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Social organization, culture and use of landscapes by livestock

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SUMMARY – The social facets of foraging typically are not considered in studies of food and habitat selection even though they are an indispensable part of the lives of most herbivorous mammals and of effectively managing landscapes. Through interactions with mother and peers, young animals learn what and what not to eat and where and where not to go in an environment, which collectively leads to "the home-field advantage". The behavior of any individual is influenced as genes are expressed through interactions with social and biophysical environments, and experiences early in life markedly influence those relationships. Social organization leads to culture, wherein young animals learn from their ancestors through their mothers, and in the process the accumulated knowledge of how to use landscapes is passed from generation to generation. Cultures develop when learned practices contribute to the group's success in solving problems, and they evolve as individuals in groups discover new ways of behaving, as with finding new foods or habitats and better ways to use foods and habitats. Unfortunately, we have lost much of the knowledge of behavior used by our ancestors whose survival depended on hunting the wild herds and on domesticating ancestors of today's cattle, sheep, and goats. Our lack of appreciation of the social facets of foraging is apparent in the problems we encounter as we attempt to manage herbivores. Conversely, we can use knowledge of sociality to enhance management of landscapes to benefit soils, plants, herbivores, and people.

Keywords: Learning, habitat, food, nutrients, toxins, sheep, goats, cattle.

RESUME *– "Organisation sociale, culture et utilisation du paysage par le bétail". Les facettes sociales de la recherche d'aliment ne sont généralement pas considérées dans les études concernant la sélection de l'aliment et de l'habitat, bien qu'elles soient une partie indispensable de la vie de la plupart des mammifères herbivores et d'une gestion efficiente du paysage. A travers les interactions avec leur mère et leur congénères, les jeunes animaux apprennent ce qu'ils peuvent ou ne doivent pas manger, où ils peuvent ou ne peuvent pas aller dans leur milieu, ce qui mène collectivement à "l'avantage de connaître le terrain". Le comportement de tout individu est influencé, car les gènes s'expriment à travers les interactions avec le milieu social et biophysique, et les premières expériences de la vie influencent notablement ces relations. L'organisation sociale mène à la culture, par laquelle les jeunes animaux apprennent de leurs ancêtres à travers leur mère, et ce faisant les connaissances accumulées concernant l'utilisation du paysage passent de génération en génération. Les cultures se développent lorsque les pratiques acquises contribuent à la réussite du groupe pour résoudre les problèmes, et permettent une évolution en tant qu'individus du groupe découvrent de nouveaux modes de comportement, tels que la recherche de nouveaux aliments ou habitats et une meilleure façon d'utiliser l'aliment et l'habitat. Malheureusement, nous avons perdu une grande partie des connaissances comportementales que possédaient nos ancêtres, dont la survie dépendait de la chasse de troupeaux sauvages et de la domestication des précurseurs de notre bétail actuel, bovins, ovins et caprins. Notre manque d'appréciation des facettes sociales de la recherche d'aliment est évident dans les problèmes que nous rencontrons lorsque nous voulons gérer les herbivores. En revanche, nous pouvons utiliser nos connaissances des faits sociaux pour améliorer la gestion des paysages au bénéfice des sols, plantes, herbivores, et populations humaines.*

Mots-clés : *Apprentissage, habitat, aliment, nutriments, toxines, ovins, caprins, bovins.*

Introduction

During my years as a college student, I worked on a ranch owned by Henry DeLuca. Henry's father and mother were originally from Italy, and they had moved to Colorado to homestead a large tract of land on the west end of the valley near the town of Salida. Henry was born and raised on that homestead, and though he had little formal education, he had a lifetime of experience working with soil, water, plants, animals and landscapes. During my sophomore year in college I took a course in genetics, and when I returned to the ranch I asked Henry about his livestock breeding program. He always kept his own replacement females, and that seemed odd to me for two reasons. First, I was taught about the advantages of heterosis or hybrid vigor – increased size, growth rate, and fertility –

that can be gained from mating two purebred lines with desirable traits. Second, I learned that the costs of raising one's own replacement females were much greater than the benefits, so I asked Henry why he didn't simply buy replacements and take advantage of the increased performance and reduced costs. He told me stories about the losses in production his animals had suffered when he moved them to unfamiliar environments, and he told me about the troubles he had encountered when he purchased replacements reared in other environments. He reminisced for over an hour, and in the end he summed it all up by saying "The trouble is the animals just don't know the range".

What does it mean to know the range?

Imagine an animal foraging in an environment with 25 to 50 plant species. These plants differ in their concentrations of energy, protein, minerals, and vitamins. They all contain toxins of one sort or another, but at the appropriate dose, many of these toxins have medicinal benefits. Envision further that how much of any one food an animal can eat depends on the other foods it selects because at the biochemical level, nutrients and toxins interact one with another – nutrients with nutrients, nutrients with toxins, and toxins with toxins (Provenza *et al.*, 2003a). These challenges are further amplified because cells, organs, individuals, social and biophysical environments change constantly. Now imagine 3 to 7 foods will make up the bulk of the diet at any point in time. Which plants should an animal choose? Clearly, given 25 to 50 species and their interactions, there are a great many possibilities to mix and match different plant species. Which species animals learn to select influences their welfare and that of the landscape (Provenza *et al.*, 2003b).

Certainly the foods an animal can eat and the possibilities to live in an environment are influenced by how the animal is built (its morphology) and how it functions (its physiology) – the expression of its genome. Morphology and physiology affect the need for nutrients, the ability to cope with toxins, and the value of medicines, thereby creating the bounds within which animals can use different foods and habitats. But genes don't operate in isolation. They are expressed, beginning at conception, through the interplay with the social and biophysical environments where an individual is reared (Lewontin, 2000; Moore, 2002). Learning itself is a genetically expressed trait that much like evolution is continually shaped by the environment (Skinner, 1981). Thus, learning in concert with the genome influences the combinations of foods and habitats an animal will select.

Importance of the social environment

The social environment influences selection of foods and habitats and creates patterns of behavior that make sense only in light of social organization and culture (Provenza and Villalba, 2005). Social organization creates culture, the knowledge and habits acquired by ancestors and passed from one generation to the next about how to survive in an environment (De Waal, 2001). Cultures develop when learned practices contribute to the group's success in solving problems, and they evolve as individuals in groups discover new ways of behaving, as with finding new foods or habitats and better ways to use foods and habitats (Skinner, 1981). Consequently, interactions with a mother and peers markedly influence what a young animal learns to eat (Mirza and Provenza, 1990, 1992, 1994; Thorhallsdottir *et al.* 1987, 1990a,b,c) and where it prefers to live (Key and MacIver, 1980; Howery *et al.*, 1998). Thus, for instance, an individual reared in shrub-dominated deserts of Utah will behave differently – and is morphologically and physiologically different – from one reared on grass in the bayous of Louisiana (Distel and Provenza, 1991; Distel *et al.,* 1994, 1996; Wiedmeier *et al.,* 2002; Provenza, 2003).

Socializing enhances learning efficiency because each animal no longer has to discover everything by itself. For example, when sheep and goats must learn to drink from a water device that requires pressing a lever, it takes only one individual to learn how to do it, and in no time all the others are drinking. Thus, when an individual discovers how to use a new resource the group benefits, but discovering new resources isn't inevitable. For instance, goats browsing blackbrush-dominated rangelands experience protein deficiencies. Of eighteen different groups of goats foraging on six separate blackbrush pastures during three different winters, goats in only one group discovered that the interior chambers of woodrat houses provide a good source of supplemental nitrogen, and they performed much better than their counterparts (Provenza, 2003). One goat likely learned the value of eating woodrat houses, and the other goats learned from it. Animals have similar difficulties learning through trial and error about the medicinal benefits of substances, especially if behavior and consequences (flavor-feedback) are not contingent (paired consistently) and contiguous (paired closely in time), as illustrated in studies that either did or did not closely pair medicine and benefit (Provenza *et al.,* 2000; Villalba and Provenza, 2001; Huffman and Hirata, 2004; Villalba *et al.,* 2005). In all of these cases, social models increase the efficiency of learning over trial-and-error learning by individuals. When a mother's behavior (eat or avoid) is subsequently reinforced by postingestive feedback (positive or negative), her offspring respond most strongly (eat or avoid) to a food (Provenza *et al.,* 1993a). Such knowledge then becomes a part of the culture, wherein young animals can learn from their ancestors through their mothers.

Critically, lessons learned early in life from a mother create a dichotomy between the familiar and the unfamiliar (novel) essential for survival. Of the many factors that interact during updates about foods in which an animal's past experiences with a food are integrated with new information about the food, none is more important than novelty (Provenza and Villalba, 2005). Novelty includes anything from a complete lack of acquaintance with the flavor of a food never before eaten, to a change in the flavor of a familiar food, to a novel food whose flavor is somewhat similar to a familiar food. The body evaluates new foods very carefully for their nutritional or toxicological effects.

While temporal contiguity – the proximity in time between a behavior and its consequences – is of upmost importance in shaping behavior, novelty is so important that it even overrides temporal contiguity. For example, if an animal eats two foods in sequence, and then gets sick, the animal will strongly avoid the food eaten just prior to illness, unless the food eaten first was novel, in which case the animal will avoid the novel food (Provenza *et al.*, 1993b). Even more critically, novel foods are evaluated cautiously by the animal and the body within a meal. Sheep eat small amounts of a novel food, and they acquire an aversion only to the novel food when toxicosis follows a meal of several familiar foods and a novel food (Burritt and Provenza, 1991). Conversely, when sheep eat the same low-energy food in two different flavors, one familiar and the other novel, and then receive intraruminal infusions of starch directly proportional to the amount of the novel food consumed, they form preferences for the novel flavor (Villalba and Provenza, 2000).

Finally, the novel-familiar dichotomy also causes animals to discriminate and generalize based on their past experiences (Provenza and Villalba, 2005). If the flavor of a familiar, nutritious substance such as molasses occurs in a novel food, the likelihood increases that animals will eat the food, provided they had positive experiences with molasses previously. Conversely, if the flavor of a familiar, toxic substance such as a cyanogenic glycoside occurs in a novel food, the likelihood the food will be eaten decreases if the animals previously experienced toxicosis after eating the food.

Experiences early in life have life-long influences on behavior and performance

Experiences early in life influence food intake and animal performance, as illustrated in a 3-year study where 32 beef cattle – 5 to 8 years of age – were fed ammoniated straw from December to May (Wiedmeier *et al.,* 2002). Although the cows were similar genetically and were fed the same diet, some cows performed poorly, while others maintained themselves. Researchers were baffled until they examined the dietary histories of the animals. Half of the cows were exposed to ammoniated straw with their mothers for 2 months early in life, while the other half had never seen straw. Throughout the study, the experienced cows had higher body weight and condition, and for the first 2 years of the study, they also produced more milk and bred back sooner than cows with no exposure to straw, even though they had not seen straw for 5 years prior to the study.

We seldom realize that past experiences have life-long influences on behavior because we know so little about the history of any animal. Nutrient-conditioned food preferences – which occurred as a result of brief exposure to a food 3 to 5 years previously – cause some animals (experienced) to readily eat a food other animals (naive) avoid (sheep: Green *et al.,* 1984; goats: Distel and Provenza, 1991, Distel *et al.,* 1994, 1996; cattle: Wiedmeier *et al.*, 2002). Likewise, food aversions often extinguish in the absence of toxicosis. However, if after an aversion has extinguished a sheep eats a meal of familiar foods, one of which previously made it ill, and then experiences toxicosis, the sheep will avoid the food that previously made it ill, not the other familiar foods (Burritt and Provenza, 1991). This point was illustrated when an adult ewe previously trained – conditioned with toxicosis – to avoid a tree (Russian Olive) began to eat the tree during meals 3 years later. When a meal of foods that included Russian Olive was followed by toxicosis, the ewe subsequently avoided the Russian Olive, the food that made her ill 3 years previously, not the other familiar foods in the meal (Provenza, unpublished data). Without knowledge of the ewe's dietary history with Russian Olive, her behavior would have made no sense.

French herders, social organization, and use of landscapes

From ancestral times, herders in southern France have met the needs of individuals, and fully used the range of plants available, by moving sheep and goats in daily grazing circuits. A circuit consists of five or more meals of different mixtures of foods designed to satisfy each animal's appetite for different nutrients and to regulate its intake of different toxins (Hubert, 1993; Meuret *et al.,* 1994). Each circuit includes a moderation phase, which provides sheep access to plants that are abundant but not highly preferred to calm a hungry flock; the next phase is a main course for the bulk of the meal with plants of moderate abundance and preference; then comes a booster phase of highly preferred plants for added diversity; and finally a dessert phase of palatable plants that complement previously eaten forages. Daily grazing circuits are designed to stimulate and satisfy an animal's appetite for different nutrients, and they undoubtedly enable individual animals to maximize intake of nutrients and regulate intake of different toxins (Provenza *et al.*, 2003a). Food intake and preference depend on how individuals are built morphologically and how they function physiologically, and marked variation is common even among closely related animals in needs for nutrients and abilities to cope with toxins. Choice enables the uniqueness of the individual to be manifest. It also allows for use of more plant species, which can prevent undesirable directional shifts in vegetation, thereby better enhancing and maintaining the biodiversity of landscapes (Provenza, 2003).

So where did French herders learn to move animals in grazing circuits? Just as the first farmers were heirs to knowledge – accumulated through tens of thousands of years of observations – of which plants to cultivate, so, too, the first nomads were heirs to knowledge of how herbivores foraged (Diamond, 1999). Prior to domestication, social herbivores likely met the nutritional needs of all the individuals in the group, and reaped the benefits of sociality – obtaining protection from predators, enhancing social status and reproductive success, learning traditional routes, and sharing feeding sites – by roaming in grazing circuits. If social organization accomplishes this without herders, we should be able to apply this knowledge to herds more closely associated with today's agriculture.

With domesticated livestock, we use fences and grazing systems, rather than social organization, to influence diet and habitat selection. Interestingly, social organization may lead to rotational grazing without fences. This notion is based on four assumptions: (i) social herbivores live in extended families; (ii) maintaining the cohesiveness of families and their home ranges influences behavior; (iii) individuals within families differ in their preferences for foods and habitats; and (iv) families maintain their unique identities by avoiding prolonged contact with other families. If these assumptions are correct, then social interactions *within* families are likely to encourage animals in small herds to eat a broader array of plants and to forage in a greater variety of locations as individuals maintain the cohesiveness of the group *and* respond to different preferences of individuals within the group. Interactions *among* families are likely to further increase movements across landscapes as different families avoid prolonged contact with one another. Hence, diet and habitat breadth both may increase through social organization, and culture may be critical not only for maintaining the integrity of species but also for the biodiversity of landscapes.

In sheep and cattle, social interactions *within* groups encourage animals to eat a broader array of foods (Scott *et al.,* 1995), and to forage in a greater variety of locations (Howery *et al.,* 1998), as individuals with different needs maintain the cohesiveness of the group *and* respond to ever-changing preferences of individuals within the group. Nutrients and toxins in all foods cause animals to satiate, and excesses of nutrients, nutrient imbalances, and excess toxins all limit food intake unless animals can eat a variety of foods (Provenza and Villalba, 2005). Thus, the ability to choose among alternative forages best enables individuals to meet needs for nutrients, balance intake of different nutrients and toxins, and obtain medicinal benefits from lower doses of plant secondary compounds that at too high levels are toxic. These biochemically mediated interactions link cells, organs, individuals, social groups, and the biodiversity of landscapes.

Stock density and food selection in social groups

So, how can a group of diverse individuals meet needs for nutrients and regulate intake of toxins? Social interactions *within* families are likely to encourage animals in small herds to eat a broader array of plants and to forage in a greater variety of locations as individuals maintain the cohesiveness of the group *and* respond to different preferences of individuals within the group. With increasing animal density – the number of animals per social group – foraging in groups may influence interactions *within* families. With livestock, grazing at *low stock densities* can encourage selective grazing – eat the best, leave the rest, and stay put – inadvertently diminishing biodiversity by increasing the abundance of less desirable plant species; conversely, short-duration and management-intensive grazing at *high stock densities* can encourage animals to be less selective – mix the best with the rest and move on (Provenza *et al.,* 2003a). Critically, when herbivores eat only the most preferred plants, they are not likely to learn to mix foods high in nutrients with foods that contain toxins, whereas herbivores encouraged to eat all plants in an area are more likely to learn to eat mixtures of plants that enhance nutrition and mitigate toxicity.

Experience and the availability of nutritious alternatives both influence food choice, as illustrated in a study that compared the preferences of lambs with 3 months' experience mixing tannin, terpenes, and oxalates with lambs naive to the toxin-containing foods (Villalba *et al.,* 2004). During the studies, all lambs were offered five foods, two of them familiar to all of the lambs (ground alfalfa and a 50:50 mix of ground alfalfa:ground barley) and three of them familiar only to experienced lambs (a ground ration containing either tannins, terpenes, or oxalates). Half of the lambs were offered the familiar foods ad libitum, while half of the lambs were offered only 200 g of each familiar food daily.

Throughout the study, naive lambs ate less of the foods with toxins if they had ad libitum as opposed to restricted access to the nutritious alternatives (66 *vs* 549 g/d). 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/d). In both cases, however, experienced lambs ate markedly more than naive lambs of the foods containing the toxins, whether access to nutritious alternatives was ad libitum (811 *vs* 71 g/d) or restricted (1509 *vs* 607 g/d). These differences in food preferences and intake persisted during trials one year later. In a companion study, when access to familiar foods was restricted to 10%, 30%, 50%, or 70% of ad libitum, lambs ate more of the foods with toxins along a continuum (10% = 30% > 50% = 70%) that illustrates animals must be encouraged to learn to eat unfamiliar foods that contain toxins (Shaw *et al.,* 2005).

Implications for managing grazing

Do high stock densities cause animals to learn different patterns of foraging behavior? Anecdotal observations suggest they do (Provenza, 2003). For example, Ray Banister, who manages 7,200 acres of land in eastern Montana, has modified his grazing management from reliance on rotational grazing to boom-bust grazing involving intense periods of grazing during the growing season followed by two growing seasons of rest (Ray Bannister, personal communication). Such intense grazing ensures that less palatable and weedy plants do not acquire a competitive advantage over more palatable species. The ranch has some of the highest vegetation cover and diversity in eastern Montana (Joe Fidel, Natural Resource Conservation Service, personal communication).

The change from rotational to boom-bust grazing meant cattle could no longer select only the most preferred plants. Based on cow and calf performance, it took 3 years for Ray's cattle to adapt to the new grazing regime. Weaning weights of calves dropped from over 500 pounds to 350 pounds before rebounding to over 500 pounds. During that time, cows learned to eat shrubs such as snowberry and sagebrush, which are usually considered unpalatable due to their levels of toxins, and they evidently learned to eat palatable and unpalatable species simultaneously to mitigate the aversive effects of toxins. Such learned patterns of behavior are transmitted from mothers to their offspring, resulting in enhanced biodiversity that benefits soils, plants, and animals. Thus, the culture of Ray's animals is influencing the structure and functioning of his ecosystems.

John Young, the foreman at the Rex Ranches in Nebraska, reports the same thing for leafy spurge, an invasive plant in the United States (personal communication). While most people know sheep and goats eat spurge, few believe that cattle will eat it too. According to John, four factors are critical: (i) the Rex Ranches use high stock densities for short periods to encourage cattle to eat a broad variety of plants; (ii) leafy spurge occurs in patches, it does not dominate the landscape, so cattle do not have to eat only spurge; (iii) other plants on the ranch complement leafy spurge biochemically, which better enables cattle to eat spurge; and (iv) the Rex Ranches keep their replacement heifers so young animals learn to eat leafy spurge from their mothers – it has become part of the culture. John's observations are consistent with research that illustrates the influence of experience and the availability of alternatives on food selection (Villalba *et al.*, 2004; Shaw *et al.*, 2005), highlights the importance of the relative availabilities of "palatable" and "unpalatable" foods (Provenza *et al.*, 2003a,b), and shows animals will include 10 to 30 percent or more of "unpalatable" foods in their diets if they have learned to do so and if complementary alternatives are available (Distel and Provenza, 1991; Distel *et al.,* 1994, 1996; Villalba and Provenza, 1997, 2000; Wiedmeier *et al.,* 2002).

By analogy, ancestors of people today learned to mix and match foods to meet needs for energy, protein, vitamins, and minerals. They also learned to cope with toxins ubiquitous in environments around the globe, and they learned to use "toxins" for medicinal purposes. Interestingly, many foods preferred by our ancestors are considered unpalatable by people today due to their high concentrations of toxins (Johns, 1994). With ready access to processed foods high in sugar, carbohydrates, fat, and salt, young people throughout the world no longer acquire preferences for critically important "unpalatable" foods because they lack the traditional cultural foundations to guide their selection of plants high in a variety of different nutrients and medicines. Likewise, studies with herbivores suggest that many of the plants originally avoided by inexperienced cattle at Ray's and John's places and by sheep in the studies of Villalba *et al.* (2004) were "unpalatable" due to their high concentrations of toxins. However, the older herbivores who were retrained to use a broader mixture of plants and the younger herbivores reared on the new mix of plants both acquired a taste for the "unpalatable" plants due to their benefits.

Undoubtedly, critical thresholds of animal knowledge and plant diversity exist below which plant diversity and animal performance decline at ever increasing rates, and above which diversity and performance can beget greater diversity and enhanced performance (Provenza *et al.*, 2003a,b). From the standpoint of knowledge, animals that have learned to "eat the best and leave the rest" will use a landscape much differently from animals that have been trained to "mix the best with the rest". Critically, in the latter case animals must be able to choose from foods that are biochemically complementary (Provenza *et al.*, 2003a). From the related standpoint of plant diversity, when unpalatable plants high in toxins reach critical thresholds of abundance, they are eaten at ever-decreasing rates relative to the alternatives. As unpalatable plants come to dominate, herbivores have no opportunity to learn to select a diet that would enable them to mix the best with the rest – they are forced to eat the best and leave the rest (Provenza *et al.*, 2003b).

Conclusions

In his discussion with me over thirty years ago, Henry DeLuca concluded that the problem with buying replacement animals, or moving animals to unfamiliar environments, is that "The animals just don't know the range". So, what does it mean to know the range? Knowing the range ultimately involves interactions among history, necessity, and chance, all of which implies knowledge of the range has value not typically considered when people suggest it is too costly to raise one's own replacement females.

An animal's foraging behavior is a function of its evolutionary history, genetically expressed, in concert with its uniquely individualistic history of the social and biophysical environments where it was conceived and reared. Thus, selecting for local adaptation is a way to match animals to landscapes. For instance, resource-rich environments with an abundance of nutritious forages low in toxins support larger animals of the same breed than resource-poor environments with little forage and plants high in toxins. Food intake and animal performance also depend on how individuals are built morphologically and how they function physiologically. Foraging decisions are affected by differences in organ mass and how animals metabolize nutrients and toxins (Konarzeski and Diamond, 1994), and marked variation is common even among closely related animals in needs for nutrients and abilities to cope with toxins. The same dose of nutrient that conditions preferences in some lambs, conditions aversions in others (Villalba and Provenza, 1996). Likewise, lambs given a choice of foods high in energy (barley) and high in protein (alfalfa) vary markedly in their preferences (Scott and Provenza, 1999). The same is true for toxins. Doses of tannins that condition aversions in some goats, do not deter others (Provenza *et al.*, 1990). Similarly, some sheep fed high levels of *Galega officinalis* failed to show any symptoms of toxicosis, whereas others were killed by a low dose (Keeler *et al.*, 1988). Collectively, these differences in abilities to metabolize nutrients and toxins form the basis for selection, be that by man or nature, in ways that can match animals to landscapes.

The behavior of any individual is influenced as genes are expressed through interactions with social and biophysical environments, and experiences early in life markedly influence those relationships. Retention of daughters within the maternal home range and male-based dispersal form the basis of sociality in many mammalian species. Social organization leads to culture, wherein young animals learn from their ancestors through their mothers, and in the process the accumulated knowledge of how to use landscapes is passed from generation to generation. Cultures develop when learned practices contribute to the group's success in solving problems, and they evolve as individuals in groups discover new ways of behaving – as with finding new foods or habitats and better ways to use foods and habitats. Experience plays a key role in an animal's propensity to learn to eat different foods. When herbivores are allowed to eat only the most preferred plants, they are not likely to learn to mix foods high in nutrients with foods that contain toxins. Conversely, herbivores encouraged to eat all plants in an area are more likely to learn to eat mixtures of plants that mitigate toxicity. Importantly, different systems of grazing management influence how animals learn to forage. Continuous grazing at low stock densities encourages selectivity and reduces diet and habitat breadth, whereas short-duration grazing at high stock densities increases diet and habitat breadth.

An animal's behavior is also a function of necessity due to its current nutritional, toxicological, and medicinal state relative to the biochemical characteristics of foods it can potentially consume at any moment. Diets and habitats that allow animals to select among alternatives enable individuals to better meet needs for nutrients and to better cope with toxins. All plants contain toxins, and the amount of toxin an animal can ingest depends on the kinds and amounts of nutrients and toxins in the forages on offer. Thus, individuals can better meet their needs for nutrients and regulate their intake of toxins when offered a variety of foods that differ in nutrients and toxins than when constrained to a single food, even if the food is "nutritionally balanced". Food intake and preference also depend on differences in how individual animals are built morphologically and how they function physiologically, and marked variation is common even among closely related animals in needs for nutrients and abilities to cope with toxins. Thus, feeding and grazing practices that allow producers to capitalize on the individuality of animals are likely to improve performance of the herd by enabling the uniqueness of individuals to become manifest.

Finally, an animal's behavior depends on chance occurrences that involve gene expression and environmental variability (Lewontin, 2000; Moore, 2002). Genes are expressed as a function of interactions with biophysical and social environments, and because both change constantly and often unpredictably, so too do expressed morphology, physiology, and behavior. Thus, social and biophysical influences that shape the development of individuals from conception to death depend critically on time and timing – the unforeseen and indiscernible role of chance in life (Taleb, 2001).

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