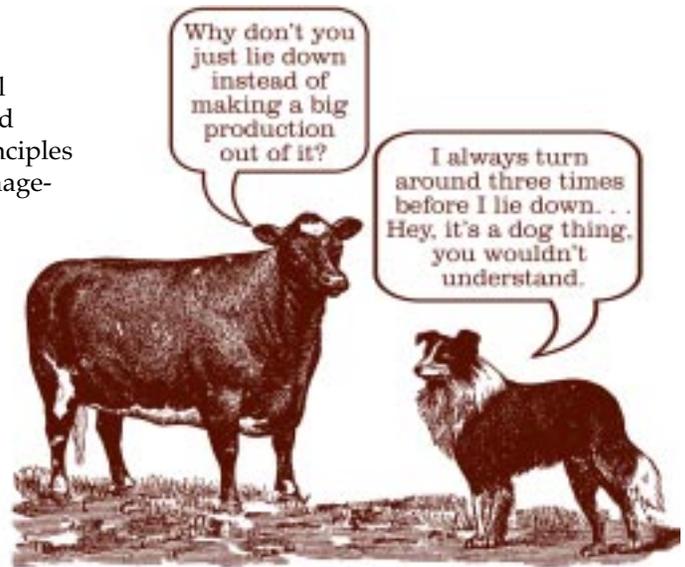


Old Dogs, New Tricks

What influences behavior, be that of cells, organs, individuals, or social groups? Several principles pertain to the behavior of all creatures, from bacteria and insects to reptiles, birds, and mammals, including humans. Understanding these principles and how they influence behavior is key to effective management of systems. In the workplace, we can force employees to work hard because they need money, just as we can force animals to move through a chute with an electric prod. Alternatively, we can create environments where employees work hard because they like their job, as well as the money, just as we can create environments where cattle move, not because they are forced to move, but because they want to. To differentiate between the two approaches is to distinguish between positive (want to) and negative (have to) reinforcement, and knowledge of that difference can be used to teach old dogs new tricks in ways that increase profitability, reduce stress for animals and people, and improve the management of ecosystems.

Behavior is a function of consequences

The variables that influence behavior of individuals are everywhere in the environment, from cells to organs to social and physical environments. At all these levels, behavior is a function of its consequences. If the probability of a behavior increases by delivery of some item or event, then that item or event, by definition, is a positive reinforcer, and the procedure is called reinforcement. When animals ingest a nutritious food or find nutritious foods in a particular location, the likelihood increases that they will eat the food and return to the location. If the probability of a response decreases after the contingent delivery of some item or event, that consequence is considered aversive and the procedure is called punishment. For example, if an animal is poisoned after eating a food or is attacked by a predator in a particular location, the likelihood decreases that the animal will eat the food or return to the location. Positive reinforcement increases response frequency, and punishment decreases response frequency. Nothing could be simpler or account for so much behavior at so many levels with so few assumptions.



Jim Winder, a rancher in southwest New Mexico, uses supplements to positively reinforce his cattle's behavior.

Two hands clapping

Deborah Shouse describes the difference between positive reinforcement and punishment in an essay in *Newsweek* (May 1, 1995), "The Sound of Two Hands Clapping." She writes: "When I was growing up, I envied Sally Culver. Though she was five years younger, she had somehow managed to get herself a fan club. It began one summer evening, when Mrs. Culver brought her 1-year-old daughter, Sally, to our house.

"I want to show you the most remarkable thing," Mrs. Culver told my mother. She set the baby down on our driveway, and Sally, diaper rustling, took a step. 'Bravo!' Mrs. Culver said, clapping. 'Wasn't that just marvelous?' she asked, turning to me. I was standing back, my jump rope in hand, wondering why anyone would make such a big deal over walking.

"Weren't her legs just the straightest things you've ever seen?" Mrs. Culver gushed to my mother. 'Her posture is exceptional,' my mother said. I took a breath and stood up straighter. My mother didn't notice. Sally took two steps before she plopped down. Again, applause. This time my mother joined in.

"I untangled my rope and jumped 10 more times. No one noticed. My mother was too busy clapping and cheering for Sally. It was my first experience with the power of applause."

Shouse goes on to describe how our personal lives are curiously devoid of tangible appreciation. Yet, if we don't experience positive reinforcement, how can we be expected to give it to others, be they people or livestock? Shouse developed a scenario—a day of two-hands clapping—for how such recognition might work: "I drive my children to school. As they collect their book bags, their extra tennis shoes, the book report that has already fallen in the mud, a team of mothers surrounds my car. 'Great job of getting your kids to school on time,' they say, applauding approvingly At work, my associates give me a standing ovation when I arrive. 'You are so responsible,' they say. I bask in the praise At the end of the workday, I drag myself through the grocery store. As I leave, the checkers and sackers stop to give their approval. 'Fabulous food gatherer,' they say encouragingly. 'What a wonderful mother and provider.'

"In my earlier life, I'd stagger into the house with bulging grocery sacks, only to have a daughter say, 'How come you didn't get chocolate-chip ripple ice cream? We never have anything good to eat.' Now, my daughters wait in the driveway, jumping up and down and cheering. 'Yeah, Mom. Thank you for guiding us nutritionally!' They stop their thunderous applause only to help me carry in the groceries.

"Do I really want to cook dinner after I've been solving problems, talking on the telephone, managing meetings all day? Sure, because as I carry the food to the table, my family applauds No wonder I'm thumbing through back issues of *Gourmet* magazine."

Shouse concludes with an anecdote that illustrates the power of positive reinforcement. "'This walkathon is not for sissies,' my friends warned me. After two hours, my new Walk-For-Life T-shirt was wet, my shoes were gnawing into my heels and my mouth felt like I'd licked 399 envelopes I was yearning for water, a fan and a new bottle of deodorant, when I heard "the sound." 'Yeah, you're great! You've come a long way. Only a few more miles to go. Great job!' The encouragement came from volunteers clustered at the intersection. Suddenly, my legs felt lighter, my mouth was moist. A gentle breeze dried my armpits. Someone had seen me—tired, sweaty and trying my best. Buoyed by the sounds of appreciation and praise, I knew I could walk a marathon."

At work, people are rewarded and punished throughout the day by all facets of the environment, just as a cow in a riparian area is rewarded and punished for her behaviors by insects, vegetation, water, shade, and social interactions. There are numerous occasions, for those with the time and interest, to encourage desirable behaviors and to discourage undesirable behaviors in people and in livestock. In so doing, we change the behavior of individuals and systems.



File Photo

Reinforcement and punishment

Consequences can be divided into two categories—reinforcement and punishment. Behavior results from various combinations of these.

Reinforcement. Consequences that **increase** the likelihood of a behavior are called reinforcement, and they can be either positive (positive reinforcement) or negative (negative reinforcement). Creatures seek *positive reinforcers* and avoid negative reinforcers. When a hungry animal searches for a particular nutritious food, or a thirsty animal walks to water, or a hot animal seeks shade, they do so because food, water, and shade are positive reinforcers—they are things the animal wants. Conversely, animals avoid *negative reinforcers*. When a hungry animal searches for a nutritious food, or a thirsty animal walks to water, or a hot animal seeks shade, they also do so to get relief from an aversive stimuli—hunger, thirst, heat.

Punishment. Consequences that **decrease** the likelihood of a behavior are called *punishment*, and they can be based either on the presentation of an aversive stimulus (positive punishment) or on the removal of a positive reinforcer (negative punishment). *Positive punishment* is the presentation of an aversive stimulus. When livestock get shocked for touching an electric fence, they stop touching the fence. When employees are harassed for making suggestions, they stop proposing new ways to do business. *Negative punishment* is the removal of a positive reinforcer. When a goat eats a plant that was once nutritious but is no longer, or when a ewe walks away each time her lamb attempts to nurse during weaning, both the goat and the lamb decrease rates of responding (eating the plant, nursing) because a positive reinforcer (nutrients, milk) has been removed.

There is a growing movement away from reliance on negative reinforcement and punishment and toward the use of positive reinforcement. Punishment arouses anger and fear in animals. If strongly aversive stimuli are used, these emotions inhibit learning and actually lead to results opposite of those intended. A submissive dog may attack its owner if beaten. A child may become unduly shy and nervous if parental punishment is too severe.

Punishment by withdrawing a positive reinforcer produces characteristic forms of emotional reaction—disappointment or depression—in people. Withdrawal of strong reinforcers may produce serious emotional reactions, the most obvious example being the death of a loved one. People who are close to us provide many reinforcers; when they die, those reinforcers are suddenly withdrawn. The same is true when animals are



For long-term sustainability, behavior is better shaped by positive reinforcement than by negative reinforcement and punishment.



moved from familiar to unfamiliar environments. All the positive reinforcers they have come to know are suddenly removed. No wonder they wander for miles, become malnourished and stressed, and don't reproduce. That's why it is so difficult to break old habits—all of the reinforcers are removed. Change, then, requires the death of old behaviors and the birth of new ones—no small task.

For long-term sustainability, behavior is better shaped by positive reinforcement than by negative reinforcement and punishment. While coercion can quickly change behavior, its long-term negative consequences—the desire to escape the circumstance and avoid anything remotely related—far outweigh its short-term benefits. People who work because they have to (negative reinforcement) are much less productive than people who work because they want to (positive reinforcement). Coercion causes stress, which reduces performance and profits. Livestock can be forced to move through chutes and in feedlots with hotshots, but that method will never cause animals to move freely. It may cause other unwanted behaviors like jumping and kicking. Livestock move readily when they are worked gently and rewarded for moving through chutes. It is less stressful on the animals and on the people.

Livestock handlers and trainers like Bud Williams advocate the use of gentle handling over harsh treatment. There is also a tendency, at least among those who publish books, to advocate use of positive reinforcement in business. It is virtually impossible to pick up a book on leadership and management that doesn't have at least one chapter, if not the entire book, devoted to encouraging people. In their book *In Search of Excellence*, Thomas Peters and Robert Waterman, Jr. state that "Nothing is more powerful than positive reinforcement. Everybody uses it. But top performers, almost alone, use it extensively."

Consequences depend on nature and nurture

What causes consequences to be positive or aversive? There has been a long-standing debate over which is more important—nature (genes) or nurture (experience). The argument is pointless because both are involved in behavior. Behavior is the ongoing integration of nature and nurture.

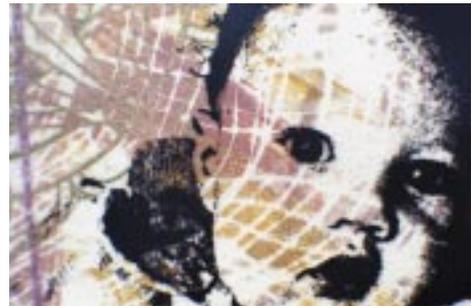
At conception, each individual inherits a genotype with instructions for its development, morphologically and physiologically. Morphology and physiology set limits within which an animal must function. For example, to continue to live all animals must ingest nutrients, and to avoid premature death all animals can ingest only limited amounts of toxins.

To facilitate adaptation, nature has constructed creatures so that nurture—social and environmental experiences—can help individuals adapt to the ever-changing conditions they encounter throughout life, even to the degree that experience influences gene expression. From conception on, each



Coercion doesn't work well for animals or people.

“Nothing is more powerful than positive reinforcement. Everybody uses it. But top performers, almost alone, use it extensively.”



Behavior is the ongoing integration of nature and nurture.

individual interacts with a social and physical environment that influences its development. As cells, organs, individuals, and social groups interact with their respective environments they are themselves changed in the process. For example, all animals are born with muscles, but their ongoing development and stamina depend on how the muscles are used. This is true with all facets of behavior, including food and habitat selection. Neural development and patterns of firing, gut morphology, and digestive physiology all are influenced by what an animal eats. Thus, ongoing interactions continually transform both the individual and the environment. Nurture complements nature by allowing an animal of a given morphological form and physiological function to learn which combinations of foods are palatable and which combinations are not, based on experience and flavor-feedback interactions. Ongoing learning and adaptation are critical for survival because foods and habitats appear in such diverse forms across time and space and over the lifetime of the individual and the species. Flexibility means that what is “palatable” to one individual may not be “palatable” to the next, depending on each animal’s genotype and its past experiences with particular foods and habitats—“one critter’s meat is the next critter’s poison.”



File Photo

All animals are born with muscles but their ongoing development and stamina depend on how the muscles are used. The same is true with all facets of behavior, including food and habitat selection.



File Photo

“One critter’s meat is the next critter’s poison.”

Using behavior to manage for ecological, cultural, and economic integrity

Some have come to accept that cattle degrade riparian ecosystems, and that nothing can rectify the situation except to remove cattle from waterways with fencing or to remove them from rangelands altogether. This view suggests that animals are somehow programmed genetically to live in specific habitats, and that cattle are bottom-dwelling swamp creatures. The belief is naive, especially when it comes to understanding the origins of animal behavior and the ability of people to change our own behavior and that of livestock.

Cattle can be trained to prefer uplands over riparian areas, but only if people manage using behavioral principles. Experiences early in life teach livestock to prefer habitats like uplands and riparian areas. No gene codes for living in riparian areas. A rider on horseback can train cows and calves to use uplands and discourage their use of riparian areas by consistently moving them to desired locations. Managers also can cull individuals that prefer riparian areas and retain animals and their offspring that prefer upland sites.



Red Canyon Ranch near Lander, Wyoming.

Gary Neuenwander

continued on next page. . .

Using behavior continued. . .

Bob Budd, an innovator who manages Red Canyon Ranch near Lander, Wyoming, for The Nature Conservancy, and his co-workers have been using these techniques for several years. They have increased cattle use of uplands and improved riparian areas. He argues that the costs of riding are offset by the benefits from additional forage in uplands, improved herd care and health, better riparian areas, and enhanced diversity of plants and wildlife.

Riding is less costly than fencing and more effective in the long run. Fencing addresses only the symptoms of animal-distribution problems. By relying on fences, managers reinforce undesirable behaviors. Riparian areas are often over-utilized, even in fenced pastures that contain both uplands and riparian areas. Riding, on the other hand, allows managers to use behavioral principles to train adults and their offspring to use upland forages and habitats, a long-term solution to the problem.



Gary Neuenwander

Bob Budd, manager of Red Canyon Ranch near Lander, Wyoming, believes a rider on horseback can train cattle to use uplands by consistently moving them to desired locations.



Fred Provenza

Riders at Red Canyon Ranch herd cattle away from riparian areas and cull individuals who persist in using sensitive areas.

While riding has proved effective for controlling livestock distribution, a rider must consider social behavior. As Budd points out, most “wrecks” occur because animals aren’t ready to move. For example, a cow without her calf moves slowly and eventually runs back, taking most of the herd with her. Cattle subgroups should be dispersed as a unit, otherwise individuals separated from their subgroup will return to their former location. A rider should purposely relocate subgroups to desirable sites. Upon arrival at the new site, the animals should be shown the locations of palatable forage, salt, and water. When moving cattle to a new site in familiar territory, it is best to move them before they have fed and watered; at the new site, they experi-

ence the positive reinforcement that comes from eating nutritious foods in the area. It also helps to plan moves to coincide with a decrease in nutritious forage in one location, which is aversive, and an abundance of food in the new location, which is positive. If done repeatedly, cattle learn to move because good things happen when they do. When moving them to new loafing areas, it is best to move them soon after they have fed and watered; a large meal is typically followed by muscular relaxation and drowsiness.

A rider also can identify cows and calves that consistently use riparian areas so individuals that exhibit repeated undesirable behaviors can be culled. Not all animals in a herd prefer the same foods or the same locations. Within any group, some individuals will never conform to management needs concerning food or habitat selection criteria while others will conform well. Intimate knowledge of where different individuals and subgroups of animals live can be used to enhance dispersion across a landscape by culling animals that use sensitive areas and retaining animals that use different areas.

Skin and gut defenses

On rangelands, just one plant may stand between an herbivore and its use of a foraging environment. In some habitats, the obstacle is a poisonous plant, like locoweed or larkspur. Though palatable, it is toxic, preventing animals from using otherwise abundant and nutritious forage. In other areas, the barrier is a tasty plant that has high agronomic value, such as apple, cherry, or Douglas fir trees. Livestock could easily graze fruit orchards and forest plantations, even improving fruit harvest and tree growth, if only they could be persuaded not to eat the trees. In such cases, the key is to teach the critters that the preferred food is harmful.

How can livestock managers accomplish this useful trick? Say a manager wants to train herbivores to avoid a particular food, for example a field of barley or fruit trees in an orchard. Two fundamentally different techniques can accomplish the task. One is to teach the animal to avoid the place with dogs or an electric fence—place aversion. Animals learn quickly to avoid electric fences. When placed in a “training pen,” they learn to avoid the wire; when they touch it, the shocking consequences are always aversive. The procedure is easy and cost-effective.

The other technique is to train herbivores to avoid the food with the use of toxins—food aversion. Animals quickly learn to avoid a food when its ingestion is followed by toxicosis. This can be induced by giving a toxin dose in a capsule with a balling gun immediately after the animal eats the food. Unlike a properly functioning electric fence, however, if an animal eats the food while foraging on pasture and does not experience toxicosis, the positive consequences of nutrients will diminish the food aversion—it is as if the electric fence no longer contains electricity.

Therein lies the challenge with food aversions. How can one create aversions strong enough to ensure that animals will never sample the food? The person who discovers the solution to this problem will certainly prosper. The findings will apply not only to livestock, but also to wildlife depredation, which results in the loss of millions of dollars annually. Here’s food for thought on the matter.

Anyone who has ever trained animals has wondered what they learn from different experiences. For instance, a person walks into a pen of animals that have just been fed, catches a lamb or calf, and puts a balling gun containing a capsule with a toxin into its throat. The animal soon will experience toxicosis, but will it associate the toxicosis with the person who just attacked it or with the food it just ate? What mechanisms enable animals to learn to differentiate between the consequences of different stimuli—food and place aversions—in the environment?



Johnny Boudreaux, a cattle producer near Perry in southern Louisiana, uses a faithful dog to move his cattle and an electric fence to contain them.

Mary Donahue



Beth Burritt, Utah State University research associate, demonstrates the use of a balling gun.

Fred Provenza

Animals learn about foods and places in different ways. As preeminent psychologist John Garcia points out, “All organisms have evolved coping mechanisms for obtaining nutrients and protective mechanisms to keep from becoming nutrients.” In many birds and most mammals, *auditory* and *visual* stimuli and sensations of pain and satisfaction are associated with the so-called skin-defense system, evolved in response to predation. The *taste* of food and sensations of nausea and satiety are part of the so-called gut-defense system evolved in response to toxins and nutrients in foods. *Odors* are readily associated with skin- or gut-defense systems. The odor of predators forewarns the skin-defense system, while the odor of food serves as a cue for the gut-defense system.

The way skin- and gut-defense systems work is illustrated in trials with hawks fed distinctively colored or flavored mice. When hawks normally fed white mice were given a black mouse, followed by an injection of a toxin, the hawks would eat neither black nor white mice. They were not discriminating between mice as a food item based on color. Rather, they were discriminating based on taste, which was the same for black and white mice. Thus, when a distinct taste was added to black mice, hawks learned to avoid black mice on sight after a single black mouse–toxicosis event. The hawks were discriminating between food sources based on taste.

These experiments show that not all cues are associated readily with all consequences. Animals made ill following exposure to audiovisual and taste cues show much stronger aversions to the taste than to the audiovisual cue. In contrast, if they receive a foot-shock following the same cues, they show much stronger aversions to the audiovisual than to the taste cues.

The same kind of response has been demonstrated for food and place aversions. Toxins decrease palatability, but they do not necessarily cause animals to avoid the place where they ate a particular food; this is the essence of the hawk-mice-toxicosis experiment. Conversely, an attack by a predator may cause animals to avoid the place where they were eating, but it does not decrease the palatability of the food. While place aversions are specific to the site, food aversions depend on the food and are generally independent of the location where the food was eaten.

Thus, when a person walks into a pen of animals, catches one, and puts a balling gun containing a capsule with a toxin in its throat, the animal will associate the person with the attack and its skin-defense system will respond, but it will associate the food ingestion with toxicosis and its gut-defense system will respond. The automatic, non-cognitive pairing of foods with postingestive consequences means that even if the person could explain to the animal that the capsule of toxin—not the food—was the cause of the toxicosis, it would still be averse to the food. The gut-defense system is designed to pair food ingestion with postingestive effects regardless of what the animal “thinks” caused the illness.

“All organisms have evolved coping mechanisms for obtaining nutrients and protective mechanisms to keep from becoming nutrients.”



In trials, hawks normally fed white mice were fed black mice followed by an injection of toxin and they would eat neither black nor white mice. However, when a distinct taste was added to black mice, the hawks learned after a single black mouse–toxicosis event to avoid black mice on sight. Taste helps to create a much stronger aversion regarding food.

Teaching herbivores about toxic foods

Most plants contain toxins of one sort or another—even plants grown in gardens. They are simply present in low amounts because people have selected for low-toxin varieties of plants. By and large, herbivores have little trouble limiting intake of toxic plants to tolerable levels, as long as they have nutritious alternatives. Poisonous plants are typically a problem only when animals lack nutritious alternatives. However, some plants like larkspur and locoweed are a problem even when alternatives are available. Training livestock to avoid poisonous plants is one alternative to the economic losses from poisonous plant deaths.

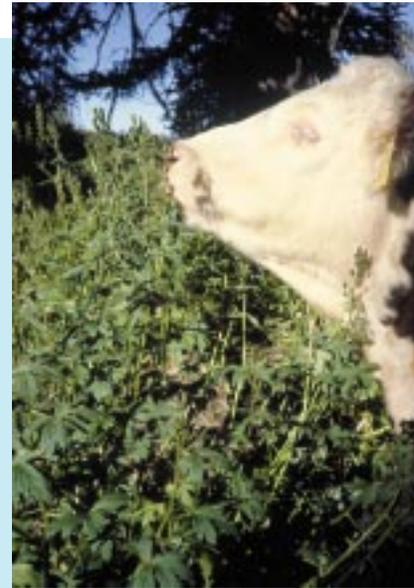
The best way to an animal's palate is through its stomach, and the best way to teach an animal not to eat a food is to pair its ingestion with toxicosis. In a typical training protocol, animals are allowed to eat the food then given a dose of a toxin like lithium chloride. Lithium chloride is ideal for inducing food aversions because it can be administered in doses high enough to condition strong aversions without fear of death. Toxins cause food aversions by stimulating the emetic system, which is responsible for nausea in humans. Aversions to plants like larkspur and locoweed have persisted for as long as 3 years with cattle herds of up to 75 individuals. Aversions to shrubs like serviceberry and mountain mahogany have persisted for at least 1 year in sheep. Animals are usually trained in pens then allowed to forage on pastures or rangelands. Several principles pertain to food-avoidance conditioning for poisonous plants or trees in fruit orchards or pine plantations.

Novelty of the food and dose of the toxin

The strength of an aversion depends on the strength of the flavor—its novelty—and the dose of the toxin. Generally, the stronger and more novel the flavor and the higher the dose of the toxin, the stronger and more persistent the food aversion. Animals most strongly avoid eating novel foods when their ingestion is consistently followed by a bout of toxicosis. That's how plants deter herbivores—the most noxious plants have strong, novel flavors and maintain high levels of toxins. Herbivores get the message the first time they eat the plant and every time thereafter. It is much harder to condition a lasting aversion to a previously eaten food—especially a nutritious food—because animals are more likely to re-sample the food. If they sample the food and do not experience toxicosis, the nutritional benefits the plant provides will quickly counter-condition the food aversion.

Frequency of flavor-toxicosis pairings

The strength of an aversion also depends on the frequency of the flavor-feedback consequence. It is important to allow the animals to eat (re-sample) the novel food over several days, always following food ingestion with toxicosis. Animals often sample some of the target plant on the day following toxicosis, even with a high dose of a toxin like lithium



A cow succumbs to the temptation of larkspur.

Jim Pfister



Jim Pfister

A field of locoweed, pretty to look at but deadly for horses.



continued on next page. . .

Teaching herbivores continued. . .

chloride, though intake of the food is greatly reduced. They often eat a little on the second day, but after the third day they typically show no interest in the plant.

Nutritious alternatives

Once an aversion is in place, it is critical that animals have access to abundant, nutritious alternatives while foraging. It is not enough to simply cause an aversion to the target plant to punish unwanted behaviors. One must also provide attractive alternatives. When the option is to eat the target plant or starve, animals eat even when plants are poisonous.

Age of animal

Younger animals can be more difficult to train than mature animals to persistently avoid a novel food. Young animals re-sample novel foods previously paired with toxicosis more readily than adults. They are more neophyllic. When a young animal eats the target food while foraging on pasture, the aversion quickly diminishes in the absence of toxicosis.

Social facilitation

Finally, trained animals should not be allowed to forage with untrained animals that eat the plant. When trained and untrained animals forage together, the trained animals are more likely to sample the plant, which allows nutritional benefits of eating the food to counter-condition the aversion. Mike Ralphs, range scientist with the Agricultural Research Service, Poisonous Plants Research Laboratory, trained one group of cattle to avoid larkspur, and the aversion persisted for 3 years. When he placed trained and untrained animals in the same pasture, the aversion to larkspur was gone within a month.



Jim Pfister

Larkspur—cattle can be trained to avoid it.

Creating cultures that enhance biodiversity

The dependence of ecosystem function and stability on biological diversity has been an integral part of ecological theory for over a century, but we are just beginning to understand the *biochemical links* between herbivores, plant diversity, and the sustainability of ecosystems. Biochemical diversity increases resiliency, adaptability, and productivity of ecosystems by creating options for plants, herbivores, and people.

Herbivores satiate on nutrients and toxins, and nutrient-toxin interactions limit the amount of any particular food an herbivore can ingest. Most plants contain toxins so ingesting plants with toxins is not simply a case of avoidance, but a matter of regulation. The ability to consume toxic plants depends on the quantity and quality of nutrients and the kinds of toxins.

Herbivores are likely to optimize intake of nutrients and toxins in a manner consistent with the *chemistry of the foods* on offer and with their *previous experiences mixing those foods*. If animals are familiar with only some of the foods, and those foods provide adequate nutrition, herbivores are unlikely to eat other foods and are less likely to learn about the possible benefits of mixing different foods. Rather, they will probably eat all of the familiar foods in an area before they accept unfamiliar foods and mix the foods so as to balance nutrients and toxins. On the other hand, if herbivores are repeatedly forced to eat all plants they may learn to eat mixtures that mitigate toxicity, if appropriate choices are available.



Fred Provenza

A variety of plant life indicates biological diversity. This produces biochemical diversity increasing the resiliency, adaptability, and productivity of the ecosystem.



Grazing sagebrush-steppe

Even though grazing can enhance plant diversity in sagebrush-steppe ecosystems, diversity generally declined during the past century as toxin-containing woody plants such as sagebrush (*Artemisia spp.*) and juniper (*Juniperus spp.*) came to dominate over 39 million hectares of land in the western U.S. This domination reflects the dearth of herbivores and changes in grazing patterns associated with grazers, such as cattle and elk,

instead of mixed feeders and browsers, such as sheep, goats, deer, and antelope. Livestock often are confined and graze the same herbs repeatedly, particularly during spring on sagebrush-steppe landscapes. The decrease in grasses and forbs reduces fine fuels for fires and creates conditions that favor severe fire storms that reduce biodiversity. The problem has been exacerbated by fire suppression policies and lack of prescribed burning.

The decline in diversity adversely affects sagebrush-steppe ecosystems. Less water is available for other plant species because sagebrush transpires year-round. Nutrient cycling, plant production, and herbivore nutrition all are badly affected because sagebrush contains high concentrations of terpenoids, compounds that are toxic to soil and rumen microbes and to ruminants. To reverse these trends, managers must decrease—but not eliminate—the dominance of sagebrush and maintain a mixture of plant species.



Fred Provenza

Over 39 million hectares of the western landscape is now dominated by sagebrush and juniper, greatly decreasing plant diversity in sagebrush-steppe ecosystems.

Grazing by livestock may be the most economical means to accomplish both objectives. Intensive grazing by sheep for short periods during the fall, when herbs are dormant, may increase diversity. Sheep and goats supplemented with macronutrients—energy and protein—eat much more sagebrush than unsupplemented animals, evidently because macronutrients facilitate detoxification. Thus, intake of sagebrush may be increased, and the adverse impacts of sagebrush on sheep mitigated, if large numbers of supplemented sheep graze sagebrush for short periods.



Fred Provenza

Sheep and goats supplemented with energy and protein eat much more sagebrush than unsupplemented animals. Macronutrients like energy and protein facilitate detoxification.

Finally, through grazing management that encourages use of all plants, herbivores may learn to mix their diets to achieve more even use of all plants, thereby maintaining plant diversity. Herbivores learn to optimize intakes of nutrients and toxins in a manner consistent with their previous experiences and with the mix of foods offered. If allowed to eat only the most preferred plants, herbivores are unlikely to learn about the consequences of mixing foods high in nutrients with foods high in toxins. On the other hand, herbivores repeatedly forced to eat all plants in an area may learn to eat mixtures of nutritious and toxic plants in ways that mitigate toxicity, assuming appropriate choices are available, given that nutrients facilitate detoxification processes.

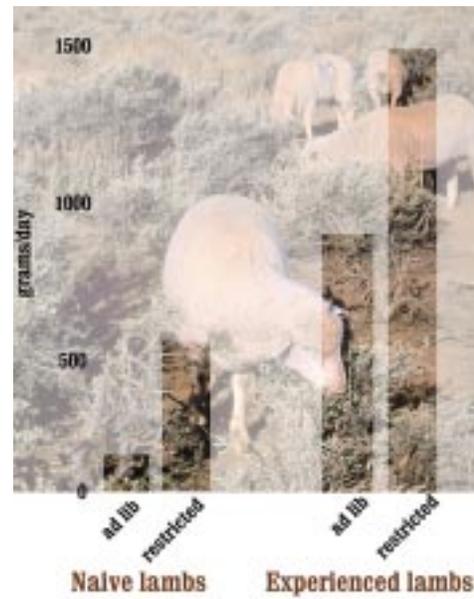
We have begun to investigate the relationship between herbivore experience and availability of foods that vary in toxins and nutrients. In pen trials, lambs who learned to eat ground rations that contained tannins, terpenes, and oxalates ate more when they had a choice of two of the foods offered simultaneously—food with tannins/terpenes, tannins/oxalates, or terpenes/oxalates—than lambs offered only one food, and lambs offered the three-way combination—tannins/terpenes/oxalates—ate more than lambs offered any of the two-way combinations.

We then compared food intake by lambs with 3 months of experience mixing foods that contained the different toxins with lambs naive to the toxin-containing foods. Lambs were offered 5 foods, 2 of them familiar to all of the lambs—ground alfalfa and a 50:50 mix of ground alfalfa and ground barley—and 3 of them familiar only to experienced lambs—ground rations with either tannins, terpenes, or oxalates. Each day, half of the lambs were offered the familiar foods ad libitum, whereas the other half of the lambs were offered only a small amount (200 g) of the familiar foods.

Experience and availability of nutritious alternatives both influenced food choice. Naive lambs ate much less of the foods with toxins if they had ad libitum rather than restricted access to the nutritious alternatives (66 vs 549 g/day). Experienced lambs also ate less of the foods with toxins if they had ad libitum as opposed to restricted access to the nutritious alternatives (809 vs 1497 g/day). In both cases, lambs with experience ate significantly more than naive lambs of the foods with toxins whether they had ad libitum (811 vs 71 g/day) or restricted (1509 vs 607 g/day) access to the alfalfa-barley alternatives.

These findings have implications for grazing management. Different systems of management cause animals to forage in different ways. Light stocking encourages selective foraging, whereas heavy stocking for short periods encourages diet mixing. What was traditionally considered proper grazing management—rotational grazing at low stock densities—may have trained generations of livestock and their offspring to “eat the best and leave the rest” thus inadvertently accelerating a decline in biodiversity and an increase in the abundance of less desirable plant species. By changing grazing practices, managers may be able to train their animals to “mix the best with the rest.”

Such learned patterns of foraging behavior are transmitted culturally from one generation to the next. Experiences early in life with mother influence preferences for foods and habitats. That knowledge, critical for the survival of individuals, may also be essential for maintaining the biodiversity of landscapes.



In both cases, lambs with experience mixing foods that contain different toxins ate significantly more of the foods with toxins than naive lambs. Experience and availability of nutritious alternatives were both factors in food choices.



Fred Provenza

Heavy stocking for short periods encourages diet mixing and, along with learned patterns of foraging behavior, may, in the long run, lead to maintaining the biodiversity of landscapes.



Fred Provenza



Boom-bust management

Ray Banister manages 7,200 acres of rangeland in eastern Montana. His management style has evolved over 40 years from reliance on rotational grazing that involved relatively short periods of grazing and rest to boom-bust management that consists of intensive periods of grazing followed by 2 growing seasons of rest. Ray's boom-bust grazing management stresses systems—soils, plants, and herbivores—with intensive grazing pressure, then allows them to recover. Ray believes that stress, and recovery from stress, strengthens systems.

The change to boom-bust grazing challenged the Hereford cattle on his ranch. The cattle were no longer allowed to eat only the most palatable plants as they had under the rotational grazing system. Instead, they were forced to eat all of the plants. Under the new management procedures, Ray monitors the least palatable plant species—shrubs like sagebrush and snowberry and various weeds—as indicators of when to move the cattle to a new pasture. Cattle are allowed to move only after their use of the unpalatable species reaches high levels. In so doing, Ray reduces the competitive advantage unpalatable plants have over more palatable species. Heavily grazed plants are at a disadvantage when competing with ungrazed plants for moisture and nutrients.

It took Ray's cows 3 years to adapt to the boom-bust style of management. During that time, the weaning weights of calves plunged from well over 500 pounds to 350 pounds, then rebounded back to over 500 pounds.

Under boom-bust management, cattle begin to eat formerly unpalatable species like snowberry and sagebrush as soon as they enter a new pasture. The cows evidently have learned how to mix their diets in ways that better enable them to eat both the palatable and the unpalatable species. Cattle likely mitigate the aversive effects of toxins by eating palatable plants high in nutrients along with unpalatable species high in toxins.

Once the older cows made the transition to a new way of behaving, the young calves were able to learn from their mothers how to thrive under boom-bust management. The calves that Ray keeps as replacements never have to make the harsh transition. They were trained by their mothers that all plants are food at Ray's place.

Ray has improved the land through boom-bust management. Occasional disturbance, followed by rest, creates and maintains a diversity of micro and macro habitats. It is hard to find any part of the ranch that lacks abundant plant cover even during years of drought. Heavy use of all plant species reduces undesirable plants. Abundant plant cover in the uplands and riparian areas mitigates soil erosion, which leads to clean water and great habitat for fish, waterfowl, and terrestrial species of wildlife.



Ray Banister of eastern Montana looks at the least palatable plant species as indicators of when to move his cattle to a new pasture.

Gary Neutenswander



Fred Provenza

Ray Banister improved his rangeland in eastern Montana through boom-bust management. Occasional disturbance followed by rest creates and maintains a diversity of habitats and abundant plant cover.

Culture, social organization, and grazing management

Bob Jackson and Sharon Magee own a bison operation in Iowa. They also have lived and worked in the back country of Yellowstone Park for many years where they spent considerable time observing social animals. They understand the interrelationships among culture, social organization, and grazing management. Intact family units—offspring, mothers, fathers, grandmothers, grandfathers—are the basis of their operation.

Frank Mayer and Charles Roth describe these social units in *The Buffalo Harvest*. “Do you remember reading about buffalo herds millions strong, moving in a solid mass, and stopping trains and wagons? . . . Of course the herd, this vast mass of animals, would be under the leadership of a grand old buffalo bull, who would trot serenely at its head, issuing orders and demanding instant and complete obedience.” But as they point out, these are misconceptions.

“Most of the herds would run from 3 to 60 animals, with an average of around 15. In these small herds the buffalo traveled and fed, scattered over the plains, but each one separate and apart from the other herds. Whenever they stampeded they did come together and charged as one vast, solid herd. But when the fright passed they’d separate into their peculiar small herd formation . . . (whose) leader wasn’t a bull at all . . . It was a cow, a sagacious old cow who by the power of her intellect had made herself a leader. Buffalo society, you see, was a matriarchy, and the cow was queen.”

Bob and Sharon manage bison and land on the basis of these “peculiar small herds” under the leadership of matriarchs. They contend that bison family units are necessary for proper management. Young animals benefit from the knowledge of social behavior,

food, and habitat selection of older generations. Bison culture, as with other social species like goats, sheep, cattle, deer, elk, and elephants, is a repository of knowledge about social and physical environments.

Members of family groups learn how to mix diets and achieve uniform use of different plant species, which enhances biodiversity. Bob and Sharon contend that managers who use family groups achieve the same outcome as those who use management-intensive grazing: more uniform use of all plant species. Competition among family groups promotes rotational grazing, without the need for fencing, as family groups displace one another while grazing across landscapes.

Social interactions also discourage the over-use of riparian areas. Matriarchs maintain identity of family groups by moving from riparian areas when other families enter the area, ensuring groups do not linger along watering points. Historical accounts



Bob Jackson and Sharon Magee manage bison and land on the basis of the small bison family unit maintained by the group matriarch.

Gary Neuwander



Jeff Henry

Part of a small family unit of bison graze in Yellowstone National Park, where Bob Jackson is a backcountry ranger and first began to study bison.

continued on next page. . .

Culture, social organization, and grazing management continued. . .

in Yellowstone and elsewhere indicate that riparian areas were heavily used primarily during the winter, when families tolerated more contact as they were forced to forage along riparian areas.

Such use of these environments is not possible when family order is disrupted or when domestic or wild animals are moved to unfamiliar environments. When cultures are disrupted, either by breaking up family groups or by moving families to unfamiliar environments, animals suffer from malnutrition, poisonous plants, and predation. This painful lesson, learned by many ranchers as they have attempted to move animals to unfamiliar haunts, is now being learned by conservation biologists who are attempting to re-introduce wild animals into habitats formerly occupied by other members of their species.



Fred Provenza

Bison in Yellowstone National Park allowed to remain in their small family units, above, versus a herd, below, where the family units are broken up and the bison behave more like cattle in their grazing movements.



Jeff Henry