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Applying the Lessons of Bernard and Darwin to Behavioral Theory, Research, and Practice

. . . any system based on the control of behavior through the use of rewards (or, of course, punishments) contains the seeds of its own destruction. There may be a temporary period, lasting even for many generations, during which some exciting new system concept so appeals to people that they will struggle to live within its principles, but if those principles include incentives, which is to say arbitrary deprivation or withholding at the whim of human beings, inexorable reorganization will destroy the system from within: nature intervenes with the message, "No! That feels bad. Change!"

—William T. Powers (1973, p. 269)

Having reached this final chapter, it is time to summarize what we have learned from the lessons of Bernard and Darwin about the what, how, and why of animate behavior, and to consider the application of these lessons to behavioral theory, research, and behavior-related issues and problems.

The What of Behavior

The question of the what of animate behavior might not at first appear to be particularly interesting, at least not for the purpose of applying Bernard's and Darwin's lessons and for distinguishing the behavior of living organisms from that of inanimate objects and systems. A falcon's dive to seize a sparrow in midflight can be objectively described in terms of acceleration and trajectory in much the same way that a stone falling to earth can be described adequately without applying Bernard's or Darwin's lessons. But closer examination reveals an important difference between raptor and rock: the falcon, by varying the configuration of its outstretched wings, continually adjusts its path so as to strike its evading prey, whereas the falling stone can do nothing but follow the path of least resistance to the earth's surface. So although the actions of living organisms can be described from the viewpoint of an objective observer, such a description misses the most striking characteristic of animate behavior: its orientation toward some goal or purpose. Such goals and purposes, whether they be conscious or not, are revealed by disturbing the suspected desired outcome and seeing if the organism takes action to compensate for the disturbance.

The answer to the question, "What is animate behavior?," that is provided by Bernard's extended lesson can be no better expressed than by referring to the title of Powers's 1973 book and responding that animate behavior is best understood as the *control of perception*. That is, by varying its behavior an organism maintains control over certain important aspects of its environment. This does not mean that an organism can control all aspects of its environment, or that the control that is achieved is always perfect. It does mean, however, that all living organisms use behavior as a means to control what they can. Or as William James observed a century ago (1890, p. 7), "the fixed end, the varying means!"

This answer to the question of the what of behavior means that a satisfactory account of observed animate behavior must specify the particular perception that the organism is controlling. Answering this question requires a methodology that is very different from standard methods used in behavioral sciences, whereby behavior is seen not as the control of perception but rather as being controlled by or caused by perception. This latter Newtonian perspective attempts to establish a one-way causal link between stimulus and response (with or without mediating cognitive processes) using statistical methods to uncover relationships between independent and dependent variables.

In contrast, a Bernardian approach applies what Powers refers to as "the test of the controlled variable," or more simply just "the test." A summary of this approach as applied to people was provided by Runkel (1990, pp. 14, 15):

1 Select a variable that you think the person might be maintaining at some level. In other words, guess at an input quantity. (Examples: light intensity, sensation of skin temperature, admiration in another person's voice.)

2 Predict what would happen if the person is *not* maintaining the variable at a preferred level.

3 Apply various amounts and directions of disturbance directly to the variable.

4 Measure the actual effects of the disturbances.

5 If the effects are what you predicted under the assumption that the person is *not* acting to control the variable, stop here. The person is indeed not acting to control it; you guessed wrong.

6 If an actual effect is markedly smaller than the predicted effect, look for what opposition to the disturbance that, by its own varying, can counterbalance variations in the input quantity. That may be caused by the person's output. You may have found the feedback function.

7 Look for the way by which the person can sense the variable. If you can find no way by which the person could sense the variable, the input quantity, stop. People cannot control what they cannot sense.

8 If you find a means of sensing, block it so that the person cannot now sense the variable. If the disturbance continues to be opposed, you have not found the right sensor. If you cannot find a sensor, stop. Make another guess at an input quantity.

9 If all of the preceding steps are passed, you have found the input quantity, the variable that the person is controlling.

Working computer demonstrations of this method are provided by Powers's "Demo 1" (DOS program) and Marken's "Test of the Controlled Variable" (Java program), available at *www.uiuc.edu/ph/www/g-cziko/twd*. What is most remarkable about the test for determining the variable that is being controlled by behavior is lack of an apparent relationship (as in a near-zero correlation coefficient) between the controlled variable and behavior. It must be recognized that this refers to lack of a systematic *one-way* relationship between stimulus and response. But this is just what is to be expected from understanding the circular causality characteristic of both living and artificial control systems, in which perception and behavior reciprocally and simultaneously influence each other to maintain some perception close to a goal or standard (reference level).

Use of the test for analyzing animate behavior contrasts with all other research methods of behavioral science. Whether behaviorist or cognitive, traditional methods attempt to establish causes (independent variables) for aspects of behavior (dependent variables) as objectively defined from the viewpoint of the researcher. This approach has two serious weaknesses. First, it is not focused on determining the perceptual variables being controlled by the behaving organism. At best it may discover disturbances that appear to cause behavior, but by ignoring perceptual variables that the organism is actually controlling, such an analysis is incomplete at best and misleading at worst. For example, imagine driving west on a straight road with winds gusting out of the north. A traditional one-way cause-effect analysis of your steering behavior will find that the gusts of wind (independent variable) cause you to turn the steering wheel to the right. Your act of turning the steering wheel can be measured objectively to the nearest millimeter if desired and correlated with wind speed and direction. But this analysis completely misses the fact that you are varying the angle of the steering wheel *to maintain your perception of keeping the car centered in its lane*.

This crucial knowledge of the variable you are controlling by varying your behavior allows us to make predictions as to what will happen if other factors act to disturb the position of the car. For example, if the road begins to slope to the right as it changes from a four-lane highway to a two-lane road with a high crown, knowledge of the controlled variable permits us to predict correctly that you will now turn the steering wheel to the left to maintain the car's position. In contrast, knowing only that there is a correlation between wind speed and steering behavior provides no clues at all as to what will happen when other disturbances to the car's position are encountered.

The second weakness of the traditional cause-effect analysis of animate behavior is that it cannot distinguish between the goals of behavior and its incidental, unintended side effects. If behavior is described objectively from the viewpoint of the impartial observer, there can be no significant difference between reaching for the salt and knocking over a glass of wine into the lap of your dining companion. Something must have caused you to reach for the salt, and something must have caused you to knock over the wine. A one-way cause-effect analysis provides no way to distinguish between the two behaviors, despite the fact that your apologies (and your companion's consequent forgiveness) indicate that an important difference does exist between intentions and accidents (a distinction also made in courts of law). In contrast, using Bernard's extended lesson to focus on the intended consequences of behavior makes a clear and important contrast between perceptions being controlled by behavior (such as the appearance of these letters on my computer screen as I type) and incidental, uncontrolled consequences of behavior (such as the clicking sounds made by the computer's keys as I type that are disturbing my wife trying to sleep in the next room).

The How of Behavior

The next question to consider concerns the how of behavior. For example, how is it that wanting some fresh bread results in the appearance of a steaming loaf in the kitchen a few hours later?

The extended Bernardian lesson, as developed by Powers, provides a clear non-Newtonian answer: we are able to achieve goals by setting and accomplishing prerequisite subgoals. The recipe for bread lists water, flour, sugar, salt, and yeast as ingredients. If these are not readily available, a trip to the grocery store is in order. Once obtained, the ingredients must be measured (four cups of flour, two cups of water, a tablespoon of sugar, one teaspoon each of yeast and salt), combined in a certain way (mixed and kneaded until a certain consistency is reached), and baked in the oven at a certain temperature until the crust is golden brown. Actually, many more subgoals are involved than can be conveniently listed here, all of which must be achieved in order to bake a loaf of bread, and with each one likely requiring its own subgoals (subsubgoals?).

In addition, each subgoal must be attained despite the inevitable real-world disturbances that will be encountered. We considered the disturbance of not having all the necessary ingredients on hand, and how that led to a visit to the grocery store. But many other disturbances are also likely to be encountered (such as variations in water pressure while measuring the water, or an oven that must be set at 475° Fahrenheit to reach 425°), and the only way to ensure that they will be successfully countered is by implementing a control system for each subgoal. It is this hierarchy of goals and the setting of lower-level reference levels by higher-level control systems that provide an accurate and useful answer to the how of behavior (introduced in chapter 6 and illustrated in figure 6.3). A useful working model of such a hierarchy of goals and subgoals is Marken's "Spreadsheet Model of a Hierarchy of Control Systems" (1990) for both Macintosh and IBM-compatible personal computers that is available at *www.uiuc.edu/ph/www/g-cziko/twd*.

Traditional cause-effect psychologists have a very different answer to how questions, believing that behavior is able to achieve what it does by generating necessary outputs. Pinker's example of reaching for an object, described in chapter 11, is a good example of this approach, which requires exceedingly complex computations of behavior as output based on inverse kinematics and inverse dynamics. But such computations are not only unnecessary, they are also incapable of producing animate behavior that remains functional despite continuous and unpredictable disturbances. An industrial robot that picks up automobile parts from a conveyor belt and places them in a box by repeating the same sequence of fixed actions over and over again can be effective in a disturbance- and surprise-free environment. But it will fail if the conveyor belt changes speed, or the spacing between the parts changes, or the receiving box is moved a few inches. For humans, it is only by seeing both one's hand and the desired object that one is able to reduce the distance between them to zero and grasp the object. Such behavior remains successful despite disturbances such as muscle fatigue, bulky clothing, or someone attempting to deflect your hand from the desired object. Computed behavioral outputs are simply incapable of achieving such goals in a real world subject to disturbances, and can be useful only in the tightly controlled, disturbance-free environment of a manufacturing plant or a computer simulation.

Questions concerning the how of behavior can be continued to levels of explanation beyond the domain of behavioral science as we ask for what could be considered to be more and more reductionist explanations. One of the answers to how you open a book involves understanding how specific reference levels are generated and sent to the control systems that govern the muscles of your arms and hands. How these reference levels are actually generated and transmitted by your nervous system to the appropriate lower-level control systems brings us to the domain of neuroscience. How the resulting error signals cause muscular contractions involves molecular biology and eventually chemistry and physics. So integration of knowledge from all these disciplines is necessary to answer all the many how questions we can formulate.

The how question is also relevant to the question of learning. How is it that we are able to do something today (such as hitting a tennis ball or playing a musical piece) that we could not do yesterday? A traditional approach sees such learning as the acquisition of new responses; a Bernardian approach sees it as the purposeful, goal-driven, within-organism evolution of new perceptual, reference, and/or motor functions (see chapter 10).

The Why of Behavior

Answering questions about the how of animate behavior leads us down the hierarchy of control systems to lower levels of control. But questions about the why of behavior are addressed by going up the hierarchy to higher levels of control.

Returning to our bread-baking example, we pick up the action as you begin to move your hand toward the kitchen faucet. Why are you changing the position of your arm and hand? Clearly, to turn on the water. Why turn on the water? To put sixteen ounces of it in your measuring cup. Why collect two cups of water? To add to the flour and other dry ingredients to make dough. Why make this dough? To bake a loaf of bread. The answer to each successive why question specifies the higher-level goal for which the current goal is a necessary subgoal.

So far, the answers to these why questions are rather obvious. Even so, they demonstrate how the answers to repeated why questions lead us to higher and higher levels of perception and control. But at a certain point things become more difficult. Why bake a loaf of bread? Perhaps you are hungry and just want something to eat. Or maybe you plan to share the bread with your family at your next meal. Or it could be you intend to give the loaf to a friend who has been sick. We cannot know the answer without further investigation. If your bread making ceased after receiving a phone call informing you that no one would be home for dinner tonight, that would suggest it was for the family to enjoy. If you made your bread despite the call, this would be consistent with the explanation that you intended to eat it yourself or give it to someone.

But in any case, continued why questions (such as why do you want to share a loaf of bread with your family, or give it to a friend, or eat it yourself?) eventually require a shift in perspective from what we have been calling the proximate explanations of behavior involving continuing processes of perceptual control to ultimate explanations involving the natural selection of organisms with adapted goals (discussed in chapters 8 and 9). The ultimate reason why we eat food rich in carbohydrates such as bread is because those who did so in the past were more successful in surviving and left more offspring (including us) than their contemporaries who did not eat such food. And there are good reasons why goals related to providing food for family and helping friends were also favored by evolution.

Humans evolved to prefer bread, whereas dung flies (having a quite different evolutionary history) prefer cow poop. But not all humans eat bread (although none eat cow poop). To answer the question of why an individual eats bread and not rice or potatoes or pasta, we must consider environmental factors, both physical and sociocultural. That all human beings eat foods containing carbohydrates is a universal characteristic of our species. Marriage, caring for children, and male sexual jealousy also appear to be universal features of humankind. But the particular foods we eat (as well as how we prepare them and with whom we eat them) vary widely from culture to culture, depending on what foods are available and what we have learned from others about their preparation and consumption. Similarly, a man's response to a mate's sexual infidelity will be influenced by local culture, with possible outcomes ranging from complete forgiveness to murder.

Universal human goals and desires interact with local conditions resulting in the quite varied proximate behavioral goals we see across human societies. A bride in India provides a dowry to her husband's family, whereas in Africa it is expected that the man make a generous contribution to his future in-laws. These behaviors may seem quite distinct, but they are in fact two different culturally adaptive solutions to the universal human concern of obtaining a high-quality mate and ensuring the survival and reproductive success of one's children.

Do all behaviors have ultimate evolutionary reasons? There is currently much debate about this. Ethologists, sociobiologists, and evolutionary psychologists tend to believe that such explanations exist for all behavior, and they point to the impressive success this approach has in making sense of animal behavior. Other behavioral scientists do not agree, particularly those who emphasize the importance of physical and cultural environments.

But if, as evolutionary psychologists are quick to point out, environmental factors do play an important role in influencing human behavior, this itself can be considered an adaptive trait that has an evolutionary origin. Humans' unmatched ability to engage in forms of within-organism purposeful evolution (see chapter 10) to modify goals and behaviors has made us the most widespread and adaptable species on the planet. This ability is so well developed that we are capable of behaviors that may even seem to be at odds with the basic concerns of survival and reproduction.

For example, we can vow, as Catholic priests and nuns do, to abstain from sexual activity and reproduction. We can, despite our long evolutionary history as omnivores, refrain from eating meat. We can endure great hardships and persecution, including torture and death, for our religious and political beliefs. We can even (which I suppose is the ultimate paradox) make a conscious effort to learn about the evolutionary origins of our desires, preferences, and consequent behaviors and decide to lead an austere life in opposition to the predilections of our selfish genes. Such flexibility can make it very difficult to apply an evolutionary perspective to all forms of human behavior. But priests, nuns, vegetarians, and religious martyrs are the exceptions rather than the rule, and I have no doubt that the general "rules" of human behavior will continue to make more sense as we continue to investigate them from an evolutionary perspective.

These Bernardian and Darwinian answers to why questions contrast sharply with answers provided by behavioral scientists using behaviorist and cognitive approaches. Skinner was not concerned with the evolutionary past of organisms whose behavior he studied, and he believed in spite of considerable evidence to the contrary (see Breland & Breland 1961) that under the proper conditions (contingencies of reinforcement) any organism could learn to perform just about any type of behavior that was physically possible. For him and other behaviorists, organisms do what they do for the simple reason that they were reinforced for such behaviors in the past.

Although cognitive scientists put less emphasis on reinforcement and more on mental processes, they also have traditionally shown little interest in adopting an evolutionary perspective to answer why questions. Exceptions, of course, are the relatively small group of cognitive psychologists who refer to themselves as evolutionary psychologists. But whereas evolutionary psychologists such as Tooby and Cosmides have learned the basic Darwinian lesson, they have not yet accepted the extended Darwinian and extended Bernardian lessons. For them, ultimate explanations for behavior are to be found in the evolutionary past of an organism. But proximate explanations are still cast in perceptual-input-causes-behavioral-output terms as used by all other cognitive scientists, rather than in behavioral-output-controls-perceptual-input terms as is consistent with the extended Bernardian lesson.

Applying the Bernardian and Darwinian Lessons

A biologically inspired approach to the what, how, and why of behavior has important implications for theory and research in behavioral science. But what does it mean for practice? Can this new approach, which takes heed of Bernard's and Darwin's lessons, provide new and effective solutions to the many serious issues and problems involving human behavior?

Skinner's Cause-Effect Approach

It was not so long ago that the application of a "truly scientific and objective approach" promised to solve such problems. By judicious application of operant conditioning techniques involving the establishment of proper contingencies of reinforcement and/or punishment as described by Skinner and his adherents, it was believed that one human could control another's behavior. In fact, this notion seems to have become the institutional policy in all societies where those in power provide rewards in the form of money and other benefits to motivate workers while meting out punishment in the form of imprisonment and hard labor to reform criminals.

It is generally accepted as common knowledge that this policy can work, but it has some serious problems. In his book *Punished by Rewards* (1993), Alfie Kohn described many disappointments encountered by those applying Skinnerian principles in a wide range of settings including the workplace, home, and school. After reviewing hundreds of such studies, Kohn concluded that attempts to control people by rewarding them for desired behaviors is not effective for a number of reasons. First, the quality of one's work suffers when emphasis is put on incentives such as money and grades. Second, the effect of reinforcement rarely generalizes to other settings (a child who is enticed to read a certain number of books over the summer to earn a pizza cannot be expected to continue reading books when no pizza is offered). Third, providing rewards for completing a task can turn what was previously an enjoyable activity pursued for its own sake into one that is perceived as disagreeable (as in the case of a child who used to read for pleasure, but now sees reading as inherently unpleasant work to be done only for a reward).

Although punishment was never actually advocated by Skinner, as it points out only what should not be done rather than what should be done, it remains a common means for controlling behavior in all societies despite considerable evidence that it is ineffective and counterproductive in the long term. Punishment may result in initial compliance to cease the offending behavior, but it also leads to resentment in the one punished and to devising ways to continue the behavior while avoiding punishment or retaliating against the punisher. Decades of research have shown consistently that children subjected to physical punishment turn out to be more aggressive and violent than other children and are more likely to use physical punishment on their own children (see Kohn 1973, p. 167). As to the effectiveness of punishment as institutionalized in the American penal system, James Gilligan (1996, p. 95) observed:

> The murder rate in the United States is from five to twenty times higher than it is in any other industrialized democracy, even though we imprison proportionately five to twenty times more people than any other country on earth except Russia; and despite (or because of) the fact that we are the only Western democracy that still practices capital punishment (another respect in which we are like Russia).

The ineffectiveness of Skinnerian methods of behavior modification should come as no surprise to one who has carefully examined the basic premises of behaviorism. According to principles of operant conditioning, the probability of certain behaviors is increased by providing a reinforcement after the behavior is completed. Reinforcement is seen as strengthening the connection between the stimulus preceding the behavior and the behavior itself. So according to reinforcement theory, if a child is given a treat after reading a book, this should increase the frequency of future book reading *even if the student knows that no treat will be given the next time a book is read*.

It may well be that providing rewards will expose an otherwise reluctant child to the intrinsic pleasures of reading and thus be successful in encouraging the child to continue to read. But you can be sure that a child who does not find reading enjoyable and does it only to obtain extrinsic rewards will not continue to read books if he or she knows that rewards are no longer in the offing. And, as already noted, a child who initially found joy in reading may well come to consider it a disagreeable task when offered extrinsic rewards.

It is not the provision of *past* rewards and punishment that influences behavior, but rather anticipation of *future* rewards and punishment. Public hangings can be quite effective in getting the population to think twice about performing acts that are punishable at the end of a rope (it is, of course, completely effective in preventing such actions in the future by the punished individual). Promises of future rewards can also increase the likelihood of certain activities (which is how most religions operate to modify the behavior of their adherents, not to mention the threat of hell as future punishment). The reason why rewards and punishment often appear to be effective in modifying or controlling another person's behavior is not because their application in the past controls current behavior. Instead, humans vary their present behavior to obtain (or avoid) that which they want to obtain (or avoid). That is, rewards do not control behavior. Rather, behaviors are used to control rewards.

Another aspect of trying to use rewards to control behavior is often overlooked and may actually go a long way toward explaining why it is ineffective in the long term. For me to use reinforcement in an attempt to control your behavior, I must be able to control the resource that will serve as the reinforcement and make sure that you are in a state of *deprivation*. That is, I must make sure that you have less of the reinforcement than you want. I cannot use food as reinforcement if you are able to obtain all the food you want from other sources. Whereas such an arrangement may work well for a rat or pigeon that cannot question the fairness of such a situation, you as an intelligent adult human being will almost certainly find such a situation unfair if not intolerable. As Powers (1973, p. 268) noted:

> Food rewards *will* cause modification of behavior, but how do you set up the conditions that give you sole control of the food supply? That is the step which Skinner and those who admire his methods have completely overlooked. That is the step that leads directly to violence.

This action of the would-be controllee against the would-be controller was recognized by Skinner who referred to it as "countercontrol," although it is seldom if ever mentioned now by advocates of his approach. In fact, anyone attempting to use Skinner's technique on another intelligent human being makes himself or herself susceptible to countercontrol. For example, a father may tell his teenage son that he must improve his high school grades to earn the right to use the family car. The teenager can then engage in countercontrol by making it known that if he can't use the car whenever he wants, he will simply not study at all! This is only one form that countercontrol can take, as more violent outcomes are also possible.

Bernard's Biological Approach

If reward and punishment fail to solve the problems caused by human behavior, why do those with political, military, and economic power persist in using them? One reason is that, as mentioned, the promise of reward and the threat of punishment can modify others' behavior, at least until ways are found to defeat the system (as in escaping from the situation or using violence to overcome the reinforcer-punisher). Another reason is the assumption of a one-way cause-effect view in which reinforcement causes desired behaviors and punishment eliminates undesirable ones.

In contrast, applying the extended Bernardian lesson leads to a very different approach. It differs from a cause-effect behaviorist approach in at least two main respects. This is due to Bernardian (as further developed by Powers) recognition that perceptions (such as the perception of stimuli as reward or punishment) do not control behavior. Rather, individuals vary their behavior as necessary to control their perceptions and thereby obtain desired outcomes and avoid unwanted ones.

A school discipline process based on Powers's perceptual control theory suggests that application of the extended Bernardian lesson can be quite effective in bringing about desired changes in behavior. The Responsible Thinking Process, developed by Edward E. Ford, was first implemented in Clarendon Elementary School in Phoenix, Arizona (1994, 1996). Ford, a social worker and counselor who discovered the work of Powers in 1981, conceived an approach to school discipline based on the Bernardian lesson that human beings act to control aspects of their environment.

No extrinsic reward or punishment (or promises or threats of them) are used, and teachers are not held responsible for the behavior of their students. Instead, students engaging in disruptive behavior are asked a series of questions by the teacher designed to have students reflect on their behavior and its consequences if continued. Students who need help learning how to behave responsibly (that is, in a way that does not disturb the learning activities of the classroom) go to a "responsible thinking classroom" where a full-time teacher-counselor helps them develop a plan for change to submit to the classroom teacher for approval.

From this all-too-brief description of Ford's process (for more information see *www.respthink.com*), it may seem that it is just another way of using rewards and punishment to control students' behavior, with reward being the privilege to remain in the regular classroom and punishment being sent to the responsible thinking classroom. But this is not an accurate assessment, since the student is always in control of his or her own situation in accordance with the rules that have been accepted by the school's students and teachers concerning acceptable behavior.

Nowadays it is almost always the case that a teacher responds to a disruptive student with the threat of punishment (if the disrupting behavior continues) or the promise of a reward (if the disrupting behavior stops). In contrast, teachers in Ford's process do not use threats, bribes, or commands in such situations. Instead, they ask a series of questions like the following: "What were you doing?" "What are the rules?" "What happens when you break the rules?" "Is that what you want to happen?" "Is what you are doing getting you want you want?" "Do you want to work at solving your problem?"

At no time is a student told what to do or not to do, or asked to explain his or her behavior. But the rules of the school are enforced in a clear and consistent way, and the student has the choice of following them and participating fully in school activities or being excluded from them until he or she comes up with a satisfactory plan to change the disruptive behavior.

Although easy to describe, the Responsible Thinking Process is not so easy to implement for the simple reason that it goes against the belief commonly held by teachers that they are responsible for the behavior of their students and that rewards and punishment can be used to control students' behavior. Ford found that it takes a serious, determined effort on the part of teachers to cease threatening and bribing their students, and he devotes considerable time and effort to help them change their reaction.

But once achieved, the results, as I personally witnessed in an elementary school near Chicago, are quite amazing. That is why in just a few years the Responsible Thinking Process has spread to more than forty schools in the United States and Australia.

Ford's work in public schools and other institutions (he has also worked in juvenile detention centers) is a clear demonstration of the potential of a Bernardian approach to behavior to solve behavior-related problems. Contingencies of reinforcement or punishment, or their associated bribes and threats, are not necessary. There is no risk of escalating control and countercontrol. Most important, it removes from teachers the onus of attempting to control students' behavior and allows them to devote their energies to teaching. As one sixth-grade teacher remarked, "We've waited for a program to come along that allows me to teach! We have finally found it!" (quotation on the back cover of Ford 1994).

Darwin's Biological Approach

If the application of Bernard's extended lesson to animate behavior has been effective as applied to education, what about applications of the basic and extended Darwinian lessons?

It is not easy to find applications to education of Darwin's basic lesson. The notion that our evolutionary past had a role in shaping the human mind and thereby influences our abilities, emotions, goals, desires, and fears does not appear to be popular among educators. This is particularly so in the United States, where the fact of biological evolution itself is not popular (and is often attacked by religious fundamentalists), and where the role of the current environment, not one's evolutionary past, is usually considered the determining factor in shaping cognitive skills and personalities. But at least some attempts have been made to use Darwin's basic lesson to change schools to optimize learning and to understand difficulties children have in learning certain concepts.

An example of the former is Gary Bernhard's book *Primates in the Classroom* (1988). Bernhard drew primarily on studies of the world's remaining hunter-gatherer groups (including the Semang of Malaysia, Mbuti Pygmies of the Congo's Ituri forest, !Kung of the Kahalari Desert, Aborigines of Australia, and Eskimos of Canada's Arctic) to understand how learning naturally occurs in groups that live in environments similar to the one in which our species evolved; that is, before the development of agriculture and industry. Bernhard (1988, pp. 178–179) pointed out many similarities among these groups and described their implications for education, stating that

> Learning by discovery in a democratic social context is one of the characteristics of our species, and we are kidding ourselves if we think that a longer school year, more rigorous basic-skills instruction, higher academic standards, and all of the other suggestions that have come out of studies such as A Nation at Risk will solve the "education problem" in this country. An evolutionary perspective also makes it clear that, in order for children to learn naturally, they need to have consistent yet varied adult models. Thus we are equally foolish if we believe children will be well served in an environment in which the only adults around are trying to get out of the children's way. Finally, an evolutionary way of looking at education issues is grounded in the need that all humans have to belong to a group and to be acknowledged as individuals by the other members of the group. It is thus hardly surprising that the more removed children are from their conception of who is in the "band," the greater their distress.

Some will question Bernhard's method of applying what has been observed in hunter-gatherer groups to urban children in modern schools, but many innovative changes taking place in education are consistent with his Darwinian perspective. Such progressive approaches typically give students more responsibility for their own learning, integrate many types of knowledge and skills in pursuing projects of interest to the students, employ adults not as authoritarian transmitters of information but rather as facilitators and role models, and have multiage classrooms in which children and teachers remain together for several years. All these, and many other progressive changes in education, are compatible with how human children appear to learn best "naturally."[1]

But many skills that we expect children to learn did not exist in the evolutionary past. Reading and writing are considered basic to all formal education, yet they are relatively recent cultural inventions that had no role in our evolution as a species. Mathematics is another branch of knowledge unknown to our early human forebears but occupies an important role in education. What might the basic Darwinian lesson have to say about learning in these areas?

Psychologist David Geary studied children's learning of various subjects and observed an important distinction between what he calls "biologically primary" and "biologically secondary" cognitive abilities. The former appear to have evolved largely by means of natural or sexual selection, whereas "biologically secondary cognitive abilities reflect the co-optation of primary abilities for purposes other than the original evolution-based function and appear to develop only in specific cultural contexts" (Geary 1995, p. 24).

A good example of this distinction is the contrast between oral language ability (listening and speaking) and literacy skills (ability to read and write language). Normal children require no special instruction to learn to speak and understand language. As long as they are exposed to a spoken language in interaction with older individuals, they will acquire this ability with little apparent effort and no formal instruction. Human evolution obviously shaped our species to excel at the acquisition and use of language (see Cziko 1995, chapter 11; Pinker and Bloom 1990).

But no evolutionary pressure existed for learning to read and write or understanding mathematics, as these skills are relatively modern cultural inventions. Accordingly, they take special concentrated effort to acquire. Geary concluded that learning secondary biological abilities must involve extensive practice, and since this may not be particularly enjoyable, ways must be found to encourage children to undertake it.

Considerable controversy exists among educators about how this should be done and what should be practiced (as in the phonics versus whole-language approaches to reading). Nonetheless, Geary's evolutionary analysis of biologically primary and biologically secondary cognitive abilities creates a useful framework for understanding the success and difficulties our children experience in school and shows one way that the basic Darwinian lesson can be applied.

What about applications of the extended Darwinian lesson? We saw in chapter 9 how within-organism variation and selection functions within the mammalian immune and nervous systems, and how the process permits these systems to adapt to new circumstances in the form of immune responses and learning new behaviors and abilities. Can this lesson be applied in practical settings? It turns out that does have important behavioral applications in at least the field of education, despite the fact that educators have for the most part ignored it.

An important exception is Henry Perkinson, a philosopher and historian of education. He observed important connections among the extended Darwinian lesson, the philosophy of Karl Popper, and major developments in educational theory and practice, notably those motivated by the work of Piaget, Skinner, Maria Montessori, A. S. Neill (of *Summerhill* fame), and Carl Rogers (Perkinson 1984). The approaches to educational theory and practice advocated by these five influential individuals certainly have important differences. But what they all have in common is rejection of the traditional cause-effect notion of education as the transmission of knowledge from teacher to student, and appreciation of education as a process of change that involves continuous modification of previous knowledge by trial and error elimination.

This essentially Darwinian approach can be summarized by the title of Perkinson's book: education involves learning from our mistakes. This means that it is facilitated by an environment in which learners are free to try out their knowledge and skills without fear of making mistakes. But it also means that the environment must provide critical feedback permitting students to discover the inadequacies of their knowledge and skills so that they can continually improve. This approach rejects the view of students as passive recipients of knowledge and sees them instead as active creators of their own knowledge. It is consistent not only with the essential core of the educational theories of Piaget, Skinner, Neill, Montessori, and Rogers, but with other progressive changes occurring in education, even if reformers are unable or unwilling to recognize the Darwinian roots of these changes (see Cziko 1995, chapter 12, for a more thorough Darwinian discussion of education).

Toward a Unified Theory of Behavior

Applying the lessons of Bernard and Darwin to the what, how, and why of behavior provides the building blocks for a unified theory of behavior drawing on biology, psychology, physiology, and ultimately physics. The concerns and contents of such a theory should be obvious from the preceding chapters. But it will be useful to conclude this book with an outline of such a theory and a consideration of its limitations.

The basic Darwinian lesson informs us that our evolutionary past provided us and all animals with certain basic preferences. We prefer certain foods, odors, and tastes and are repulsed by others. We prefer environments that are not too hot and not too cold. We look for certain characteristics in mates, which differ depending on our sex. We do what we can to assist the well-being of our children, close relatives, and other individuals from whom we can expect such assistance in return. We prefer the company of family members and others who are most like us, and are wary of others whom we perceive as physically, racially, or culturally different. But these preferences, naturally selected for their past survival and reproductive consequences, are not necessarily advantageous in these respects in the modern environment we inhabit.

The extended Bernardian lesson provides an explanation for how such preferences, existing as reference levels within feedback-control systems, influence our behavior, and how we are able to purposefully vary our behavior to make our perceptions match these reference levels. The extended Bernardian lesson, in its cybernetic formulation as perceptual control theory, shows how goals, desires, intentions, likes, and dislikes are emergent properties of thoroughly materialistic systems, having no need for spirits, souls, or other supernatural entities or processes.

But we humans have many goals and preferences that cannot be traced back to our evolutionary past. Thus we need the extended Darwinian lesson to explain how new goals can evolve in the service of more basic ones. An Eskimo spears seals and whales to make a living. A farmer in Illinois plants hundreds of acres of corn and soybeans for his livelihood. A musician in Paris supports herself by producing certain sounds with her flute. Such behaviors require preferences and control systems that cannot be provided by our evolutionary past, but they can be created by within-organism variation and selection as a process of purposeful evolution.

I have no doubt that a biologically inspired view of behavior that uses the insights of Bernard and Darwin is far superior to the one-way cause-effect approach currently embraced by mainstream behavioral scientists. But I also recognize that this new approach has certain inherent limitations of its own concerning our understanding, prediction, and control of animate behavior.

First, our search for the ultimate, evolutionary accounts for behavior are hampered by unavailability of fossil records of behavior (although certain extremely rare fossil finds, such as that of a dinosaur apparently guarding her eggs and newly hatched offspring, do provide some behavioral evidence). So whereas we can provide all sorts of evolutionary accounts of the emergence of our preferences and abilities (such as language), we cannot know for sure which if any of these comes close to what actually took place.

Also, compared with other species, our behavior is remarkably diverse, reflecting our varied physical and cultural environments. Pandas eat only bamboo shoots, and robins always make a nest of a certain shape in which to lay eggs; but we humans engage in a wide variety of tasks to accomplish whatever basic goals evolution has provided us. This diversity makes it especially difficult to find universal human behavioral characteristics. Nonetheless, a Darwinian approach offers clues as to what fundamental universals may exist. Furthermore, recognition of the hierarchical nature of human perceptual control systems is a way of recognizing similarity in the underlying goals of human behavior in spite of their apparent superficial diversity.

Considering first the extended Bernardian lesson that organisms act to control their perceptions, we must recognize that the actual behavior implemented by an organism has to compensate for disturbances that are encountered. To the extent that these disturbances are unpredictable, the organism's behaviors will also be unpredictable. For example, even if I know that you are driving down a straight road to travel from your home in Eastville to a friend's home in Westville, I cannot know in advance how you will move the steering wheel, since I cannot predict the wind, traffic, and road conditions you will encounter. Nonetheless, knowledge of your goal (that is, the perceptual variable that you are controlling) will allow me to predict the outcome of your behavior (arriving in Westville), even if the precise actions you make while driving remain unpredictable.

The extended Darwinian lesson of within-organism variation and selection also poses challenges to understanding and predicting behavior. Through reorganization, organisms acquire control over new variables in new situations. Since this process has an essential random component in the generation of variation (mathematicians refer to it as a *stochastic* process), it is in principle impossible to know exactly what type of reorganization will take place. A boy who is deprived of attention at home will look for it elsewhere. Whether he will attain it by excelling in academics, sports, or by committing a violent crime will be determined by the results of control system reorganization, whose outcome is by its very nature impossible to predict.

All of these are important limitations to a unified theory of behavior based on the Bernardian and Darwinian lessons. But this biologically inspired framework allows us to ask many new, interesting questions about behavior, and conceive of a methodology for answering them that avoids the push-pull straightjacket of cause-effect behavioral science, taking into account our evolutionary past and present (the latter in the form of within-organism variation and selection).

We have no guarantee that applying the lessons of Bernard and Darwin will ultimately allow us to answer all the important and interesting questions about animal and human behavior. Nor can we be certain that they will lead us to solutions for the major behavior-based problems our species is facing, such as failing schools, violence, pollution, overpopulation, spread of disease, and the growing division of the world's population into haves and have-nots.

What is clear is that the currently accepted one-way cause-effect model, successful in explaining much of the workings of the inanimate world, cannot account for the purposeful, goal-directed behavior by which living organisms control important aspects of their environment. It is also clear that attempts to modify human behavior based on the push-pull approach inherited from Newton have failed both as a theoretical account for animate behavior and as an applied tool for behavior change.

Major revolutions have taken place in the fields of astronomy, geology, physics, and biology, with important consequences for our understanding of the universe and our ability to predict and control important aspects of our environment. It is not unreasonable to expect that the consequences of a major revolution in the much younger discipline of behavioral science may have consequences as great as or greater than those of these earlier revolutions.

When the lessons of Bernard and Darwin become widely understood by behavioral scientists, the life, behavioral, and physical sciences will have achieved an integration that future scientists will find so obvious, satisfying, and useful that they will have difficulty understanding why, after Bernard's and Darwin's revolutionary breakthroughs in the nineteenth century, it was not until the twenty-first century that their lessons were widely learned and applied.