Antlers

Deer antlers have long fascinated humans. Ice Age man painted pictures of deer on his cave walls, and the ancient Greeks did experiments on antler growth. Buffon, a French scientist in the 1700s, thought antlers were made of wood. After all, he reasoned, they do have a "bark" that is shed as they grow. Modern research has led to a better understanding of antlers, but some mysteries and misconceptions persist.

A common error is to confuse antlers and horns. Horns are permanent structures made of dead tissue and have no blood or nerve supply. They grow from the base and are composed of keratin, a protein that also makes up hooves, fingernails, and hair. Generally, both males and females of a species carry horns.

Antlers, on the other hand, grow as living tissue and are true bone. While growing, they have both blood and a nerve supply. Antlers are deciduous–they grow, harden, and are cast each year, then replaced. Like the colorful plumage of some male birds, antlers are a secondary sexual characteristic, and except for caribou and reindeer, just the males of each cervid species have them.

Some deer, such as the Chinese water deer and the musk deer of Asia, have no antlers, but they do have tusks that can be used in battle. Other species, such as the brocket deer and pudu of South America, have very small spike antlers. Still others, like the Asian tufted deer and muntjac, have both tusks and small antlers.

Antler Functions

Deer biologists and evolutionists have studied antler function for years. Most agree that antlers seem to have evolved primarily as weapons for fighting to determine male dominance for breeding rights. The question that remains is whether antlers really are needed as weapons or merely are "display organs" serving a function similar to body size or color in other animals.

Just how formidable a weapon antlers are depends on the species. Many of the smaller species, such as the muntjac, and even some of the larger ones, such as the sika deer, have straight, bayonetlike antlers perfectly suited for goring an opponent. Most deer have curved and branched antlers, however–not the best design for killing a foe. These complex antlers are used more for rubbing on trees and brush and digging in the ground or snow than for fighting. When white-tailed deer do spar or fight, they seem to take great care to lock their antlers with their opponents', thus avoiding slippage and serious injury. These battles involve a lot of pushing and twisting, much like a wrestling match. The curves and branches of whitetail and mule deer antlers are less lethal than the straight bayonets of other species. Nonetheless, fights between equal-size males can be vicious, and injuries and deaths do occur.

Geist has found that 10 percent of all adult mule deer bucks have been injured in this way.

The display rituals of many species may obviate the need for sparring. The palmated antlers of moose and reindeer, however impressive they are to behold, are not well designed for fighting. A.B. Bubenik has shown that moose, elk, caribou, and maral deer with large antlers can intimidate rivals with smaller racks to establish dominance without actual combat.

Other theories have been offered as to why deer have antlers. Stonehouse has suggested that they are thermal radiators: growing antlers are probably the only appendages in the animal kingdom that have a temperature equal to that of the body's core. There is no question that they dissipate heat. If this were their primary function, however, we might wonder why most females don't have antlers for the same purpose, why some species (Pere David's and roe deer) grow antlers in the winter, and why there is not a direct relationship between climate and antler size.

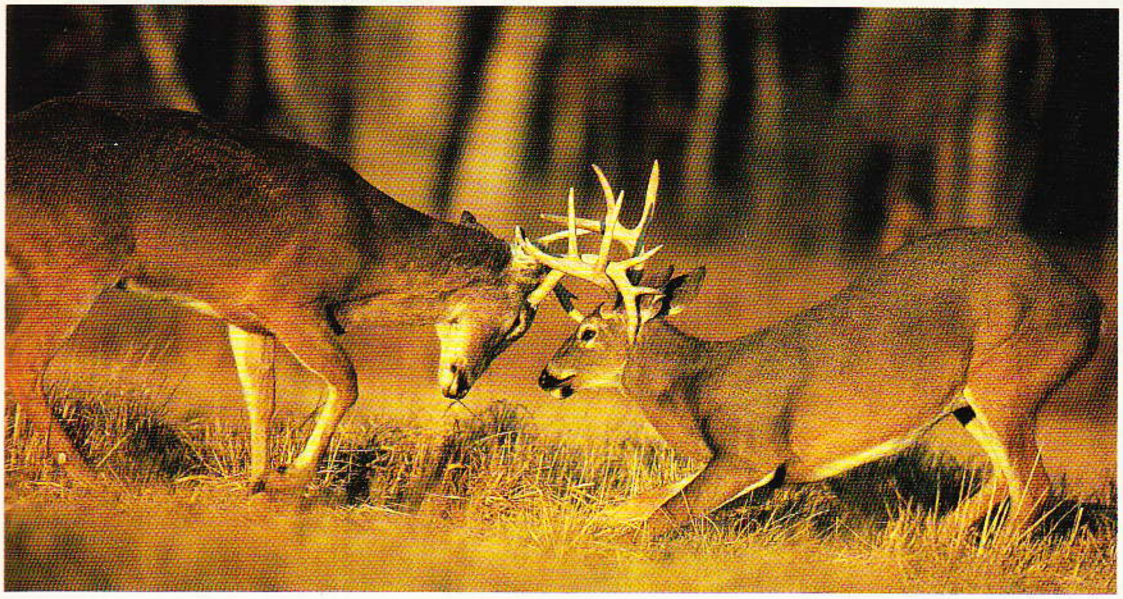
A.B. Bubenik has theorized that antlers are used as scent markers. Velvet, the skin that covers growing antlers, does indeed have oil glands, but deer have other, more potent odor-producing glands.

In most cervid species antlers are a secondary sexual characteristic. To explain the appearance of antlers in reindeer and caribou females, biologists have suggested that the does need antlers to protect their young from predators. But don't mule deer and elk females have the same need? The final answer must be that antlers serve as many functions as there are antler shapes. Even within a species, antlers may have multiple purposes.

Antler Growth

In most species of deer, fawns are born in the spring or summer and have no antler growth that first fall. The male fawns have pedicles–skull platforms on which the antlers will develop. Some fawns may grow small antlers and become "button bucks." The buttons are cast the following spring before the first real set of antlers begins to grow. Goss has reported that the male fawns of mule deer, whitetails, moose, and roe deer all can grow such buttons. Reindeer and caribou, however, usually grow spike antlers as fawns.

Most male deer begin to grow their first real antlers in the spring, just before their first birthday. The growing antler is supplied with blood through the many blood vessels of its velvet and through its core. If the antler is damaged during its growth, it bleeds profusely, but the blood clots quickly. Injuries may cause misshapen antlers, although these can be difficult to distinguish from nontypical antlers, such as the genetically determined drop tines seen in whitetails. In fact, it is said that gamekeepers in Europe used to shoot the antlers of deer in the velvet with shotguns, in order to cause more



BRYAN

The elegantly curved tines of whitetail antlers allow bucks to catch an opponent's thrust, as well as lock together for spirited sparring matches.

Nontypical antlers, like this whitetail's palmated tines, may be caused by a variety of factors. Limited observations of such animals indicate that genetics, nutrition, and behavior could be involved.

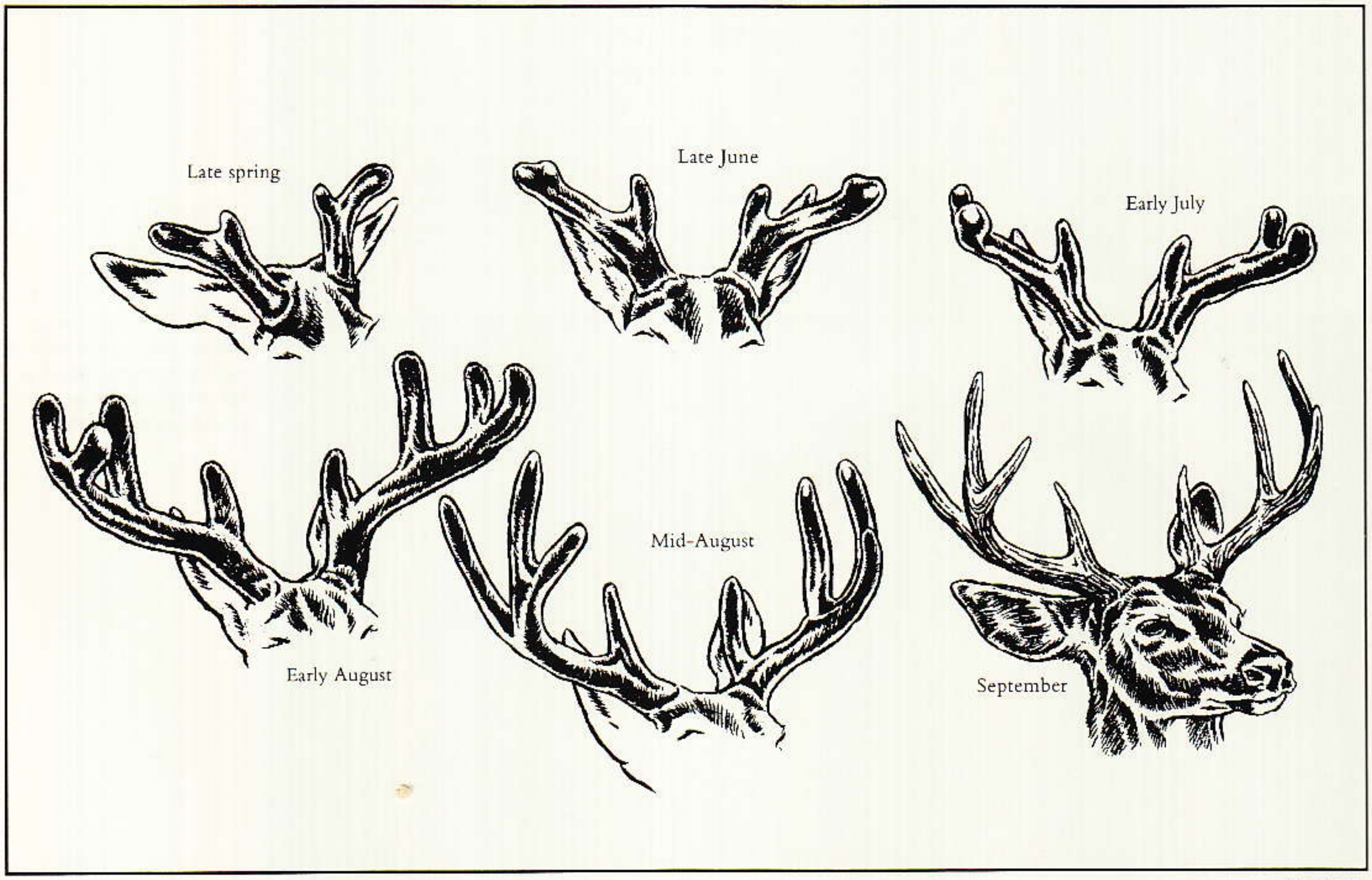
SMITH

points to grow. George and A.B. Bubenik report that serious injuries to the pedicle region will be "remembered" by the nerves, and subsequent sets of antlers will be misshapen for years to come.

There are numerous reports that injuries to other parts of the skeleton, such as the legs, have caused misshapen antlers. These reports suggest that if a deer injures or breaks a leg, the antler on the opposite, or contralateral, side will be stunted or misshapen in future years. It has been suggested that the injury caused the animal to limp, thus requiring uneven antlers to balance the gait. Others have called these reports mere coincidences, since deer have been found with misshapen antlers on the same side as leg injuries. Extensive controlled experiments would be necessary to settle the issue, but this is not the type of research many biologists would undertake.

Once the velvet antlers mature in size and shape, the velvet dies, or necroses, sometime in the fall. This apparently causes some irritation or itching to the deer, which rubs out the velvet against trees and brush. As the

A mule deer's antlers branch as they grow. While in velvet, the antlers are sensitive and easily damaged; a buck moves gingerly to protect them from injury. The size and shape of any particular buck's rack are determined by a combination of genetics and nutrition.



BESENGER

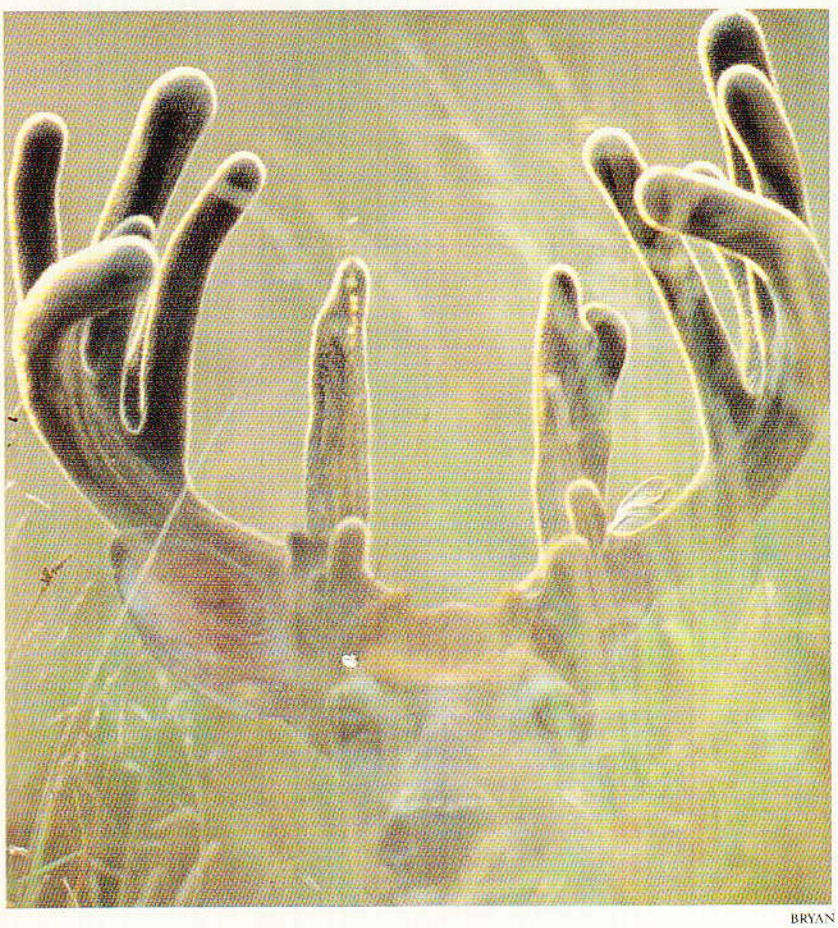
velvet rubs off, minute pores are visible in the antler where the blood vessels entered. The amount of blood staining that occurs during this period determines the color or darkness of the hardened antler. The rubbing or sparring with trees may also serve other purposes. It can give the buck a better sense of the size and shape of his antlers, help sharpen the antler points, and strengthen the buck's neck muscles for the battles to come.

Rub-out occurs as the buck or stag's level of male sex hormone, testosterone, is increasing. He becomes fertile and more aggressive. Low hormone levels, perhaps caused by injuries or tumors, can cause the buck to rub out incompletely. Once the rub-out is complete, the deer is ready to compete with other bucks during the mating season.

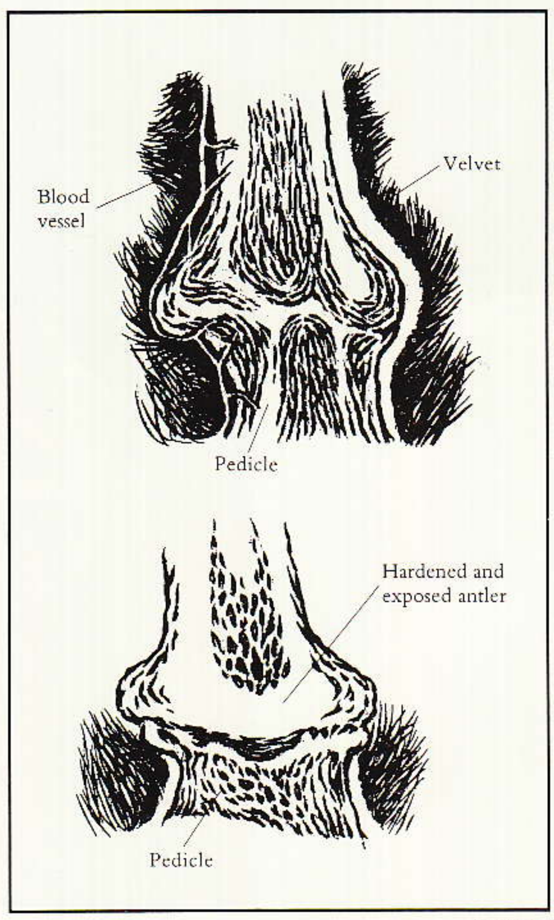
Now large antlers are an advantage in winning the does or hinds, but they may be a mixed blessing, as dominant males often die at a younger age as a result of the stress and injuries that come from constant fighting with challengers.

J. MILLER

As a secondary sexual characteristic and tools for fighting, antlers help bucks sort out their social hierarchy. The broken tine on this mule deer's rack can lower his status.



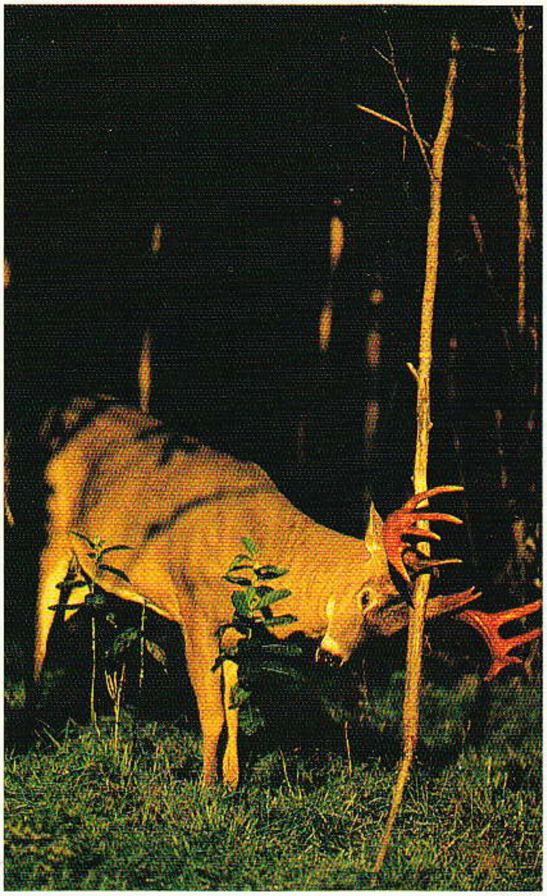
BRYAN



BESINGER

Blood vessels supply essential nutrients to the growing bone that becomes a rack. Calcium and other minerals are supplied through the blood vessels in the velvet. By the time the velvet necroses, the antlers have stopped growing and are fully mineralized.

The amount of bleeding that occurs during rub-out determines the final color of the rack. The bone is stained by both blood and bark.



KINNEY

Having served its purpose in nourishing the growing antler, the velvet shrivels, cracks, dies, and peels in strips.

SMITH

After the rut, a buck's testosterone level drops precipitously and his antlers are cast. The degeneration of the bone-to-bone bond between antler and pedicle is the most rapid deterioration of living tissue known. A deer can be picked up by its antlers one day, and cast them the next. There is little or no bleeding, and the two antlers usually fall off within hours of each other. When this happens, the buck's social status drops. This was demonstrated in experiments by Lincoln of Scotland, who found that a red deer's status in the herd dropped as parts of its hardened antlers were cut off, a piece at a time. In some species, such as axis deer, a new set of velvet antlers begins growing immediately. In others antler growth does not start for two or three months.

Antlers are the only regenerating living tissue in the entire animal kingdom. Hair gets replaced, but it is dead; baby teeth get replaced by permanent teeth, but just once; and broken bones and injured skin heal, but with the very different scar tissue. The only analogous replacement of an organ as complex as an antler is the growth of a lizard's tail when the original has been severed.

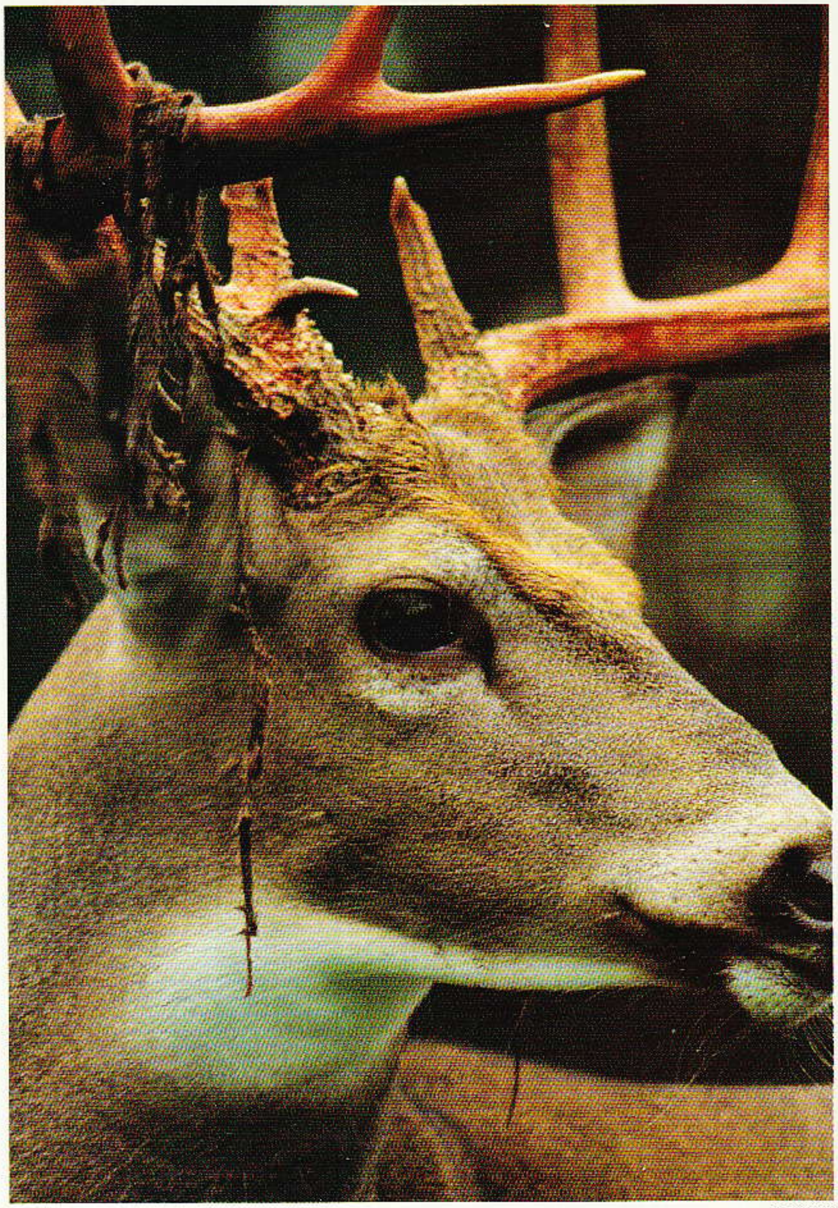
Environmental Control of Antler Growth

The first pedicle and antler development of yearlings are largely innate and not determined by environmental cues. After that, however, antler growth is controlled by a variety of hormones that are activated by the environment. The key environmental cue seems to be light cycles, or day length. Temperature and rainfall, although seasonally variable, do not affect the antler cycle.

Antler growth usually begins when days are lengthening, between the spring equinox and the summer solstice. Rub-out occurs as days are shortening, just before the fall equinox. Goss, expanding on the work of Jaczewski of Poland, has shown that when day lengths are artificially altered, penned sika deer grow antlers six months out of phase with their normal cycle. When a twelve-month cycle is lengthened into twenty-four months, the deer grow antlers only every other year. When the cycles are shortened or condensed, the deer grow two and eventually three sets of antlers a year. That seems to be the limit, as antlers, regardless of their size, take three to four months to grow. Goss also points out that when deer of nearly any species are transported to zoos in another hemisphere, their antler cycles quickly adapt to the new light cycle.

The farther deer are from the equator, the more defined their antler cycle. Whitetail bucks in Michigan or Pennsylvania tend to shed their antlers within a month or so of each other. Whitetails in south Texas, however, are less synchronous and shed their antlers over a longer period. Deer near the equator actually rub out and shed their antlers throughout the entire year. The specific date on which a buck rubs out or sheds is determined by its individual antler cycle. This cycle is independent of that of other bucks and believed to be centered on each animal's birth date.

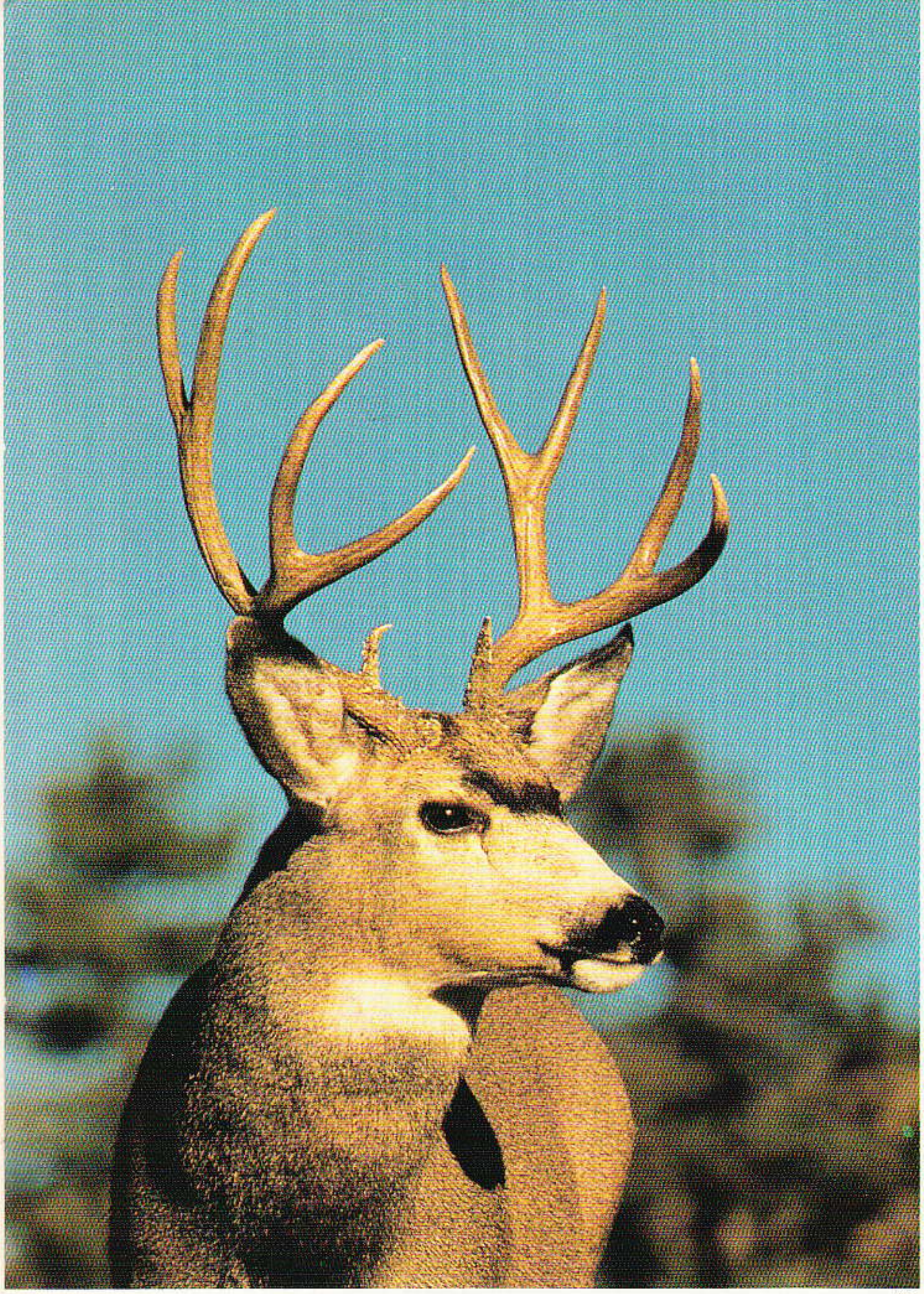
Goss found that when deer were maintained under constant conditions approximating the winter solstice (eight hours of light and sixteen hours of darkness) or the summer solstice (sixteen hours of light and eight hours of darkness), the antlers cycled but at irregular intervals of about ten months. The result was the same for deer held in constant daylight, twenty-four hours a day. This suggests that an endogenous, or internal, mechanism causes the antler cycle but that changes in day length are needed to time the cycle to twelve months. Jacobson has reported a deer that was born blind and held in captivity for four antler cycles. These



WERNER

GETTLE

The interplay of hormones determines when a buck rubs out velvet (above) and, after the rut, casts the antlers (left). Both antlers may drop within minutes, or the second may not be cast for several days. The bloody pedicle heals quickly.



LEA

A mule deer's brow tines, if present at all, are smaller than a whitetail's, and each main beam usually splits into several forks on mature bucks.

cycles averaged 373 days in duration. The fact that it had antler cycles at all in the absence of day-length cues again confirms the existence of an endogenous mechanism.

Hormonal Control of Antler Growth

Day length does not affect the first antler cycle, but hormones certainly do. More than two thousand years ago, Aristotle reported that "if stags are castrated before their first antlers, they will grow none. If they are castrated with antlers, they will not harden or be shed."

Without a doubt, the male sex hormone testosterone is the primary hormone that controls antler growth. Just how removal of the testes affects antler growth depends on when the deer is castrated. If castrated as a fawn, the young deer grows no antlers at all. If castrated when mature, the buck grows antlers but never receives the hormonal cue to begin rub-out; he remains in velvet the rest of his life. Each year the antlers grow more points and begin to resemble a saguaro cactus. Such deer are called cactus bucks. If a buck is castrated when his antlers have hardened, he soon casts them–within a few days–and then grows velvet antlers the next season.

Such ablation experiments (in which organs were removed) were the first attempts to study the endocrinology of deer. In more recent times, scientists have removed the thyroid, parathyroid, pituitary, and pineal glands from deer. Only the removal of the pituitary, the master gland of the body, caused antler growth to stop. The pituitary produces many hormones, one of which is luteinizing hormone (LH), which controls the production of testosterone by the testes. Day length seems to control the pituitary through a pea-sized endocrine gland at the base of the brain, the pineal.

Early work on the pineal showed that its removal altered antler cycles but the mechanism was not understood. Now, however, there are ways to measure the levels of hormones in a deer's circulatory system and even ways to synthesize many of these hormones, which can then be injected in order to study their effects. The pineal produces a hormone called melatonin, which suppresses the production of LH in the pituitary and thus holds back testosterone. Studies have shown that melatonin is produced in greater quantities during hours of darkness. Some message regarding day length, probably a neural one, must be sent from the eyes via the optic nerve to the pineal gland. As nights get shorter, melatonin production decreases, releasing the pituitary to produce LH. The resulting increase in testosterone leads to velvet shedding and antler hardening. These hormonal interactions take time, so there is a lag of several months between the changing of day length and the antler cycle event.

Some questions–why testosterone levels decline rapidly after the rut, why female reindeer have antlers and cast them after their young are born–require further study. Scientists such as George Bubenik in Canada and Suttie in New Zealand have shown that the reproductive cycle and antler growth in deer can be regulated by artificially altering their light cycles or by injecting or implanting doses of melatonin. Injections of testosterone into whitetail does have been demonstrated to cause antler growth. Melatonin and testosterone, however, are only part of what must be a complex endocrine regulation of the antler cycle. Many other as-yet-undiscovered hormones are thought to be involved.

Nutrition versus Genetics

As symbols of male dominance and sexual potency, the well-developed antlers of a mature whitetail buck inspire awe and respect. They also raise questions about whether the size of an animal's antlers is determined by its genes, or whether it is environmental factors that spur growth. Research indicates that both genetics and nutrition play important roles.

In the 1940s Austrian Franz Vogt demonstrated the effects of paternal and maternal nutrition on antler growth in red and roe deer. Starting with deer with mediocre antlers and feeding them high-energy, high-protein rations, he increased the body weights of the stags and the average size of the antlers by nearly 50 percent in just three generations. More recent experiments have been few and less spectacularly conclusive, but they have shown similar results: good nutrition means large antlers.

There is no question that antler growth puts a nutritional strain on the animal. The rack of a moose may span 1.8 meters (6 feet) and weigh 28 kilograms (60 pounds)–no less than one-sixth the weight of its entire skeleton. Imagine growing an adult human skeleton, which also weighs about 28 kilograms, in three to four months. Numerous studies have shown that restricted diets can lead to stunted antlers, as body growth seems to take priority over antler growth in all deer species when rations are short. In fact, malnutrition has been invoked to explain the rare Scottish hummel, a sort of polled red deer that never grows antlers.

WERNER

All the tines of the typical whitetail antlers grow from the forward-arcing main beams.

But the effects of poor nutrition differ, depending on the species. In white-tailed deer a restricted diet has been found to cause the bucks to cast their antlers early; in red deer it delays antler casting. Even if rations are in short supply for a time, the lack of body and antler growth will be compensated for in most deer once food becomes more plentiful.

It is difficult to separate out the effects of nutrition, but antler size is also related to the deer's body size. As one might expect, the larger the deer in body weight and shoulder height, the heavier the antlers and the longer the beam length. In fact, some evidence suggests that as the deer grows larger, its antlers become proportionally larger, thus making up a greater percentage of the animal's total body weight.

Interestingly, the overall energy requirements of all animals are equal to the body weight to a power of 0.75; in other words, as an animal gets larger, it needs proportionally less feed per pound of body weight. If these relationships hold true, then as deer get larger, they eat proportionally less but have even greater antlers. This puts greater demand on their bodies to provide minerals for the antlers during mineralization. (Antlers are made of protein as they grow in velvet, but the protein later gets replaced by solid mineral.) Cowan and others have shown that during antler mineralization, most of the calcium and phosphorus in the antlers comes from the other bones of the skeleton, not directly from the diet.

A less orthodox theory of antler size has been proposed by Bartos of Czechoslovakia. He observed red deer in pens and found that the ultimate size and number of points of the deer's antlers were determined not by body size but by the serial rank of the stag, as determined by sparring while in the velvet. He suggests that if nutrition is equal among deer, the individual deer's rank somehow affects antler size. He found that higher-ranked stags shed their velvet first and cast their antlers first, regardless of age. This must be interpreted cautiously, however, since attempts to demonstrate it in white-tailed deer have been inconclusive, and behavior of deer in pens may not match behavior in the wild.

Does all this mean genetics is not important? Of course not. There is no question that superior sires can produce superior offspring. We now believe, however, that the doe may contribute as much to the antler size of the male offspring as do the sires. This complicates the debate about yearling spike bucks, which occur in most species of deer. Some sportsmen want to protect spike bucks, believing they will grow bigger antlers later and just need a chance to mature. Others consider these animals inferior and call for them to be culled from the herd.

The evidence is conflicting. Harmel's studies in Texas showed that whitetail sires that were spikes as yearlings produced more spiked offspring than did a sire that had been a six-point yearling. Jacobson's work in Mississippi, on the other hand, showed that there was no correlation between a whitetail's first antlers and those he grew as an adult. Here's a case from my own research. A 4½-year-old whitetail sire carrying fifteen-point antlers produced eight male offspring from different does. Four of those bucks had impressive four- to eleven-point antlers as yearlings; the other four had just 1- to 2-inch spikes. Perhaps the sire failed to pass on his antler characteristics to some of his offspring, perhaps he passed on only some of the characteristics to some of the offspring, perhaps some of the characteristics were passed on by the does.

–Robert D. Brown

Antler velvet

Think of antler velvet as fur. Though it differs considerably from the skin and hairs that sheathe the deer's body, antler velvet is a modified skin with modified pelage. It grows each year from the skin that rims the wound on the pedicle after the dead antlers have been cast–the only example of complete regeneration of skin among mammals.

What makes this skin velvety is the profusion of short hairs, approximately twelve filaments per square millimeter, each just 5 millimeters long, that cover the antlers. These hairs do not molt, at least not in normal deer. Once the antlers are completely formed, the tissue dies because blood flow into the pedicle is interrupted, in much the same way as a heart attack occurs when blood vessels are blocked: the arterial walls harden and fatty material clogs the passageways. Dead and dry, the tissue sloughs off with vigorous rubbing.

In castrated deer, however, the antlers continue to grow, and the velvet–longer and thicker than in normal deer–molts seasonally, just like the body pelage.

The velvet lacks skin muscles but has no shortage of sebaceous glands. Shaped like elongated droplets, they reach 0.2 to 0.7

The many nerve fibers in antler velvet–which is, after all, a specialized skin with short, dense fur–are vital in controlling the normal growth of antlers. An injury to velvet antlers may reappear as a deformation for several years.

WALLNER

millimeters below the surface. Although secretion of sebum proceeds more slowly than from regular skin, oily droplets sometimes appear on whitetail antlers late in the mineralization process, apparently because the drying and contracting of the velvet pushes the sebum from the dying glands. Sebaceous glands may contain pheromones, so when the buck rubs off the dead velvet on trees, he may be leaving olfactory signals about his presence and condition. In ancestral forms of deer, A.B. Bubenik theorizes, antlers may have been permanently in velvet and served mainly as dispensers of pheromones that informed does about available bucks.

Just about everything to do with velvet is species specific: the particulars of density and length of hair, for example, differentiate whitetails from other species, as do the structure and density of the sebaceous glands. The presence of sudoriferous glands may also be species specific; such glands are known to exist in the velvet of red deer and elk stags but have not been observed in whitetail antlers.

–George A. Bubenik

pinecone-shaped organ in the center of the brain. It produces a hormone, called melatonin, and starts releasing it into the blood at dusk. When the days begin to lengthen after the winter solstice, the body receives a little less melatonin each day. The cumulative effect is a lower level of melatonin in the bloodstream. This initiates the spring molt–but not directly. The fluctuation of melatonin levels modifies the secretion of the pituitary hormone prolactin. It is the level of prolactin–rising in the spring, peaking at the summer solstice in June, and falling until the long dark night of the winter solstice–that ultimately triggers the molt.

Or does it? Another hormone from another gland may be involved as well. The thyroid produces, among other secretions, triiodothyronine (T_3 for brevity's sake), an anabolic hormone that stimulates the metabolism to provide more energy for the growth and development of skin and skin derivatives, such as hair and horns. Levels vary with day length, but on a slightly different schedule from prolactin: T_3 is at its peak in late spring and early summer (late April to early June), and then declines until the beginning of winter. The combination of peak levels of T_3 and rising levels of prolactin results in the spring molt, which throughout most of the United States, is complete by May or June. As prolactin declines in late summer, the level of T_3 is still relatively high, and the fall molt begins.

Experiments indicate that still other hormones can affect pelage, from the timing of the molt to the quality and color of hair growth. Injections of thyroxine, produced in the thyroid and eventually metabolized into T_3, greatly improve the condition of the coat in white-tailed bucks (and also increase muscle bulk). High levels of androgens, the male hormones such as testosterone, can result in darker hair and earlier molting, a finding that should not be surprising to those who have observed how prime bucks (which have particularly high levels of testosterone) have the darkest faces and are the first deer to molt in the fall. High levels of testosterone also increase the activity of the sebaceous skin glands that produce secretions to make the coat water repellent. Cortisol, the main hormone produced by the adrenal cortex, may also affect the timing of the fall molt since studies by Johnson indicate that cortisol inhibits new hair growth. Whether cortisol also affects the spring molt is not known.

Temperature. It has long been assumed that day length is the prime mover, setting in motion the complicated conversations between the body's hormones that ultimately signal shedding and regrowth of hair. But perhaps not alone. Growth of the winter coat proceeds in two stages, guard hairs first. That this first stage indeed depends on day length can be proved by penning deer in artificial light and hastening the onset of winter: as the days grow shorter, the winter guard hairs grow in. But the underfur, which would normally appear soon after, does not appear if the thermometer still reads "June." Not until the return of chilly nights in October does the woolly undercoat grow, suggesting that this aspect of molting is temperature-dependent.

Consider also two cases of temperature extremes. In the warm tropical lowlands of South America, Brokx has observed, the winter coat of whitetails, though gray, has no underfur. And in the Andes, where whitetails live at altitudes of 4,000 meters (13,120 feet) and endure near-freezing temperatures during even summer nights, deer have only winter coats; they molt gradually–or so it is believed–from gray to gray.

The cost of a new coat. Nursing does, it is well known, often keep their summer pelage longer than bucks and mothers that have weaned their fawns. One reason is chemistry. Prolactin, the hormone from the pituitary gland that, when declining and acting with other hormones, signals the body to produce the winter coat, is also the hormone that regulates lactation. The high level of prolactin associated with milk production is at odds with the low level associated with hair growth. The other reason is energy. Both processes drain the doe's energy reserves, and she cannot accomplish both at once.

For all deer, in fact–not just lactating does–molting is metabolically expensive. A buck weighing 100 kilograms (220 pounds) produces 2 kilograms (4½ pounds) of hair

The molt begins at the head and neck, progresses down the spine, then ends with the sparsely furred legs.

FRANZ

MCFALLS

In regions with reddish soils, the difference between a whitetail's summer and winter coat is pronounced. The dark hairs of the winter pelage act like miniature solar collectors, absorbing solar energy and saving stores of body fat from oxidation.

per season, according to one estimate. To grow that much hair—good, thick hair—he must consume 2 grams (0.07 ounces) of nitrogen per day. Since nitrogen is derived from proteins, he needs a diet high in protein, which such foods as willow buds, alfalfa, and bluegrass can provide.

Protein is most important for hair growth, but a lack of essential vitamins and minerals may affect pelage by preventing certain body cells from forming or operating properly. No studies on deer have been completed, but in cattle, for example, a lack of copper in the diet causes the hair to turn gray.

The drain on energy and protein reserves deer experience during the molt explains why animals in good physical condition molt first—before weak bucks and late-born fawns as well as before lactating does. In fact, a late onset of the development of woolly fur is a better (and easier-to-read) indicator of undernourishment than the estimation of integumental fat.

Pelage may also serve as a biological measure of environmental pollution. Heavy metals, toxic to animals, can accumulate in deer hair. Although the coat of a sick deer may not appear to differ from that of a healthy animal, chemical analysis of individual segments of the hair shaft can reveal the presence of toxic pollutants and even indicate the approximate date of exposure. Studies have yet to set forth the correlations, however.

A coat of high-quality underfur is essential for winter survival, and in the colder regions of North America, it must be in place by the end of November. Deer with underdeveloped secondary hairs—or with no underfur at all—draw down their winter fat reserves fast. Whether they will ultimately succumb to exhaustion, predation, or hypothermia is only a matter of time: these deer have a poor chance of survival.

—George A. Bubenik