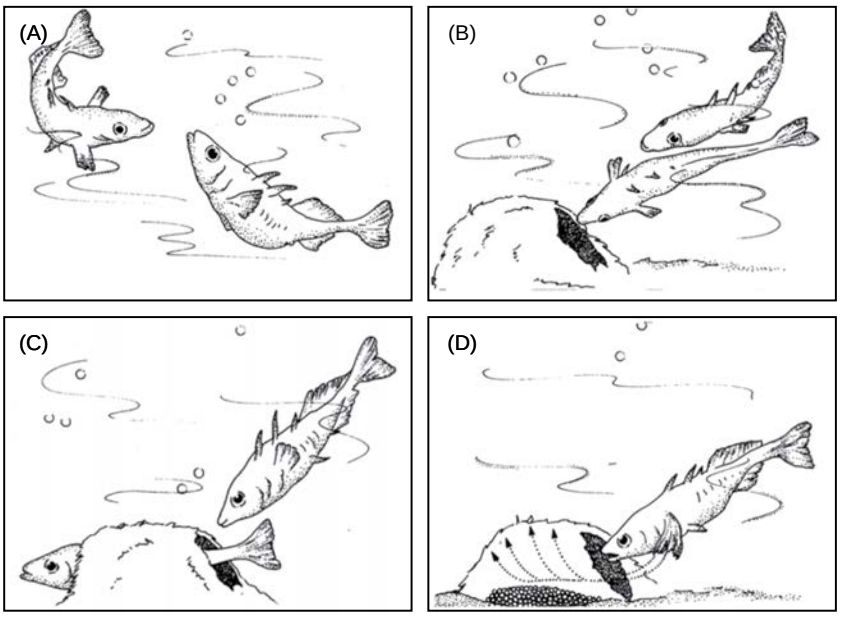
Note. The environmental stimulus for the reflex response activates a sensory neuron, which transmits the sensory message to the spinal cord. Here the neural impulses are relayed to an interneuron, which in turn passes the impulses to the motor neuron. The motor neuron activates muscles involved in the reflex response.

COMPLEX FORMS OF ELICITED BEHAVIOR

Ethologists discovered that complex social behavior in various species is made up of response components that are elicited by social stimuli. A male stickleback fish, for example, establishes a small territory and builds a nest tunnel during the mating season. After the territory has been set up, the approach of a male intruder elicits an aggressive defensive response from the resident male. In contrast, if a female enters the territory, the resident male engages in courtship zigzag swimming movements (see Figure 2.2). The courtship zigzag movements stimulate the female to follow the resident male to the nest tunnel. Once the female is in the tunnel, with her head at one end and her tail at the other, the male prods the base of the female's tail. This causes the female to release her eggs. The female then leaves the nest and the male enters and fertilizes the eggs. After that, he chases the female away and fans the eggs to provide oxygen until the eggs hatch (see Tinbergen, 1952).

In this complex behavioral duet, the male and the female play their own special roles. Stimuli provided by the female trigger certain actions on the part of the resident male (zigzag swimming), the male's behavior in turn provides stimuli that trigger other responses on the part of the female (following the

FIGURE 2.2. The Sequence of Courtship and Reproductive Behavior in the Stickleback



Note. (A) The male swims toward the female in zigzag motions. (B) The male guides the female to the nest. (C) The female enters the nest and releases her eggs. (D) After fertilizing the eggs, the male fans them to provide sufficient oxygen for development. Based on Tinbergen (1952).

resident male to the nest), the female's behavior then leads to further responses from the male, and so on. The outcome is a sequence of nicely coordinated social responses. The behavior sequence progresses only if the male's behavior provides the necessary stimulation to elicit the next response from the female, and vice versa. If the response of one participant fails to produce the next response in its partner, the sequence of actions is interrupted, and the social interaction may come to an end.

Unconditioned Modal Action Patterns

Careful observations by ethologists have revealed numerous examples of complex social and nonsocial behaviors that are made up of sequences of elicited responses of the sort illustrated by the sexual behavior of sticklebacks. Elicited responses have been shown to be involved in, among other things, nest building, incubation, parental feeding of the young, grooming, foraging, and defensive behavior (Rubenstein & Alcock, 2019). Each unit of elicited behavior is made up of a characteristic response and its corresponding eliciting stimulus.

The units of elicited behavior we have been discussing are commonly called **modal action patterns**, response patterns that occur in much the same fashion most of the time and in most members of a species. The phrase *action pattern* is used instead of *response* because the activities involved are not restricted to a single muscle movement, such as the blink of an eye or the flexion of a leg muscle. Elicited responses involved in grooming, foraging, courtship, and parental behavior require a coordinated set of various muscles. The word *modal* is used to signify that most members of the species perform the action pattern in question and do so in a highly similar fashion. An action pattern is a characteristic of the species. For example, infant mammals typically feed by suckling, infant gulls typically feed by gaping and receiving food from a parent, and infant chickens typically feed by pecking small spots on the ground. Because modal action patterns are characteristic of a species, they are examples of **species-typical behavior**.

Originally modal action patters were called *fixed action patterns* to emphasize that they are a stable feature of a species. However, the responses are not "fixed" in the sense that they occur exactly the same way each time. Because there is some variability in the elicited responses from one occasion to another, the term *modal action pattern* is now used in preference to *fixed action pattern*.

Modal action patterns are evident in the behavior of all animals, including human beings. Our facial expressions (how we smile or express anger) are species-typical responses elicited by social and other stimuli. Suckling in infants is a modal action pattern, as is chewing in older individuals. How we comfort one another also reflects species-typical modal action patterns.

Sign Stimuli

Modal action patterns occur in the context of a rich and sometimes complex array of stimuli. However, often only a limited stimulus feature is necessary

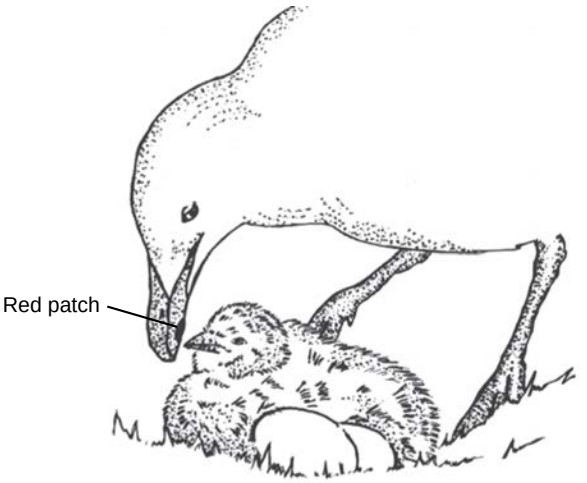
to elicit the response. Using models of different types of sticklebacks, investigators have found that a male stickleback that has established a nest recognizes an intruding male by the red color on the intruder's ventral surface. In contrast, they respond to an intruder with a swollen belly as a female. The pecking response of herring gull chicks, for example, is elicited by a prominent red spot on their mother's or father's bill (see Figure 2.3). The pointed shape of the parent's bill, together with this prominent spot, stimulates the chicks to peck the parent's bill, which then causes the parent to feed the chick by regurgitating food. Other aspects of the parent (the shape of her head, her eyes, how she lands on the edge of the nest, the noises she makes) are not important (Tinbergen & Perdeck, 1950).

The limited stimulus feature that is sufficient to elicit a modal action pattern is called a **sign stimulus**. Sign stimuli have also been identified in the activation of human behavior. Much of the cosmetic industry is built on reproducing sign stimuli that control human social behavior, and fast food relies on sign stimuli that elicit human ingestive preferences (Barrett, 2010).

Reflexes and modal action patterns are the smallest units of the preexisting behavioral organization that is the substrate on which learning and training procedures operate. Notice that reflexes and modal action patterns involve specific responses and specific stimuli. The suckling response of a newborn involves activating the muscles of the lips and mouth in a coordinated and highly organized fashion without learning. This response is triggered by a nipple-like stimulus placed in the mouth. Infants may suckle a finger placed in their mouth, but they will not suckle in response to a tone or light.

An important feature of the unconditioned behavioral substrate on which learning operates is that it involves specific responses and stimuli. As we will see in later chapters, knowing what these unconditioned stimuli and responses are is critical for the design of successful learning procedures. Organisms have evolved

FIGURE 2.3. The Sign Stimulus for the Pecking Response of Herring Gull Chicks Is a Red Spot Near the Tip of the Parent's Bill



to perform modal action patterns in response to sign stimuli, and thus tasks that involve such responses and stimuli are learned more easily and are said to be biologically prepared. In contrast, tasks that are contradictory or unrelated to an organism's evolutionary history are likely to be difficult, if not impossible, to learn.

THE ORGANIZATION OF UNLEARNED OR UNCONDITIONED BEHAVIOR

If each reflex or modal action pattern occurred automatically whenever its eliciting stimulus was encountered, behavior would be somewhat disorganized. Elicited responses do not occur independently of each other. Rather, they are organized in special ways. Some of this organization is a result of learning and experience. However, much of the organization of unconditioned behavior does not require learning or input from experience.

Motivational Factors

One prominent factor that serves to coordinate modal action patterns is the motivational state of the organism. In numerous species, for example, courtship and sexual responses occur only during the breeding season or only in the presence of the right combination of sex hormones. In fact, the necessary conditions can be even more restrictive. Male sticklebacks court females only if they are in the breeding season and have already established a territory and built a nest. These preconditions serve to prime or create the motivation for courtship behavior.

Motivational factors have been identified for a variety of modal action patterns, including aggression, feeding, and various aspects of parental and sexual behavior. The motivational state sets the stage for a modal action pattern, the actual occurrence of which is then triggered by a sign stimulus. In a sense, the sign stimulus releases the modal action pattern when the animal is in a particular motivational state. For this reason, a sign stimulus is also sometimes referred to as a **releasing stimulus**.

Ethologists considered the motivational state of the organism to be one of the key factors involved in the organization of behavior (e.g., Lorenz, 1981). Using motivational concepts, ethologists formulated an influential model of how modal action patterns are organized, referred to as the **hydraulic model** of behavior. The hydraulic model assumes that certain factors lead to the buildup of a particular type of motivation or drive. The term *hydraulic* was used by analogy with a hydraulic engine, in which the buildup of pressure causes pistons to move until the pressure is released or dissipated. The hunger drive, for example, is created by the expenditure of energy and the utilization of nutrients. This drive then induces selective attention to food-related stimuli

and lowers the threshold for activating food-related modal action patterns. Once food is found and eaten, the motivational state of hunger is discharged. Thus, the motivational state facilitates modal action patterns related to eating, and the opportunity to perform those responses in turn reduces the motivational state.

Appetitive and Consummatory Behavior

Elicited behavior is also organized sequentially. Certain responses tend to occur before others. Ethologists characterized the response sequence involved in the discharge of a drive state as consisting of two major components, appetitive and consummatory behavior (Burghardt & Burkhardt, 2018). **Appetitive behavior** is the initial component of a species' typical behavior sequence. It tends to be highly variable and flexible and occurs before a specific sign stimulus is encountered to elicit a modal action pattern. In the case of the feeding system, appetitive behavior consists of responses involved in searching for a patch of food. Initially searching for food occurs in response to general spatial cues. For example, a squirrel searching for a patch of food will initially focus on spatial cues that help identify trees and bushes that may contain nuts and fruit. Appetitive behavior tends to occur over a wide area and involves a range of possible activities. During the course of its foraging, the squirrel may run across open grass, scramble over rocks, climb trees, jump from one tree limb to another, and so on.

Once the squirrel encounters an edible nut, its behavior becomes much more stereotyped and focused. Now the squirrel remains in one place, sits back on its hind legs and tail, takes the nut in its front paws, cracks it open, and chews and swallows the food. These more stereotyped species-typical activities are examples of **consummatory behavior** because they complete or consummate the response sequence. Consummatory modal action patterns end the response sequence because these responses discharge the motivation or drive state.

In the feeding system, consummatory behavior involves the consumption of food, but the similarity in wording in this case is merely a coincidence. In the sexual behavior system, consummatory behavior consists of the copulatory or coital responses that serve to complete a sexual interaction. In the defensive behavior system, consummatory behavior consists of the circa-strike responses an animal makes when it is not just threatened but physically attacked by a predator (see Chapter 12).

Appetitive behavior consists of activities that enable an organism to come into contact with the sign stimuli which then elicit the modal action patterns that permit completing the response sequence. For example, the appetitive sexual behavior of the male involves searching for a female. Once the female is encountered, the stimuli provided by her elicit a more restricted range of courtship and copulatory responses. These copulatory or coital responses

then discharge the motivation to engage in sexual behavior, thereby consummating or ending the sexual behavior sequence. Appetitive responses tend to be more flexible than consummatory responses and occur in response to a wider range of stimuli, therefore the responses that are learned in conditioning procedures are more likely to involve appetitive rather than consummatory behavior.

Behavior Systems

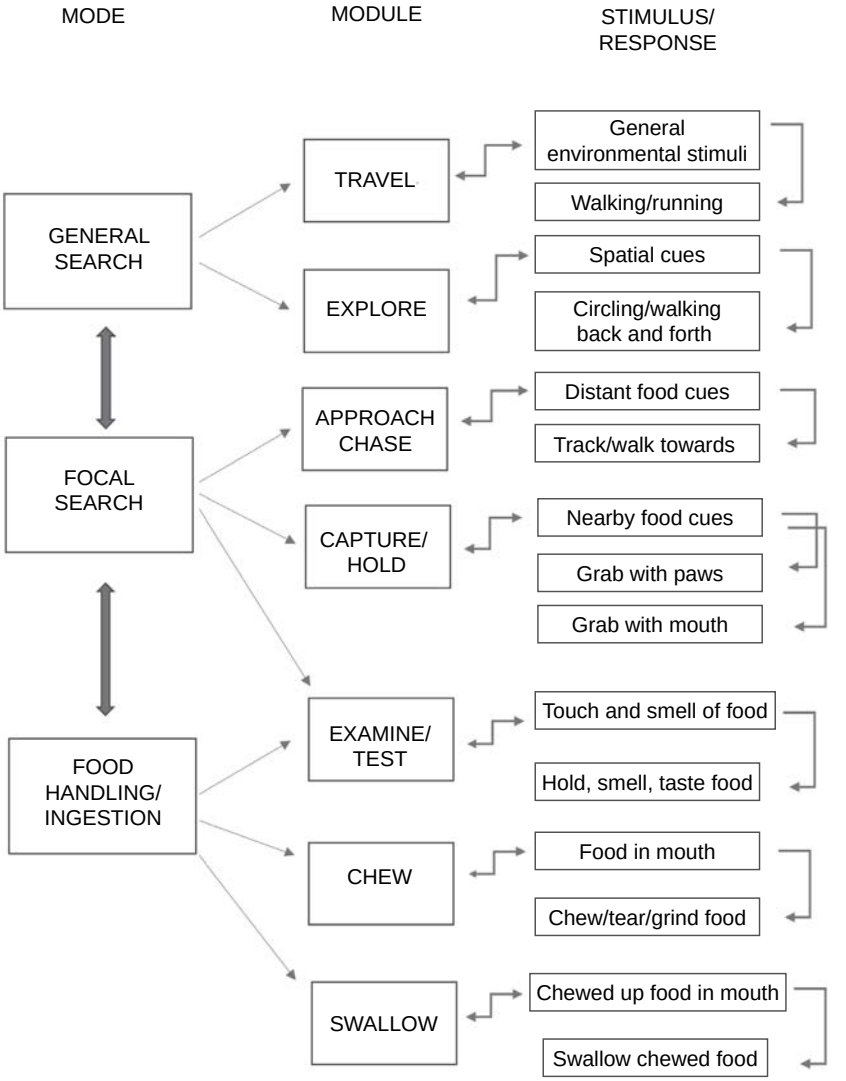
The distinction between appetitive and consummatory responses was just the beginning of efforts to understand the genetically determined structure of behavior before a conditioning procedure is introduced. Initially, these efforts were primarily of interest to ethologists (Bowers, 2018), but in recent years psychologists have also come to appreciate that understanding the outcome of a conditioning procedure requires understanding how behavior is organized before learning ever starts (Cabrera et al., 2019). These considerations have required going beyond the appetitive–consummatory distinction. They have required considering whole behavior systems. A **behavior system** consists of a series of response modes and response modules. These include general search, focal search, and consummatory behavior.

Timberlake (1994), a prominent advocate of the behavior systems approach to learning, described the structure of feeding behavior as consisting of a series of response modes and modules, as illustrated in Figure 2.4. According to this more detailed view, the feeding behavior sequence starts with the **general search mode**, in which the animal reacts to general features of the environment with responses that enable it to come in contact with a variety of potential sources of food. A squirrel, for example, may move around looking for trees that might have nuts or fruit to eat. As Figure 2.4 illustrates, the general search mode includes two response modules, travel and explore.

Once the squirrel has identified a potential source of food, it switches to the **focal search mode**. In the focal search mode, the squirrel approaches things that look like nuts and fruit and captures and examines them. In the focal search mode, the squirrel is especially sensitive to food cues that are visible from a distance. Once the squirrel has captured the food, it moves into the food handling and ingestion mode. In this mode, the squirrel examines and tests the food, chews it, and swallows it. These response modules are activated by detailed features of the food itself, such as the touch and smell of the food before ingestion, and the taste and texture of the food once the squirrel has put the food in its mouth.

In the behavior systems analysis, the general search and focal search modes (along with the response modules associated with these modes) correspond to what ethologists referred to as *appetitive behavior*. Thus, the behavior systems approach provides a more detailed characterization of appetitive behavior. Consummatory behavior (food handling and ingestion) is also described in greater detail, including several response modules.

FIGURE 2.4. Components of the Feeding Behavior System



Note. The feeding behavior sequence begins with a general search for potential food sites. Once a potential food site has been identified, the animal engages in a focal search of that site. Upon finding the food, the animal engages in food-handling and ingestion responses. Adapted from "Behavior Systems, Associationism, and Pavlovian Conditioning," by W. Timberlake, 1994, *Psychonomic Bulletin & Review*, *1*(4), p. 411 (https://doi.org/10.3758/BF03210945). Copyright 1994 by Springer Nature. Adapted with permission.

As we will see, behavior systems are highly relevant to predicting the behavioral manifestations of learning. Several features of behavior systems are important in contemporary studies of learning:

1. Behavior systems usually consist of a sequence of three or more modes of behavior, rather than just appetitive and consummatory behavior. The organism moves from one mode of responding to another (general search to focal search) depending on the environmental events that it encounters.
2. The sequence of response modes is linear. An animal typically moves from one response mode to the next without skipping any steps in the sequence. A squirrel cannot handle food, for example, without first having encountered the food in its focal search mode.
3. Although the response sequence is linear, it is not one-directional. An animal may go either forward or backward in the sequence depending on the circumstances. If the focal search behavior of a squirrel is not successful in locating nuts, the squirrel will move back to its general search mode.
4. Because response modes are ordered in a linear fashion, they are also organized in time. General foraging responses tend to occur farther in time from the end of the feeding behavior sequence than ingestive responses. Because of this, temporal variables in learning are related to temporal factors in preexisting behavior systems.
5. Finally, each response mode involves not only characteristic responses but also increased sensitivity or attention to particular kinds of stimuli. In the general search mode, the squirrel is responsive to general environmental cues and spatial cues. In the focal search mode, its behavior is governed by cues of nuts and fruit that the squirrel can see at a distance. More intimate features of the nuts and fruit (texture and taste) control behavior its behavior in the food handling and ingestion mode. Thus, the various response modes differ not only in terms of the types of response that are involved but also in the types of stimuli that guide the behavior.

SUMMARY

All instances of learning reflect an interaction between the training procedures that are used and the individual's preexisting behavioral organization. Therefore, understanding how learning occurs requires an appreciation of unconditioned behavioral mechanisms. Unconditioned behavior is not homogeneous and modifiable in any direction but has its own determinate structure. The simplest unit of unconditioned behavior is the reflex, which consists of a specific eliciting stimulus and a corresponding elicited response. More complex forms of elicited behavior, studied by ethologists, involve modal action patterns that are elicited by sign stimuli or releasing stimuli. Ethologists identified motivational factors involved in the control of modal action patterns

and pointed out that elicited behavior consists of a predictable sequence of activities that begins with appetitive responses and ends with consummatory behavior. These ideas have been extended in contemporary conceptualizations of behavior systems. A behavior system is a set of response modes that is activated in a coordinated fashion to achieve an important behavioral outcome such as nutrition, defense, or reproduction. The response modes are organized sequentially, and each response mode is characterized by particular responses and increased sensitivity to particular types of stimuli.

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