

## ON IMMEDIATE FUNCTION

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Behavior is a property of living organisms, not of inanimate matter. The problems of physical science are to understand how a phenomenon works; biological science adds the questions of what a phenomenon does and how something that does such things came to be. Exclusive dedication to cause-effect explanations ignores how behavior helps creatures cope with their internal and external environments. Laws of causation describe the precursors to behavior; laws of function describe the effects of behavior. The numerous instances of learning reflect the many ways that selective pressure for altering behavior on the basis of experience has been manifested. Little basis exists for assuming that the various forms of learning reflect either common functions or common processes. Instead, it seems that evolutionary processes have resulted in domain-specific learning. The rules of learning must be understood in terms of the function that the particular manifestation of learning serves for the organism. Evolutionary theory provides the framework for understanding function as well as relations between function and causal mechanisms.

*Key words:* evolution, function, causation

No student of learning ever suggested that learning is a property of inanimate matter. Learning theories and textbooks often begin by referring to learning as the outcome of evolutionary processes, most typically the process of natural selection. Because natural selection and reinforcement both entail variation and selection, they may be analogous processes (cf. Skinner, 1988; Staddon & Simmelhag, 1971). However, saying that learning is a characteristic of living organisms and believing in evolution are at best only necessary precursors to a biological orientation. They are not sufficient to put learning in a biological context.

What is a biological perspective? In his classic "Four Why's Of Biology," Tinbergen (1963) said that a biological explanation of any behavior means knowing its internal and external causes, the role it plays in survival, how it evolved, and its ontogenetic development. In contrast, behavior analysis and learning have been virtually exclusively concerned with causation. For biological science, causation is not enough. The biologist is not even likely to be interested in determining the causes or evolution or ontogeny of a phenomenon until it has been found to play a role in main-

taining life. Mayr (1983) pointed out that finding the function of a given structure or organ has been the basis for every advance in physiology, and the same holds for botany, animal behavior, and even biochemistry. The next section explores why the analysis of function has not been applied to learning.

THE CENTRALITY OF FUNCTION:  
BIOLOGY VERSUS PHYSICS

Because *function* has many meanings (see Wright, 1973), it is easily misunderstood. It is not now intended in any of its mathematical senses. Nor does it refer to the usual meaning of functional analysis, which describes some behavior as the outcome of antecedents. That usage corresponds to causation. The problems of causation are the rules of how preceding events initiate, guide, and coordinate learned behavior. Function means effects. Hearts pump blood, lungs supply oxygen and eliminate carbon dioxide, kidneys control sodium balance, livers secrete bile, hormones influence growth, behaving in a certain way gets food. These are not antecedent causes of hearts, lungs, kidneys, livers, hormone secretion, or behavior; they are consequences of the action. Causation looks back in time to describe how the behavior is determined. Function looks forward to describe what the behavior accomplishes.

Important consequences are what make behavior critical in human affairs. The ability to find clear cause-effect relations provides no perspective on whether or not the behavior is

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worth studying. Rigor, replicability, logical consistency, and experimental control have no necessary relation to importance. Some behavior patterns that we observe or even study in detail may not contribute to survival or to the welfare of the behavior or of anyone else or to the environment. Suspicions that this is so probably underlie judgments that a particular behavior is trivial and not worth understanding in detail. Behavior without consequences of any sort is hard to imagine, maybe because it would necessarily be so boring. Accomplishment puts behavior and subsequent causal analyses in context.

Function never refers to organisms striving to achieve certain outcomes. To confuse function with goal-directedness is to confuse the effects of behavior with its causes. Eyes see, but seeing does not cause eyes; maternal behavior results in caring for offspring, but caring for offspring does not cause maternal behavior. The functions of behavior are its effects on the behavior and on the social and physical environment. Antecedent conditions are its causes.

Function can seem strange to psychologists indoctrinated in a scientific psychology modeled on physical science. The Newtonian tradition meant commitment to causal law (mechanism) as the only real science. Asking about accomplishment in physics seems to harken back to medieval theology. Biology proceeded more or less independently of physics and astronomy because of the unique properties of life. Nothing comparable to the ability of life to regenerate itself, or the changes in bodies that occur with shifts in geographic distribution and over the course of evolution, or how parts contribute to maintenance of the whole exists in physics, but these are primary concerns of biology. The essence of biological systems is that they are means to achieving ends (Williams, 1966). The first question raised by observation of living organisms is what a feature is accomplishing.

Actually, function is relevant whenever inanimate matter is organized so as to produce objects that do things. Invention entails function, because parts must be chosen on the basis of their suitability in facilitating an outcome. Understanding a machine begins with discovering its function. According to the Gaia hypothesis (Lovelock, 1979), even the physical properties of the Earth have been determined

by the role that they play in sustaining life. Marr (1982) described the first level of understanding as discovering what a system does. The next level is to understand how that outcome is implemented by a program. The third level is to find the hardware that actualizes the first two levels. The challenge is to pinpoint the important problems that are being solved by organized systems, whether the problem is to understand a new computer or the nature of learning or maybe even the Earth itself.

Because psychologists were overwhelmed by the accomplishments of Newtonian physical science, they focused exclusively on causes (e.g., how environmental variables instigate behavior, or the physiological processes that intervene between input and output, or the transformation rules by which antecedent inputs are translated into behavior) and ignored the role of mind and behavior in life. William James (1890) and early Functionalists (e.g., Angell, 1907) embraced function, but their impact was fleeting. Hollis (1990) discussed how function has returned to the psychology of learning through biologists who generated the field of behavioral ecology (e.g., Krebs & Davies, 1984). However, their concept of function has more commonly been evolutionary significance than immediate accomplishment.

#### IMMEDIATE AND EVOLUTIONARY FUNCTION

Tinbergen (1963) separated immediate from evolutionary accomplishment in his distinction between survival value and evolution. Understanding the role of a feature in allowing animals to survive is different from understanding the means by which the feature came about. The benefits and liabilities of a behavior pattern are important to discover even if evolution was unknown.

For a paper as widely cited as Tinbergen's (1963) to be so ignored in this respect is puzzling. Confusion between short-term effects and evolution is as rife as confusion between causation and function. Optimal foraging theory is a case in point. Optimal foraging theory determines the behavior that will maximize the rate of obtaining food or will maximize net energy intake under a given set of quantifiable constraints (MacArthur & Pianka, 1966). Yet the theory is framed in terms of fitness and survival, probably because of the still untested

assumption that natural selection will always favor maximally efficient food-getting. Whether or not that is true, the data used to support optimal foraging theory have always involved immediate returns like getting food or salt or mates, rather than long-term fitness (Stephens & Krebs, 1986).

Although it is unfair to blame one source, one influential paper contributed to both causation-function and function-evolution confusions. Baker (1938) described the problems for behavioral biology as explaining both the *ultimate causes*, the determinants of the genetic programs responsible for behavior, and the *proximate causes*, the factors responsible for triggering the program at a given time. Proximate causation—a concept used throughout behavioral biology—has invariably included both causation and function, probably because of the implicit belief that goals determine behavior. Ultimate causation also has incorporated function because of the explicit belief that consequences always have selective value.

Fitness enhancement is an accomplishment, although it occurs over a longer time span than do the immediate consequences of behavior. The terms *immediate function* and *evolutionary function* distinguish between current accomplishments and future effects on individual reproductive success or inclusive fitness. “Immediate” implies no commitment to any particular molecular or molar level of accomplishment, but only excludes evolutionary effects. Evolutionary function involves a genetic effect on numerous later generations, whereas immediate functions are consequences now. They are linked theoretically, because important current accomplishments can lead to increased opportunity for individual or inclusive fitness.

Methods for dealing with immediate and evolutionary function are different. Immediate function appears in ongoing behavior and so can be studied experimentally. Evolutionary function can only be studied with the methods of historians until techniques are developed to observe how particular behavior patterns influence fitness.

#### THE EXPERIMENTAL ANALYSIS OF IMMEDIATE FUNCTION

The sheer occurrence of some behavior is not proof that it is or was important or even

that it is or once was adaptive. Speculation about the importance of some behavior is a reasonable starting point, but story telling, no matter how thoughtful or creative, does not show what the behavior accomplishes. Experimental analysis and good theory are just as essential in understanding function as they are in understanding causation.

Hollis (1990) is among those who have studied the functions of learning. Her interest has been in how learning about signals for intruders influences the ability of blue gouramis to maintain control of breeding grounds and territories. Fish that have learned are more likely to win fights against intruders than those that either have not had a signal for arrival of an intruder or those that have had an unpredictable signal. In present terms, at the behavioral level the immediate function of the learning is better fighting. At the neuroendocrine level, it is the secretion of certain hormones. Those hormones then may act as a causal mechanism for improved fighting ability. Improved ability perhaps leads to increased reproductive success (evolutionary function). The mechanisms are first the processes that control learning about such signals and signaled events, then the processes responsible for hormonal production, and finally those that convert hormonal activity into fighting. Recent reviews suggest that research in this vein is increasing (Hollis, 1990; Timberlake & Lucas, 1989).

Hollis' gouramis did not die if they lost a fight. What, then, was the survival value of fighting? Sometimes behavior results in immediate life or death, as when an animal confronts a predator or dies if it loses a fight, but most often survival value is inferred as a long-term potential. Continued existence usually does not hinge on getting food or a mate right now. How immediate function generally relates to survival is an open question. Survival value is a theory of immediate function; it is not often directly observable in behavior.

The study of operant behavior puts immediate function in an experimental context, because this kind of behavior is defined by its consequences. Staddon (1983) discussed several kinds of operant behavior in terms of feedback between ongoing behavior and its immediate function. Most theories of operant behavior are theories of immediate function. The law of effect itself is a theory of immediate function, because it is about consequences. Ho-

meostatic theories of why events are reinforcers are about outcome, not about causation.

Two theoretical approaches warrant further discussion. The first, optimality theory, is central in behavior-analytic and ecological approaches to immediate function. The second, behavior systems theory, is a theory of learned behavior based on immediate function.

### *Optimality Theory*

Many theories of operant behavior are optimality theories in that they hypothesize that behavior maximizes benefits. The benefit can be local or molar maximization of some payoff like food or money, or minimization of time to food, or reduction in frequency of electric shock. That so many different theories of outcome exist means that the function even of presumably simple kinds of behavior is not all that obvious.

However, because the experimental reports rarely have been written from the perspective of function, it is necessary to paraphrase their findings. The common method is to determine whether behavior takes the form predicted by some form of optimality theory and thereby to conclude whether or not the hypothesized function is the correct one. Shortcomings in a particular form of optimality theory (optimal foraging theory) have received publicity (Kitcher, 1985), but it is probably safe to say that all versions have been problematic in that, at best, predictions have loosely approximated the observed behavior.

There are many reasons for discrepancies between optimality predictions and behavior that are not mutually exclusive. The most often-cited ones are inherent constraints on perfect performance. In the real world, inadequate sensory capacity, or inability to run faster, or limits on metabolic or respiratory rate, or inadequate memory, or any other less-than-perfect attribute can make ideal performance impossible. What others are doing and how many are doing it can alter what is best (Maynard Smith, 1982). What an animal does when working on an experimenter-defined task (e.g., for food) may include what it must deal with when foraging outside of the laboratory. The most fabulous feeding patterns of the world's best food-getter will not be selected if the forager immediately becomes a meal itself. To the extent that such demands and other necessities involved in making a living outside of the lab-

oratory also influence what occurs inside, they may prevent food-getting in either place from being optimal.

In behavioral biology, optimality has been used to relate behavior to evolutionary function, even though tests have always involved immediate function. This notion of optimality essentially followed from concepts like the selfish gene (Dawkins, 1976) and direct determination of behavioral phenotypes by genes. Slight advantages in observed characteristics accumulate genetically until the best possible emerges. Even though the assumptions of phenotype-genotype correspondence, genetic reductionism, adaptationism, and evolutionary gradualism are not plausible to all evolutionary biologists (e.g., Lewontin, 1984), they do lead to empirical tests. Testability is such a novelty in the analysis of behavioral evolution that it perhaps justifies using questionable assumptions. But unless nature is equally impressed, it should not be surprising if predictions from flawed hypotheses are not confirmed.

Optimality theory ignores the fact that natural selection works on what it has, not on ideals. A variation must occur before it can be selected. For a trait to be honed to perfection the best form must first appear, and then it must do well enough to outweigh costs that it might bring with it. Even properties necessary for survival may never have appeared, much less those that accomplish something at the best possible level or many things at the best level of compromise. People might be far more successful than they are if they could fly like birds and not have to walk by circuitous routes to get from one place to another, or if they could orient in space by using magnetic fields, or if they could thrive on nuclear waste. But the incipient ability to fly never existed for people nor did sensitivity to magnetic fields, so natural selection could not favor either. Even the organ often cited as the epitome of design—the human eye—could do better if it could see around corners and as well in the dark as in the light. Evolution is not a designer given free rein; it makes do with existing bits and pieces.

*Optimizing* means to do the best conceivable. However, natural selection need not maximize returns. What selection must do is follow a satisficing principle (Simon, 1969). To *satisfice* means to do well enough to get by, not necessarily to do the best possible. Doing well enough is more complicated to express quan-

titatively than is doing best, but satisficing models are beginning to appear (Houston & McNamara, 1988).

Optimality theory is flawed by the tendency to overlook the relation between outcome and controlling process (between function and causation). Behavior may not perfectly implement function because behavior is generated not by outcomes but by antecedent causal conditions. Accomplishment of an immediate function well enough is relevant to natural selection, but the route for achieving it is not. Causal mechanisms that have evolved over evolutionary time are what determine behavior right now. As Cosmides and Tooby (1987) pointed out, the invariances that must hold are between causal mechanism and behavior, not between behavior and its accomplishments. But these causal mechanisms need not ideally accomplish a given function; they may just happen to be the ones that worked well enough on average to be selected. So it should not be surprising to find discrepancies between behavior and optimal achievement. Perfect achievement requires either a fortuitous causal process that perfectly implements function or an evolutionary process that invents mechanisms as needed. As long as natural selection can only use what it is given, optimization is likely to be rare.

### *Behavior Systems Theory*

Timberlake has developed a theory of behavior and learning based on hierarchies of immediate function (Timberlake, 1983; Timberlake & Lucas, 1989). Behavior is organized around important functions such as feeding, defense, mating, territoriality, care of young, and so forth. Each function defines a behavior system. Within each system are subsystems. So, for the feeding system of rats, the subsystems include obtaining food by predation (pursuit of moving prey) and obtaining food by browsing (procuring stationary food items). Each subsystem is further divided into component functions of the necessary behavior sequence. For example, in both feeding subsystems, the components (modes) are searching for food, procurement of it once found, and handling and consuming it once obtained. (Collier, 1983, has similarly analyzed the feeding chain and reports data showing how each component can be studied experimentally.) Each mode contains perceptual-motor modules that constitute predispositions to react in

certain ways to certain stimuli. The responses usually are relatively stereotyped, but they are neither wholly rigid nor permanently fixed. The appropriate stimuli release these action patterns, guide the patterns as they are emitted, and also influence motivation. The perceptual and motor modules are related to the releasing stimuli and fixed action patterns of ethology, although they are more flexible. As with all other biological properties, the various levels of the system stem from the complex of genetic and experiential factors that determine development.

Learning can modify the working system in many different ways. Most learning occurs within and between modules, but it can also occur at higher levels. Learning is determined by how particular demands interact with the current motivational state, sensitivity to the particular stimuli that occur, and the particular response patterns that prevail. Data explained by the theory include autoshaping of the pigeon's key-peck response; behavior under extinction in maze learning; the misbehavior of animals being conditioned to produce a certain kind of behavior; the details of superstitious behavior; why taste-aversion learning is more likely to occur with gustatory cues but not with lights or sounds, whereas shock-avoidance learning shows the opposite effects; why the ease of avoidance or escape learning depend on species, responses, and the nature of the aversive stimuli; and many of the phenomena observed in standard operant and Pavlovian conditioning experiments (Timberlake & Lucas, 1989). New effects predicted that adult rats would orient towards other adults that signaled food delivery but not toward pups that did the same, and that hamsters would not orient towards other signaling hamsters of any age (Timberlake, 1983).

Timberlake describes the systems in terms of immediate function, but he views function as involving motivational states. Because motivation refers to factors responsible for initiating and guiding behavior, this raises the question of the relation between immediate function and the instigation of behavior. From the present perspective, functions are outcomes; they do not instigate. This suggests that motivational processes result in behavior that is likely to have certain immediate functions. The behavior may or may not actually have those effects. The consequences that do occur

then may feed back to become part of the complex determining subsequent behavior. This hypothesis closely resembles the theory of feedback functions that has been used to explain characteristics of behavior under various schedules of reinforcement (cf. Staddon, 1983).

#### THE CAUSES OF LEARNING: BIOLOGY VERSUS PHYSICS AGAIN

Once immediate and evolutionary function are seen as critical, the relevance of Newtonian physical-science concepts become less clear, even for understanding the classic problems of causation. One criterion for a causal law in physical science is that the relation between cause and effect is invariant or can at least be stated with some known probability (Nagel, 1961). The Newtonian perspective distinguishes between real-world observations, which provide only approximations, from the ideal frame in which these laws are truly realized, but matter follows the same underlying laws whether it occurs in animate or inanimate form, on Earth or on Mars, in water or on land. Belief in universality was built in to the associationist philosophy that led to psychology. The durable causal mechanisms of mind and later of behavior were assumed to be invariant, albeit distorted by having to observe them in the real world instead of in the abstract ideal state.

For this to be true requires that a phenomenon be conceived in a pure context-free form. Vacuums and frictionless states are at least imaginable for physics, but behavior cannot even be defined without reference to an environment. Furthermore, environments do not exist without reference to the activities that occur in them. There is no standard environment, much less an ideal one. Nor is there a standard organism for observing ideal environments. Behavior plus the other properties of organisms and their surroundings comprise the  $n$ -dimensional space that defines each ecological niche. The consequence is that no property can be understood independent of that niche. Perhaps effects of gravity, gas transfer, and osmosis continue unchanged—they are fixed properties of the physical matter that makes up the biological system—but the systems, as working systems, depend on the whole in which they appear. The properties of complex systems exist only in context (McIntosh,

1985). Remarkably, some are now arguing the same even for physics (Anderson, 1991)!

This means that what is true of behavior at one time need not be true at another. The rules of food getting depend on the food seeker's physiological state, the availability of prey and time since the last success, what food was found last, and other specifics of food as well. They also depend on whether the temperature is below freezing or very hot, whether other animals are also searching, the presence of predators, the need to tend to offspring, and a nearly infinite number of other unstable factors as well. What to do, when to do it, and how to do it depend on the particular problem that learning is attempting to solve.

Perhaps an example can clarify the distinction between fixed processes and situational determination. Two experiments studied how animals' behavior was controlled by time (Zeiler, 1991). One dealt with how pigeons discriminated the durations of antecedent stimuli. On each trial a light appeared for either a constant duration or a longer comparison duration. If the light had been on for the constant short duration, pigeons got food for pecking one key; if it had been on for the longer comparison duration, they got food for pecking a different key. Correct responses after the comparison duration made that duration shorter on the next trial; incorrect responses lengthened it. The idea of this staircase procedure was that the comparison duration should oscillate around the difference threshold, thereby allowing analysis of the difference in duration required to discriminate long from short time intervals. The second experiment studied how pigeons timed their own behavior. Here the pigeons received food whenever a response was separated from the preceding one by a specified time interval. Timing involved the pauses generated by the pigeon. The relation of the time requirement to the mean pause produced described the relation between time requirements and the timing of behavior. The variability in the pause lengths measured certainty or sensitivity.

Both kinds of timing were studied in open and closed feeding economies. In open-economy conditions, pigeons were deprived of food, obtained small portions of food for correct responses, and received supplementary feeding outside of the experimental chamber when necessary. In the closed economy, they were

not food deprived, ate as much as they wanted following correct responses, and received no additional food.

A general timing process manifested across situations would yield equivalent results in the various procedures given due allowance for differences in measurement technique. However, the results did not indicate a common process. First, compare the timing of antecedent stimuli with the timing of pauses. In both feeding economies, the pigeons' sensitivity to time depended on whether they were timing previous stimuli or their own behavior. Now consider the two economies. The timing problems were identical in both, yet curves showing the properties of either stimulus or response timing reversed their directions. Not only did timing differ depending on whether the problem involved stimulus or response durations, but the timing of either stimuli or responses differed radically with the change in feeding economy. Temporal control bore no resemblance to a fixed process, and the effects of economy differed depending on what was being timed.

Surely the effects can be attributed to interacting variables, for example, to levels of attention, response bias, and other factors that combine with a timing process in different ways in different situations. Perhaps factors involved in one kind of timing do not operate in others; perhaps timing of antecedent stimuli and ongoing responses bring different factors into play; perhaps open and closed feeding economies mean major motivational changes. But when interactions reach such a high order, the net effect is that the characteristics of a process become unique to particular situations. Such observations are reminiscent of the revolution that occurred in the study of ecology when the entire ecosystem became its basic unit (Odum, 1953). Each particular manifestation of learning may depend on the details of the situation in which it occurs. The necessary view seems to be that of a system that determines how its parts work.

Why would one think that learning to play tennis, learning to read, learning where you live, learning the demands of a job, and learning social conventions are all the same? The assumption of general learning principles is that natural selection must have occurred for processes that deal with all unpredictable variations in the same way. An opportunist like

natural selection could have taken advantage of a learning system developed in the context of one important need (e.g., avoiding predation) and used it to embrace all forms of novelty and unpredictability. But any one of the now familiar biological constraints on learning shows that this did not occur. The uniqueness of taste-aversion learning (beginning with Garcia & Koelling, 1966, and studied extensively thereafter), the instinctive drift from coin carrying to rooting in pigs (Breland & Breland, 1961), the difficulty of training animals to make arbitrary responses to avoid shock (Bolles, 1970), the tendency for male pigeons to peck and females to orient towards walls and not to peck in superstition experiments (Timberlake & Lucas, 1985), or differences in timing in open and closed feeding economies (Zeiler, 1991) show that learning is context dependent. The view that learning is more likely domain specific than domain general is becoming increasingly prevalent (e.g., Cosmides & Tooby, 1987; Gallistel, 1990; Rozin & Kalat, 1971).

The nature of learning is a microevolutionary issue. Microevolution is the problem of adaptation. Animals with wings live in trees, those with gills live in the water, plants living in the desert need little water to survive, and so forth. How did these fits between life and environment come about? How are they maintained or lost? The only current explanation of directionality is natural selection. Chance processes or mutations would at best have an equal chance of improving or worsening the fit. They might suddenly create opportunities for new features of the environment to become relevant, just as an existing feature could bring about a whole new range of possibilities (e.g., feathers evolved for thermoregulation made it possible for the environment to select for ability to fly), but selection is necessary to explain why features that fit persist and why those that do not are lost.

Buried in this scenario is a theory of mechanism. Mechanism (causation) describes how outcomes are achieved. An evolutionary theory of causation based primarily on the principle of natural selection might go as follows. Although selection is based on outcomes, it chooses mechanisms. When an adaptive function is achieved, selection is for the causal mechanisms that produced it. For example, the process that resulted in food getting in some an-

imals and starvation by others may have been the response patterns elicited by movement. The survivors perhaps attacked the moving object but the others ran away or were unable to detect it. Responding to movement by attack is the causal mechanism that had the appropriate immediate function. If this process is heritable, offspring will also attack such movements. A particular causal mechanism might not be the best one possible for having achieved that outcome, but evolutionary forces can act only on what was already there. Responding to a certain pattern of light and sound might be a better way to get food than is responding to movement. However, selection can only stamp in controlling processes from what it had to work with.

All instances of learning share the general principle that animals adjust their behavior to the present state of the environment. They learn the significance of events, remember them, and ignore them when they no longer are relevant. But all instances of learning are not equally important. Differences in significance provide the basis for domain-specific adaptive specializations to occur. Natural selection is necessarily most intense when outcomes make an important difference in the ability of organisms to cope with their environments. It is more important to avoid a predator right now than it is to find food immediately, unless starvation is imminent. Errors in responding to vocal communication are likely to be less costly than is eating bad food. Each instance of learning occurs under a certain set of complex conditions, and each cannot be understood divorced from those conditions. Yet a vast literature shows uniformity in how learning occurs and is maintained. How could such order occur in the absence of general principles of acquired behavior? A closer look at the nature of this learning provides a potential answer.

Learning is almost always about stimuli and responses arbitrarily related to each other and to their consequences. In Pavlovian conditioning research, the lights or tones used to signal food or electric shock delivery are not events that naturally accompany food or aversive events outside the laboratory. In operant conditioning experiments, the responses usually studied are not part of food getting or dealing with aversive stimuli in nature. This practice reflects the time-honored beliefs in general

process and the interchangeability of stimuli and responses in behavior. Ebbinghaus (1885) did not use nonsense syllables because he was interested in them per se. He did so because he believed in a general memory process and that all individual exemplars are essentially valid in finding out how memory works, and because he wanted an experimental preparation that was free of prior experience. Skinner (1938, pp. 10–12) argued against the “botanizing of reflexes” on the assumption that all behavior is reflex, so any convenient stimulus and response can be chosen to study the causal laws.

Much learning by humans and other animals (including most higher education) is arbitrary. Green lights do not have to mean “go,” the language we first learn is an accident of birth, we may learn to drive either on the right or the left, which house you live in is essentially unpredictable. The learning literature provides information about the mechanisms that have evolved for adjusting behavior so as to achieve suitable returns in arbitrary situations.

However, the standard preparations may not even be representative of arbitrary learning. In Pavlovian and operant versions of arbitrary learning, the reinforcing stimuli typically have been of a very special nature. Food or water usually appear from out of nowhere. In nature, animals usually locomote towards food and water sources, and stimuli indicate progressively increasing proximity. Where in nature are aversive stimuli both invisible and silent, like electric shock? Even if shock is signaled, the signal is not part of the aversive event, as when a predator has a distinctive sight, sound, or smell. When (outside the laboratory) does the same arbitrary response have the same arbitrary consequences under the same arbitrary stimulus conditions?

That the same patterns of arbitrary repetitive learning appear in species from humans to honeybees (Bitterman, 1988) poses an interesting evolutionary problem. A glance at the world around us shows many different animals and plants that change over time and with where the observations occur. The fossil record reveals that present forms did not always exist and that other forms once existed but now do not. Yet arbitrary learning has revealed little diversity. Either common descent in the evolution of this kind of arbitrary learning is based



on physiological mechanisms that emerged before mammals split off from insects, or there is such a small range of adaptive solutions that convergence has arrived at the same causal laws for arbitrary repetitive learning independently across species. Or perhaps existing analyses may not be sufficiently sensitive to indicate degrees of similarity and differences among species.

The mistake is to assume that the causal laws of a subclass of arbitrary learning are representative of all learning. The behavior has shown invariances because the same kinds of behavior have been observed under essentially the same conditions. Turn to other kinds of learning and the same principles seem less important. Galef (1990) has conducted extensive research on how animals learn about good and bad food. Sidman (see Sidman, Wynne, Maguire, & Barnes, 1989) has investigated how people learn equivalences between stimuli. Many researchers have studied how birds learn their particular songs (Marler, 1984). A vast literature on imprinting testifies to the many scientists interested in how animals learn their species and develop sexual preferences. Experimenters have studied how chimpanzees learn language, grammar, and numerical relations (Rumbaugh & Pate, 1984). Each of these types of learning has revealed its own mechanisms.

In these investigations, the learning phenomena have not been modeled by drawing analogies to other systems. Contrast this with contemporary laboratory analyses of foraging. Key pecks or bar presses that produce food have been considered analogous to the response patterns used in natural foraging, changes in the colors of stimuli have been seen as analogous to shifts in feeding patches, delays in onset of stimuli have been viewed as analogous to the time spent traveling between patches, and so forth. The validity of these analogies is questionable. These studies actually involve arbitrary repetitive operant learning. That conclusions of prior research in operant conditioning also seem applicable to these simulations is not surprising given the essential similarity in experimental conditions. Verbal proficiency in arguing that a laboratory construction is a model of the nonlaboratory world is not the criterion for assessing validity. Rather, the criterion is highly similar results when

relevant variables are manipulated in both model and modeled environment.

### LEARNING IN EVOLUTIONARY CONTEXT

Ecology and psychology have much in common. Their concerns with the environment and with human conduct are the most pressing ones of our time. Ecologists are supposed to tell us what we need do to make it possible for life to continue and prosper, and psychologists are to tell us how human behavior can be managed so as to produce this better world. The similarities go beyond centrality in human affairs. Both have been highly quantitative descriptive sciences. Both have been ad hoc sciences. Basic conceptual principles of ecology—the food chain, the niche, the ecosystem—are inherently descriptive terms that themselves demand explanation. Principles of psychology—reinforcement, stimulus control, levels of processing—are equally descriptive and nonexplanatory. Both fields have had their theories, but both have been without first principles. Evolutionary theory provides both with an integrating conceptual framework and a relation to the rest of science. It gives these hitherto ad hoc sciences the needed conceptual framework for explaining phenomena and for unifying their practitioners into coherent sciences.

The ability to learn and thereby to modify subsequent behavior must confer enough advantages to compensate for the fact that facultative processes are considerably more difficult to attain evolutionarily than are obligate reactions (Williams, 1966). Any form of learning must have offered survival advantages over rigidly stereotyped behavior in order to develop at all. Animals are more successful if they can adjust their behavior to unpredictable events in the environment and adjust the environment to their abilities than if they cannot. Many demands on organisms cannot be predicted in advance. Previous food resources become depleted, and new ones must be found and used. Foraging animals must go to different places under different conditions and do different things to obtain different returns for their activities. New predators may appear, and old ones may be found in new locations. All members of the same species cannot live in the same nest or den, and each must learn the location

of its living place. Social species face the need to modify their behavior based on what others are doing. Humans, nonhuman primates, and other mammals as well must learn the meaning of vocal communications (Gouzoules, Gouzoules, & Marler, 1985). Animals must learn where water is to be found in their particular locale. Humans working on jobs do not do exactly the same thing for the same payoff all the time, although animals working in experimental situations often do. Social learning may be responsible for self-sacrifice and other forms of altruism (Simon, 1990).

Learning evolved because of advantages accruing to behavior that accomplished outcomes in a variable and often unpredictable environment. Behavior that had certain results led to increased reproductive success, so the mechanisms that led to behaving that way became more common in subsequent generations. An effective psychology of learning needs to find out what various kinds of learning accomplish and the events that guide how these kinds of learning take place. If general principles exist, they need to emerge from detailed study of important kinds of learning and not be assumed at the outset.

Evolution provides the theoretical link between causation and function and between accomplishment and existence, but it is not the same as either causation or function. It is the framework for understanding why behavior having certain effects right now should occur, and why mechanisms that accomplish certain outcomes are present and why those that yield other outcomes are likely to vanish.

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