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Mink weren't LeGrande Ellis's first choice in experimental animals. Any animal destined for fur coats is obviously too expensive for laboratory studies. And their downright nasty dispositions, a legacy of their predatory past, made handling about as much fun as wrestling a compressed hurricane with teeth. Sharp teeth.

The attitude of the USU endocrinologist and reproductive physiologist toward mink has softened considerably during the two decades he has used ranch-raised mink in his studies. He thinks mink hold the clues to several ailments that afflict humans.

Ellis's studies of mink were prompted by a request from ranchers to help solve reproductive problems in mink. Among their attributes as a research animal (which are not necessarily attributes in production) is their relatively short life span (most live no longer than five years, and most breeding stock is kept for no more than three years), highly inbred breeding populations, and the fact that most of their reproductive problems are of genetic origin.

The same traits that make them useful in research diminish their productive potential. Ellis says the genes governing productivity, growth, reproduction and the immune response are located closely together on the same chromosome. (This linkage of traits is common in many other species.) These genes are located near the centromere, the location where chromosomes appear to attach to the spindle during mitosis, which limits the exchange of genes during meiosis. As a result, these genes are usually inherited as a group. Coupled with the extensive inbreeding of ranch mink, mink breeders who select for high productivity also often select for infertility.
The highly inbred dark mink produce extremely desirable pelts but have smaller litters. Average litter size for dark mink is 3.2 kits, compared with 5.6 kits for mink of other pelt colors.

Polyandry, the mating of female mink to more than one male, increases the likelihood of fertilization and can increase litter size, but often makes it difficult to determine the male parentage (and thus the genetic heritage) and to detect infertile males.

Ellis and his co-workers identified five different causes of male infertility in mink. The testes in some male mink never mature or fail to produce viable sperm. Other males appear to be victims of an autoimmune reaction that destroys the testes, or of a cytotoxic reaction in which their sperm storage duct, the epididymis, is blocked with scar tissue. Another genetic ailment doesn’t impair fertilization but arrests kit development.

"We are developing chemical tests so mink ranchers can identify and eliminate mink with deleterious genes," Ellis says. Most of the traits are recessive and carriers can’t be identified except in kits that inherit both recessive genes. Occasionally, however, there is a “nick” in the chromosome which allows the exchange of desirable genes for productivity and fertility.

Ellis’s research concerning fertility and pelt priming problems has fostered a long-term cooperative relationship with Utah’s mink producers, including several in collaboration with David Patten, director of research for the Fur Breeders Cooperative in Sandy.

Ellis says mink are an excellent model for the study of several human diseases. A form of neonatal kit death in mink is similar to human crib death. Mink are also prone to malignant hyperthermia, a heat stress syndrome. "Environmental heat triggers a rapid rise in temperature, about one-tenth of a degree per minute to 110 degrees. It’s lethal, and it’s something we’ve also observed in horses, swine and dogs. In humans, sometimes anesthetic will trigger the rapid rise in temperature. We know that on hot summer days, neonatal death loss goes up tremendously," Ellis says.

Mink are also afflicted by cardiomyopathy, the destruction of the muscle fibers or the valves of the heart, and to spongiform encephalopathy, a virus-like disease similar to scrapie in sheep, that destroys brain tissue. A veterinary scientist in Wisconsin has linked the disease to contaminated animal by-products. Apparently mink can get the disease from and pass the disease to cattle. Spongiform encephalopathy also affects both neonatal kits and lactating females.

Ellis believes highly reactive free radicals, partially reduced oxygen molecules, may trigger these and other ailments. He has measured high levels of lipid peroxides, a type of free radical, in many afflicted animals. In mink, the production of free radicals is apparently precipitated by several factors, including pathogens and high temperatures. Mink have high requirements for vitamin E, which several studies have indicated may ameliorate the effects of free radicals.

"I am a firm believer that most disease processes in all animals, including humans, involve free radicals," Ellis says.

The subject of his studies, *Mustela vison*, is a small brown long-bodied, short-legged carnivore native to northern North America. Adult females weigh about three pounds, males about five. Including the tail, they are 20-30 inches long.

Thick, warm furs of cold-climate carnivores furs have always been highly prized. (Furs from felines from warmer climates are valued more for their beautiful markings than their insulative properties.) In Medieval England, the right to wear furs of the mink’s European relatives—sable, ermine and marten—was restricted to royalty and high nobility.
Commoners wore coats of herbivores—rabbit or sheepskin.

The mink’s coat has a dense underfur about one-half inch long and short, lustrous guardhairs just over an inch long. Mink ranching, raising mink in captivity for their furs, began to be commercially feasible in the early 1900s. Originally, the large, dark Pacific Coast and Alaskan minks were the most desirable breeding stock. By the 1940s and 1950s, mink with black guardhairs and slate-colored underfur were the standard on fur farms, and by the 1960s, mink were developed that had both black guardhairs and underfur. Over the years, color mutants have resulted in several true breeding forms.

The black color is the result of numerous genes. Two dominant genes known as jet black and Finn black intensify the dark color. The effort to produce dark pelts has encouraged intensive inbreeding.

In 1988-89 4.6 million mink pelts were produced in the United States (from 952 ranches), and only Denmark (12.7 million), the Soviet Union (5 million pelts exported) and China (5 million exported) exceeded U.S. mink production. Only about 10 percent of the pelts are from wild mink.

Utah ranks second among U.S. producers with 175 ranches located primarily in Morgan, Summit, Salt Lake, Cache and Utah counties. Utah ranches produced 780,000 mink pelts from 225,000 females in 1989, a 12 percent increase above Utah’s 1988 yield.

The average market price per pelt was $25.80 in 1989 (down from $32 in 1988 and $43 in 1987). Certain of the color mutants command higher prices. For instance, “volvalia pink” pelts have sold for $420 each, and at a Hudson Bay Co. auction in the 1960s, 40 “black willow” pelts from Utah sold for an average of $1100 each. Judicious breeders may raise a mink to pelting for an investment of $16 to $20 per animal, Ellis says.

LeGrande Ellis 750-2563
USU researchers are trying to thwart two deadly protozoan parasites. The target of their research: Eimeria tenella, which causes avian coccidiosis, and Cryptosporidium parvum, which attacks young livestock and debilitates AIDS victims and others with weakened immune systems.

The complex life cycles of both protozoa incorporate some nefarious adaptations to their hosts. For example, once chickens ingest oocysts, the infective stage of the E. tenella, the parasite enters cells lining the intestines, rupturing these cells as protozoa go through several cycles of asexual reproduction. The parasite continues its destructive rampage during a period of sexual reproduction. Eventually oocysts are released, which are carried in the feces to begin the destructive cycle again.

In the United States in 1985, estimated livestock losses due to coccidiosis totalled $300 million.

The life cycle of C. parvum is similar, but it is a zoonosis, a disease that can be transmitted from livestock to humans. Infections, which usually cause a mild diarrhea, have been reported in travelers, residents of day care centers, animal handlers and veterinary students, but the parasite can be deadly when it gains a foothold in AIDS victims. The parasite also causes diarrheal illness in young livestock (especially calves and lambs).

E. tenella is the most pathogenic of the nine species of coccidian parasites that infect chickens. This parasite attacks the blind pouches (ceca) of the small intestines, and causes unthriftiness, hemorrhages, diarrhea and anemia and, in severe cases, debilitation and death. Veterinary scientist Mark Healey says several drugs stop reproduction but new drugs must continually...
Before 1980, documented C. parvum infections were rare in animals and seldom a problem in humans. That's all changed in the last decade or so. Researchers discovered that the protozoa were a relatively common cause of diarrhea in newborn livestock. Of even greater concern is that the protozoa infect approximately 5-7 percent of all AIDS victims, causing a potentially fatal cholera-like illness.

"In animals and humans with a normal immune system and in very young animals C. parvum may cause a mild form of diarrhea that may last a week or so. Victims usually recover as their immune systems arrest reproduction of the protozoa," Healey says.

Young animals with immature immune systems and immunosuppressed victims of AIDS cannot limit asexual reproduction of the parasite, however. There are no effective treatments to prevent the protozoa from multiplying in humans and causing severe diarrhea and dehydration. "More than 100 drugs have been tested, but nothing works," Healey says.

Another complication in immunosuppressed patients is that about 20 percent of the oocysts generated in the intestine excyst prematurely,
Life cycle of Cryptosporidium

Unsporulated oocyst is shed in feces.

Life cycle of Cryptosporidium

Sporulated oocyst

Cycle begins again.

releasing sporozoites that renew the infection. The ability of these thin-walled oocysts to persist in the body mean that there is no respite in the cycle of infection.

The USU researchers are trying to facilitate the desperate search for effective treatments by developing animal and test-tube models to screen drugs. Mice with normal immune systems rid themselves of the protozoa too soon to enable researchers to assess the effectiveness of drugs. To overcome this barrier, Healey and coworkers Michael Arrowood and Jan Mead are studying two immunodeficient strains of mice, both of which will sustain the infection. A strain of rat currently being studied by Kathleen Rasmussen may also be a suitable test species.

Several cell lines are also being examined as possible test-tube systems. Ideally, one could be found in which C. parvum undergoes a complete cycle of development in order to screen drugs.

The USU researchers are developing and screening monoclonal antibodies to identify antigens useful in developing a vaccine against C. parvum. In collaboration with biochemist Dr. Jesse Jaynes at Louisiana State University, they are also studying synthetic lytic peptides (small protein antibiotics) for potential antiprotozoal activity. In recent tests, one of these proteins killed more than 90 percent of the infective sporozoites in a test tube system by disrupting the parasite outer membrane.

KG

Michael Arrowood 750-1897
Mark Healey 750-1901
Jan Mead 750-2282
Kathleen Rasmussen 750-1897
What are sheep and cattle doing when they graze?

Remembering, apparently. Some remember what their mothers taught them. Others recall advice from their buddies. Some of their gastronomic actions are simply the result of culinary messages from the gut. And a few hundred sheep and goats are eating because that's how Fred Provenza taught them to eat.

Six years ago, Provenza, a USU range scientist, thought he would try to determine why livestock nibble on a tuft of grass, for example, rather than nab a mouthful of sagebrush.

Many studies stressed the importance of "experience" in an animal's diet selection, but none specifically defined the term.

For good reason. For animals, eating appears to be almost as rich and as varied an experience as for humans.

Unraveling the Origins of ANIMAL APPETITES
Provenza's efforts to decipher the foraging behavior of livestock now involve a large "school" on the outskirts of Logan (attended by some 200 sheep and 80 goats annually), monitoring the culinary preferences of sheep and goats on range-lands, and rummaging through reports in nutrition, psychology, physiology, toxicology and behavioral ecology in search of appropriate concepts.

The end result? Something which Provenza says is a theoretical "collage," a theory with some loose ends but one that "contains all the basic elements to describe foraging behavior."

An intricate system of instruction apparently has evolved naturally to help animals distinguish between a thistle and a blade of grass, and between a nutritious compound and one that will kill them. Cows and sheep don't just randomly bumble around a pasture or rangeland in search of something to eat, nor is their search driven solely by natural instincts. Animals learn from
parents and peers, sometimes by trial and error, and sometimes as a by-product of bodily functions. The system works well, but there may be considerable room for improvement. In other words, once we determine how livestock learn, farmers and ranchers might be able to establish a better curriculum for their ovine and bovine students.

Mind you, livestock already do fairly well on their own. Provenza says a grazing sheep or cow has to choose between dozens of types of plants. The landscape changes with the seasons and the climate. Plants take on different guises and change their nutritional characteristics during the year. And the food sometimes fights back. The defenses plants muster range from spikes and thorns to potentially
harmful chemicals. Every nibble or bite may not require a hefty I.Q., but it involves more than dumb luck.

**Theories of Diet Selection**

Provenza says none of the theories of foraging behavior seem to adequately incorporate the role of learning in foraging.

Consider taste. Some theories assume that animals will eat tasty forages and avoid those with unsavory flavors. Provenza thinks taste is important, but says what occurs after eating—the postigestive consequences—determines whether an animal will like or dislike the taste, much as we may relish something while eating it, but not after it has made us ill.

And then there’s chemistry to consider. One theory of grazing behavior assumes that livestock could intuitively taste and smell the nutrients and toxins in plants, and select accordingly. Not so, says Provenza, who instead attributes selection to chemical reactions leading to desirable or undesirable consequences. His research shows that goats learn quickly—within a matter of a few hours—to avoid potentially harmful plants, an attribute that many researchers have mistakenly attributed to an intuitive ability to sense toxins in plants.

Another popular theory assumes that diet selection reflects body morphology, physiology and size, which Provenza says simply doesn’t consider innumerable other attributes of plants and animals that affect diet selection, nor does it account for the wide variation in preferences within a species. For example, cattle and bison, commonly considered to be grazers, often prefer ranges dominated by shrubs while goats and mule deer, commonly considered to be browsers, often prefer grass diets.

Optimal foraging theory, which assumes that animals forage in order to get as much energy (or as many nutrients) as possible while expending the least amount of energy, is perhaps the most popular explanation of foraging behavior, but Provenza says it doesn’t explain how animals select nutritious diets and avoid toxins.

Ironically, these theories ascribe a holistic wisdom to livestock, the apparent result of an evolutionary *pas de deux* between plants and livestock. Unfortunately, they also fail to explain the dietary blunders of livestock—why some animals occasionally kill themselves by eating poisonous plants or ignore seemingly nutritious morsels.

None of us learn perfectly. Neither do livestock. Provenza’s embryonic theory seems to explain why.

**Unconscious Aspects of Learning**

"Diet selection involves an interplay between some actions that are under an animal’s conscious control and others that aren’t," Provenza says. He calls the “automatic” responses, like gagging, affective processes. If the animal feels awful after eating, it forms a conditioned aversion for the taste of the food. If it feels good, it forms a conditioned preference for the taste.

Conditioned food aversions (dislikes), which have been documented in numerous studies involving species as ecologically diverse as garter snakes, bluejays, rats, coyotes, baboons, humans, sheep, goats, and cattle, involve a series of chemical, physiological, and neurological reactions.

Food aversions are formed when a food triggers the emetic system (the same system that controls vomiting). A food can automatically trigger this reaction, even when animals have been anesthetized or deeply tranquilized. A conditioned aversion can develop even if there is a long delay between eating and nausea—as long as 12 hours in rats and 8 hours in sheep.

However, some substances seem to “short-circuit” this system. An animal won’t learn to avoid foods containing drugs such as strychnine and cyanide, which affect the nervous system but which don’t stimulate the emetic system. And unless foods also stimulate the emetic system, animals won’t avoid foods laced with compounds that cause muscular paralysis, or foods associated with allergies, bloating and lower intestinal discomfort.

Aversions also vary with location. When eating a food containing a toxic compound in familiar surroundings, an animal can seemingly gauge how much to safely eat. In an unfamiliar environment, they seem to miscalculate, as confirmed by the increased deaths among livestock grazing new terrain. Researchers find the same phenomenon in rats: In unfamiliar surroundings, many rats died when administered the same dose of heroin that they had tolerated in familiar surroundings.
Foods and Positive Consequences

Animals also form conditioned preferences for foods. By studying their relative preferences for a flavor that had been paired with glucose—a sweetener with some nutritional value—and the same flavor paired with saccharine—a nonnutritive sweetener—researchers in Provenza’s lab found that lambs preferred flavors that were associated with calories. Without the flavor, lambs didn’t prefer either the glucose or the saccharin solutions, further evidence, Provenza says, that preferences reflect what happened after lambs eat, and are not simply a reaction to the taste or smell of a food.

There’s plenty of other evidence to support his belief. Sweet and bitter tastes aren’t as influential in molding an animal’s preferences as once thought. Animals prefer bitter-flavored foods if they feel good after eating. Their preference for sweet foods subsides if they become ill or nauseous after eating. Other researchers have found that rats prefer foods or flavors that are paired with calories, or that help them recover from nutritional deficiencies or nausea. It is not known whether the same is true in ruminants, whose digestive systems differ markedly from those of rats.

“What we learned is a first step in understanding the ability of ruminants to form conditioned food preferences,” Provenza said.

It should eventually be possible to discover the chemical origins of ruminants’ conditioned food preferences. The compounds might include those formed during rumen fermentation. Levels of some of these compounds in the bloodstream that change within 15 minutes after a ruminant starts to eat may be the signal that links a food with its consequences. In rats, nerves from the liver carry messages to the brain that are responsible for conditioned flavor preferences. The gastrointestinal tract and liver of ruminants have similar sensory receptors to the brain.

Cognitive Aspects of Learning

Cognitive processes involve more “thought,” much like deciding whether or not to have another piece of pie. This system lets animals link the smell and sight of a food to its taste. Research by Provenza and others shows that some of these cognitive likes and dislikes are formed before birth (based on what its mother eats), when very young (based on the flavors of milk), from interactions with others (mother, other adults, siblings and buddies), and through trial and error.

Learning Early in Life

As the adage goes, it’s sometimes tough to teach an old dog new tricks. It appears to be far easier to teach younger animals than older animals. During development of a ruminant’s neurological, morphological and physiological systems from conception through the first year of life, animals must also acquire many of their survival skills. Young ruminants appear to be particularly receptive to learning—and tend to remember what they’ve learned—during weaning when they make the transition from a monogastric (single-stomach) to a ruminant.

Because many compounds in plants easily cross the placenta to the fetus, animals probably have a hankering for (or an aversion to) certain flavors before they ever take a bite of solid food. Newborn rats (and perhaps other animals) have flavor preferences. Fetal lambs have a sense of taste by the last trimester of gestation.

Flavors in foods that affect the flavor of the mother’s milk also affect the food preferences of suckling rats and ruminants, as demonstrated in one study in which lambs given onion-flavored milk during the first month of life preferred onion-flavored solid foods after weaning.

Acquiring Foraging Skills

Livestock acquire their foraging skills in much the same manner as they learn to distinguish between types of food, which explains why livestock forage more efficiently and seem to do better in familiar environments. Farmers and ranchers often say livestock from another region don’t do as well as native animals, probably because livestock from different areas learn different foraging habits and skills. Inexperienced animals spend more time foraging but eat less forage, spend more time walking and walk for greater distances in search of preferred foods, and suffer more predation, malnutrition and the harmful effects of poisonous plants than animals that know the terrain.
Learning from Others

Ruminants are gregarious creatures, and their social life also seems to dictate what tickles their taste buds. “Of all the factors we have considered, social influences appear to be much more important in determining diet selection than we had thought,” Provenza says.

Like teenagers and their shared penchant for potato chips and pizza, young animals learn many of their foraging habits from their peers. Simply changing who lambs and calves hang around at certain ages might alter what they eat later. But perhaps the most important influence is mom, as was apparent when researchers in Provenza’s lab trained ewes to eat the palatable shrub serviceberry but averted them (by administering lithium chloride, which makes them nauseous) to another highly palatable shrub, mountain mahogany. For several months afterwards, the lambs of these ewes also ate serviceberry but avoided mountain mahogany.

The age when young animals are trained is important. Until the age of 3 to 4 weeks, lambs derive most of their nourishment from mother’s milk and have little interest in solid food. A few weeks later, lambs still depend on their mothers and readily eat solid foods. Their dependence on their mothers—and willingness to mimic their behavior—seems to fade quickly, however. The USU researchers found that lambs 12 weeks of age mimicked their mothers’ eating habits far less than lambs 6 weeks of age.

As an older lamb depends less on its mother, its young companions become more influential in molding its behavior. Provenza found that lambs can be deterred from grazing mountain mahogany only as long as they grazed with other lambs that had been similarly averted. When they foraged with untrained lambs, however, the lambs’ aversion to mountain mahogany faded quickly.

Foraging livestock may learn other culinary facts from their cohorts. Humans gauge the popularity of a diner by the number of cars and trucks parked outside. Livestock have a similar rating system, but one involving smell. Rats tend to forage where odors indicate that other rats have eaten. Although this phenomenon hasn’t been studied in ruminants, livestock use odor to identify each other and to assess each other’s physiological state. And because they can also smell where other animals have been, it’s also likely that they can use smell to determine what and where their colleagues have eaten.

Trial and Error

Young herbivores that start to forage by themselves have probably already learned a lot from their mothers, peers, and from exposure to flavors in milk and in utero. Still, they must be able to determine whether to eat an unfamiliar plant or leave it alone. Sampling any new food lets them decide, Provenza says. They attribute any unpleasant consequences to the new food. In several studies, the USU researchers fed sheep and goats as many as four familiar foods and one new food. The animals attributed any unpleasant consequences to the new food, even when they didn’t become ill for 6 hours after eating the new food.

Morphological Effects

Provenza says diet may subtly affect an animal’s morphology, thus improving its adaptation to the environment where it was born and reared. In one of Provenza’s studies, the rumens of young goats reared on rangeland dominated by blackbrush were 30 percent larger than those reared on a concentrate ration, an adaptation to bulkier forages. These goats with larger rumens ate 27 percent more blackbrush than goats reared in other environments.

And feeding young lambs whole barley and protein mineral pellet for just a few days affected their subsequent rumen development. When these lambs entered a feedlot several months later, they gained weight more rapidly than their counterparts.

Phytotoxins

Provenza thinks herbivores may be poisoned because some toxic plants contain compounds that don’t trigger the emetic system. Other toxic plants may have positive consequences, such as tall larkspur which seems to improve ruminal fermentation, forage intake and digestion 2 to 4 days after cattle first eat it. “The longer the delay between eating and the aversive consequences, and the higher the proportion of positive to aversive consequences, the more likely livestock will sample and continue to eat the food,” Provenza says.
Subtle changes in plant chemistry can render nontoxic plants toxic, and herbivores may find it difficult to detect or respond to such changes, Provenza says. It is also difficult for animals to associate specific foods with toxicity if they ingest different toxins from two or more plants, or when they eat a familiar toxin in an unfamiliar food. Some toxins are also more potent when eaten with another toxin.

Tannins, compounds found in about 80 percent of woody plant species and about 15 percent of herbaceous plant species, are a good example of the relationship between the chemical composition of forages and foraging behavior. "The preponderance of tannins in nature makes them one of the most important classes of secondary metabolites affecting grazing. However, many important forages contain high levels of tannins, so the presence or absence of
tannins by itself doesn’t reliably indicate food quality,” Provenza says.

One form of these compounds, condensed tannins, deters grazing. Differences in the structure of condensed tannins from different plant species may explain why they differ in their ability to deter feeding by herbivores. “The structure of condensed tannins affects the rate and extent of their breakdown in the digestive system, which may affect the strength of a conditioned food aversion,” Provenza says. “The more rapid the rate of breakdown, the more rapid and aversive the consequences, and the stronger the conditioned food aversion.”

For 15 years, Provenza and other USU range scientists have studied the interactions between goats and blackbrush, a shrub containing condensed tannins that grows in dense stands on infertile soils in the southwestern U.S. It appears that some goats may have physiological mechanisms that let them tolerate higher levels of condensed tannins, a difference which may be useful in breeding programs. Similar mechanisms may help herbivores detoxify compounds in poisonous plants.

**Developing A Curriculum**

The curriculum for goats and sheep at Provenza’s school isn’t too taxing. Researchers control when animals are allowed to eat certain foods, and with whom. Sometimes the postigestive consequences are pleasurable, sometimes not.

The results can be startling. Following the simple training regime, animals will assiduously avoid some of their favorite plants or start munching plants that they previously avoided.

There are definite limits to the malleability of dietary preferences. Nonetheless, it appears that farmers and ranchers can mold the taste buds of livestock, perhaps by feeding a smidgeon of this or a smattering of that to pregnant livestock, providing special diets at weaning or paying more attention to the social life of young livestock.

**Potential Benefits of Training**

There are plenty of reasons why it might be advantageous to train livestock. Millions of cattle and sheep around the world still derive most of their sustenance from rangelands and pastures. In the West, ranges are periodically modified to improve livestock production, usually in ways that only temporarily change the plant succession. It might be better—and less costly—to match the foraging behavior to existing conditions, Provenza says.

Grazing of public lands has become an increasingly contentious issue in the West, one that’s likely to persist as a coalition of recreational users and environmentalists draws strength from a burgeoning urban population. The foraging behavior of livestock often raises the ire of recreational users of the same lands. One festering problem is that cattle and sheep tend to prefer the lush vegetation next to streams and lakes, a habit which can lead to overuse of these highly visible, ecologically sensitive areas. Provenza believes that the grazing habits might be malleable enough so that livestock can be trained to graze elsewhere.

He also envisions livestock that are trained to be much more useful as they eat. Squadrons of sheep and goats can be trained to control weeds in orchards (the results of trials already underway are promising). Perhaps armies of cattle and sheep can be educated to avoid poisonous plants. And it might be possible to develop programs to whet animals’ appetites for less palatable but abundant feedstuffs.

An animal’s appetite does not appear to be as immutable as once thought, nor is foraging governed by indecipherable forces. The truth is closer to a shopworn adage, the one about the stomach being the best route to a man’s heart. In this case, what happens in an animal’s stomach (or rumen) apparently has quite a bit to do with what happens in its brain. The gastronomic implications—including the ability to mold livestock appetites to fit the landscape—may be hard for some to digest.

After years of research, Fred Provenza doesn’t have any trouble swallowing them.

*KG  Fred Provenza 750-1604*
Y
ears ago, cowboys rode on their horses. Today, cowboys (and cowgirls) ride with their horses.

It's a fundamental difference for both horses and their riders, says J'Wayne “Mac” McArthur, who has taught horsemanship at USU for 21 years. And thousands of hours in the saddle as cowboy and instructor have convinced McArthur that it's a change for the better.

"The old ‘cowboy' style of riding wasn't as functional for the horse. We rode to make it comfortable for us. Now I teach riders to keep in balance with the horse. Most cowboys didn't know how to get a horse on the proper lead," McArthur says.

Among other principles, McArthur teaches a rider to find the horse's center of balance and go lightly on the bridle, so lightly in fact that the bridle can be removed and the horse brought to slide stop relying solely on cues from the legs, body and voice. "Much of what we do is just logical," McArthur says.

Logical, perhaps, but far different from the way McArthur learned to ride as a ranch hand in Idaho and Wyoming. After earning his bachelor's degree at USU and a stint as an instructor of vocational agriculture in Wyoming, when he also bought and sold horses, McArthur earned a master's degree in agricultural economics at USU and worked for the
USDA for 6 years before returning to USU and taking over the horse program.

From his hat to his boots, McArthur is very much a cowboy. He is a prolific writer who writes a column about horses for several publications, has written two books, *Training for Western Horse and Rider* and *The Cowboy Life in Short Story and Poems*, and is a member of the indigenous literati of the West, a cowboy poet.

And he's a popular teacher, having been named Teacher of the Year by the Animal, Dairy & Veterinary Sciences Department in 1989, and by the College of Agriculture in 1990.

The new style of riding gives "much more communication and feeling with horses. Before I just used the horse as a tool. Now there is much more interaction and bonding with the horse."

"Horses often don't perform to their best because riders get in their way," McArthur says.

Horses thrive on the increased attention. "People are amazed at how our horses come up and seek attention, even some of those horses that we once had to rope, horses that once didn't care for people at all."

A similar transformation occurs in students as they gain self-confidence with their horses.

A few of his students enroll in his classes to learn how to use horses on ranches, but most ride for pleasure. Students travel to his night classes from as far as Provo and McCammon, Idaho. He provides all horses and tack. McArthur sells the horses the first week in June at what has become one of the leading horse auctions in the Intermountain region.

The only thing students must bring to class are cowboy boots, which are *de rigueur* for riding, in the interests of safety, not fashion. (They are the only type of footwear that will not come off if the foot slips through the stirrups). The continued emphasis on safety explains why none of his classes have been marred by a serious injury.

Cowboys may have receded from the Western landscape, but horses are still very much a part of the Western ethos. More than a decade ago, McArthur estimated that there were about 132,000 horses in Utah, most of them used for pleasure. There are probably as many horses in the state today.

And thanks to Mac, fewer riders are getting in the way of their horses.

**Courses That Let You Horse Around**

J'Wayne MacArthur teaches the following courses at USU's Horsemanship Program:

- Horsemanship I
- Horsemanship II
- Horsebreaking
- Judging, Fitting and Showing
- Horse Packing (Includes six hitching, 20 knots and map reading)
- Practical Ranch Roping ((Eight loops and trick roping)
- Cowboy Crafts (Leathersewing, making chaps and sundry items, and horsehair spinning)

Enrollment is limited to 10 students per class.

MacArthur also offers the Rodeo Queen Clinic every March, which usually attracts entrants from several states. Women learn how to hone the modeling, speaking, makeup and horsemanship skills. Graduates of the course include many state rodeo queens and the first runner-up in the Miss Rodeo America competition. MacArthur teaches the horsemanship skills; other instructors impart other queenly arts.

Enrollment is limited to 45.

Riding in **BALANCE**

**WINTER 1990 145**
My Friends
Talk To
Me

My memories are filled with horses.
Everyday there’s a horse between my knees.
Hopes and dreams are filled with horses.
Now tell me I’m not a horse lover.

Everyone knows I talk to horses.
What they don’t know is horses talk to me.
You tell me horses can’t talk!
You know ‘cause they never spoke to you.

Who hears the tree fall in the forest?
No one heard it, yet it lies there.
You say you didn’t hear it fall!
Does that mean it never fell?

When I walk among the horses
They all want to talk at once.
Order is there, each knows his place.
Mr. Aggressive speaks first, then each in turn.

A nose on my cheek, as we exchange breaths,
A nuzzle on my arm, as our eyes meet.
Words pass that make sounds on my mind.
My horses talk to me, of that I’m sure.

These horses are my friends.
Each has his own special aura.
I feel it with all my senses.
It’s special when my friends talk to me.

"Mac"

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Life In Short Stories and Poems
Grain-Rich Diets Can Cripple Young Horses

Many grains, particularly oats and wheat, contain high levels of phytic acid that bind calcium and other minerals. Young horses that lack adequate calcium for bone calcification can develop weak or deformed bones, warn J'Wayne McArthur, director of the USU's horsemanship program, and Randy Wiedmeier, USU animal scientist.

If dietary calcium is deficient, a young horse will draw calcium from its bones, which, if the calcium deficiency persists, weakens and deforms bones. Simply raising the level of calcium in high-grain rations won't help—phytic acid also binds the additional calcium.

The only solution is to feed less grain, no more than one-half pound per 100 pounds of body weight, and preferably less than that amount. Feed a mixture of grain, not just oats, to reduce levels of phytic acid. And at least one-third of the calcium and phosphorus requirement of young horses should be supplied as inorganic form, such as dicalcium phosphate or bone meal.

Problems can also occur when rations are very high in dietary calcium. These rations reduce the solubility and availability of calcium and other minerals, especially phosphorus, magnesium and manganese. High-quality, green alfalfa is rich in calcium and should be fed with some grass.

Epiphysitis (a form of rickets) and contracted tendons have become more prevalent as breeders feed more grain to spur the development of foals so they can compete in futurities. High-protein diets can also accelerate growth so rapidly that it is difficult to provide an adequate intake of minerals. Excesses of certain types of protein also interfere with the metabolism of minerals.

In some cases, young horses are so badly affected that they have to be destroyed. Other foals survive but with permanently damaged joints (contracted tendons, steep pasterns and hooves) and a greater likelihood of suffering degenerative joint disease.

McArthur and Wiedmeier are alarmed that some experts continue to advocate high-grain diets for young horses. They have seen some weanling rations that contain 1.12 to 2.5 pounds of concentrate per 100 pounds of body weight. The lower level is more than desired and the upper level is not attainable in practice.

A calcium deficiency can also result from feeding only mature grass hay or when horses graze mature, weathered and dry grass.

At the first signs of knuckling in the front or hind ankles, remove grain from the ration until you see improvement in knuckling. Then feed only one-quarter pound of grain per 100 pounds of body weight. Also replace up to half of the alfalfa with high-quality tame grass hay. If the problem is detected early enough, leg development in the weanling should return to normal in about 3 months.

J'Wayne McArthur 752-1251
Randy Wiedmeier 750-2151

WINTER 1990 147
Tracking the Causes of Airborne CANCER

"It causes cancer."

The colloquial use of this phrase belies both manifestations of this disease (there are hundreds of types of cancer) and its complex causes. Although the carcinogenic potential of man-made substances can match the potency of aflatoxin, one of the most potent carcinogens known.

Aflatoxins, naturally occurring toxins produced by molds, are common contaminants of corn, peanuts, cottonseed and variety of other products. Nearly all of the concern about aflatoxins involves its effects in food. USU toxicologist Roger Coulombe is studying its potential effects when inhaled. Airborne concentrations of aflatoxins can be high in grain silos, loading dock and food-processing plants.

To determine whether aflatoxin can goads cells in the lung into abnormal growth, Coulombe choreographs the morbid development of malignancy using little more than bits of flesh and dollops of chemicals.

Results will clarify the risk of lung cancer faced by workers exposed to contaminated dust. “What
we learn about aflatoxins will serve as a model for other airborne environmental contaminants such as diesel exhaust," Coulombe says.

The greater the number of nonciliated cells in the trachea, the greater the vulnerability to aflatoxin. Nonciliated cells in the airway contain the enzyme that converts aflatoxins into the ultimate carcinogenic form. Without this enzyme, cytochrome P-450, aflatoxins and other carcinogenic agents are relatively ineffective.

The enzyme is found in smooth endoplasmic reticulum (SER), organelles found only in nonciliated cells. "A cell which lacks SER doesn’t contain cytochrome P-450 and is relatively resistant to the effects of airborne carcinogens,” Coulombe says.

To learn how dustborne aflatoxin might cause cancer, Coulombe incubates snippets of trachea (including human tissue obtained from organ donors) with various amounts of aflatoxin. He uses an antibody to probe for cytochrome P-450, and analyzes the compounds that the nonciliated cells in the outer lining of the trachea form to activate aflatoxins into cancer-promoting compounds. As with many other carcinogens, most of the metabolic changes are fostered by cytochrome P-450, which is also found in the lungs, livers and other tissues.

Species differ markedly in their susceptibility to aflatoxin. Hamsters and rabbits are much more sensitive to aflatoxins than rats and Rhesus monkeys. The difficulty of obtaining healthy human airway tissue has slowed this aspect of the study.

The deadly changes in the trachea occur when the harmful metabolites formed latch onto the guanine base of DNA, thus fouling up the "genetic architecture" of cells. "Presumably this is the first step in the development of cancer. Mutations occur every day but the immune system corrects most of them. Only a small proportion of mutations result in anything serious," Coulombe adds.

There are several types of aflatoxins, the most potent of which is a type known as AFB1. Aflatoxins—AFB1, AFB2, AFG1, AFG2, AFM1, and AFM2—are named according to their behavior, including their characteristic fluorescent colors, in an analytical test.

Unlike aflatoxins in food, dust-borne aflatoxin is not “diluted” before it reaches cells in the airway and lungs, which may make it more harmful, Coulombe says. Tiny amounts of the aflatoxin may be damaging. For example, researchers found that Dutch workers prone to higher rates of respiratory cancer apparently inhaled 0.04 to 2.5 µg of aflatoxin daily, barely enough to fit on a pinhead, but a considerable amount considering that food containing less than 1 part per billion (ppb) of aflatoxin can cause cancer in laboratory animals.

Under certain conditions, the fungi Aspergillus flavus and A. parasiticus, can infect a variety of commodities, including grains, and produce various forms of this mycotoxin. The risks associated with aflatoxin-contaminated food have been studied for decades but it is not known whether inhaling aflatoxin-contaminated dust induces respiratory cancers. One study indicated that cancer was more common among workers who breathed dust while they processed aflatoxin-contaminated peanuts.

Coulombe says aflatoxins are widespread. In the United States, commodities that can contain aflatoxins are peanuts, corn, cottonseed, grain sorghum, millet, Brazil and pistachio nuts, almonds and other tree nuts, and dried fruits. In other areas of the world, it has been detected in barley, beans, cassava, cowpeas, millet, peas, sesame, soybeans, sweet potatoes and wheat.

Growth of the fungus is promoted by drought, high temperatures, damage during harvest, insect infestations, rain during harvest and moist storage conditions.

Contamination of peanuts probably pose the greatest risk to humans because of its importance as a food and because Aspergilli are present wherever peanuts and peanut products are produced. Several surveys indicate that the majority of samples tested contain less than 20 ppb (the current “action guideline” established by the U.S. Food and Drug Administration), but many contain more than 100 ppb. The average amount of AFB1 in peanuts and peanut products is estimated to be 2 ppb.

From 0.25 to 1 percent of the dry weight of corn is lost as dust during drying and handling. AFB1 levels in these dusts far exceeds those in contaminated food. In the smaller, more respirable particles of grain dust, the average AFB1 level was almost 700 ppb.

Roger Coulombe 750-1598
A molecule with eight "arms" may make future immunizations against viral diseases more efficient and effective.

The "octopus" molecule has eight sites that can carry several copies of the same antigen or different types of antigens to stimulate immunity against several different diseases, says Joseph Li, a molecular biologist at Utah State University.

Lysine, an amino acid, provides the branched skeleton used to attach the antigens. Li is creating an experimental vaccine against bluetongue, a viral disease that affects cattle and other grazing animals. Current vaccination schemes against bluetongue are generally ineffective. Mortality in infected animals is high.

Li's experimental bluetongue vaccine is "genome-free"—it contains no virus genetic material. The vaccine consists of specially constructed peptides (strings of amino acids) that act as antigens, which stimulate the host to manufacture specific antibodies against them. Li says the genome-free vaccine is a fine-tuned, targeted approach to immunization against a particular disease.

A genome-free vaccine is safer than a vaccine that contains viral genes, which might be capable of "hiding" in the host cell DNA. Li says there is no evidence that this occurs with the bluetongue
virus, which kills its host cells, but it can occur with vaccines based on DNA or retroviruses.

Viruses are extremely small particles, much smaller than bacteria, consisting only of genetic material (DNA or RNA) surrounded by a protein jacket. To create the genome-free vaccine, the USU researchers employed a variety of biotechnological techniques to separate and identify proteins, and parts of those proteins, in the viral covering that can stimulate antibody production in a host.

The antigen-antibody reaction is the basis of induced immunity. When a foreign molecule, virus or bacterium—an antigen—is introduced into the blood of a host animal, the cells of the host’s immune system produce antibodies against it. Antibodies combine with the antigen, rendering it ineffective. However, there is a lag in the immune response following first exposure to a foreign antigen. An infected animal may exhibit the disease symptoms during this lag period.

Animals that recover from the first exposure manufacture antibodies against the foreign antigen, which circulate in the blood plasma. If the animal is exposed to that foreign antigen again, the circulating antibodies immediately react and combine with it. The antigen does not have time to cause the disease, and “immunity” has been achieved.

Most vaccines use inactivated viruses to induce the production of antibodies.

“A potential problem with inactivated vaccines is that they aren’t always 100 percent inactivated, and there’s the risk of infecting an animal. The chemicals used to inactivate a virus may also be harmful if injected into an animal, Li says.”

A better approach, he says, is to use just the component of the protein coat that will stimulate production of the desired antibody. The lack of whole viruses in the vaccine eliminates the chance that the vaccine will infect an animal.

Li and his co-workers have also determined the genetic makeup of the five strains of bluetongue virus in the United States, and the probable evolutionary relationships among these strains. Twenty-four strains of the bluetongue virus are found worldwide, Li says.

Each bluetongue virus serotype contains 10 genes, which can be exchanged between types of the virus to create new mutants that can escape a host’s defenses, Li says.

“By studying the gene sequences and genetic relatedness of the BTV,” Li says, “we can determine the ‘hot points’ where genetic changes are most frequent within each viral gene. This information is important to the design and development of new vaccines.”

During preliminary tests of the octopus antigen carrying bluetongue immunogenic peptides, just one injection and a booster, increased antibody production 40- to 100-fold over production stimulated with the attenuated (weakened) virus, Li says.

Li recently received a $220,000 grant from the U.S. Department of Agriculture to begin development of octopus antigen vaccines.
Birth Defects and RETINOIC ACID

Retinoic acid is a natural derivative of vitamin A useful in treating skin disorders such as severe acne and psoriasis and some forms of cancer. It's also being touted as an anti-wrinkling cream, although regulatory authorities have not approved its use for that purpose.

When used by pregnant women, retinoic acid can cause severe birth defects, says USU toxicologist Raghibir Sharma, who found that the toxicity of retinoic acid appears to be directly related to its effectiveness.

Sharma and his colleagues studied the effects of about 40 different chemical forms (congeners) of retinoic acid in hamsters, which are more sensitive to effects of the compound than rats or mice. So far, toxicity has been directly related to a congener's biological effectiveness. One form was 700 times as toxic as retinoic acid. (Many of the congeners Sharma studies are not used therapeutically.)

Sharma is ascertaining the mechanisms underlying birth defects, which depends on the form and amount of the compound, and when it is administered during pregnancy. Officials with the Food and Drug Administration recently called for tighter restrictions on the use of the compound by women.

A protein, cellular retinoic acid-binding protein, plays a key role. Separately, neither the protein nor retinoic acid can enter the nucleus. Once the protein binds with retinoic acid, retinoic acid is translocated into the nucleus. Retinoic acid then combines with nuclear receptor proteins that regulate gene expression. "No one knows how many genes are influenced, but it appears that retinoic acid-binding protein stimulates some genes and inhibits others," Sharma says.

Some retinoid-like chemicals do not bind to the protein and are biologically effective. However, their interaction with nuclear proteins has not been investigated.

Central nervous system malformations are among the most numerous and severe human birth defects, and occur in about 1 per 1,000 live births. They include hydrocephalus and spina bifida. Determining how retinoic acid causes birth defects could identify other substances likely to have similar harmful effects.

Sharma has been studying retinoic-induced malformations for 5 years. His research is supported by the March of Dimes Foundation for Birth Defects, the National Institutes of Health, and the Utah Agricultural Experiment Station.

KG

Raghubir Sharma 750-1890
SCRAPIE:
Cause Unknown But Control Possible

Scrapie still remains shrouded in uncertainty, but we can’t wait for more information before trying to control the baffling ailment, according to USU animal scientist Warren Foote, who has studied the transmission of scrapie for 11 years.

Scrapie, a neurodegenerative disease of sheep, is a member of a family of diseases known as spongiform encephalopathy, a name that reflects the holes it creates in the brain. It and related diseases have puzzled researchers for decades.

Its cause is unknown. Diagnosis is often problematical. Treatment is nonexistent.

In spite of this, the disease can be controlled by employing what is known about the ailment, says Foote. In a process known as “negotiated rulemaking,” Foote is helping the USDA, the Utah Department of Agriculture, producers, veterinarians and representatives of various industries develop a control program. Provisions of the control program should be approved within a few months.

The program utilizes risk reduction procedures—identifying the points where scrapie might be transmitted and minimizing the risk at each of these points. Important factors in the control program are limiting contact with infected flocks, inspecting flocks for signs of infection, controlling the introduction of new animals, and making sure that any premises have either not been used by infected animals or have been thoroughly cleaned, disinfected and left vacant for 1 year.

“A flock might be considered to be scrapie-free 5 years after completion of these procedures” Foote says.

Scrapie surfaced in western Europe over 200 years ago, and was first diagnosed in the United States in 1947. From 1947 to 1988, it was detected in 438 flocks in 38 states. Clinical signs of the disease vary. After a long incubation (2 to 4 years), infected sheep may itch and start to rub against objects, (this “scraping” is the source of the name of the disease), lose wool, lick excessively, and experience body tremors. Affected animals are highly excitable and have an irregular and uncoordinated walk. Weight loss is common. The disease is always fatal.

The virus-like disease agent is remarkably resistant to inactivation by heat, ultraviolet irradiation, many chemicals, and enzymatic degradation. It’s not known how scrapie spreads. The disease agent—whatever it is—appears to enter the body orally, then spreads and replicates slowly before it attacks neurons. The scrapie agent is found in many tissues and fluids of infected animals, but it has not been detected in embryos and fetuses, the urine or feces, drinking water or bedding.

The most important route for spread of the disease appears to be from an infected dam to young lambs during the period from birth to weaning.

Foote found that embryos and semen from infected animals seldom, if ever, carry the disease agent, which should make it possible to import valuable germ plasm to upgrade domestic breeds. These procedures also make it possible to salvage germ plasm from genetically superior animals infected with scrapie. Embryo transfer and artificial insemination could also be important elements of a control program for scrapie and related diseases.
Scrapie has been diagnosed in 10 breeds of sheep in the United States, but at least 80 percent of the flocks diagnosed with scrapie are Suffolk. It is not a genetically transmitted disease, but genetics influence susceptibility, Foote says. Sheep with one form of a gene have a short incubation period. The incubation period in sheep with another form of the gene is so long that the sheep die from other causes before scrapie is expressed.

In collaboration with the Institute for Animal Health, Edinburgh, Scotland, Foote is using a DNA gene probe to identify forms of the gene that determine the length of the incubation period. The probe could also be used to select animals according to susceptibility (length of the incubation period).

Foote says the emergence of a scrapie-like disease known as mad cow disease (bovine spongiform encephalopathy or BSE) in cattle in Great Britain has increased the sense of urgency surrounding scrapie control in the United States. Cattle may have been infected with BSE from rendered sheep offal (waste products).

Other livestock diseases similar to scrapie are transmissible mink encephalopathy, perhaps caused by feeding infected offal or dead animals to mink, and chronic wasting disease of captive mule deer and elk, a debilitating disease of mule deer and elk kept for long periods in animal parks or zoos.

There are similar diseases in humans; Kuru afflicted natives of New Guinea who practiced cannibalism. Creutzfeldt-Jakob disease, which causes a deterioration in intellectual ability, has an annual incidence of about 1 per one million population.

Scrapie doesn’t seem to pose any risk to human health, Foote says. Epidemiologic studies show no relationship between the prevalence of Creutzfeldt-Jakob disease and scrapie, nor is the incidence higher among those who work with farm animals or in slaughterhouses or in butchershops.

“We can no longer consider scrapie as a disease that is limited primarily to the Suffolk breed nor can we wait for additional information to develop a control program. What we do know about scrapie can make significant contributions to an effective control program.

“Time has run out,” Foote says.

KG Warren Foote 644-2569

New Faculty

Raymond D. Dueser has been appointed head of the Department of Fisheries and Wildlife. He earned his Ph.D. in wildlife ecology from the University of Michigan. Dueser came to USU from the Department of Environmental Sciences at the University of Virginia.

Robert C. Lamb, new head of the Animal, Dairy and Veterinary Sciences Department, previously served as acting head of the department. Prior to that, he was research professor with the department and research leader in dairy management with the USDA Agricultural Research Service at USU. Lamb earned his Ph.D. from Michigan State University.

Keven Jackson, research assistant professor with the Animal Diagnostic Laboratory, joins the Animal, Dairy and Veterinary Sciences Department from Washington State University, where he earned his Ph.D.

Molecular geneticist Noelle Muggli-Cockett joins the Animal, Dairy and Veterinary Sciences Department from the USDA Meat Animal Research Center, Clay Center, Nebraska. She earned her Ph.D. from Oregon State University. Her research concerns genetic markers for economically important traits in livestock, such as disease resistance in cattle and spider lamb syndrome.
This special section is devoted to the addresses of three scientists who spoke at 1990 Land Grant Days, held September 7-8 at Utah State University. (The topics of many of those who addressed this year's conference on food safety were reported in the last issue of Utah Science.) The theme of next year's conference is "Sustainable Agriculture in a Global Environment."

We will provide more information about the third annual event when available.

We welcome your participation.
A

mericans take for granted the abundance of food products available in the marketplace at readily affordable prices. Fewer than 2 percent of Americans are directly engaged in farming and ranching and they produce enough food to feed 250 million Americans with a sizeable surplus for reserve and export. Americans spend just 11.8 percent of their disposable income (after taxes and housing) for food, one of the lowest rates in the world. This amount includes meals eaten at restaurants.

In spite of this inexpensive abundance, many Americans think that our food is unsafe and that toxic chemicals are added during production, preparation and preservation. These beliefs reflect the generally negative attitude that the public has of all types of chemicals, and their inability to distinguish between relatively safe and relatively hazardous chemicals. In fact, we live in a world filled with (and made from) chemicals. The American Chemical Society recently listed more...
than 10 million known chemicals, both natural and synthetic; 6000 new entries are recorded each week.

Food is a mixture of organic carbohydrates, fats, proteins, oils, vitamins, flavors and aromas, amino acids, and minerals, most of which are essential for life. Some are relatively innocuous. All are harmful if taken in excess, in accord with the following well-known axiom advanced by Paracelcus in the 16th century, which is as valid now as it was then: “All substances are poisons; there is none which is not a poison. The right dose differentiates a poison and a remedy.”

This axiom means that everything is a poison if taken in excess or in the wrong manner—even “natural” substances like oxygen, water, and salt. It is futile to try to differentiate between “good” and “bad” chemicals unless we consider the dose.

A corollary of Paracelcus’ axiom is that there is a threshold level of exposure, below which the chemical will exert no biological effect (good or harmful); this makes it even more difficult to attempt to differentiate between “good” and “bad” chemicals, particularly because the threshold varies with species, mode of exposure, duration of exposure, presence of other substances, and from one individual organism to another. We deal with this uncertainty by setting permissible levels of exposure (tolerances) based on “safety factors”. However, even tolerances are the subject of disagreement, given the varying routes of exposure, biological responses, and individual idiosyncrasies.

**Synthetic versus Natural Chemicals**

The three most toxic chemicals known to date are natural products—botulinum toxin (less than 1 microgram can kill a man), tetanus toxin, and diphtheria toxin. Curare and strychnine—natural plant products—are three and two orders of magnitude, respectively, more toxic to mice than sodium cyanide. Of course, there are also highly toxic synthetics, such as tetrachlorodibenzodioxin (TCDD or “dioxin”) and organophosphorus nerve poisons. However, some of these synthetics (such as TCDD) also appear to be “natural” because they are products formed during combustion.

None of these considerations should alleviate our justifiable concern that toxins—or “toxics” as mislabeled by the media—may be present in our foods at levels high enough to cause harm. There are, unfortunately, many examples where this has occurred: mercury from industrial pollution in the seafood consumed by residents of Minamata, Japan, in the 1950s; and tricresylphosphate in bootleg liquor in the United States from Jamaica in the 1930s. Today, one of our concerns is levels of aflatoxin in high-oil dietary staples in Africa.

When people talk about food safety and toxics in foods, they are referring to the following five groups of chemicals (presented roughly in the descending order of importance from the public’s viewpoint):

1. Pesticides—Residues of chemicals used to combat pest insects, weeds, and microorganisms at some stage of production.
2. Animal drugs and related animal products—Includes pharmaceuticals, antimicrobials and antiparasiticals and feed additives. Potential problems with residues of these drugs in the meat and dairy products include allergic or hypersensitive reactions and antibiotic resistance.
3. Food additives—Antioxidants, coloring agents, emulsifiers, artificial sweeteners, flavor enhancers, etc. Included are sulfites, nitrates, MSG and other chemicals of real or perceived toxic concern.
4. Industrial and environmental chemicals—Includes toxic materials such as lead, mercury, and cadmium, as well as organic contaminants (PCBs, dioxins, solvents, plasticizers, etc.).
5. Natural toxins of plant and microbial origin—Includes natural toxicants produced by plants that people commonly consume (alkaloids, cyanogenic glycosides, amino acids, etc.) as well as metabolites produced by microorganisms.
We must prevent toxic chemicals from entering our meat, dairy products, crops, processed foods, beverages, and water. How well we are doing, and whether our efforts are properly directed are legitimate national concerns.

Is Our Food Safe?
The safety of our food is being examined by scientists, producers and consumers. The results of these assessments seem to vary with the perspective of each group. For schools such as Utah State University and the University of California, the answers will reflect how well we have met the land-grant mission, which is to:

- Develop and apply knowledge that will ensure a continuing supply of nutritious foods and useful fibers and forest products in adequate amounts at low cost without adverse effects on the physical environment or to the consumer.

It was for these reasons that Congress appropriated land (Morrill Land Grant Act, 1862) and funds (Hatch Act, 1887) for each state to establish agricultural experiment stations and a cooperative extension service (Smith-Lever Act, 1914).

Have we emphasized production and productivity over safety and quality? And have federal agencies (FDA, USDA) and state departments of agriculture and health fulfilled their responsibilities? Critics of the present system often cite some of the following examples to support their contention that food safety has been neglected:

Episodes of Mass Poisoning. Critics say the existing regulatory and surveillance system is inadequate. For example, in 1987, more than 1,000 people in Oregon and California became ill, some violently so, from consuming watermelons over the July 4 weekend. The culprit was aldicarb, a toxic insecticide applied to the melon vines for pest control and growth enhancement.

Aldicarb is not registered for use on watermelons, and its use by two growers from California was illegal. The causative agent was identified within two days of the first report of illness, and melons were recalled immediately. No one died, and there is no evidence of any long-term health effects. The responsible growers were prosecuted, convicted, and fined. In my opinion, this episode is the rare exception that confirms that the system of regulation and enforcement is adequate.

There has not been a single substantiated case of death or illness from pesticide residues in foods when a chemical is used in the manner prescribed on the label.

Food Safety is Inadequately Monitored. Critics claim that too few samples are collected, and too few chemicals of concern are analyzed.

Let's consider the monitoring program for pesticides. At the federal level, food entering interstate commerce is monitored primarily by the FDA (the USDA monitors meat, poultry, and eggs). Data on pesticide residues from nearly 20,000 samples of domestic and imported food analyzed by the FDA Los Angeles District lab over a 5-year period (1982-1986) show that 48 percent of all samples had no detectable residues, 49 percent had detectable residues within legal tolerances, and 2.7 percent were violative. The analytical scheme was capable of detecting 253 different chemicals at typical limits of 0.01 ppm. These figures represent only one-quarter of FDA's national samples.

In addition to these random monitoring efforts, the FDA has conducted a market-basket survey of residues in foods in the diet of a typical American consumer for nearly 20 years. This Total Diet Study is designed to estimate the dietary intakes of pesticide residues (as well as some industrial chemicals, toxic elements, and minerals) by eight age/sex groups, from infants to senior citizens. Foods are purchased from local supermarkets or grocery stores throughout the United States by FDA personnel four (or sometimes five) times per year. Each of the four market baskets represents a different geographic region and is a composite of foods collected in three cities in the particular region. The cities are changed each year.

Each market basket contains 234 food items that have been chosen, based on nationwide dietary surveys, to represent the diet of the U.S. population. The foods are table-ready—preparation ranges from peeling bananas to making beef and vegetable stew—and then are analyzed for pesticide residues. These results, in combination with food consumption data, are used to calculate dietary intakes, and to estimate of the actual amount of pesticide resi-
dues consumed by Americans. Some pesticides cannot be detected by multi-residue methods used in the Total Diet Study.

Both the FDA surveillance monitoring program, designed to eliminate produce which exceeds tolerance levels, and the Total Diet Study, which indicates the actual exposure received by American consumers, show residue averages far below (1/100th to 1/1000th) the legal limit or tolerance.

The Natural Resources Defense Council (NRDC) claims the results are inaccurate because too few samples are taken, the methods are not statistically valid, and the multi-residue screens used by the FDA detect only about half of the registered pesticides. These criticisms are technically correct, but do not provide a compelling justification for ignoring FDA’s data, or that of the California and Florida Departments of Agriculture, the National Food Processors Association, and other organizations, all of which have detected very low levels of pesticide residues.

The NRDC would base estimated exposure on the assumption that levels of pesticide residues were at the legal limit or tolerance for all foods, which would mean unacceptably high levels of exposure. But this assumption is inaccurate. Only some crops are treated with pesticides, and those that are treated are typically treated with just a few chemicals. Even in treated crops, residues decline below tolerance at harvest, and decline further during packing, shipping, cleaning, processing and preparation.

Low-level Exposure Can Lead to Cancer. High doses of some pesticides, animal drugs, and food additives cause cancer in laboratory animals. Because carcinogens seem to be exceptions to Paracelsus’ axiom, and have no definable no-effect level, they should have a zero tolerance in foods and should not be allowed to be used in ways that contaminate food.

...the real cancer risks—cigarettes, alcohol, and fatty foods—are largely ignored while we focus unnecessarily on pesticides.

The cancer scare-tactic attracts attention. No one wants to willingly jeopardize themselves or their families. Some supermarkets have used this fear as a sales gimmick, offering “residue-free” food, and “no detectable residue” food at premium prices (10 percent or so above retail). One company—Nutriclean—was founded just to ensure that foods are residue-free. The tactic initially attracted consumers, but its appeal seems to be fading. The following reasons indicate why low-level exposure is unlikely to cause cancer.

• Results of laboratory tests with rodents are flawed. Bruce Ames, University of California toxicologist, says these tests are useless because the massive doses administered stimulate cell division, regardless of the chemical. Ames and others have argued that the real cancer risks—cigarettes, alcohol, and fatty foods—are largely ignored while we focus unnecessarily on pesticides. And pesticides may not even cause cancer in humans, even those pesticides that are positive when administered to laboratory animals at high doses.

• Zero tolerance is impossible to achieve. Every food is contaminated with low levels of every chemical. The difference between a finite residue and “no detectable residue” simply reflects the sophistication of the analytical method.

I agree with a few of the allegations—residues of older pesticides are permitted even though they have recently been found to cause cancer in laboratory animals; residues in processed foods are more stringently regulated than in fresh foods; and because of consumption patterns and body size, tolerances offer children less protection than adults. These regulatory inconsistencies should be corrected. But it is quite misleading to tell people that they will significantly reduce their risk of cancer by
reducing levels of animal carcinogens to non-detectable levels.

- **Chemicals are no longer necessary in food production.** Critics claim that pesticides, animal drugs, some food and feed additives are unnecessary. They believe food can be produced by substituting biological and cultural control for chemicals, by improving the environment in which livestock are raised to reduce the incidence of disease in animals, and by using better preservation techniques to replace food additives.

The tenets of low-input, sustainable agriculture, which examines the entire system of production, are beginning to be accepted in mainstream production agriculture. Several examples are cited in the recent study by the National Academy of Science: a family farm in the Central Valley of California that relies on biological control to control insects on table grapes and manages grape canopies to prevent fungi on the grape clusters; and a rice farm in the Sacramento Valley that employs cultural techniques and rotation to limit herbicide use, which is a major source of pollution in the Valley. Sustainable agriculture centers are being created at all major land-grant, and non-land-grant universities, including states like Iowa. A recent poll indicates that the majority of Iowans favor greater restrictions on pesticide use to reduce groundwater contamination.

These are positive developments. But it is preposterous to think that within a few years we will replace a production system that has served agriculture remarkably well for over 50 years, a system which achieved the largest increases in yields in history, with non-chemical farming techniques. Furthermore, there is no evidence that our food will be any safer once we have done this. If fungicides are not used, will contamination by fungi—many of which produce carcinogenic mycotoxins—increase? Will tolerating more insect damage facilitate the entry of disease organisms into foods? Will new insect- and disease-resistant crop varieties contain higher levels of natural toxicant? We must determine why these new varieties, which require less chemicals, are “resistant.”

Research concerning sustainable agriculture is expected to increase dramatically. This type of research is emphasized in the new $500 million “National Research Initiative” designed to infuse new money (and new ideas) into agricultural research. Optimists anticipate that $100 million will be allocated to the initiative during fiscal year 1990-91, with incremental increases in funding during each of the succeeding three years. (These projections were made before Iraq invaded Kuwait.)

**The Real Problems**

Our record concerning residues of pesticides, animal drugs, and food additives in food should definitely reassure Americans that their food contains safe levels of these substances. But there are serious problems related to food safety, as FDA toxicologist Robert Sheuplein recently delineated:

- **There is a link between diet and cancer.** According to the 1988 Surgeon General’s Report, 22 percent of all deaths in the U.S. in 1984 were from cancer. Roughly 35 percent of all cancer deaths can be attributed to diet, including diets rich in high-fat foods and lacking in vegetables. Thus the total risk of cancer deaths from foods is 0.22 multiplied by 0.35, which is equal to 0.077, or 7.7 percent. Of this total risk, almost all (98 percent) is attributable to traditional foods (including fat). Spices and flavors comprise 0.98 percent of the risk, and food additives contribute 0.2 percent to the total risk of cancer.

Malcolm Pike, professor of preventive medicine at the University of Southern California, recently offered the following advice: “First, don’t smoke, don’t drink, and eat lots of nice green and yellow vegetables. These other things (pesticides, animal drugs, etc.) are tiny in comparison.” Of course, even small risks of cancer should be avoided whenever possible. However, the real question is whether the costs associated with removing tiny risks justify the small improvement in the health in the general population.

- **There is evidence that microbes in foods pose a greater risk to health than once thought.** Michael Doyle, Food Research Institute at University of Wisconsin, said, “Each year in the U.S. there are an estimated 6 to 24 million cases of foodborne illness, with 9,100 deaths.” These deaths and illnesses are
due to bacterial gastroenteritis carried in poultry, other organisms in undercooked seafood (e.g., sushi from improperly certified restaurants), salmonella in eggs, listeria infections in cheese, and the like.

Reducing these risks will require improvements in safety inspections of production facilities, slaughter houses, food processing plants, and restaurants, as well as providing accurate information to consumer. 

• There is little information about many of the chemicals that may contaminate foods. These include plastic additives that can migrate into food from wrappers, containers, and microwave equipment; environmental chemicals (PCBs, dioxins, polynuclear aromatic hydrocarbons) that accumulate in ecological food chains; solvents, metals, and the like.

• Natural toxicants in foods. In 1987 Bruce Ames and his colleagues produced a landmark report stressing the abundance of natural toxicants in foods:
  - Carcinogens in parsnips and celery.
  - Cyanogenic glycosides in lima beans and cassava.
  - Alkaloids in herbal teas and potato sprouts.
  - Oxalates in rhubarb.
  - Linoleic acid, a potential natural carcinogen, in vegetable oil.

There is a lot we do not know about the effects of these natural toxicants. If we allocate most of our resources on the more visible (but probably insignificant risks) from pesticides and other synthetics, we might overlook some major threats to food safety.

According to a May 1990 report in the New York Times, most of the 30 food safety bills in Congress concerned pesticides, drugs, and food additives. Apparently, we are doing a rather poor job in providing good information to federal legislators.

The Future
Younger generations appear to have the most misconceptions about food safety, which indicates where we might focus our educational efforts. We may disagree with how the public views food safety, but agriculture certainly needs to more aggressively address all food-safety concerns, including pesticides, fertilizers in groundwater, animal bioethics and sanitation, farmworker education and safety and similar issues.

Farmers should once again be viewed as stewards of the land, rather than polluters motivated primarily by profit.

Food processing retailers, and fast food outlets must increase their efforts to provide appealing, healthful foods, and to make sound nutritional information available in readily understood terms.

And we certainly must focus more attention on the real problems and the unknowns, and less on the borderline, fictitious issues related to tiny residues of little or no consequence. (More-responsible journalism concerning food safety is also desirable, but this may be the most difficult objective to achieve!)

We also need to take a more enlightened look at how we adopt new technologies that might improve food production and food safety, e.g., bovine somatotropin, food irradiation, and genetically altered plants and microorganisms. If concern over food safety cause synthetic pesticides to be banned, similar pressures might prevent producers from applying other technological innovations.

If so, this could be the largest “risk” to food safety that we confront.

...it is preposterous to think that within a few years we will replace a production system that has served agriculture remarkably well for over 50 years with non-chemical farming techniques. Furthermore, there is no evidence that our food will be any safer once we have done this.
Food Safety
THEN AND NOW

What happens after food arrives in the kitchen may provide more cause for concern than all of the chemicals and processes used in the production and manufacturing of food products. Dramatic changes in food preparation methods in the last few decades have also necessitated changes in proper food-handling procedures. However, the following rules are still valid, regardless of how food is prepared or handled:

1. Careful personal hygiene (hand washing, covering coughs and sneezes and using a clean spoon for tasting) is essential in the kitchen.
2. Use appropriate storage temperatures, either above 140°F or below 40°F. No food should be held for more than 2 hours in the 40-140°F range, including thawing, preparation and serving time. Be especially careful with high protein foods containing eggs, milk, meat, poultry and fish.
3. Follow safe preparation techniques. Serve food immediately after cooking, use only fresh, unbroken eggs, thaw meat, poultry and fish in the refrigerator, cool foods immediately after the meal, divide large amounts of food into smaller containers to cool quickly, and use hot water and soap to clean equipment and countertops.
Safe Kitchen Rules

**Bacteria which cause food poisoning can be controlled by keeping food hot.**
- 165°F-212°F temperatures kill most bacteria.
- 140°F-165°F holding temperatures prevent bacterial growth.
- Two hours maximum holding time.
- Cook meat and poultry thoroughly - at least to medium (140°F).
- Don’t interrupt cooking. Cook thoroughly.
- Allow frozen food about 1-1/2 times the cooking time.
- Thoroughly reheat leftovers.

**Cold temperatures prevent bacterial growth.**
- Refrigeration temperatures should be 40°F or lower.
- Freezing temperatures should be 0°F or lower.
- When shopping pick up perishables last, take directly home, and refrigerate immediately at home.
- Handle meat and poultry as little as possible. Leave in store wrap.
- Check canned meat products; some require refrigeration.
- Fresh poultry, hamburger and variety meats should be kept in refrigerator 1-2 days; other meats for 3-5 days.
- Frozen meats should be well wrapped to prevent drying out and stored no more than 6-12 months.
- The safest thawing technique is in the refrigerator.
- For faster thawing place food in plastic bag in cold water.
- Thawing in the microwave is rapid enough to control bacterial growth.
- Never leave food at room temperature more than two hours, including preparation, cooking and serving time.
- Place all leftovers immediately in refrigerator.
- Place large amounts of food in shallow containers to refrigerate.

**Select only safe food.**
- Frozen foods should be solid.
- Refrigerated food should feel cool.
- Check dates on products.
- The “Sell By” date is the date to be taken from the shelf.
- The “Use By” date is the maximum date which will still be top eating quality.

**Keep food clean.**
- Store food in appropriate place, refrigerator, freezer or clean, dry place.
- Keep pets away from food.
- Store household cleaners away from food.
- Control household pests (rats, mice, roaches).
- Always wash hands before beginning food preparation.
- Teach children to wash hands.
- Avoid contact with food if you have a cut or infection on your hand.
- Do not cough or sneeze on food.
- Keep dish cloths and towels clean.
- Use hot soapy water to wash hands, countertops and utensils.
- Do not put cooked food on dishes, board or countertops where raw food has been.

**Safe microwave cooking.**
- Allow standing time (10-15 minutes) for even heating of food.
- Use meat thermometer to check for doneness.
- Covers, lids and cooking bags give more even cooking temperatures.
- Never use microwaves for home canning.
Eating patterns reflect changing lifestyles. New rules are often required to safely prepare and handle many of the new food items.

More men and children now purchase foods. Do they know how to select high quality products and the appropriate transportation and home storage methods? Food preparation tasks are also shared by members of the household. Convenience foods, which range from peeled vegetables to foods that must only be heated, often require special preparation to ensure safety. New food items include shelf-stable, fully prepared main dish combinations sealed in plastic pouches, frozen complete dinners, vacuum packaged meats that can be refrigerated for several weeks and many partially cooked foods. These foods must be appropriately stored, heated and cooled. Most prepared foods from supermarket delicatessens should be refrigerated as soon as possible after purchase.

More than one-fourth of the food consumed in the United States is eaten away from home. Protect food in sack lunches from bacterial growth by keeping it cool or by keeping it hot in a thermos. Gauge the temperature of food at fast food restaurants, salad bars and food vendors by feeling the containers.

Long, slow cooking or very quick cooking methods have become more popular to accommodate working schedules. Monitor low-temperature cooking methods to make sure that the food does not remain at temperatures between 40-140°F for more than two hours. Rapidly heating food and starting with thawed rather than frozen foods can minimize these risks.

Microwaves are ideal for convenience and partially cooked foods. Twenty years ago it was estimated that almost half of American homes would have a microwave by 1990; they will probably be found in four of five homes today. Although convenient, improper microwave cooking can increase the risk of food-borne illness.

Use of leftovers. Microwave cooking is uneven and food should be stirred, rotated, covered with a lid and allowed to stand after cooking to make sure it is thoroughly heated. Check temperature with a thermometer.

Reheating partially cooked food. Carefully cool and heat partially prepared foods. The more a food is handled, the greater the bacterial contamination. The two-hour rule applies to total preparation, cooling and reheating time. Thoroughly cooking meat destroys any bacteria in raw meat. Meat can then be reheated quickly before serving.

Defrosting/refreezing. Defrosting and refreezing, especially of meat, increases the risk of food poisoning. If meat is only partially cooked, the warmth of thawing increases bacterial growth. Meat thawed in a microwave should be immediately and thoroughly cooked.

Cooking utensils and covers. Only use microwave-approved containers. The extreme temperatures produced during microwave cooking have prompted concern about the chemical breakdown of some plastic wraps and containers.

Take special care when transporting food, especially in warm weather. Use coolers or thermos containers when taking food for family reunions, camping trips, holiday dinners, picnics, potluck, church dinners and other occasions.

Georgia Lauritzen 750-3464
People are concerned about pesticide residues, as was evident when the Food Marketing Institute asked consumers to evaluate various hazards. In 1988, 76 percent of those surveyed considered pesticide residues in food to be a serious hazard. In 1989, 82 percent expressed such a concern. In October 1989, about half the people contacted in a national survey reported that they had become more concerned about pesticide residues in food.

At least some of this concern can be attributed to how the media cover the issue. The media have a profound effect on consumer attitudes and knowledge, as was clearly illustrated by how 60 Minutes covered the Alar controversy. The portrayal of apple products as carcinogenic resulted in a $100- $200 million loss in apple sales and precipitated a reduction in consumer confidence in the safety of the food supply.

...there is no scientific evidence to support the view that organic and conventionally grown produce differ in taste or quality.
Paradoxical Attitudes About Produce
Consumers have paradoxical attitudes about fruits and vegetables: they view them as potentially hazardous and healthful. They recognize that produce contains relatively few calories, has high nutritive value, and offers good value. In the national survey conducted by the Food Marketing Institute, many people said they had increased their consumption of fruits and vegetables.

The FDA says pesticides are poisons but does not consider them to be a public health hazard. And the National Research Council states that the benefits of eating produce outweigh the potential risk associated with pesticide residues.

In contrast, national surveys show that only 54 percent of consumers now believe that “the potential health benefits of eating fresh fruits and vegetables outweigh the potential risks from pesticide residues.” Twenty-six percent of the consumers participating in a national survey said they had changed their buying habits in an effort to reduce the risk of pesticide residues. Some have switched to organic or “pesticide-free” produce. Others (17 percent) said they have reduced their purchases of fresh produce.

A national study conducted by packers detected similar trends: 6 percent of the consumers said they no longer purchased some produce. Of those 6 percent, 57 percent said they no longer purchased apples, 29 percent had stopped purchasing grapes and 8 percent had stopped buying tomatoes. Half of the California consumers surveyed said they had changed their buying practices; 8 percent indicated that they purchased less produce or purchased organic produce.

The results of these surveys show that the fervor about pesticides could cause consumers to eat less healthful diets because they contain less produce.

Misconceptions About “Organic” Produce
Many consumers mistakenly believe that chemicals are not used in the production of organic foods, as was confirmed by responses to a survey conducted by the University of California. More than half of the respondents believed that organic produce is better, even though no research has confirmed that organic produce has any superior nutritional qualities. Studies conducted at the University of California during the 1970s also found little difference in taste between conventionally produced and organic produce. Of course, varieties can have different tastes, but there is no scientific support for the view that organic and conventionally grown produce differ in taste or quality.

The increased popularity of organic produce, which is usually more expensive than conventionally grown produce, may have a major effect on the food costs of consumers in the lower income brackets. On the average, US consumers spend 11.8 percent of their disposable income on food. Consumers in the top 20 percent of the income brackets spend 9 percent of their disposable income on food, while those in the bottom 20 percent income bracket spend 42 percent of their disposable income on food.

Organic foods appear to have more appeal to those in the lower income brackets. Fifty-seven percent of respondents in the packer survey agreed with the statement that they would rather buy organic produce, regardless of cost. A higher percentage of people in lower income groups (incomes of less than $10,000) said they would buy organic produce than in higher income groups (incomes exceeding $30,000).

Exaggerating the Perils of Pesticides
Do pesticides threaten the safety of our food? Consider the following evidence:

The federal monitoring program has detected relatively few violations of established tolerances for pesticides. In 1987, 4,178 samples of fruit were analyzed; residue levels in 50 percent were lower than the detection range. Ninety-six percent of the produce sampled was within established safety
standards. Compliance rates would probably be even higher if the samples were collected randomly. (Samples are now selected in part according to production levels and prior residue problems.) According to the FDA, the proportion of violative samples in vegetables is similar to that in fruit.

The state of California also extensively monitors produce and tests about 15,000 samples of raw commodities prior to harvesting. This surveillance program focuses on chemicals known to be applied to specific crops. Thirty-five percent of the samples involve imported produce, 10 percent involve produce from other states, and 55 percent involve California-grown commodities.

Consistently, about 98 percent of all produce is in compliance. No pesticide residues were detected in about 78 percent of the samples. Only 1.2 percent of the samples, which are selected from wholesale and retail markets, packing houses, and points of entry, are violative. Ninety-four percent of the samples with violative levels involved pesticides not authorized for the use on the crop in which they were detected. Produce found to be in violation is quarantined.

Only one case involving illegal residue was detected in a focused monitoring program involving pesticides deemed to pose a special risk to health (only crops treated with the target pesticide were sampled). This one case involved drift from an adjoining field.

The preharvest monitoring program in California concerns possible illegal use during the growing season. Of the 2,511 samples taken, less than 1 percent contained pesticides not registered for use on the commodity. Most of the violations resulted from pesticide drift, not direct application. Levels are also consistently low in imported produce.

Levels of pesticide residues continue to decline as products go from the farm gate to the table. Because more cosmetic damage is tolerated in processed produce, pesticide residues may be lower in these products. Pesticide residues are further reduced during washing and heating. For example, rinsing reduces residual levels of carbaryl by 75 percent to over 90 percent.

Although risk assessment isn't a perfect science and information on toxicity isn't as comprehensive as we would like, pesticide residues in food do not appear to pose a health hazard. Pesticides, however, can contaminate the environment. The most important pesticide-related problems are pesticide-related illnesses among applicators, mixers, loaders, and field workers. (There were 1,065 confirmed pesticide-related illnesses in California during 1986.)

Further Reducing Pesticide Use

Research conducted at the University of California, USU and other institutions is leading to methods to reduce pesticide use and to improve the speed and accuracy of detecting residues. University of California toxicologists are developing easier multi-residue screening tests and more rapid tests for specific pesticides. They are also studying the fate of chemicals after they enter the environment, and the natural toxins in food and mutagens produced by cooking. Other researchers are examining the metabolic pathways and fate of a chemical in order to more accurately determine the withholding time between treatment and slaughter.

Integrated pest management (IPM) is a promising ecologically based approach to pest management. Several methods are used to maintain pest populations below levels that cause economic injury to crops and to avoid hazards to humans, domestic animals, plants, and the environment. Methods include reducing pesticide usage through improved timing and methods of application, biological control and new pest-resistant varieties.

For example, mealy bugs, which damage fruit, can be controlled by encouraging increases in the population of a predatory beetle. (Reliance on insect predators is not the complete answer. A parasitic wasp kills aphids that attacks lettuce, but the dead aphids remain on the plant. Obviously, consumers don't want any aphids on their salads, whether aphids are dead or alive.) Garden snails, which climb orange trees and attack the fruit, can be controlled by pruning lower branches, thus leaving only the trunk as an access route. A copper strip is installed to prevent snails from crawling up the trunk.

The pesticide used to control the lygus bug, which damages strawberries, causes the population of harmful mites to increase. Some strawberry growers are using a bug vacuum to control the lygus
A bug. An IPM advisor in Santa Cruz is comparing the effectiveness of the bug vacuum, a soap solution and the vacuum, and pesticide applications. The soap solution burns plants. The bug vacuum reduces the number of lygus bugs, but the most effective treatment appears to be combining pesticide applications with use of the bug vacuum. This combination makes it possible to reduce the number of pesticide applications from about 18 per season to three. The pesticide is a product of fermentation used by both organic and conventional growers.

Many insects find their mates by scent, which is impregnated in a sticky plastic sheet. Hanging the sheet in an orchard attracts the males, who are caught in the sticky paper. Apple growers determine their spraying program according to the number of moths caught in traps, and on when larva will hatch, which is based on weather information. This has allowed growers to reduce the number of sprays needed to control the moth from a dozen to 3-4 sprays per season.

Pheromones can also be introduced to confuse an insect so it cannot find its mate, a method which more than half the peach growers in northern California use to control the oriental fruit moth. Other IPM techniques include plowing under weeds that harbor harmful insects, and allowing weeds that shelter beneficial insects to remain.

Growers do not apply pesticides indiscriminately. And with integrated pest management techniques, they monitor insect populations and use pesticides only when no other method is available and only when enough insects are present to cause economic damage to the crop.

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**The Importance of Educating Consumers**

How can science educators respond to the food safety concerns of consumers?

We must describe the system that is used to safeguard our food supply, accurately report the results of residue testing and risk assessment, and describe the research programs which will help increase food safety. We must educate consumers so they can make an informed decisions about the risks associated with food.

Fortunately, many consumers appear to be eager to receive information about this topic. In 1989, almost half of consumers polled said they looked for information about food safety. Consumers believe information that appears to be reasonable, that is repeated, and that is provided by credible sources.

Many consumers do not know that microbiological hazards pose the greatest threat to food safety. Researchers estimate that 6.5 million to 33 million Americans become ill each year from microorganisms in their food. An estimated 9,000 of these illnesses result in death, or 4 deaths in 100,000 people. This is a far greater risk than that posed by pesticide residues in food.

The best advice for consumers is to eat a variety of foods and to handle foods safely. A healthful diet should include five servings of fruits and vegetables a day. Rinsing produce removes dirt, grime, and any pesticide residues. Peeling may remove additional residues but also reduces the amount of valuable dietary fiber. Consumers should also be aware that pesticides may have been used on many so-called organic foods.

In *Nutrition and Your Health, Dietary Guidelines for Americans*, the Surgeon General noted that epidemiologists have found a relationship between diet and cancer. A high intake of fat and calories and other factors are related to an increased incidence of some forms of cancer. A high intake of fruits and vegetables appears to have a protective effect. In spite of the exaggerated concern about pesticide residues, a healthful diet is one that includes fruits and vegetables.

References:


Allan Adams, Logan is the recipient of the second annual Utah Land Grant Hall of Fame Award from Utah State University.

The award recognizes Adams, who operates a ranch in Rich County, for his support of research, teaching and extension activities at USU, the state’s land grant institution.

Adams served on numerous local, state and national agricultural groups and encouraged closer ties between agriculture and USU. Doyle Matthews, dean of the USU College of Agriculture, who presented the award at a banquet during Land Grand Days, said “Adams combines good business sense with a western rancher’s characteristic pioneering spirit.”

Adams held several offices with local, state and national agricultural groups, including the Utah Cattlemen’s Association, the Utah Society of Range Management, the Cache District Woolgrowers and the National Live Stock Producers Association. He also held several positions with financial institutions.

Matthews also cited Adams for his support of a USU Extension program to upgrade range cattle in Rich County that markedly improved the quality of calves, and increased the prices that buyers are willing to pay for calves from Rich County.

Matthews said Adams operates “one of the most progressive ranches in the Intermountain Region.” Adams is also known as an architect of cattle-handling facilities. The cattle shed and working corral that he designed are utilized by cattlemen around the country.

Booth Wallentine, executive vice president of the Utah Farm Bureau Federation, was the first recipient of the award.

ALLAN ADAMS

Receives USU Land Grant Hall of Fame Award
Recent Grants and Contracts

Robert Sidwell, Animal, Dairy and Veterinary Sciences Department, has received a contract from the National Institutes of Health to study animal models of human viral infections for evaluation of experimental therapeutics. The U.S. Department of Defense/U.S. Army continues to support his research concerning the effectiveness of compounds against punta toro virus.

The National Science Foundation is funding research by Jon Takemoto, Biology Department, concerning the mechanisms of phytotoxin-host membrane interactions.

Conly Hansen, Nutrition and Food Sciences Department, is designing a bioreactor for the biological removal of mercury from dairy manufacturing wastes. The research is funded by Kansas State University/U.S. Environmental Protection Agency.

Terry Glover, Economics Department, is examining economic incentives for managing non-point pesticide pollution of groundwater with a grant from the Cooperative State Research Service (USDA).

The biological control of Ascosphaera pathogens of bees is studied by Nabil Youssef, Biology Department, with a grant from the Animal and Plant Health Inspection Service (USDA).

Gail Bingham, Plant, Soils and Biometeorology Department, is updating consumptive use information and isohyetal precipitation maps (Utah Division of Water Resources) and developing a miniature in-chamber CO2 and H2O sensor for photosynthesis studies (National Science Foundation).

Robert Hill, Agricultural and Irrigation Engineering Department, is estimating evapotranspiration for Utah with calibrated empirical methods with a grant from the Utah Division of Water Resources.

Roger Coulombe, Animal, Dairy and Veterinary Sciences Department, is studying the preclinical pharmacology of antiviral agents for the U.S. Department of Defense/U.S. Army, and the pulmonary toxicology of aflatoxin B1 for the National Institutes of Health/University of California-Davis.

Neil West, Range Science Department, is studying the stability of plant community composition and Yield in sagebrush steppe relics under the special grants program of the Cooperative State Research Service (USDA).

Larry Rupp, Plant, Soils and Biometeorology Department, is studying water yields in semiarid environments under projected climate changes with a grant from the U.S. Department of Interior/Bureau of Reclamation.

The Cooperative State Research Service (USDA) is funding research by Joseph Li (Biology Department) concerning the molecular analyses of antigenic epitopes critical for bluetongue virus infection.

Richard Peralta, Agricultural and Irrigation Engineering Department, is developing a prototype of economic incentives for managing non-point pesticide pollution of groundwater with a grant from the Cooperative State Research Service (USDA).

The Utah Energy Office is funding the development of energy software by Stephen Poe, Agricultural Education Department.

Gary Straquadine, Agricultural Education Department, is assessing and implementing an agricultural safety program in the state with funding from the University of Utah.

Warren Foote, Animal, Dairy and Veterinary Sciences, has received a grant from the Animal and Plant Health Inspection Service (USDA) to study the vertical transmission of scrapie in sheep and goats.

John Evans, Plants, Soils and Biometeorology Department, is determining the distribution of goatsburr and strategies to eliminate the noxious weed. His work is funded by the Animal and Plant Health Inspection Service (USDA).

Carol Windham, Nutrition and Food Science Department, is revising nutritional information about meat to for vendors of nutrition software; her work is funded by the National Livestock and Meat Board.

Jeffrey Walters, Animal, Dairy and Veterinary Sciences Department, is developing an animal genetics course for the AGSAT satellite network that will link land grant colleges and universities around the country. His work is funded by the Cooperative State Research Service (USDA).

Anne Anderson, Biology Department, is studying the biological control of sugar beet diseases with a grant from the University of Idaho.

Ben Norton, Range Science Department, is studying sustainable agricultural systems on marginal lands in Bolivia with a grant from the University of California-Davis.

The Western Dairy Foods Research Center funds the following studies in the Nutrition and Food Science Department: the control of age gelation of ultra-high temperature sterilized milk concentrates (Donald McMahon), development of a process to produce ultrafiltered milk retentate powder (Conly Hansen), the membrane fractionation of immunoglobulins from milk and whey (Paul Savello), characterization of milk protein by lactococal starter culture strains using amino acid analysis (Rodney Brown), and the causes and prevention of sticky texture in mozzarella cheese (Gary Richardson).

Included in research recently funded by the Agricultural Research Service (USDA) is a study to evaluate and enhance cool-season grass, alfalfa, clover and special purpose legume germplasm (Melvin Rumbaugh, Forage and Range Research Laboratory); funding was also provided for bee research (John Vandenbergen), and dairy research (David Clark).
Good research requires good animal care. And that's why care is an overriding concern of the Institutional Animal Care and Use Committee, which oversees the care of animals used in research at USU.

"Our underlying premise is that research is no better than the care we give our animals. The results of even the greatest research will be questionable if animal care is not good," says Stan Allen, veterinarian and director of the Laboratory Animal Research Center, and executive secretary of the committee.

The 12-member committee, which includes a representative of the general public and representatives from most of the units that use animals in research, monitors approximately 125 research projects that currently utilize animals.

The committee enforces hundreds of rules, regulations and guidelines, including those promulgated by 20 organizations concerned with agricultural animals used in agricultural research and teaching. There are also guidelines for the care of laboratory and wild animals. The standards cover nearly every aspect of animal care.

For example, selected guidelines for laboratory animals deal with the immunizations required by animal care personnel (tetanus, and perhaps immunizations against rabies virus and hepatitis B virus), types of bedding, sanitation, relative humidities and temperatures of facilities, space provided per animal, and the use of anesthetics.

Since its passage over 25 years ago, the university also complies with the Animal Welfare Act, whose provisions are enforced by USDA inspectors.

The number and types of animals used in research projects vary widely, from 12,000 mice to 1 rabbit. Much of the research directly concern human health, including studies of iron metabolism, the action of oxygen radicals (implicated in a wide range of diseases), opportunistic infections associated with AIDS, and asbestos-induced ailments.

"We've got to do a better job of educating people about the value of animals in research," Allen says.

"Animal rights activists have been extremely effective in using the media to persuade the public that animal research is irrelevant and inhumane. In my experience, researchers are extremely concerned about the humane treatment of animals. Animal research has made some remarkable contributions to animal and human health, as well as increasing our understanding of the basic principles of the life sciences."

Stan Allen 750-1900
They are all clues. A brain or kidney. Perhaps some lung tissue, or maybe an entire carcass.

About 3,000 times a year Ross Smart, the soft-spoken veterinary pathologist and director of the Animal Disease Diagnostic Laboratory at USU, and other lab employees scrutinize body parts, fluids or an entire carcass as they try to determine the cause of death of a cow, horse, parakeet, chinchilla or any of the innumerable other species of livestock, wildlife or pet in the region.

The sleuthing often ends quietly with Smart quietly peering at thin slices of tissue through a microscope, using the best diagnostic tool at his disposal—his 33 years of expertise.
Diagnosing livestock diseases can be as formidable a task as tracing the origins of human disease—and sometime it's more difficult considering the number of species involved. Veterinarians only send those cases to the USU lab that they can't diagnose. Smart is seldom stumped, although he's too modest to admit it.

Among the recent cases: Sheep from central Utah dying with symptoms characteristic of enterotoxemia but having none of the intestinal lesions associated with the disease. A more complete necropsy found brain lesions, focal symmetrical encephalomalacia. This rare disease was originally reported in New Zealand. Horses from Idaho appeared to be afflicted by some disorder of the central nervous system. Smart's eventual diagnosis, based on a lesion at the base of the brain: poisoning due to Russian knapweed. (He also spotted the remnants of a parasitic infection in the brain that has so far eluded identification by several experts.)

All in a day's work for Smart and another veterinary pathologist, Kevin Jackson, three full-time technicians, a secretary-receptionist and part-time student help that he supervises.

The laboratory is a small but important investment in the protection of livestock production in the state, now worth more than $550 million annually. The first line of defense against livestock disease is the husbandry of farmers and ranchers. Veterinarians usually spot any unusual problems, and they often turn for help from the USU Diagnostic Lab, which can turn to several state and federal laboratories for assistance. The lab works closely with the State Veterinarian, Mike Marshall, and Extension Veterinarian, Clell Bagley.

Veterinary medicine has nearly conquered some ancient scourges, such as tuberculosis, but hundreds of other ailments, such as brucellosis, remain. There are zoonoses, diseases that can be transmitted from vertebrates to people, such as salmonelosis. Exotic diseases lurking in other countries always threaten to cross our borders. Of recent concern is mad cow disease (bovine spongiform encephalopathy) in Britain, which riddles the brain with tiny holes. Some researchers feel it is related to the scrapie, an unconventional virus-like agent that affects the brains of sheep. The disease has not been detected in

Two Cases

There is nothing unusual about these cases: Fecal samples from a couple of horses, one sick, the other well, (case no. 2409) and a dead 2-day-old Holstein calf, apparently killed by scours (case no. 2416).

The cases illustrate how the USU Diagnostic Laboratory functions. Like most of the cases, they involve by-products of death and disease—waste material, tissues, blood, bones. One animal or an entire herd might be afflicted. At stake might be a pet, someone's livelihood, or an entire industry.

Most of the tasks are routine. Some are distasteful. It's often not glamorous work.
Case No. 2409

A veterinarian sent fecal samples from the horses to be cultured. The culprit is probably a parasite or bacteria, but treatment requires identification of the offending organism.

Research technician Mike Paskett has worked in the lab for 21 years, so he knows exactly what to do with two globs of feces wrapped in plastic baggies. He slips on a pair of plastic gloves, and puts some of the green feces in a small plastic cup, adds water, strains the mixture to remove straw and coarse material, and pours the debris-free solution in a test tube and centrifuges the solution for a few minutes. He adds a sucrose solution to the top of the test tube, and carefully covers the open test tube with a glass slip, which he removes after a few minutes and puts on a glass microscope slide to examine under the microscope. Any eggs from round worms and tape worms will float to the surface and appear on the slide.

There are none.

He also cultures samples in petri dishes containing different media; MacConkey agar, which identifies organisms on their ability to ferment lactose, favors the growth of enteric bacteria. Blood agar, which contains sheep, horse or rabbit blood, favors the growth of several other types of bacteria. After 24 hours in an aging but sturdy incubator at 98 °F, the appearance of colonies on the agar plates indicate the presence of strains of Bacillus, Streptococcus, Corynebacterium, Staphylococcus and Coliform organisms.

There’s no wasted space in the laboratory, and equipment of various vintages occupies every bench and table. In spite of thorough cleaning and meticulous maintenance, the facility shows its age. Wooden cabinets date from the 1920s and 1930s when the building was originally constructed. Ancient autoclaves at one end of the laboratory loom like locomotives compared to their modern counterparts. Paskett conducts dozens of types of tests involving hundreds of techniques in serology, clinical pathology, and bacteriology in the cramped facility. Last year, he ran 12,600 serological tests and 8,787 bacteriological cultures. His economical movements between shelves, benches and equipment are choreographed by repetition and necessity.

In the histopathology lab downstairs, Elaine Covert made almost 3,000 slides last year, from thin slices of tissue embedded in a special paraffin.

"We have the bare necessities as far as equipment is concerned," Paskett says. "At least we have a separate facility for virology, which is very sensitive to contamination. A lot of laboratories have problems with contamination of tissue samples. Contamination is also a concern in bacteriology, but it’s not as sensitive as tests involving viruses."

To identify the species of enteric bacteria, Paskett uses a diagnostic kit with 15 wells, each of which contains a different type of media. Before the kit was available, the lab had to employ a student full time to mix the media required in diagnosis. Paskett assigns a number based on the reactions in wells and then refers to a code book to identify the bacteria. The bacteria cultured from the healthy horse (code number 64270) are Enterobacter agglomerans, a species found in soil, water, dairy products and the intestines of animals, including humans. Its presence is probably normal.

The organisms from the sick horse fail to react in any of the wells of the kit, and Paskett cultures them on other media for identification. The results of those cultures show some normal inhabitants of the intestinal tract—E. coli, Coliforms, Enterobacter cloaceae, Streptococcus, and Baccilis. "These bacteria aren’t considered highly pathogenic, and under most conditions are normal flora. They can cause problems outside of the intestinal tract, and certain serotypes of E. coli can cause lesions in the intestinal tract. At this point, we have probably not identified the reasons why this horse is sick," Smart says.

They have, however, eliminated several possible causes.
American cattle, but the USU lab and other diagnostic facilities continually monitor cattle for any sign of its appearance.

The laboratory began 70 years ago with brucellosis testing of cattle. Like the State Department of Health, which monitors human disease, the diagnostic laboratory doesn’t treat disease, but identifies and keep records on disease problems. The laboratory in Logan serves Utah and limited areas of Nevada, Idaho and Wyoming. A branch laboratory in Provo serves the central part of the state. State appropriations and nominal service fees fund the services.

Most of the diagnostic requests are from veterinarians although animal disease regulatory agencies, public health agencies, wildlife agencies, laboratory animal caretakers, animal research units and livestock and pet owners also submit specimens.

The arsenal of diagnostic tools includes serological, microbiological and pathological tests. Smart also relies on his knowledge of bacteriology, virology, toxicology and parasitology. Pathogens are often cultured. Tissues are fixed and stained for microscopic examination.

There are fecal samples from cats. Coccidiosis, perhaps. A biopsy sample from a cow. The diagnosis: A highly treatable skin cancer. A diagnosis usually takes three to ten days, but infectious diseases can be diagnosed sooner to avert further losses.

Postmortem examinations of horses, cattle, sheep, dogs, cats, chickens, turkeys are common. Cases have also involved parakeets, mice, rabbits, rats, chinchillas, deer, muskrats, bats, geese, pheasants, pigs, wild ducks—even camels.

Smart says they rely on the observations and skills of veterinarians who do the original necropsy and sampling. The condition of the carcass or specimen affects diagnosis, as does information such as the species, age, sex, breed, circumstances of death, symptoms, vaccinations, management practices, feed and feeding methods.

The laboratory collaborates with several researchers with USU and at associated federal...

Case No. 2416

The attrition rate among calves in some dairy herds is high, and can exceed 20 percent. With access to superior sires through artificial insemination, the loss of male calves, most of which are raised for veal or beef, doesn’t threaten the genetic foundation of a herd. The loss of heifer calves is a different matter. Many are irreplaceable—they represent the herd’s next generation of lactating cows. High attrition among any calves, male or female, could signal a disease that signals the death knell for a dairy enterprise. The farmer who delivered the calf to the necropsy room at about 2 p.m. did so upon the recommendation of the veterinarian for tests in an attempt to stanch further losses in the herd. Almost half the necropsies conducted last year involved cattle, most of them calves.

Ross Smart cuts and saws through the sternum of the 100-pound calf, which has been placed on a stainless steel necropsy table. He has seen thousands of calves like this one. The slightly sunken eyes mirror the dehydration that accompanies the loss of fluids during scour, a general term for an ailment caused by a variety of organisms. Once the abdominal cavity is open, he removes the 20-foot-long intestinal tract to the side to examine the other organs. The lungs are slightly congested, but the congestion does not appear to be the cause of death. The effects of dehydration are apparent in the internal organs, which stick together slightly due to the lack of moisture. They are normally slippery. Smart methodically cuts through the trachea, esophagus, thymus, lungs, the compartments of the heart, spleen and kidney, and quickly assesses whether anything appears to be abnormal.

Fortunately, this calf was delivered within a few hours after it died. Smart asks clients to deliver animals for necropsies within a few hours after death, particularly during warmer weather. Sometimes people wait longer. Occasionally too long.

Billions of microorganisms thrive in and on every animal. It doesn’t take long for them to multiply once an animal’s defenses are quashed by death. Odors accompanied each of the 600...
necropsies conducted at the lab last year, some more noticeable than others. A veterinary pathologist who is averse to disagreeable odors is as rare as an astronaut who is afraid of the dark.

Sometimes animals are too decomposed to warrant a necropsy, although last year Smart did examine a dog that had been dead for several weeks to help police determine whether it had been shot. (It had.) The smell is worse, Smart says, the first few days after an animal dies; the odors then seem to dissipate. The odor of decomposing flesh in the large coolers where animals are taken following necropsies is not completely masked by disinfectants. Larger animals are picked up periodically for rendering; smaller animals and larger animals contaminated with certain diseases or toxic chemicals are stuffed in a small incinerator downstairs, but not until the large plastic trash containers have been drug down a dark, narrow stairs.

Trucks bearing dead animals must wind their way through part of the campus to deposit animals at the lab. Although the necropsy room is clean and functional, the gray paint, poor lighting and bare concrete floor lend a grim pallor to the stark room. And when a large animal is necropsied on the floor, there is barely room to walk. The need for a new facility is clear.

"You get used to the smell. It doesn’t ruin my appetite," Smart says, noting that the diseased and damaged tissue that he sees is not what people eat, thanks to rigorous inspection in meat processing plants.

Smart offers laconic comments occasionally during the necropsy. "All of its mesenteric lymph nodes are enlarged...some post mortem pallor...there’s no tone to the intestines, partly due to death, partly due to problems with the intestines. Actually not very severe lesions. The bowel doesn’t look too bad. Some diseases affect only the small intestine, others just the large intestine. Salmonella affects both. Campylobacter usually affects the small intestine.

"Calf scours are a complex disease. K-99 (a specific serotype of the bacterium Escherichia coli) can be a problem during the first week of life. After a week, E. coli, Cryptosporidium, or viruses can be responsible. Cryptosporidium is usually not too severe by itself, but it can cause problems in combi-

nation with a virus. We don’t usually find Salmonella until after 2 weeks," Smart says. His tentative diagnosis: infectious enteritis. The cause: uncertain—perhaps K99, Cryptosporidium, E. coli, rota virus, acting alone or in combination. Satisfied that the problem resides in the intestines, he cuts a section of the bowel and squeezes out its contents into a petri dish for Paskett to check. He prepares to necropsy a goat lying on the floor.

Paskett uses a latex agglutination test to detect rota virus, a procedure which involves mixing a reagent and the supernatant from the centrifuged solution from the calf’s feces on two oval black spots on a card. The latex reagent will clump and form granules if the virus is present. No clumps form.

If K99 E. coli are present, their antigens will react with the monoclonal antibodies in a test kit, and turn the solution blue. The pale blue color of the solution indicates that this the bacterium is probably not the major cause of the calf’s demise.

The test for Cryptosporidium, a coccidial protozoan of the intestinal tract, involves swabbing a sample on a glass slide, letting it dry, then “fixing” it by briefly passing it through the flame of a bunson burner. Following a series of staining procedures, none of the parasites are detected during microscopic examination.

Paskett cultures the feces on MacConkey and blood agar. The MacConkey agar contains a differential indicator that will turn red if Coliform bacteria grow and will remain clear when other enteric bacteria grow. A red stain on the bacteria growing on the MacConkey agar indicates the presence of Coliform bacteria, as does the round, mucoid, grayish colony with a smooth edge growing on the blood agar. Coliform is a generic term for several types of bacteria, including E. coli and Enterobacter, but it does not include Salmonella, a distinction of value to most practitioners. Further tests could identify the specific type of bacteria, a procedure requiring an additional day. A susceptibility assay could also be conducted to indicate resistance or susceptibility to 23 commonly used antibiotics.

But enough has been learned. One calf from the herd has died. The information gleaned from its corpse will be used to save the rest.

KG
laboratories, including a recent study by the USDA-ARS Poisonous Plants Laboratory of the causes of poisoning in cattle.

Smart, a graduate of the University of Idaho and Colorado State universities, spends 80 percent of his time in diagnostic work, the remainder in research and teaching. The work, he says, is "fascinating. Every case is a challenge. Every case is a puzzle. Some cases remain mysteries. I've been here a long time, and I always see something new."

The Veterinary Sciences Building at USU currently houses the main laboratory, but the Utah Legislature has appropriated planning money to look at the feasibility of constructing a new facility, to be located north of the campus.

"It's needed," Smart says, "but I didn't think I would see it during my time here. Moving the laboratory off-campus would improve our capability, reduce the risk of exposure, and make carcass handling easier."

**PLASTIC DOMES Too Hot for Calves**

Too warm.
That seems to be the biggest problem associated with plastic domes used to house young calves from birth through weaning at about 2 months of age, according to USU dairy scientists who compared how young calves fared in domes and conventional wooden hutchies.

During the 12-month study, calves raised in wooden hutchies tended to gain slightly more weight than calves in plastic domes, although they didn't gain weight as efficiently as calves in the domes.

Domes were 8 to 10° F warmer, an advantage during cold weather but a definite detriment when temperatures exceed 80° F. When it was that warm, plastic domes may be warm enough to subject calves to heat stress and should not be used unless modified to increase air circulation or an outside run is provided.

Researchers plan to study a rectangular A-frame type of plastic hutch that might be warmer during the winter than conventional hutchies, but would not be as hot in summer as the plastic domes. Several types of plastic calf hutchies are available. USU dairy scientists note that performance claims for some types of hutchies are often not substantiated.
Enclosed or open freestalls? It doesn’t seem to make much difference to dairy cows.

For years, dairy farmers have wondered whether the benefits of enclosed freestall housing offset its increased cost. According to a recent USU study, enclosed freestalls may be warmer during the winter, but the warmer temperatures apparently don’t translate into increased milk production.

During 1987 and 1988, researchers used automatic weather stations to continuously monitored temperature and relative humidity in both outside housing (open, butterfly free stall units) and inside housing (naturally ventilated via side windows and an open ridge) at USU’s Caine Diary Teaching and Research Center. According to dairy scientists Ann Macaulay, David Clark and Robert Lamb, temperatures in both types of housing consistently fluctuated with outdoor temperatures. During the winter, inside housing was considerably warmer than outside housing.

USU dairy scientist Clive Arave and visiting dairy scientist Nikolii Russov from Bulgaria studied the milk production of 20 cows in both types of housing last winter, and failed to detect any significant differences in milk production between the two groups of cows. Last winter was warmer than usual, however.

“If additional studies confirm that there is not much difference in milk production between the two types of housing, dairy farmers probably don’t need to build more-expensive closed housing,” Lamb says. When the Caine Dairy Center was constructed, about half the new dairy housing in the state was open and half was enclosed. Both types of housing were constructed at the Caine Center to facilitate a comparison of the two types of housing.

Lamb notes that there has been considerable research in the southwestern U.S. on the effects of heat stress, but relatively little research on the effects of cold stress encountered during winter in Utah.

Clive Arave 750-2160
David Clark 750-3297
Robert Lamb 750-2145
Ann Macaulay 750-3788

WINTER 1990 179
USU Professor Aids Revival of

NAVAJO SHEEP & WEAVING

F

or more than four centuries, a hardy breed of sheep known as churros grazed the inhospitable desert rangelands in the Southwest, providing Navajos with meat and long coarse wool which they wove into clothing, rugs and blankets.

The rugs and blankets almost outlasted the sheep. In 1864, “Kit” Carson and the U.S. Army sought to subdue the Navajo by slaughtering livestock. Churro bloodlines were diluted when supposedly more productive breeds were introduced. More churros were killed to control overgrazing in the 1930s. By the 1970s, fewer than 400 mixed-blood churros remained, mostly in remote areas of the reservation. The art of Navajo weaving declined and the sheep faced extinction.

Today both the churros and Navajo weaving are making a comeback, thanks in large part to Lyle McNeal, a USU animal scientist. In 1977, McNeal, then with California Polytechnic University at San Luis Obispo, took an interest in the unusual sheep and started a breeding program with two churro rams and six ewes, later bolstered by breeding stock on the Navajo reservation.

In 1979, he moved to USU and brought the Navajo Sheep Project with him. Some of the 350 Churros now in the breeding program at USU will eventually be placed with livestock producers on Navajo reservations.

The renaissance of the churro has renewed a way of life for Navajo weavers. “I’ve seen the eyes of the elderly Navajo women fill with tears when they see us arrive with the sheep on our truck,” McNeal says. “The sheep represent a way of life for them.”

About 90,000 of the 187,000 residents of the Navajo reservation raise sheep, and about 20,000 are weavers. Weaving is often the only source of family income beyond federal assistance.

Spanish explorers brought churros to the United States almost 400 years ago. Soldiers and priests from the east coast of Mexico herded the sheep to what is now Arizona and New Mexico, where they thrived and became an integral and revered part of the Navajo culture. The sheep are particularly suited to the harsh conditions of the arid Southwest, McNeal says.

Churros’ 14-inch-long coarse outer wool with a soft, fine undercoat has long been prized by weavers. Rugs and blankets woven with churro wool command premium prices. Each ewe provides 6 to 8 pounds of wool, some of which has sold for as much as $12 a pound at a time when other wool commands 60 to 70 cents a pound.

“We can’t get enough churro wool for top weavers,” McNeal says. “We have long lists of people who want it. We also sell it to museums to restore their older Navajo rugs.”

McNeal is also developing six genetic lines of Navajo churros, one line with desirable carcass traits, four lines with desirable wool characteristics, including color, and one line with four horns.

“These lines can eventually be line crossed. We may consider developing a new milking line,” McNeal says.

McNeal also holds clinics on the reservation to teach modern shearing techniques, as well as workshops on health, breeding, range improvement, predator control and other aspects of flock management. He has organized two highly successful conferences at USU on “Sheep and Wool on a Small Scale” in which experts address topics ranging from sheep diseases to identifying Navajo rugs.

At this summer’s conference, MacArthur Foundation Fellow Maria Varela discussed the founding of Ganados del Valle, an agricultural and...
weaving cooperative in Los Ojos, N.M. The cooperative's ultimate goal is to decrease poverty and unemployment in the area through the regeneration of a centuries-old hispanic agro-pastoral culture and economy. Varela said McNeal's project was vital in restoring the self-esteem and independence of Navajo weavers.

In 1986, the Utah Agricultural Experiment Station provided the land to house the flock. Building, feed and other costs are covered by sales of sheep, wool and products, private donations, grants and other gifts. The broad scientific and humanitarian goals of the Navajo Sheep Project have attracted support from small funding agencies and individuals, including the Charles A. Lindbergh Foundation. "They award 10 grants each year to projects that support the pilot's philosophy of achieving a balance between nature and technology. The award amount is the same as the original price of the Spirit of St. Louis: $10,800," McNeal says.

The project has also been supported by Hewlett Packard, El Paso Natural Gas, the Richard and Susan B. Ernst Foundation, and by more than 5,000 individuals. Another enthusiastic supporter is livestock producer J. R. Broadbent who is interested in the resistance of churros to internal parasites and contagious footrot, as well as the churro's role in increasing the self-sufficiency of the Navajo people.

Support from McNeal's wife, Nancy, graduate students, and volunteers is also essential. McNeal hopes the project will eventually encompass a centers that would offer education and hands-on training in meatpacking, wool processing, pelt tanning, cheese manufacturing, feedlot operation and flock management.

McNeal's concern for the churro is obvious. So are the results of his work.

JC Lyle McNeal 750-2154
Navajo weaving has experienced several periods of decline and resurgence since Navajos learned the skill from the Pueblo Indians during the 17th century. The fortunes of weaving closely follow the fate of the churro and of economic plight of the Navajo people. Today Navajo weaving reflects the interplay between tradition and progress, and between economic necessity and the pride of craftsmanship.

Regions have developed unique styles (experts have identified from 11 to 13 regional style weaving centers), and many traditional designs have passed from generation to generation. However, historians say Navajo weaving reflects the tastes of outsiders and scarcely resembles the work of the mid-19th century. Even many of the early designs reflect the preference of Eastern customers for Oriental-looking rugs instead of the ancient Navajo designs based on black, white and blue stripes.

The changes in traditional styles are often so imperceptible that even the weavers often don't realize how much their work has shifted from that of their ancestors. A novice weaver will initially copy patterns of her teachers, and gradually incorporate more of her own designs. Changing styles often mean that photographs are the only reliable method of documenting a family's work.

Many rugs and blankets are sold at trading posts. However, a buyer can't assume that the style of a rug is characteristic of the region where it was purchased as weavers sometimes travel hundreds of miles to obtain the best bid. Some experts also predict that regional differences will diminish, fostered by greater individuality among weavers, blurring of regional boundaries and increased popularity of commissioned rugs.

A skilled weaver can weave about 1 square foot daily on a loom consisting of two uprights and two crosspieces of logs usually cut from small pine trees. The fineness of a textile depend on the number of warps and wefts per inch. A fineness of more than 80 wefts per inch is considered "tapestry" quality. Most of the changes in weaving have involved materials and dyes, not the form of the loom and the technique. It's estimated that a high quality rug 3 by 5 feet made by traditional methods can require almost 400 hours of labor, including shearing, cleaning, carding, spinning, washing, gathering plants for five vegetal dyes, dyeing, loom construction, warping, and weaving. Using commercial yarn can reduce labor requirements by about 50 percent, but experts say churro wool produces a rug with a more beautiful finish with more uniform dyes. Still, it's far easier to buy processed wool than to raise the sheep and hand process the wool.

Generally, only the daughters of skilled weavers take up the trade because only skilled weavers make enough money to justify the time and effort required by the craft. A finely woven rug with a complex design can command several thousand
dollars, but the weaver may receive less than one-third of the selling price. A sense of tradition more than potential remuneration often attracts women to weaving. The potential rewards of other less traditional employment still lure weavers to other trades and threaten to extinguish the art. McNeal believes the higher quality rugs woven from churro wool will command higher prices, and foster greater interest in traditional weaving. So far, he seems to be right.

KG

Lyle McNeal 750-2154
USU Studies Show Value of

BOVINE SOMATOTROPIN

Bovine somatotropin works. In trials involving the USU dairy herd conducted during the last five years, bovine somatotropin (BST), which is produced by genetically engineered bacteria, increased milk production by an average of 15 percent. And during a recent 16-week field study with three herds in Utah and southern Idaho, BST increased average milk production by 16 percent (first lactation cows) and by 19 percent (cows, in their second or subsequent lactations), says Robert Lamb, USU dairy scientist.

"As in other studies, our research shows that BST works in most cows. It has not been used during the first 60 days of lactation.

"And it works slightly better in some herds than others, perhaps due to management-related factors. So far, we have not noticed any detrimental effects associated with the use of BST," Lamb says.

BST also doesn't appear to affect levels of some important reproductive hormones, as had been suggested in studies conducted elsewhere. Dairy scientist David Marcinkowski and graduate student
Joe Dalton found BST did not elevate levels of luteinizing hormone (LH) or of progesterone, which is mediated through LH. The USU dairy scientists injected BST 50-80 days postpartum, during the period when cows are usually bred. In the other studies, BST had been administered soon after calving when BST is not likely to be used, Marcinkowski says.

Several companies produce forms of BST. Because it is a protein hormone that is digested if eaten, BST must be injected at intervals (depending on the formulation) ranging from one to 28 days. The USU studies involved BST injections at 14-day intervals.

The commercial use of BST now hinges on FDA approval, which could occur as early as next year. Lamb says additional research is needed even if BST is approved for commercial use, including determining the best rations during dryoff and during treatment to help cows handle any BST-induced increase in milk production. Milk production usually increases 24 hours or so following BST injection, but it takes an additional 6 weeks for feed intake to increase. Cows go into a negative energy balance during this period and utilize stored body reserves for milk production.

"The FDA has already determined that there is no health risk to humans who drink milk or eat meat from BST-treated cows. Now we need to educate dairymen on the proper use of BST, and to address any problems that might be associated with marketing treated milk to avoid any negative backlash to the dairy industry," Lamb says.

Lamb says use of BST is unlikely to precipitate a large milk surplus because it will not be used by all dairymen and will be administered only during the last two-thirds of lactation. Thus, milk production in treated herds will probably increase by an average of 9 percent if cows are treated for 60 percent of their lactations. Thus, the milk supply in the U.S. is likely to increase by only 4.5 percent if 50 percent of the cows are treated.

Lamb doesn’t think that BST favors large herds. If anything, BST probably will be easier to use in small herds. It will be of little value in poorly managed herds, however. "BST improves the efficiency of feed conversion. Dairymen must feed cows better and utilize better management, just as they would with any high-producing cows."

Cost will be a factor. "We don’t know how much BST will cost, but anticipate that manufacturers will market it at a price that dairymen can afford. Dairymen still need to look at BST’s economic feasibility.

"It does give an immediate response, unlike genetic improvement that isn’t realized for years. And it does not require a major capital outlay, except perhaps for locking mangers to give injections."

Ultimately, BST’s fate probably depends on how the public perceives the product, Lamb says.

KG Robert Lamb 750-2145
David Marcinkowski 750-2144
The spurred blue flowers of larkspur resemble garden delphinium. The blue, purple, yellow or white blossoms of locoweed look like sweetpeas. Western brackens create a luxuriant green carpet on many wooded hillsides.

Beautiful plants...and deadly. Toxic compounds in these and other poisonous plants kill thousands of sheep and cattle annually. In the 17 western states estimated losses due to death and abortion exceed $340 million annually. Actual losses, including such factors as lost weight gain, are probably far higher, but are difficult to quantify.

Poisoning can be awful to witness.

Sometimes death occurs rapidly, as happens when an animal suddenly exerts itself after eating larkspur. There is the loss of muscular control, frothing at the mouth, convulsions and comas associated with lupines. Milkvetch paralyzes an animal’s leg muscles so they fall after the slightest excitement—their hearts beat wildly before they fail. Horsebrush causes severe liver damage and photosensitivity so severe that any exposed skin is irritated and sloughs off. There is the crazed behavior of animals poisoned by locoweed. When ingested by pregnant animals, many toxic compounds cause twisted limbs and gnarled features associated with birth defects.

Lynn James, director of the USDA-ARS Poisonous Plant Research Laboratory at USU, tends to

Loosening

POISONOUS

PLANTS’

Deadly Grip

Small wonder that ranchers around the turn of the century asked for help in coping with poisoning in free-ranging livestock. Since then, fencing, grazing programs and feeding programs have helped ranchers avoid many of the problems. Many problems remain.

Acute intoxication was thought to be the main problem associated with plant poisoning. In recent years other effects of toxic chemicals in plants have attracted more attention, particularly the relationship between poisonous plants and birth defects. (Some birth defects caused by poisonous plants were similar to those associated with the use of thalidomide, the sedative that caused malformations in infants born to mothers using it during pregnancy.) The more researchers learned about the chemicals, the greater and more varied the toll. Western false hellebore causes cyclopaic (one-eyed) lambs if ewes eat the plant on the 14th day of gestation. Veratrum eaten on the 28th or 30th day of gestation causes skeletal defects in lambs. Congenital skeletal malformations occur in cattle that eat certain species of lupine between the 40th and 70th day of gestation. In cattle, compounds in locoweeds can dampen sexual desire and sperm production in male cattle, and stop estrus in females. Locoweed consumed during gestation disrupts maternal-infant bonding.

With dozens of poisonous plants containing hundreds of potentially toxic compounds (some potentially useful in human medicine), the chemists, plant and animal physiologists, veterinary scientists and range scientists employed at the laboratory are plenty busy trying to protect the nearly 18 million cows and hundreds of thousands of sheep that graze nearly nearly one billion acres of pasture and rangeland in the United States.

“Livestock poisoning by plants can usually be traced to problems of management or overall range conditions, rather than simply to the presence of poisonous plants,” James says. Some poisonous plants are indigenous and increase with heavy grazing. Others invade after overgrazing or disturbance.

A hungry animal is more likely to be forced to eat poisonous plants.

Cattle consumed more Ponderosa pine needles as temperatures dropped, but temperature wasn’t the only factor that determined their craving for the needles.

And hunger is often the result of overgrazed ranges, or of trailing, trucking, or introducing animals onto a range.

Losses can often be stemmed by proper management. Proper management is based on accurate knowledge, which is the objective of the following studies underway at the laboratory.

Pine needle abortion. The seemingly innocuous needles of ponderosa pine cause cattle to abort, particularly when ingested during the last trimester of pregnancy. James, who has studied aspects of the problem for nearly 25 years, estimates that pine needles cause losses totalling $20 million annually in the western U.S. Even if cattle don’t abort, their reproductive performance usually suffers and they often give birth prematurely. Premature calves tend to be unthrifty, smaller and more prone to diseases. Why cattle snarf down pine needles is still a mystery, however.

James and research chemists with Agricultural Research Service (ARS) Western Regional Research Center in Albany, Calif., are trying to isolate and
identify the compound(s) in pine needles that causes cows to abort. Bark is as toxic as the needles. Buds, which cattle seldom eat, are the most toxic.

Identifying the compound is essential in developing effective treatments and management regimes, and in diagnosis. “We have not yet identified a lesion characteristic of pine needles,” James says. And there’s always a chance that the compound might be useful in human medicine, as is true of swainsonine, the toxin in locoweed that interferes with glycoprotein metabolism and that is a promising cancer treatment. (In 1987, James also sponsored an international conference at USU concerning swainsonine.)

Range scientist James Pfister has studied the pine needle problem in a cow herd in Montana. During one winter, pregnant cows gobbled up enough pine needles to make up 30 to 40 percent of their diets. During the next, and milder, winter, they barely touched them, particularly at temperatures above freezing. Cattle received alfalfa hay both years, so their hankering for the needles wasn’t prompted by hunger. During the first winter, cattle ate more needles as temperatures dropped, but there seem to be other factors governing their craving for needles.

One thing seems to be apparent: Pine needles don’t do much for rumen microbes. Results of preliminary studies with USU animal scientist Randy Wiedmeier indicate that pine needles have an extremely adverse effect on rumen microflora.

Sheep are much less susceptible to larkspur alkaloids and can be used to control the plant to make grazing safe for cattle. Something in them kills many bacteria and reduces the rate of feed passage through the rumen.

Larkspur poisoning. Larkspur, a showy perennial found in thick clusters in high mountain meadows, is probably the most lethal poisonous plant on western rangelands, at least as far as livestock losses are concerned. Range scientist Michael Ralphs and USU economist Darwin Nielsen recently determined that about 1,000 cattle in the Intermountain region were killed by larkspur annually. Larkspur is most toxic during early growth, and toxicity gradually declines over the growing season. Death occurs rapidly from muscular paralysis and respiratory failure.

Chemists at the ARS Western Regional Research Center have identified at least 20 alkaloids in a single plant sample. After chemists analyze and characterize the alkaloids, toxicologist Kip Panter and veterinarian John Olsen conduct trials to determine which are the culprits. “The most abundant alkaloid in larkspur is relatively nontoxic,” Panter says.

Once the guilty toxin has been identified, Ralphs will determine how concentrations vary with temperature, moisture, shade and defoliation during the grazing season. “Ultimately, we want to be able to predict how toxic the plant is under various environmental conditions so we can predict when the risk of poisoning is greatest,” Ralph says.

Several of the herbicides studied promise effective control. Glyphosate seems to be the most effective, but its nonselectivity is a drawback. Ralphs, USU range scientist Chris Call and USU weed scientist Jack Evans are studying more selective application methods, including a carpeted roller and spot sprayers. Picloram, the only herbicide registered for larkspur control, is selective and effective throughout the growing season. However, metsulfuron, a selective herbicide, offers effective control of larkspur in the early stages of growth and at extremely low concentrations (1 to 2 ounces per acre). It does not provide good control as plants mature. Ralphs says research on the herbicide control of larkspur is nearly complete. Data have been submitted to companies to register herbicides that are most effective.

Attempts to aversively condition cattle to avoid larkspur have been only partially successful, Ralphs says. (See the article on training livestock in this issue). Averted heifers avoid the plant for as long as 2 years—but only as long as they graze with other averted animals. Social facilitation (copying the
behavior of others) takes over when trained heifers graze with nonaverted animals. “It now appears that averted animals should be grazed separately at least until their preferences are well established. Training may be feasible where losses are high year after year. A rancher could train replacement heifers and keep them separate from the rest of the herd,” Ralphs says. Researchers are also determining whether a mother’s behavior might strengthen aversions in her calf.

For unknown reasons, sheep are much less susceptible to larkspur alkaloids than cattle and, with a bit of management, can serve as woolly biological control agents for cattle. Unfortunately, sheep relish larkspur only after it matures a bit and it’s the early growth which is most toxic to cattle. When confined or trailed on larkspur patches, sheep will eat larkspur early in the season. (Larkspur tends to grow in patches, so herding is feasible.) Ralphs is also studying whether positive conditioning will overcome the reluctance of sheep to eat the early vegetative growth.

Another potential option is to provide cattle with chemical defenses against the toxic alkaloid in larkspur, perhaps by administering the protective compound with small pumps. Pfister is testing miniature osmotic pumps that are surgically implanted in cattle. These pumps are large enough to slowly release drugs for about 28 days, which might be long enough for them to avoid larkspur poisoning. Eventually, pumps might be developed that can be implanted under the skin as easily as growth implants.

“Larkspur is dangerous to cattle for only 6 weeks or so, so the pumps could protect cattle through the period when larkspur is most palatable and toxic,” Pfister says. A protective compound also must be identified. Pfister is cooperating with researchers with the Colorado State University Department of Anatomy and Neurobiology to determine which toxic compounds in larkspur affect the junction between nerves and muscles.

Pumps might eventually work. Mineral supplements don’t seem to, Pfister says. Many ranchers fork out a considerable amount of money for mineral supplements that supposedly reduce susceptibility to larkspur poisoning. However, during grazing trials conducted over 3 years in Idaho, Utah and Colorado, Pfister says mineral supplements didn’t seem to reduce consumption of larkspur by cattle, nor did they change the rumen environment in a manner that might protect the animal. “If mineral supplements do something, we don’t know what it is or how it occurs,” Pfister says.

**Locoweed.** While there’s still no antidote to many of the chemicals in poisonous plants, the information has helped ranchers and farmers avoid livestock poisoning, and in some cases utilize plants when they pose less of a threat. That’s certainly true of locoweed, which is particularly hard to deal with because affected animals are subsequently more susceptible to locoweed poisoning. While larkspur probably poses the greatest threat to livestock in the Intermountain region, locoweed probably is the most important poisonous plant on other western ranges.

In the Raft River Mountains in Box Elder County, cattle voluntarily graze locoweed only in the early pod stage, not when plants are in bloom or when pods are mature. “During most years, there is a narrow window of vulnerability and grazing can be deferred during that time to reduce the risk of poisoning,” Ralphs says. Ralphs found that most rangeland herbicides will control locoweed, but large reservoirs of seed lurk in the soil, just waiting to germinate and repopulate sites when conditions are favorable.

Circumstances differ on the foothills of the Henry Mountains where Ralphs found that the locoweed population is cyclic. Outbreaks generally occur every 6 to 8 years following a wet fall, mild
winter and wet spring. After a year or two of drier conditions, the locoweed tends to retreat. Locoweed-infested regions in the Henry Mountains are usually used for winter grazing. Sheep and cattle prefer senescent locoweed, which is more palatable and contain more protein than other plants. The best option under these circumstances is to herd livestock from infested sites and or graze noninfested areas.

Panter and USU animal scientist Tom Bunch are determining how locoweed affects embryonic development and reproduction. Researchers with

The deformities associated with several types of poisonous plants may be due to these plants’ effects on fetal movement.

converts selenium to an organic form, while grasses contain an inorganic form of the mineral that apparently has fewer effects on livestock. Panter and James are studying how selenium affects reproduction in cattle, whether sulfate rather than selenium causes alkali disease, and why sheep are less susceptible to blind staggers and alkali disease than cattle.

Broom snakeweed. This noxious, poisonous weed causes abortions in cattle and aggressively crowds out desirable vegetation. Ralphs, Evans and Call are determining what factors favor the spread of this weed. Grazing studies will determine when and how much cattle eat. Toxicology studies of the weed are also on tap.

Tansy mustard. This annual weed prefers dry, sandy soils in semi-arid areas. Intoxication in cattle, which usually occurs only after they eat large amounts over an extended period, results in partial or complete blindness, inability to use the tongue and aimless wandering.

Several years ago, ranchers in Montana reported photosensitization (an allergy to sunlight) in cattle. The ailment is characterized by swelling of skin
exposed to the sunlight, including the head and udder. It can be caused by several factors, including toxins in plants. Plant toxins can either directly enter the bloodstream (primary photosensitization) or can damage the liver, affecting its ability to metabolize chlorophyll (secondary photosensitization), thus increasing levels of phylloerythrin in the blood.

"Photosensitization is generally not fatal, but it often occurs in the spring when cattle are nursing calves," Pfister says. Affected cows with sensitive udders won’t let calves nurse. They also tend to lose weight and don’t rebreed well.

Many ranchers attributed the ailment to tansy mustard. Pfister conducted two feeding trials with the weed over 2 years. None of the cattle in the experiment developed any of the symptoms reported by ranchers in Montana, even though every time Pfister investigated a report, cattle had been grazing on fields infested with tansy mustard. He then collected plants and seeds from a field where photosensitized cattle had been grazing. Hamsters that were fed the material for 3 weeks developed severe liver lesions.

"We don’t know why these lesions did not occur in cattle during the feeding trials, but we will repeat the experiment and also try to identify the toxin," Pfister says.

Ultrasound. Panter uses ultrasound to determine how and when poisonous plants affect fetal growth and development, information ranchers can use to reduce risks associated with grazing. Narrowing the period of susceptibility also facilitates diagnosis.

Ultrasound indicates that several poisonous plants reduce fetal movement by reducing muscle contractions. The reduced movement doesn’t deform bones but does cause deformities such as cleft palate and curvature of the spinal column.

As many as 20 to 30 percent of the calves in some herds have been deformed following the ingestion of lupine, a major poisonous plant in the western states. Ultrasound indicates that lupine and poison hemlock appear to affect fetuses from days 40 to 70 of gestation in cattle and days 30 to 60 in sheep. "We can probably narrow this range to a 5-day sensitive period," Panter says. The most vulnerable period appears to be 35 to 40 days in sheep and 40 to 45 days in cattle.

Protective conditioning. Animals seem to have some control over their susceptibility to harmful substances, a phenomenon which might eventually be useful in increasing their resistance to poisonous plants. For example, rats excrete more saliva and change the composition of saliva in order to bind and excrete harmful tannins.

To determine whether it's possible to condition an animal’s physiological responses, Pfister, USU psychologist Carl Cheney and USU range scientist Fred Provenza will give rats a drug that enlarges their salivary glands, thus mimicking their response to tannins, and will then pair this drug with a particular flavor. The researchers will then determine whether rats will enlarge their salivary glands and change the composition of saliva when just the flavor is administered. If so, they will see if the response varies in different environments or contexts.

Pfister notes that cattle exposed to some plant toxins tend to produce different liver enzymes, a defensive response that might be analogous to how rats respond to tannins. Some drugs also induce the production of these enzymes. Pfister says there is also plenty of anecdotal evidence to indicate that cattle do poorly—and sometimes drop dead—when they eat poisonous plants after having been moved to an unfamiliar environment. Such a response may have a human equivalent in an unfamiliar environment: Some drug addicts become fatally intoxicated by a drug dose that they usually tolerate in familiar surroundings. "There is a substantial body of literature on context-specific effects, and we have all heard about animals that have died soon after they have been moved," Pfister says. Researchers will eventually determine if levels of protective liver enzymes are a conditioned response, and whether livestock compensate for unfamiliar environments by altering enzyme levels.

Poisonous plants are still the harbingers of grisly death and garish disorders, but researchers have loosened their grip on western rangelands. Someday, it might be possible to help livestock improve their own defenses against these plant-borne toxins.

JC/KG

Poisonous Plant Research Laboratory 752-2941

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What has several billion inhabitants and four legs?

Any ruminant, of course. Although we have relied on these versatile creatures for thousands of years, only now are scientists plumbing the secrets of the digestive system of these mobile fermentation vats. And what they’re learning could markedly improve the efficiency of producing meat and milk.

Scientists are still trying to figure out how these microbes break down feed, but it’s clear that they do better on some diets than others. And that can make a whopping difference in the performance of cattle, says Randy Wiedmeier, USU animal scientist who is studying how to make more productive use of low-quality forages.

“Potentially, there’s almost as much energy in barley straw as in the grain,” he says. The secret is to help the fiber-digesting microbes break down indigestible components so they can transform them to a form that can be utilized by cattle.

- Adding a supplement such as natural proteins can stimulate desirable rumen microorganisms. This can improve the degradability of forages by 5 to 10 percent.
Chemical treatment. Treating low-quality forages with ammonia can increase degradability by 10 to 15 percent above that achieved by supplementation, Wiedmeier says. And digestibility can be further increased by 20 to 25 percent by simultaneously treating forages with ammonia and hydrogen peroxide. Ammonia detaches the lignin from forages so it is more accessible to rumen microbes. The hydrogen peroxide oxidizes and breaks down the lignin, further enhancing digestibility. Wiedmeier’s studies show that treating barley straw with ammonia and hydrogen peroxide increased the digestibility of barley straw to sheep from 45 percent to 75 percent.

Plant selection. According to studies by USU agronomist Ralph Whitesides, the digestibility of straw from various wheat varieties used in breeding research varies from 38 percent to 62 percent. “With that type of variation, there’s definitely room for selection. Perhaps the digestibility of straw could be included as a criterion in plant breeding,” Weidmeier says. Researchers elsewhere have found that selection improved the digestibility of corn stalks by 40 percent.

Genetic selection of livestock. Weidmeier has just started to study whether genetic factors determine a cow’s ability to digest forages. “During the last 4 years, there has been a great deal of variation in animals’ response to low-quality forages,” he says. For example, cattle were fed ammoniated straw for 160 days last winter. Some lost more than 400 pounds while others maintained or gained weight.

A study now underway is determining whether it’s feasible to select and breed cattle for their ability to utilize low-quality forages.

Weidmeier says there could be several genetic traits governing any differences in the ability to utilize forages. For example, a cow able to lower its normal body temperature of 39°C by just 2°C would save substantial amounts of energy during the winter. Inherited traits governing the rumen environment could also alter the efficiency of metabolism, as could subtle changes in physiology or metabolism.

Events in the rumen may also explain why the ponderosa pine needles induce abortions in cattle. When Wiedmeier and range scientist J. A. Pfister with the USDA Poisonous Plants Research Laboratory fed Holstein steers diets in which pine needles replaced 15 or 30 percent of the grass hay, pine needles dramatically changed the numbers and proportions of several types of rumen microorganisms, perhaps enough to reduce nutrient utilization. Altered products of rumen metabolism have been linked to other diseases, such as acute bovine pulmonary emphysema.

The rumen environment also affects milk production. One problem is that rumen acidity increases on high concentrate rations. Sodium bicarbonate is often added to rations as a buffer, but USU dairy scientist Michael Arambel thought that dolomitic limestone, which is less expensive, might work as well. Not so. Although cows readily ate rations containing limestone, the limestone “just was not as effective as sodium bicarbonate,” Arambel says.

Arambel is also studying ways in which high-fat feeds, which are good sources of energy for high-producing cows, might be protected from degradation in the rumen and absorbed in the intestine, thus bolstering milk production. “When broken down in the rumen, the fat from high-fat feeds coats feed particles and reduces the digestibility of other feeds,” Arambel says.

Increased premiums for protein have also spurred interest in a rumen environment that will increase the protein content of milk. In a 100-cow herd with a 60-pound average, each point (one-tenth of a percent) increase in the protein content of milk could mean $500 more income per month, Arambel says.

One method is to protect protein from ruminal degradation (by-pass protein). “It’s more efficient for a cow to absorb protein in the intestine than for bacteria to break down and resynthesize protein in the rumen,” he says. Rumen bacteria do not require protein and can thrive on less expensive sources of nonprotein nitrogen such as urea.

Feather meal made from processed feathers was a potential source of by-pass protein, but Arambel found that it was equivalent to soybean meal, a degradable source. However, feeding nondegradable sources of protein such as meat, bone and corn gluten meal to cows injected with bovine somatotropin increased the protein content...
of milk by about 2 points, and also increased milk’s casein levels.

Other studies involved a commercial product containing cellulase, an enzyme which breaks down fiber and would ostensibly allow the fiber-digesting bacteria in the rumen to increase. The number of fiber-digesting bacteria tended to increase in some diets, but not as much as expected. However, Arambel says the results indicate the potential value of the product in manipulating fermentation in the rumen.

Because the rumen must be stimulated by large particles in order to function properly and efficiently, forages are essential, and top-quality alfalfa is one of the best. Even though the rumen contains billions of microbes, a few more might help, particularly if they’re added to alfalfa before it’s eaten. Arambel inoculates alfalfa with bacteria before ensiling in an attempt to enhance the fermentation process. Adding bacteria that produce lactic acid can decrease pH during ensiling and inhibit the growth of undesirable spoilage organisms. There’s also some indication that inoculation can increase the nutritional value of the feed. A commercial inoculant that he studied did stimulate a more rapid decline in pH, but apparently didn’t affect feed quality.

THE RUMEN:
FORM
AND
FUNCTION

he rumen could be one of our best allies in alleviating human hunger.

The supposedly voracious appetite of the U.S. beef cattle industry for cereal grain, which critics claim should be used to alleviate human hunger, still sparks considerable criticism. Currently, about 2,000 pounds of cereal grain are required to produce a 600-pound carcass.

Not all of the criticism is warranted. Even with grains, beef cattle make considerable use of otherwise inedible forages, says USU animal scientist Randy Wiedmeier. However, it’s at least theoretically possible for ruminants to extract as much energy from straw as from grain, although it’s currently economically advantageous to feed grain.

“More and more land will be designated for human food production. Our job is to prepare for that day,” Wiedmeier says. “That day” is edging closer with escalating fossil fuel prices and a burgeoning human population.

The ruminant’s stomach represents the pinnacle of stomach evolution among mammals. The events in its four compartments—the reticulum, rumen, omasum and abomasum—and its ecology are a masterful fusion of form and function.

Trillions of microorganisms—bacteria, fungi and protozoa—reside in any normally functioning rumen, gently sloshed by muscle contractions (every 50 to 70 seconds or about 1,500 times daily in the
Rumen muscle contractions are choreographed to properly stir and move food. (Without contractions, the stagnation would cause a fatal accumulation of feed and gas.) Waves of contractions follow waves of relaxation. Some sacs may dilate while others contract.

The rumen is not a simple fermentation vat filled with a random assortment of microorganisms. Scientists have identified about 60 species of bacteria in rumen contents and think that half of these species may be important in digestion. Some are attached to feed particles, others cling to the rumen wall. Some prefer to stay in the liquid. Yeasts and aerobic fungi, whose roles have not been identified, proliferate on a high fiber diet. Protozoa attack bacteria and may stabilize fermentation.

On a normal diet, one that contains enough forage particles longer than 1/4 inch to stimulate muscle contractions, cattle spend about 8 hours a day eating, 8 hours ruminating, and 8 hours resting. "Chewing the cud" (rumination), is often viewed as a contemplative activity. It isn't. Rumination starts when enough large particles spill into the reticulum, causing it to contract. The cardiac sphincter leading into the esophagus then opens, and liquid and particles are propelled into the mouth (The regurgitated bolus of food and liquid in the esophagus has been clocked at speeds of 4 to 6 feet per second.) Ecologists think this system lets ruminants eat rapidly so they can chew later at a location safe from predators.

Gas, mostly carbon dioxide and methane, is released during regurgitation. Unlike a belch, any gas belched from the rumen passes into the lungs before it leaves the animal, perhaps another noise-reduction tactic to avoid detection by predators. The ruminant immediately swallows much of the liquid and mixes feed with saliva. Lots of saliva, perhaps about 180 liters of saliva daily by a cow on a high-forage diet. The alkaline saliva buffers the rumen contents at a pH of 6.0 to 6.7, partially neutralizing the acid wastes created by the formation of microbial cells.

This intricately controlled digestive system means ruminants have much simpler and cheaper dietary requirements than nonruminants. With the energy in fibrous compounds like cellulose, they can synthesize B vitamins and utilize poor quality proteins to produce highly nutritious meat, milk and innumerable other products.

Researchers have long used cannulae in fistulated animals to monitor events in the rumen. The four cows and eight sheep that Wiedmeier studies don't mind (there are no pain nerves in the rumen) and often don't even stand up during sampling. One cow has been cannulated for eight years without any ill effects. Another cow lived with the device for 18 years.

Wiedmeier uses stainless steel strainers to take samples without actually reaching into the rumen, which avoids the pungent odor that seems to penetrate even the plastic sleeve worn over the arm. ("My family knows when I've been taking rumen samples," Wiedmeier says.)

Farmers are already reaping the benefits of products, such as monensin, that change rumen fermentation and improve feed utilization. The more researchers learn about rumen functions, the better the diets that capitalize on ruminants' remarkable abilities.
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