Anatomy OF AN ANTLER

Photo: Jason Loftus

By Jim Heffelfinger

Throughout history, those who observed deer closely found the process of antler development bizarre and mysterious. It seemed the more we learned, the more complex and confusing the whole process became. Many early writers sought to explain and understand the antler cycle without experimentation or real knowledge of what was going on. Even the philosopher, Aristotle wrote about the antler cycle in deer. As we started to apply research principles to investigate the growth of antlers, we found more and more pieces of the puzzle and started to put them together to form a clearer picture of this complex process.

In 1981, researchers from around the world came together for the "First International Symposium on Antler Development." This was an opportunity for the leading antler researchers to present what was known about the science of antlers at the time. To those in the antler world the list of attendees was impressive. This meeting resulted in a book titled "Antler Development in Cervidae." The meeting was such a success it eventually evolved into the International Biology of Deer Congress which is still held every 4 years somewhere in the world to provide an update on new deer research. I was part of the team that organized the last one in 2018 in Estes Park, Colorado.

One of the attendees of that first meeting was the famous antler researcher Richard Goss who wrote antlers were an *"extravagance of nature...so improbable that if they had not evolved in the first place they would never have been conceived even in the wildest fantasies of the most imaginative biologists."* One of the most fascinating things about antlers, and the source of much research, is the fact that antlers are the only appendage in mammals that regenerate and replace themselves. This phenomenon is well-known in some reptiles and amphibians, but just doesn't happen in mammals. Some have offered the opinion that since antler breakage occurs during rut, it would be important for deer to be able

Photo: Jason Loftus

to refresh their antlers somehow. Regenerating a new set of antlers each year would also serve to maintain a size that matched their growing bodies. Probably most important is that the size of the antlers serve as a visual representation of how "fit" the bearer is. Females can then select their suitors based on something related to the quality of their potential mate. Regardless of the reason, there is no other part of the deer life cycle that intrigues deer enthusiasts more than the process of antler development.

The External Bones

In 1898, Professor H. Nitsche wrote about how peculiar it was that the death of a body part, and later regeneration, could become a normal healthy process. Antlers are actual bones that exist outside of the body and are supplied with nutrients via blood flow while growing. These bones we all admire so much eventually die, drop off, and then the body immediately begins growing new ones. These external boney appendages on the heads of members of the deer family start to develop on males after their first few months. Underneath a buck fawn's forehead skin is a region of thickened tissue, essential for the growth of antlers. Researchers have shown this tissue can be transplanted on to boney places elsewhere on the body and produce antlers at that new location.

The growing antlers are basically cartilage that is primarily made up of protein and full of the same enzyme normally found in other cartilage. However, this is no ordinary cartilage because it is full of vertical blood vessels needed for rapid antler growth while normal cartilage is not. During antler growth, this cartilage is spongy in appearance and even rubbery to the touch. As fall approaches, the cartilage is replaced with bone material (mineralization) from the outside in, which is why we may still see some blood flow in the center of the base after most of the mineralization is complete. Also, if you saw through a hardened antler you may see porous bone material in the center where it did not fully ossify in the middle. The mineral content of antlers is about the same as true bones—mostly calcium and phosphorus.

The small platforms on the skull from which antlers grow are called "pedicles." According to famous antler researcher Anthony Bubenik, this word should be pronounced to rhyme with "medicals." However, English was only one of Tony's six languages (and not his first) so I have always wondered if we aren't all pronouncing this word with a thick Czech accent! Bubenik also used the old Russian term "panty" for these actively growing antlers, but that terminology never caught on in the U.S. for some reason. Probably not a good idea to Google that at work.

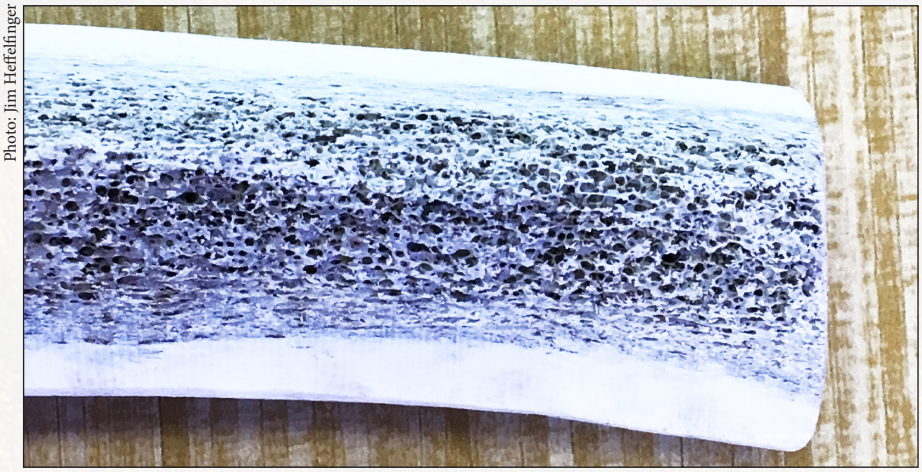
Photo: Austin Killiam

When the antler is shed, a scab forms over the wound which turns into velvet skin to start the cycle all over again.

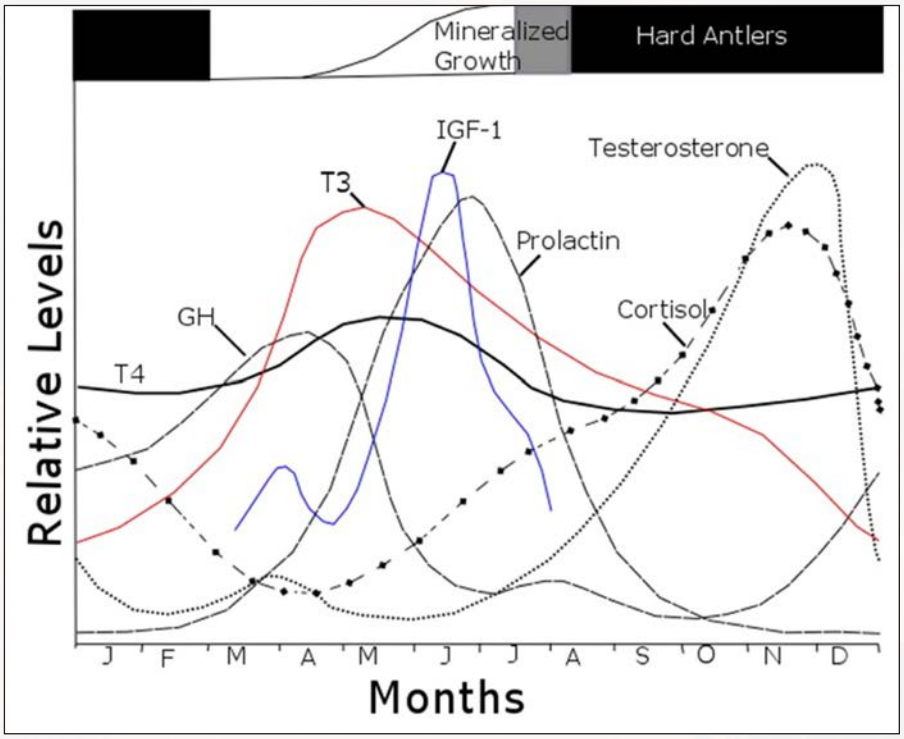
The buck's nutrient intake while he is growing his antlers cannot keep up with the energy and protein required and later the calcium and phosphorus needed to fully mineralize them. To mineralize large antlers in such a relatively short period, the buck's body mobilizes minerals from the skeleton. The body later replaces the minerals in the skeleton with dietary nutrients when the process of antler mineralization has slowed. One fascinating sidebar here is that researchers have found that more calcium is taken from bones that are not under stress, such as ribs; whereas leg bones retained more calcium so as not to jeopardize the animal's life by breaking a leg.

This unique mobilization and replacement of calcium has spurred some human physiologists studying this process to find a cure for osteoporosis. This connection between the skeleton and antler minerals may also be why antler deformities are related to injuries to a leg bone. Calcium would be needed to heal the very essential long bone and thus not as much calcium and other nutrients are available for antler growth. This relationship gives us some

Photo: Jim Heffelfinger



With a rise in testosterone in the fall, antlers mineralize from the outside inward, sometimes leaving porous cores.



Graphic adapted by Kelley Stewart from George Bubenik

There is more than just testosterone driving antler growth—a complex orchestra of hormone fluctuations regulate the entire antler cycle.

insight into how important nutrition in the preceding winter is to antler growth. Nutrient levels stored in the body in early spring will determine how much "extra" is available to antler growth.

Hormones and the Endocrine System

Although testosterone is necessary for the initial development of pedicles in buck fawns, large amounts of this hormone are not needed to grow antlers. In fact, even moderate levels of testosterone actually inhibit the growth of antlers. Research conducted by Anthony's son, George Bubenik showed testosterone levels fluctuate throughout the year and are at a very low level in the spring when antler growth starts. A large combination of other hormones, including IGF-1 and derivatives of testosterone, increase and decrease during various phases of the antler growing period. This complicated orchestration of hormones is not yet completely understood, but serves to promote and sustain antler growth.

In the fall, levels of testosterone rise and other hormone levels fluctuate, triggering first the mineralization of the protein matrix and then the drying of blood vessels in the velvet-like skin. After breeding is complete, more hormonal changes such as declining testosterone levels, trigger a weakening of the layer of bone tissue at the base of the antlers. This thin layer of bone simply degrades at the attachment and allows the antlers to fall off. After only a few weeks, the next cycle of antler growth begins.

The connection between dead bone (hard antler) and live bone (skull) is a curious one. The connection holds very tight as long as testosterone levels remain high, then falls apart when testosterone drops after rut, separating the live from the dead. If castrated early in life, buck fawns never experience their initial pulse in testosterone and thus never grow the pedicles on their skulls, meaning they never grow antlers at all. In these animals, an injection of testosterone later in life, can start the growth of pedicles and they will then grow antlers. Likewise, an injury to the buck's testes, or anything else that causes a drop in testosterone could result in the antlers being shed early. Interestingly, each individual deer has a unique shape to the shed antler base that remains the same each year. The bases of sheds are not as unique as fingerprints, but enough to help identify the same deer's sheds from different years.

Velvet Skin

Antler velvet develops out of the small swirls of hair on the frontal bone of a buck fawn's skull. As antlers start to grow, the overlying fur thins into a dark, velvet-like skin full of blood vessels. This "velvet" has hairs that grow out from the skin at 90-degree angles which is what gives it the velvet appearance. In some species, such as the Sika, the hairs are sparse, but in others like elk it can be quite furry. Each hair has a sebaceous gland at its base that produces oil which is why the lightly-haired velvet sometimes looks shiny.

Velvet was thought to be a type of bark by an 18th Century French scientist who thought antlers were made of wood. It didn't take long to disprove that theory, but regardless this skin is unlike any other in the animal kingdom because it is densely packed with nerves. Somehow after casting the previous year's antlers, the resulting wound does not form scar tissue like normal skin, but rather scabs over and then develops into a healthy, productive, and regenerative skin designed for fast growth. Nowhere else will you find such a strange process in skin.

When the velvet tissue has dried somewhat, the buck rubs off the velvet on a sapling or bush. The stripping of velvet occurs rapidly once it's started, usually within 24-48 hours. When freshly stripped, antlers are pure white, but stained by blood. The brown pigment in tree bark called tannin, along with some residual blood, stain the antlers with their familiar brown color.

Blood Flow

Growing antlers are warm to the touch because of the abundant blood flow in the velvet. Besides carrying nutrients to the growing antlers, the warmth promotes cell division and rapid tissue growth. The arteries feed the growing tips where the blood flows through the active growth zone and returns down the center of antler early in development, and later by way of veins as the antler begins to harden. If an antler is cut off soon after velvet is shed, you see active blood flow in the center of some antlers. If the antlers were left on, this remnant blood flow would soon dry up as the antlers become dead bone all the way down to the bases.

Arteries in the velvet share a unique quality with umbilical cord arteries; they both have the ability to constrict very quickly when severed to stop the loss of blood. When the arteries in the head that supply growing antlers are blocked or cut, other surrounding arteries enlarge to divert the blood flow around the severed or damaged path to continue to supply the antlers. In this way, normal growth continues without any negative effect to the final antler.

Nervous Antlers

Velvet contains a large number of nerves that make them sensitive to the touch. Even the tamest captive buck does not tolerate you touching his velvet antlers. This sensitivity undoubtedly allows the buck to learn the size and shape of his antlers as they grow. This is important during the velvet stage so bucks can avoid hitting their soft antlers on brush, trees, and hard objects that might damage them. Nerves also allow the buck to learn the exact location of each tine which will come in handy during sparring matches and fights.

One interesting question is how antlers grow to become the specific shape of that species of deer. There is a huge diversity of antler shapes in the deer family and yet each species has its own basic shape. What force or process guides antlers into the shape they are supposed to have? The answer appears to lie in the nervous system. One experiment connected a device to several bucks and applied a low electrical current to their growing antlers. The electrical current from the device appeared to interrupt the communications and guidance of the nervous system in shaping the antlers. These antlers branched in odd ways and were shorter than normal. Clearly the impulses from the nerves in velvet are related to the shape that antlers grow.

Anthony and George Bubenik observed that some of their captive bucks injured their velvet antlers and grew nontypical points at the place of the injury. This is not new information but what was remarkable is that they observed those antlers growing nontypical points the next year even without being reinjured. How could a set of growing antlers "remember" the previous year's injury? This question remains unanswered but the Bubeniks surmised that since antlers are shed completely each year, the Central Nervous System must somehow store information about antler shape and injuries allowing it to be expressed the next year.

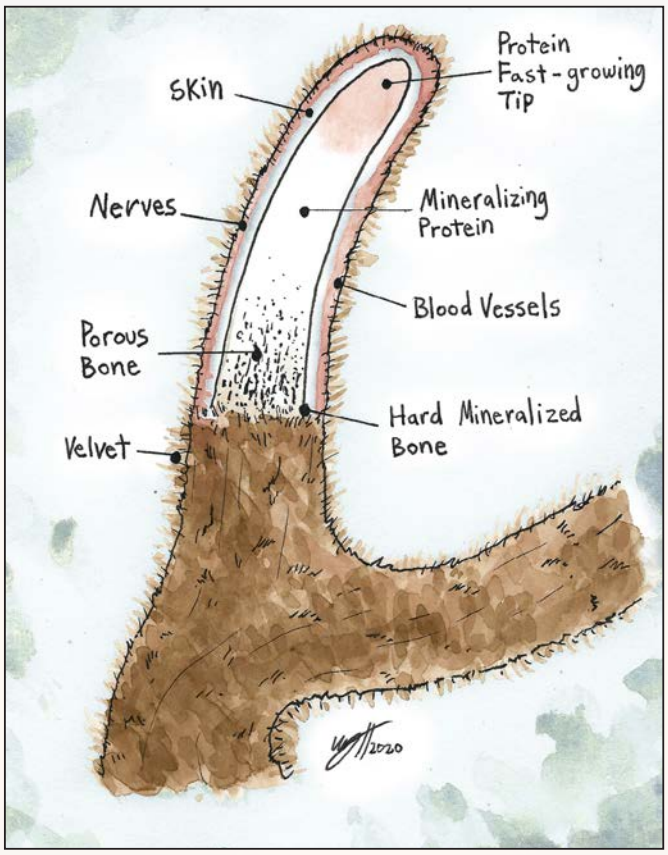


Illustration by Wyatt Heffelfinger

Recent Research

Although some of the great antler researchers are no longer with us, important and interesting antler research continues. Some continue to work towards relating genetic variation with antler characteristics to learn more about the genetic basis for antler growth. Because of the uniqueness of the antler cycle, there is potentially much more we can learn that might improve therapies for human bone disease, healing of fractures, or maybe even human limb regeneration. The mobilization of calcium from the skeleton to help supply the rapid growth of antler material in mature animals is similar to the process of osteoporosis in mature humans which provides a model to study that biological process. Recently a research group reported that rapid antler bone growth was similar to bone cancer, which led some reporters in the news media to report that antlers were actually cancer. Not true, but this fast bone growth does provide insights into the growth of bone cancer cells and may play a role in helping to develop a cure for cancer someday.

There are many complex components and processes involved in the antler cycle which will provide fodder for decades or centuries of research. Undoubtedly, some of this work will provide real benefits to our society. Despite the dizzying array of research opportunities, we must not let the mysteries of antler development stand in the way of us very unscientifically admiring a beautiful set of antlers.

Jim Heffelfinger is a Certified Wildlife Biologist who has worked as a biologist for the federal government, state wildlife agencies, universities, and in the private sector. Jim has authored or coauthored more than 200 magazine articles, scientific papers, and 20 book chapters in regional, national, and international publications. He is a Full Research Scientist at the University of Arizona and Professional Member of the Boone & Crockett Club. Visit www.deernut.com for a copy of his book "Deer of the Southwest" and follow him on Instagram: @Jim.Deere