UTAH SCIENCE is a quarterly publication devoted primarily to Experiment Station research in agriculture and related areas. Published by the Utah Agricultural Experiment Station, Utah State University, Logan, Utah 84322-4845.

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A Publication of the Utah Agricultural Experiment Station at Utah State University. Volume 58 Number 4 Summer 1998
Last year a little lamb named Dolly, cloned by researchers at the Roslin Institute in Scotland, made headlines around the world and pushed cloning to the front of our mainstream consciousness.

But cloning is not new to agriculture.

Reproductive biologist Ken White is quick to point out that while huge advances have been made in the past few years, experiments in cloning agriculture animals have been going on for 20 years. However, familiarity hasn't squelched the enthusiasm White and his USU colleagues have for finding ways to painstakingly assist nature with embryo transfer, cloning and engineering transgenic animals.

The economic benefits of transplanting healthy animal embryos with desirable genetic characteristics into recipient mothers probably seems straightforward to most people. But methods used to create clones and the reasons for cloning animals may sound more like science fiction to people outside the biotechnology industry.

Creating animals to economically produce proteins needed in pharmaceuticals and increasing the populations of endangered animal species are just two applications of cloning that drive researchers.

When you cut through all the hype, cloning simply means creating an exact duplicate of an organism. In the early 1980s, researchers in the embryo transplant industry began slicing embryos in half to create the possibility of producing two identical calves from a single embryo. White says the practice became very common, driven by the economics of being paid according to how many pregnancies your transplant methods produced.

Also in the early 1980s, a scientific paper was published about transferring cell nuclei into unfertilized eggs which already had their own genetic material.
removed. Work began to speed up in labs all over the world.

White said the mechanics of nuclear transfer are really quite straightforward and simple once you learn the process and work through it several times. In the lab, immature eggs—oocytes—are removed from animal ovaries. Once cattle or sheep oocytes are removed from the ovaries, they begin to mature spontaneously and the eggs are grown in a culture medium in the lab for about 24 hours.

Under a microscope, the nucleus of each egg is removed using a tiny, hollow needle. What's left is the shell of the former egg, or an enucleated egg. The nucleus is then replaced with a normal cell taken from an embryo, fetal tissue or, in Dolly's case, an adult animal. The egg and cell are then placed in a chamber between two electrodes and the jolt of electricity the pair receives rearranges the membranes of the cell and enucleated egg, fusing them into a single egg.

Once scientists could transfer cell nuclei into eggs, they created the possibility that a single cell could be used to generate a new embryo and thought perhaps they could grow embryos in culture for several days producing embryonic stem cells that could be grown for several weeks or months before being used to produce more animals.

"Being able to hold those cells makes a number of things easier," White said, "It makes it easier to produce a tremendous number of identical animals with desirable characteristics. It also allows you to introduce genes for desired traits and test the cells to make sure the genes work properly so you only use good ones to produce animals."

It all sounded like a good idea. But before 1996 no one was able to generate an embryo that would develop to term. Many groups generated embryos and established pregnancies in animals, White said, but most were lost at about 60 days. "It left us wondering why these cells didn't seem able to reprogram to maintain a full term pregnancy," he said.

In 1996, Ian Wilmutt and his colleagues, who announced Dolly's birth last year, altered some laboratory procedures and managed to produce live lambs from embryonic stem cells. Then in 1997, Dolly gave a bleating wake-up call about how far the technology has come.

"Everyone is hung up on Dolly, but she was the product of just one of three cell lines," White said. "They experimented with embryonic and fetal cells, and Dolly was produced from an adult mammary cell. It's remarkable though, because just a year ago few
people would have believed you could take a cell from
a fetus or an adult and make a new animal.”

In the world of science though, even a remarkable
creature like Dolly is only an oddity until someone
else manages to duplicate an experiment and get the
same result.

A team of USU animal reproductive biologists,
including White, Thomas Bunch, William Reed and
Shukhrat Mitalipov, are focused on cloning as a tool to
reproduce an endangered species of sheep. Argali
sheep are native to Central Asia and found mainly in
Tibet, China and Mongolia at elevations of 12,000
feet or higher. Bunch said it’s difficult to estimate the
number of surviving Argali, but their overall numbers
have diminished drastically over the past few years and
they are no longer found in Pakistan and Northern
India where they once were.

Bunch, who has spent many years studying various
species of wild sheep, said the Argali are the largest of
all wild sheep, with a striking white bib of hair around
their necks and have the largest horns of any wild
sheep.

Bunch did chromosomal studies of Argali a few years
ago, and, because they are a rare breed, he preserved
some adult cells in liquid nitrogen.

“When the group in Scotland announced its work, we
decided to try using the Argali cells,” Bunch said.

White said the endangered species application of
cloning gets less attention than does creating clones to
produce proteins for pharmaceuticals. One reason is
concern over losing genetic diversity in a small
population of animals.

“It’s true we don’t want to lose genetic diversity, but in
some cases there are so few animals that genetic
diversity is already gone,” White said.

Cloning could prove very important if the goal is to
save a species from extinction. If the procedure can
become routine, White said it makes more sense to
close together an animal from
one zoo and one from another zoo, and hope that they
mate.

“Even if they did produce offspring, who do they mate
that animal to the next time?” White said. “If the
numbers of a population are very low you are left
with mating siblings or parents and then genetic
diversity is lost. If cloning becomes more efficient, you
could take cells from animals in different places and
then place cloned offspring in other areas of the
world to alter the genetic pool.”

Key to the cloning process is that the nucleus donor, in
this case an Argali sheep, the egg donor and the
surrogate mother must be closely related. If two of
the three animals in the equation can’t hybridize,
chances are small that an embryo will develop and grow to full term.

Bunch has spent many years studying big horn sheep and knew that Argali’s do hybridize with domestic sheep. That suggested that the two species are compatible. White and Bunch did preliminary work transplanting Argali cells into cattle oocytes and managed to produce healthy embryos.

“We thought that if we could put bovine and ovine cells together and get an embryo, there was high likelihood we could put Argali cells and domestic sheep oocytes together and get embryos from that,” White said.

Guided by their previous efforts, and using Rambouillet and Columbia sheep, the team performed embryo transfers early this year. Now, like all expectant parents, they are left to wait for a much anticipated delivery.

The pharmaceutical uses of proteins produced by cloned animals—pharming—are very attractive to industry for many reasons. Proteins are complex structures and more than just a matter of lining up the right amino acids in the right order.

“Some proteins require that specific sugars attach to specific points on the protein backbone, others require special kinds of folding,” White explains.

Proteins can be produced using engineered bacteria or harvested from plants or animals. But bacteria also produce toxins that must be purified away from the needed drug, creating a lot of waste that can’t just be flushed away. And bacteria don’t add sugars or cause the complex folding some proteins require. Sometimes a needed protein is only found in a single type of plant or animal that exists in just one obscure region of the world. If genes from those plants or animals can be introduced into animals that produce milk, the animals will make the protein and secrete it in the mammary glands, which White calls the “perfect model of efficiency for protein production.”

Then it’s just a matter of cloning those very special animals to produce a very cost-effective supply of proteins.

Research at USU is being funded by Utah Centers of Excellence program through USU’s Center for Developmental and Molecular Biology, a federal Small Business Innovation Research Grant through PanGenics, Inc., and a private donation from Donald Cox through the USU Foundation.

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USU’s team of animal reproductive biologists, (from left) Ken White, Thomas Bunch, Shukbrat Mitaipev and William Reed are working on endangered species cloning.

The Utah Agricultural Experiment Station
In unscrambling the puzzle of sheep genetics, researchers at USU and the University of Illinois have found the genetic defect responsible for the disorder commonly known as Spider Lamb Syndrome, and have developed a relatively simple test to identify animals carrying the defective gene.

Spider Lamb Syndrome, also known as hereditary chondrodysplasia, is believed to have arisen as a genetic mutation that occurred in the late 1960s in a Suffolk bloodline. That particular genetic line was heavily used for breeding, disseminating the spider gene, as well as the line’s outstanding production and show-ring genetics.

Spider lambs have curved spines and get their name from the abnormally long, bent limbs that are sure signs of the defect.

USU molecular biologist Noelle Cockett, who tracked down the genetic marker, said some lambs are more difficult to diagnose by sight than others, but some are born with such severely splayed legs and malformed spines they are unable to walk or even stand.

Originally found in Suffolk sheep, spider lamb syndrome now appears in several breeds, including Hampshires, Shropshires, Oxfords and Southdowns.

When the disorder first appeared, breeders were baffled as to what was causing the problem, said Cockett. For a time, sheep producers blamed the misshapen lambs on poisonous plants ewes may have consumed during pregnancy. But some scientific detective work soon pointed to a genetic abnormality.

What researchers found was a recessive mutation, which spider lambs inherit from both parents. Since it is a recessive gene, “carrier” animals have a normal
appearance, but have one copy of the spider gene and can produce a spider lamb when this gene is paired with a spider gene from another adult carrier.

After testing about 150 genetic markers, Dr. Cockett found a marker called OarJMP8 that was closely linked to the spider lamb gene. Because the marker had been previously mapped and assigned to sheep chromosome 6, Dr. Cockett knew the spider gene must lie on the same chromosome.

Dr. Cockett and her collaborator, Jon Beever of the University of Illinois, aligned sheep chromosome 6 with its human counterpart and found that the culprit for spider lamb syndrome is a mutation in gene known as fibroblast growth factor receptor 3 (FGFR3).

Defects in the FGFR3 gene can also cause skeletal deformities in humans, such as dwarfism and abnormally shortened limbs. Dr. Cockett explained that the gene is involved in the precise developmental timing that is crucial for normal bone growth.

In humans with the defective FGFR3 gene, bone growth is turned off too early. In spider lambs, it appears that when bones should receive a signal to slow their growth, the message doesn't get through. As a result, bones grow abnormally long.

In support of this idea, Dr. Cockett said recent studies have shown that when FGFR3 is functionally removed...
in mice, they are born with the same sort of curved spines and abnormally long limbs that spider lambs exhibit.

Dr. Cockett and Dr. Beever have developed a commercial genetic marker test that can identify the genetics for spider lamb using blood or semen. The test can be completed in a matter of days, replacing the need for progeny testing in which animals are bred with known carriers to see what sort of lambs they produce months later.

As expected, some sheep producers have been resistant to having their sheep labeled as carriers. However, breeders can keep carrier sheep in their flocks and play a carefully planned game of genetics roulette when pairing sires and dams in order to avoid the production of spider lambs.

But why would breeders avoid testing their flocks when the industry has hoped for a diagnostic test for so many years? There are reasons:

Although the mutation originally occurred in a Suffolk bloodline, spider syndrome is now found in several other breeds. If tests confirm carriers in flocks of other breeds, these breeding lines would not be as pure as believed or professed.

"The consumer will prefer the callipyge lamb chop on sight," Dr. Carpenter says, because consumers often equate size with quality.

Its leaner meat will also satisfy current consumer demands for a lower-fat diet. "But," Dr. Carpenter says, "if you want the advantage of leaner meat, it's going to be less juicy."

The inherent toughness comes from a difference in its myofibrular (contractile) proteins. In most lamb meat, tenderness is determined primarily by the connective tissue; in the callipyge buttocks only, the primary determinant of tenderness is the myofibrular proteins, which override the effect of the connective tissue.

Dr. Carpenter's method of tenderizing the chop is called Ultra High Temperature (UHT) processing, which was patented by USU food scientist Von Mendenhall. As meat ages, enzymes will tenderize it naturally, but the process creates spoilage. UHT solves that problem by searing and pasteurizing the surfaces of the cuts only a couple of millimeters deep, killing all the microorganisms.

Meat only needs to be sterilized on its surfaces because, except for where it comes into contact with machinery or human hands, all meat is sterile. Otherwise, "we'd all be sick all the time," Dr. Carpenter says.

UHT sears the surface but leaves the rest of the meat raw, and as the meat ages, it tenderizes naturally. Tests using instruments that measure how much force it takes to cut into meat (simulating the action of chewing), have yielded positive results. The end product, Dr. Carpenter says, can be microwaved in minutes and tastes as if it were grilled.

A series of taste tests just conducted by Dr. Carpenter bore out his research. "Our results showed promise to the industry, but unless people are interested and want to put up money for research, it will end here," he says.

Not only have cost efficiency and leanness been unable to overcome the bad publicity about toughness of the chops, another disadvantage is producers would have to change their breeding processes. The callipyge gene is part of a complicated genetic process; it's not straight dominant-recessive producers are used to.

In its unique mode of inheritance, the gene is turned on and off by the mother, but passed on by the father. The different genetics would be difficult, but may be worthwhile for producers, Dr. Carpenter says, adding, "Sheep producers are smart
people. Even if they didn’t understand [the biochemical processes] they would understand [practical applications] if it would make them money."

Even if the lamb industry never accepts callipyge, research will continue because of general scientific interest in the gene. While researchers have not located the actual gene, they have discovered its markers, and USU biochemist Noelle Cockett is working on locating and cloning the gene. (See accompanying article.)

Whether the gene is expressed in muscle or if the muscle is just responding to other factors is not known. "Muscles respond to so many different things," Dr. Carpenter says, such as hormones. As a contrast to callipyge, he cites "double-muscle cattle," which, as their name implies, are also heavily muscled.

"The end result—hypertrophy—is similar," Dr. Carpenter says. "But the biochemical mechanism is different."

Double muscle cattle have more muscle cells than normal cattle, while the callipyge gene causes an enlargement in the individual cells.

If scientists can understand the callipyge gene, they can understand the growth and development of all meat.

"There is a fair amount of interest from the scientific community," Dr. Carpenter says, so the research in that arena will continue.

As for Dr. Carpenter, he’s finished. He’s compiled the data and written the paper on UHT. Barring a dramatic and unforeseen change, he’s said goodbye to the project that has occupied his time for nearly three years.

As for the callipyge gene’s future in the industry, he says, "It will all come down to industry perspective."

—Angela Hill

The body conformation sought by breeders of show lambs may be the factor even more responsible for producers’ reluctance to eliminate carrier sheep from their flocks. Judges currently tend to reward sheep with tall stature and slender bodies.

Researchers originally thought sheep that carried one normal and one spider gene looked just like the animals with the normal/normal genetic combination. But Dr. Cockett and Dr. Beever have found that the normal/spider carriers tend to be “leggier” than sheep without the spider gene - just the appearance that is emphasized by breeders.

Genetic testing may indicate that the very sheep producers are pampering for showstock are carriers of the spider gene.

“At this point, I think the real use of the test will be for breeders who want to have their flocks certified ‘spider free,’” Dr. Cockett said.

— Lynnette Harris
UAES Information Office
FORMER ASTRONAUT GIVES GRADUATES LAND GRANT LESSON

(The following is a portion of the text of Mary Cleave's address to the 4,200 members of the USU Class of 1998. Dr. Cleave, a USU alumnus and a recipient of an honorary doctorate in Engineering Science at this year's ceremonies June 6, was selected as a NASA astronaut in 1980. She logged 262 hours in space on two missions. She left the astronaut program in 1991 and is now project manager for NASA’s sensor program that monitors global marine chlorophyll. While a student at USU in the mid-1970s, she received a master's degree in microbial ecology and a doctorate in civil and environmental engineering.)

The tradition of land grant schools, that we embody, is one we can truly be proud of. Although you are certainly aware of your responsibilities as a graduate of a land grant institution, I would like to take this opportunity to refresh your memory.

In the early 1800s, university education was available only to the privileged few who could afford tuition at private universities. President Lincoln signed the Morrill Act, which gave 10,000 acres of federal land to each state, with which to establish public universities. This was the origin of land grant schools, 156 years ago. These schools educate formally in classrooms, informally through Extension Services, and conduct research for the benefit of civilization. Land grant schools promote lifelong learning, and that is what is required of an ever greater portion of our population as technology advances. As aggies, we are trained to help civilization benefit from our technological advances. That is quite a responsibility considering how very deeply technological advances are affecting all of us and the planet we live on. Our educations are subsidized by taxpayers for the greater good of our civilization. You may want to reflect on that as you make decisions in your life, and also when you fill out your first working tax return and suffer what some refer to as "sticker shock."

...When I was young, all astronauts were male test pilots and I never would have set a goal of flying in space. However, the world changed, and my goals changed. Flying was a favorite hobby of mine from the age of 14. I soloed at 16, and got a private pilot's license at 17, but it never occurred to me that I could be a pilot. Before graduation from Colorado State in 1969, I aspired to a career in aviation. I applied for a job as an airline stewardess, but my height was two inches too short. One decade later, I was accepted into astronaut training. Stay flexible and keep looking for those opportunities. It makes life a lot more fun.

One commitment we all need to make is to honesty. Each of you will need to be a leader at one time or another. You will be setting the example. You will be leading by example. If any of that baggage you are carrying along isn't honest, it will probably catch up with you. This information age facilitates greater accountability for our actions, as our statistics are collected, saved, and provided on line. Some states are now increasing accountability for child support payments by using driver license records, for example. You may need a security clearance or a confirmation hearing some day. Honesty is the best policy.
One thing that space flight does for you is shrink the planet. You go around the Earth every 1 1/2 hours. It takes 7 1/2 minutes to fly across the United States. It gives exercise a whole new meaning; 7 1/2 minutes of running on the treadmill and you can claim to have run across the U.S. But it also makes you understand how small our planet is. In the four years between my two space flights, I could very easily see the changes that we humans are making on the surface of this planet. That rate of change is very fast, too fast for us to really understand the potential impact those changes could have over the long-term to our existence on this planet. Deforestation, erosion, dust storms, and smoke from large fires are all very evident from low Earth orbit. Cities look like big gray smudges, and these smudges are getting bigger. We are using resources like trees, water, soil, and clean air at a faster rate than they are being replaced naturally. We need to think about how many humans on the planet are too many, and hopefully find a solution that is humane. Do we want a “gourmet” or “gourmand” existence on this planet? You will all help decide.

**FIELD DAYS 1998**

Each summer the Utah Agricultural Experiment Station and USU Cooperative Extension sponsor field days aimed at giving growers a firsthand look at research plots, direct access to new information, and an opportunity to pose questions to researchers.

For more information regarding field day times and activities, check the UAES site on the World Wide Web at [http://ext.usu.edu/agx/], call your local county Extension office, or the faculty member listed.

**July 15** - Small grains research  
Blue Creek Dryland Farm Field Day  
18 miles northwest of Tremonton on I-15,  
take the Valley Exit, then six miles north  
to the Blue Creek Farm.  
Ralph Whitesides, (435) 797-2259

**July 22** - Irrigation, soils, grass, pasture,  
asparagus, shade tree, and  
other research plots.  
Greenville Farm Field Day  
1857 N. 800 East, North Logan  
Ralph Whitesides, (435) 797-2259

**August 18** - Onion Growers Summer Tour  
Meet at Hines & Co.  
1140 W. Gentile St., Layton  
Dan Drost, (435) 797-2258

**August 20** - Horticulture Field Day  
Kaysville Field Station  
Corner of Main St. and  
Burton Lane, Kaysville.  
Just south of Davis High School  
Vegetable, weed control, integrated pest  
management, tree fruit research  
Dan Drost, (435) 797-2258

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*The Utah Agricultural Experiment Station* 11
By page 15 of the handout for Fred Provenza's annual summer short course on range management, any doubt has been erased that something different is at hand. Scheduled discussion topics listed there include Newtonian Mechanics, Quantum Theory, Relativity Theory, Non-equilibrium, Mathematics, Significance of Mythology, and the Unity of All Things.

And that's just the subject matter for the first day.

The USU range science professor advises his audience that the going will be difficult, maybe even bewildering at first. But a short course within the short course is required before the 30 or so range managers and scientists from around the country can have a hope of understanding Provenza's main point: good range management is based on how well you adapt to change, not how well you predict it.

Provenza first herds his flock away from traditional thinking—that the ultimate goal of science is to lead to accurate forecasting of animal behavior.

Consider for a moment, Provenza says, what has been discovered about life the past century:

- Nature is relative, not absolute.
- Nature might be knowable but it is inherently unpredictable.
- Physical and biological processes of animals and their environments are never static.
- Change is not an exception to the rule; it is the only rule.
- Life for all animals, humans included, is comprised of periods of instability, choices in the face of uncertainty and interludes of tranquility.
- There can be no absolute characterization of behavior.

The behavior of any individual—be it foraging animal, a human being, an elementary particle—reflects its evolutionary history, its cultural history and its ongoing interactions with its environment, Provenza says.
Its behavior will follow some predictive laws, but any system is ultimately unique and self-organizing; any animal's life evolves from action and feedback loops that change the animal and its environment irreversibly over time, he says.

"In other words, things were never the way they were, and they never will be again."

After the laughter dies down, Provenza assures the group he isn't joking, even though the statement sounds as if he must be.

The classical Newtonian notion of cause-and-effect must be supplemented with a fact of life Provenza calls "self-organization," which views life as transformation; the only constant is change.

A self-organizing system, such as a foraging animal, is greater than the sum of its parts, he says. The behavior of the animal cannot be deduced fully from its parts or from the rules by which they interact.

"Ultimately, each individual organizes its own world and behaves in its own unique way."

Therefore, foraging can be understood only in a "dynamic context" that begins at conception and ends with death, which in itself another transformation. "It can be said that eating is the realization that from death comes life, and if you're eating you are part of that cycle."

Research and observation clearly show that interactions between an individual and the environment transform both the individual and the environment, he says. The individual acts in accordance with the structure of its body. It reacts and changes in response to feedback and constantly reshapes itself and its environment.

On the range, the interactions between the foragers and the food sources can lead to some remarkable foraging patterns that give the illusion that the animals are obeying some blueprint. However, each individual is behaving according to information it has obtained through interpreting a constant flux of signals.

A thought-provoking example of self-organization can be found in our own central nervous system, Provenza says. When the olfactory system is at
rest, electrical activity is random and chaotic. But when we, or any animal, encounter a familiar or new odor, neural activity reorganizes after being destabilized by new information.

"That is clear support for the notion that learning and feedback are ultimately inseparable."

In other words, he says, the body determines the structure of experience, which in turn determines the structure of the body; environments shape individuals, which in turn shape environments.

When considering foraging animals, you have to consider motivations that humans have attributed to animals, such as the widespread notion that an animal's ultimate goal is to find the most and best food.

Animals do learn about different foods. But unlike many animal behavior scientists, Provenza's research shows that animals don't actively pursue occasions to learn. They don't eat to learn, they learn while they eat.

"We argue that animals interact with their environment no more 'actively' or 'passively' than they 'labor' to evolve, or the sun 'works' to heat the Earth."

Provenza's research has prodded him toward that conclusion because it has shown that food preference changes in animals are involuntary and will in fact occur even when an animal is anesthetized or deeply tranquilized.

Ruminants eat an array of foods, varying in nutrients and toxins. For instance, sheep prefer to eat clover in the morning and grass in the afternoon. Provenza says that selection of a variety of foods makes intuitive sense, but no theories adequately explain this diversity.

Some say that animals eat a variety of foods because doing so inherently reduces the likelihood of overingesting toxins. Others theorize that eating a variety of foods help meet nutritional needs.

However, Provenza says, both theories are inconsistent with the tendency of herbivores to consume a diversity of food even when toxins are not a concern and nutritional needs are met.

Provenza proposes and his research shows that aversion—the decrease in preference for food just eaten—drives all animals to seek a variety of foods.

Deficiencies will also cause an animal to seek variety, Provenza says, noting that goats in Utah near St. George went against common feeding patterns by eating woodrat houses because they were lacking protein that was available in the rats' urine-soaked houses. Cows have eaten rabbit bones if they are low in phosphorus.

For any individual to survive, it must be able to cope with change, Provenza says. Any animal's preferred behavior regarding where, when, what and if they eat is determined by an infinite number of factors, including not just availability...
of food, but what the animal has learned to like and to avoid.

They face the additional challenge of meeting their nutritional needs because a plant's chemical makeup—nutrient and toxin content—changes continually throughout the year, not to mention that an animal's own physiological condition changes constantly throughout its lifetime and the hazards of whatever terrain they inhabit.

People in agriculture—ranchers, dairy and feedlot operators—want to provide their animals with an ideal diet, Provenza says. Yet, as a result of each animal's unique evolutionary and cultural history, and its current physiological state, predicting food selection and behavior of an individual is impossible.

"When you get right down to it, nature does not dictate—nor can ranchers or scientists adequately predict—which foods an animal will prefer, what it will consider hazards, or even where it will prefer to live in the environment. But nature guarantees animals will do all these things, no matter where on the globe they live." JT

The Problem with Food

Plants present a perplexing array of chemical compounds to herbivores, says USU Range Scientist Fred Provenza. Understanding how herbivores respond to plant chemistry lends one element of predictability to the process of foraging, he says.

Animals as diverse as insects, rodents and ruminants select and respond to nutrients. Animals will select nutritious patches of grass, for example. But they can also acquire preferences even for poorly nutritious food because of where they are and what they have been taught to eat and to avoid.

There are numerous examples of animals avoiding what appears to be an abundant supply of nutritious feed in a new environment after being herded away from the place that had been grazed down but where they felt comfortable.

Ranchers in Southern Louisiana, like many around the country, tell stories of cattle being moved to what they should consider a heavenly supply of grasses, but they will stand and bellow at the fence wanting to get back to where they were. Some even swam a canal to get back "home," one rancher said.

They were not being dumb animals; they were doing what any animal does—trying to hang on to the familiar.

In Provenza's words: The behavior of an adult is influenced by where the animal was born and reared, and by patterns of behavior that emerged from interactions with the social (mother and peers) and physical (different foods) environment.

As a result of experiences early in life, offspring come to prefer the foods and environments where they are reared. "When resources are abundant, animals prefer familiar to strange environments, and they prefer to eat a variety of familiar foods."

Conversely, a lack of resources can cause animals to sample novel foods and move to unfamiliar environments.

continued on next page...
Over-familiarity (i.e., satiety from eating foods too frequently or in excess) can also encourage animals to sample novel foods and to forage in new locations.

"The interface between the familiar (known, safe) and the unfamiliar (unknown, potentially dangerous) are moments of choice that lead to self-organization. By making a choice to venture into the unknown, an individual literally creates its own world. A human does it by deciding to take a new job or to buy a house; an animal tries eating a new kind of plant."

The behavior of any individual cannot be understood independently of its connections to a larger whole, which in the case of foraging includes an animal’s evolutionary and cultural history and its ongoing experiences with its environment.

A Brief History of Change

Considering the fluctuations of the earth and creatures that inhabit it, tranquil periods are the exception, not the rule, in life. The notion that life experiences can be foretold, or that behavior of animals can be predicted, runs counter to nature’s nature, which, as its history shows, is constant change.

Geologically, the Earth has always been active. Its surface is a rocky exterior divided into enormous plates that scour each other, causing the continents to ‘float’ on the somewhat pliable mantle beneath them. The process creates mountain ranges, volcanoes, earthquakes and ocean trenches.

Just as continents ‘drift’ on the mantle below, plants and animals migrate on the surface above.

Earth’s flora and fauna are a diverse mix of millions of species that thrive in a range of environments, from ocean floors to mountaintops, from icy polar caps to sweltering deserts.

During the mountain-building era of the earth, grasses that evolved with horses, antelope-like grazers, giant bison and camels were replaced east of the Rocky Mountains during the Ice Age that followed with bluestems, Indian grass, gramma grass and buffalograss. West of the Rockies, needlegrass, ricegrass and wheatgrasses flourished.

Horses, the grazers, giant bison, and camels that foraged in western North America moved to South America during the Ice Age. As the glaciers retreated some 12,000 to 20,000 years ago, most of the epoch’s megafauna became extinct. They were succeeded by great herds of bison, elk, deer, sheep, goats and pronghorn.
Changes in physical environments today affect the dispersion of herbivores by altering the distribution, abundance, nutritional, and toxicological characteristics of plants. At the level of the landscape, the availability of water, nutrients and sunlight affects soil fertility, which in turn affects plant chemistry.

Resource-rich environments are characterized by nutritious plant species low in plant metabolites that deter feeding by herbivores. Resource-poor environments are characterized by plant species high in compounds that deter feeding, such as tannins, terpenoids, alkaloids, cynogenic glycosides.

Within environments, soil fertility and moisture, as well as sunlight and the kind and amount of past herbivory all affect the nutrient and toxin concentrations in plants.

Nutrient and toxin concentrations change continually as plants grow, mature and senesce. Changes even occur within a day, and livestock—cattle, sheep, goats—manifest, strong preferences for forages—tall fescue, alfalfa—harvested in the afternoon compared with those harvested in the morning.

Environmental perturbations—drought, fertility, fire—also affect plants in ways that are dynamic and difficult to predict. One study shows that nutrient and toxin concentrations of tomatoes change when subjected to increasing drought stress, and in turn create many possible effects on herbivores.

Sunlight, soil moisture, nutrients and the way an area has been grazed all affect the nutrients and toxin in plants, and probably explain why herbivores show such variable responses to plants of the same species growing under different environmental conditions.

(In the second part of this report, coming in the fall issue, several ranchers and range managers will explain how they put Provenza’s methods to work.)
More than five square miles of Cache County's most fertile farmland has been converted to non-agricultural uses during the past 10 years, the North Cache and Blacksmith Fork Soil Conservation District recently reported.

That means that since 1967, the county's food-producing acreage has been reduced by more than 15 percent, or by 30 square miles.

The three-year assessment by the Soil Conservation Districts shows that incorporated areas of the county have lost 36 percent of prime and statewide important farmlands, compared to a reduction of 3.5 percent in the unincorporated areas.

Land in the study is defined as acreage capable of producing food at the last cost with the environmental impacts.

Logan has lost the most land during the past 30 years. Of its 6,825 acres, 1,797 acres remain. That is a reduction of 73 percent.

"The land is the natural resource from which nearly every commodity in the world originates," said Gordon Zilles, chairman of the Blacksmith Fork Soil Conservation District. "This study should raise concerns for elected leaders and planners who desire to maintain our rural quality of life, ensure a sustainable community for future generations and protect this important productive and renewable natural resource."

This map shows the change in farmland and residential/commercial uses between 1986 and 1996. It also details where development is creating pockets of residential use throughout the county. The red and yellow areas indicate hot spots where agriculture is losing ground.
# Loss of Prime Farmland by City:

A Community Report Card—Prime and Statewide Important Irrigated Farmland—Cache County

<table>
<thead>
<tr>
<th>City (Incorporated)</th>
<th>Total Acres</th>
<th>Total Loss Since 1974</th>
<th>Total Loss 1986-96</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Acres</td>
<td>Percent</td>
</tr>
<tr>
<td>Amalga</td>
<td>1626</td>
<td>197</td>
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<tr>
<td>Clarkston</td>
<td>371</td>
<td>269</td>
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<tr>
<td>Cornish</td>
<td>2310</td>
<td>171</td>
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<td>Hyde Park</td>
<td>1581</td>
<td>716</td>
<td>45.3</td>
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<tr>
<td>Hyrum</td>
<td>1905</td>
<td>1211</td>
<td>63.5</td>
</tr>
<tr>
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<td>12,944</td>
<td>1087</td>
<td>8.4</td>
</tr>
<tr>
<td>Logan</td>
<td>6825</td>
<td>5028</td>
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<tr>
<td>Mendon</td>
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<tr>
<td>Millville*</td>
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<tr>
<td>Newton</td>
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<td>379</td>
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<td>418</td>
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</tr>
<tr>
<td>North Logan</td>
<td>2841</td>
<td>1373</td>
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<tr>
<td>Paradise</td>
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<td>495</td>
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<td>Providence</td>
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<td>Richmond</td>
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<td>Trenton</td>
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<tr>
<td>Wellsville</td>
<td>1645</td>
<td>856</td>
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<tr>
<td><strong>Total Incorporated</strong></td>
<td>44,763</td>
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<tr>
<td><strong>Total Unincorporated</strong></td>
<td>82,537</td>
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<tr>
<td><strong>Total</strong></td>
<td>127,300</td>
<td>19,305</td>
<td>15.2</td>
</tr>
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</table>

*Does not include recently annexed property.

Utah Commissioner of Agriculture and Food, Cary G. Peterson, says Cache County's population growth and the associated sprawl further hampers agriculture's ability to help meet the world's demand for food, which is only expected to double or triple during the next 45 years.

A color map published by the Utah Association of Conservation Districts shows the change in farmland and residential/commercial uses between 1986 and 1996. It also details where development is creating pockets of residential use throughout the county.

For more information about the study, contact Jennifer Hines at 435-753-6029.

Fifteen percent of the total farmland in the county, has lost 30 square miles to development since 1967.

**JT**
Although agricultural chemicals are widely scrutinized for their toxic or carcinogenic effect on animals and people, little is said about the carcinogenic qualities of naturally occurring plant compounds.

USU toxicologist Roger A. Coulombe, Jr. is helping get the word out about plant-derived toxins as a contributing writer of a new book on food safety.

In his chapter on plant compounds, Dr. Coulombe writes that "while the popular notion remains that 'natural is good,' it is clear that natural toxins pose a far greater risk than that posed by synthetic chemicals in our foods."

Fortunately, he says, many foods can also contain natural chemopreventives that are associated with a reduction in risk to many types of cancer.

A survey of approximately 200 studies that examined the relationship between fruit and vegetable intake and incidence of several cancer types showed that an overwhelming majority of the studies demonstrated that intake of fruits and vegetables statistically lowered cancer risk.

The case was "particularly striking for fruits," Dr. Coulombe writes, showing a statistically significant protective effect in 28 of 29 studies against cancers of the esophagus, oral cavity, and larynx, and in 24 of 25 studies for protection against lung cancer.

"Given these strong data already available, organizations such as the National Cancer Institute recommend that people eat a balanced diet with five servings of fruit and vegetables daily."

These chemical compounds are not chemotherapeutics or cancer antidotes per se, but agents that have been shown in various experimental protocols to somehow interfere with the cancer process rather than cure advanced malignancies.

Dr. Coulombe says that experimental protocols that have identified anti-cancer compounds from plants usually involve the administration of the chemopreventive either before, after, or concurrently with some chemical carcinogen.
Chemopreventive action is manifest in several ways, such as reducing the number of tumors, a delay in the time in which tumors develop, or a reduction in the number or size of a malignant or premalignant lesion in an animal.

Many of the plant compounds that are potentially carcinogenic in people are commonly termed “nature’s pesticides” because they are often toxic to predators, such as insects and animals.

“Although these chemicals are in every meal we eat, they have received little attention compared to that given to minute residues of synthetic chemicals such as PCBs and pesticides,” he writes.

“Our food contains significantly greater amounts of natural plant toxins and carcinogens than the synthetic kind, and our bodies aren’t able to distinguish between the two.”

Cancer is a multi-stage process, with a multitude of biochemical and molecular events that, left unchecked, culminate in cellular malignancy.

Dr. Coulombe says several questions need to be answered before chemopreventives can truly become a practical and safe protective therapy in people, noting that the antineoplastic benefits of at least some compounds are seen only when they are a natural part of the food from which they were derived. That means their benefits may not be seen when taken as a dietary supplement.

**Canavanine**—Found in significant quantities in alfalfa sprouts. It is suspected of causing autoimmune disorders such as lupus erythematosus. Primates fed alfalfa sprouts develop a severe toxic syndrome resembling human lupus.

**Cyanogenic glycoside**—Cyanide-containing compounds in seeds from apples, apricots, cherries, peaches, pears, plums and quinces. It is also found in almonds, sorghum, lima beans, cassava, corn, yams, chickpeas, cashew nuts and kirsche. Sweet varieties of these foods contain much less than the bitter-tasting varieties. Cases of acute human poisoning from the cyanide released from certain varieties of lima beans, cassava and bitter almonds are a regular occurrence.

**Allyl isothiocyanates**—A group of major naturally occurring compounds that confer a pungent flavor to foods such as mustard and horseradish. Inhibits binding of iodine in the thyroid gland. Normal processing steps such as chopping, rinsing or milling ensures safety of the food.

**Hydrazines**—Common mushrooms, the shiitake and the false morel, all contain substantial amounts of compounds in the hydrazine family, many of which are potent liver toxins and animal carcinogens.

**Glycoalkaloids**—Potatoes that have been damaged, exposed to light or sprouted contain two glycoalkaloids. Healthy potatoes contain negligible amounts the toxins. Poison symptoms include gastric pain, weakness, nausea, vomiting, labored breathing.
A sampling of natural chemopreventives in plants:

Isothiocyanates—A large group of natural plant compounds that exhibit promising anti-cancer properties. Sulforaphane is a recently discovered powerful chemoprotective found in broccoli and other cruciferous vegetables such as cabbage, brussel sprouts and cauliflower. They appear to be particularly effective against lung carcinogenesis in rats induced by the nicotine derived tobacco carcinogens.

Polyphenols—A type of plant tannin found in strawberries, blackberries, cranberries, walnuts and pecans as ellagic acid, which has been shown in numerous studies to be a versatile inhibitor of tumors.

Chlorophylls—Found in green, leafy fruits and vegetables. Chlorophyllin, copper/sodium salt of chlorophyll, has been shown to inhibit or reduce the cancer process.

“Because it is practically impossible to avoid all plant-derived toxins in a normal diet, the best way to minimize potential hazard would be to eat a wide variety of foods, but not too much of any one dietary item,” Dr. Coulombe says. “Because natural chemopreventives are associated with a reduction in risk to many types of cancer, it is also important to include generous helpings of fruits and vegetables in the daily diet.”

Dr. Roger Coulombe believes the best way to minimize the potential hazards of natural toxins is to eat a wide variety of foods... but not too much of any one dietary item.
As I read on, I didn’t feel quite as cornered by the news of the shooting spree, but I couldn’t help wonder why it seems only tragedy or news of it grab our attention. We certainly do need to know about that kid in Oregon, but don’t we as certainly need to know about how another kid in Oregon says hello to the Pacific Ocean?

I thumbed up another article in the folder. This one was by Barry Lopez who in so many words claimed Americans have lost track of each other. He said we spend our days swimming in a continual stream of stimulation from our material purchases. ‘We are more anxious if we get separated from that stream than we are in knowing that we are completely untethered to each other.’

We’re untethered from more than each other. Our communities are fraying. Some children seem to even be detaching themselves from the basic human need of self-preservation. Our relationship with the land is nearly unraveled. Vegetable gardens are dietary supplements, not necessity. The closest many of us get to farming is pushing a grocery cart and a lawnmower. Many if not most of us are even a step removed from watering our yards, letting timed sprinklers wet the lawn. So much of what we do seems to be pretend living. So much of the newsdeadens us, and so much of what passes for information in this era of tabloid TV is not human expression. We raise a lot of flotsam that trails behind for a while and then quietly sinks to the bottom.

I’m not saying newspapers should stop covering the news or that farmers should uncouple their irrigation systems or homeowners need to turn off their Toros. But maybe we could try not letting this summer season pass without retethering ourselves to it in some way. That might be, as Brian suggests, by writing a letter—preferably by hand. Or maybe we could just use summer as a chance
to find one big thing in a little thing? Here's an example I found deep in my folder that day that shows what I mean. The writer is James Agee:

"I want to speak now...of the fathers of families hosing their lawns. The nozzles were variously set but usually so there was a long sweet stream of spray, the nozzle wet in the hand, the water trickling the right forearm and the peeled-back cuff. First an insane noise of violence in the nozzle, then the still irregular sound of adjustment, then the smoothing into steadiness and a pitch as accurately tuned to the size and style of stream as any violin. The short, still arch of the separate big drops, silent as a held breath, and the only noise the flattering noise on leaves and the slapped grass at the fall of each big drop. That, and the same intensity not growing less but growing more quiet and delicate with the turn of the nozzle, up to that extreme tender whisper when the water was just a wide bell of film."

Who says there's nothing stimulating in daily chores? Maybe it's just how they're perceived. Then again, perhaps nothing is ever routine. Maybe everything people do—be it holding a garden hose or pointing a gun—happens for the first time. Perhaps nature is just organized chaos. Maybe all things, especially the nature of human nature, are unpredictable, no matter how many news stories we read or how many articles I stuff into my footrest. Perhaps, as Dr. Fred Provenza states in another folder article I saw that day, and says in this issue of Utah Science, life is self-organizing and is constantly reorganizing. The world and its inhabitants never were the way they were and they never will be that way again. The summer fields are green again for the first time. So are we.

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