The deer on the right was treated with doses of Melatonin and has its winter coats and hardened antlers, which is the opposite of the untreated deer on the left in velvet and a summer coat.

PHOTO BY DR. GEORGE BUBENIK

PHOTOPERIOD AND ANTLERS

ARTICLE BY
JIM HEFFELFINGER

Humans have been pondering and observing natural cycles since the beginning of time, and cavemen no doubt gave thought to the annual changes occurring on the heads of those animals they pursued. As with all cultures since, they surely had their own elaborate explanations for the causes behind seasonal changes in antlers.

Photoperiodism

At the equator, each 24-hour period has 12 hours of darkness and 12 hours of daylight every day of the year. As you move north or south from the equator, the proportion of light and dark changes throughout the year with the seasons. Changes are more dramatic near the poles where we have 24 hours of darkness or light during certain times of the year. The changes in this proportion of light and dark throughout the seasons (away from the equator) is what we call changes in "photoperiod." Photoperiod plays a huge role in the timing of not only the antler cycle, but also many important seasonal events in the animal world, such as hibernation, migration, reproduction, summer/winter coat change and the deposition of body fat for winter.

In northern areas, with harsh winter conditions, fawns born during much of the year would quickly die. Throughout the eons, deer and other animals have solved this problem by regulating the timing of breeding – and thus fawning – via the annual photoperiod cycles of day length. Without wristwatches and calendars, deer have no way to know when in the annual cycle they should breed to give the fawns the best chance of surviving, but nature has a knack for always finding a way. Since fawns in northern climates die if born outside the spring/summer period, natural selection has favored only those animals that breed in the fall and drop fawns when the vegetation and nutrition is optimal.

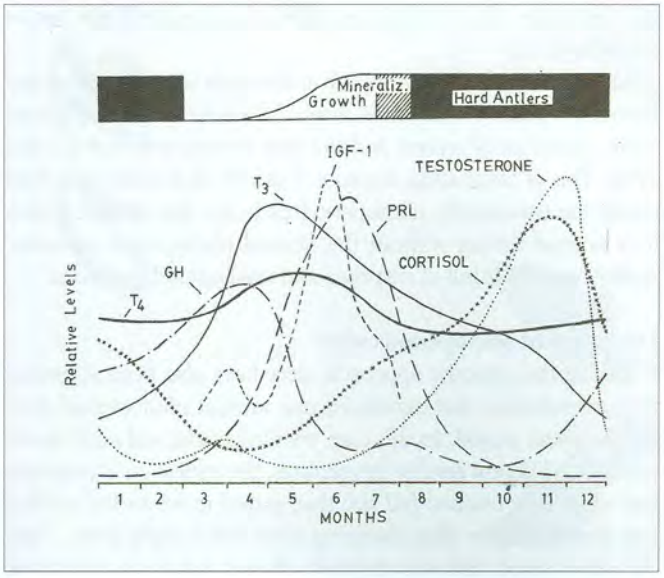
Antlers

The timing of the antler cycle has an underlying genetic basis because natural selection has selected the most optimal fawning period, but this annual cycle is driven primarily by changes in photoperiod each year. Dr. Harry Jacobson, formerly of Mississippi State University, describes this phenomenon as

genetics setting the alarm clock for these processes and local photoperiod running the clock. The genetic contribution to the timing of the breeding and antler cycle was demonstrated when Jacobson transported captive deer from Michigan to Mississippi (and vice versa) and found the deer retained their breeding dates from their state of origin for at least three years. In addition, offspring of Michigan x Mississippi matings bred at a time that was halfway between the dates of their parents.

So how do changes in the amount of daylight result in physical changes in the deer? Researchers have been able to fill in some of the blanks, but there is still much we don't know. What is known is that as the days get shorter in the fall, the retina of the eyes register these changes and transmit signals to the pineal gland at the base of the brain. The pineal gland regulates the production and release of many hormones that regulate body processes, including the antler cycle and hair molting. When darkness falls each night, the pineal gland triggers the secretion of melatonin. In the middle of the night, there may be five times as much melatonin secreted as during daylight hours. This fluctuation of melatonin each 24-hour period acts as a messenger to trigger seasonal changes in the complicated orchestra of hormones that drive the antler cycle and other annual processes.

In a series of experiments, researchers have surgically removed the pineal gland and found that the deer completely lost the synchrony and timing of the antler cycle, breeding season, and even the molting of their summer/winter coats. By feeding deer melatonin in amounts and times to simulate shortening daylengths, researchers also caused changes in all these seasonal biological events as if the photoperiod was changing with the seasons.



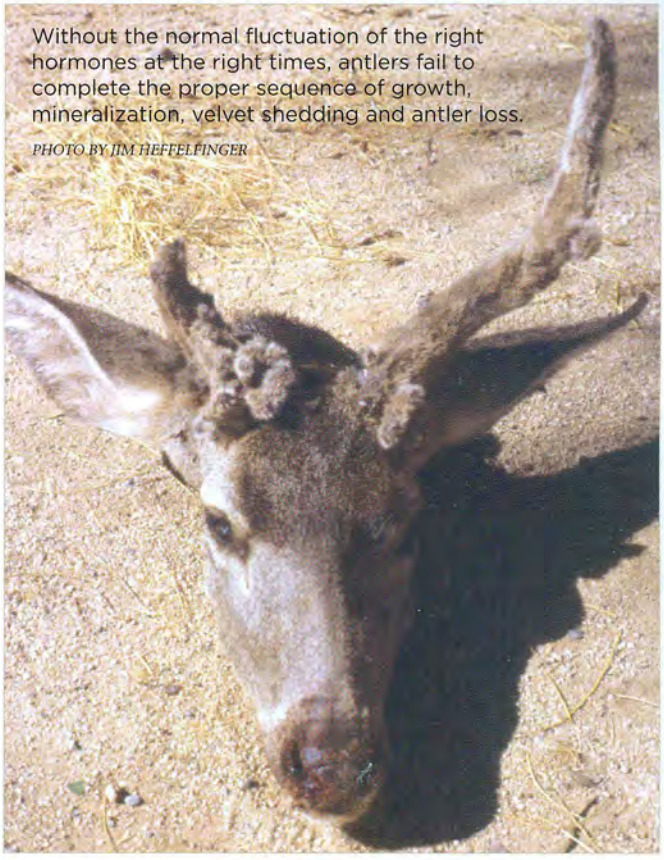
The antler cycle is driven by an incredibly complex orchestra of hormonal fluctuations throughout the year - all of which play a role in some part of the cycle.

ILLUSTRATION COURTESY OF DR. GEORGE BUBENIK

Messing with Photoperiod

In the 1950s, Zbigniew Jaczewski pioneered antler photoperiod research by herding some of his captive deer into a dark shed in the afternoon to simulate a shorter day and longer night during the summer. The deer mineralized their antlers halfway through the normal growing period and the velvet dried and was stripped off. The bucks soon became aggressive as they entered a false rut in midsummer. When he could no longer get the aggressive bucks into the shed he had no choice but to let keep them out in the pasture exposed to normal photoperiod cycles. The bucks then promptly shed their abbreviated antlers and re-grew another set the same summer, which then hardened and were shed on the normal schedule with the other deer in the herd.

THIS SHOWED THE IMPORTANCE OF THE PHOTOPERIOD IN REGULATING THE ANTLER CYCLE AND LEAD RICHARD GOSS TO DESIGN A SERIES OF EXPERIMENTS IN THE LATE 1960S WITH SIKA DEER TO MORE FULLY INVESTIGATE THIS PHENOMENON.



Without the normal fluctuation of the right hormones at the right times, antlers fail to complete the proper sequence of growth, mineralization, velvet shedding and antler loss.

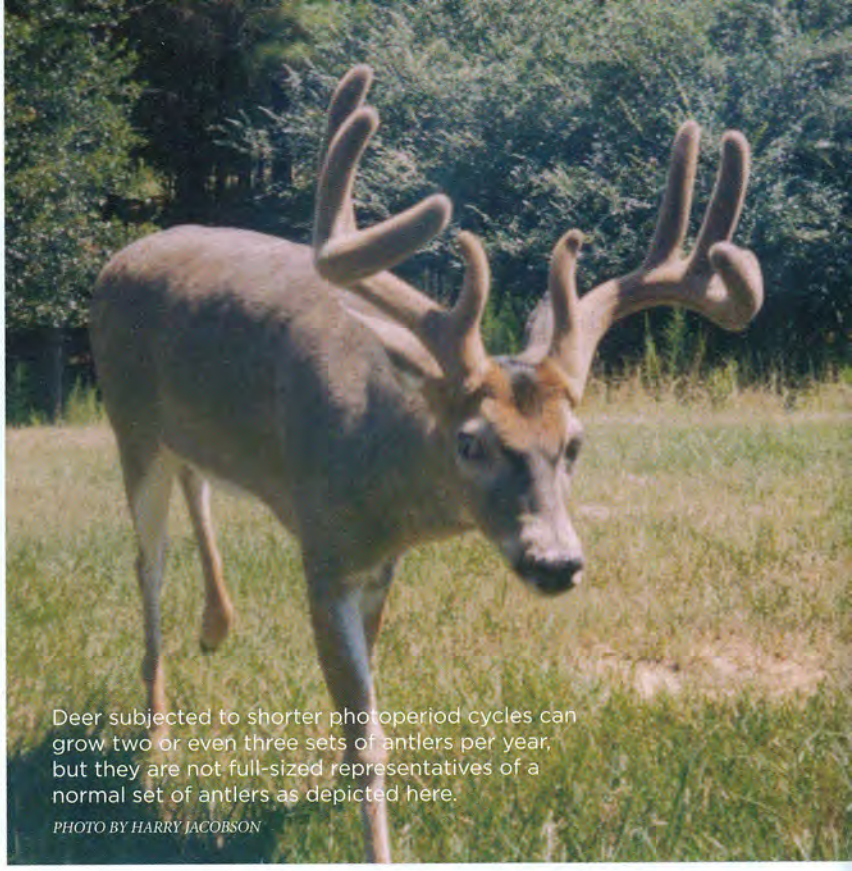
PHOTO BY JIM HEFFELFINGER

This showed the importance of the photoperiod in regulating the antler cycle and lead Richard Goss to design a series of experiments in the late 1960s with sika deer to more fully investigate this phenomenon.

Reversed photoperiod cycles

One of the first experiments Goss tried was to maintain deer under an artificial light/dark cycle indoors that simulated the exact opposite of what was going on outside. When days were increasing, his deer were experiencing a decreasing trend in daylight. This artificial cycle ultimately resulted in deer that grew antlers in the winter and shed them in spring, exactly the opposite of the rest of the herd outside.

Translocated deer from the northern to the southern hemisphere experienced the same effect. For example, white-tailed deer that were moved from the United States to New Zealand in 1905 switched their antler cycles to grow antlers during our winter (the New Zealand summer). These deer rut in May and the fawns are born in December and January, which is exactly six months out of sync.



Deer subjected to shorter photoperiod cycles can grow two or even three sets of antlers per year, but they are not full-sized representatives of a normal set of antlers as depicted here.

PHOTO BY HARRY JACOBSON

More frequent photoperiod cycles

Goss then placed bucks indoors under controlled lighting and artificially reproduced two annual cycles of increasing and decreasing day lengths in a 12-month period. Bucks under these artificial lighting conditions grew and shed two complete sets of antlers in one year. This experiment was then carried further by shortening the cycles to only four months and the bucks produced three complete sets of antlers in one year! When the cycles were shortened to only three months each the trend started to break down and become inconsistent. There is a natural limit to the number of antler sets that can be produced.

ONE OF THE FIRST EXPERIMENTS GOSS TRIED WAS TO MAINTAIN DEER UNDER AN ARTIFICIAL LIGHT/DARK CYCLE INDOORS THAT SIMULATED THE EXACT OPPOSITE OF WHAT WAS GOING ON OUTSIDE.

Normally, antlers are growing and in velvet for about four months. If we try to get several complete antler cycles in a single year the time of actual growth in compressed. Since the rate of antler growth cannot be sped up to produce a normal-sized set of antlers in less time, the antlers produced under these more frequent cycles are smaller. With an annual cycle of photoperiod changes simulated in only three months time, antlers spend about one month in velvet and two months in hard antler about two to six inches long.

The growth rate of antlers cannot be sped up so when deer are subjected to shortened photoperiod cycles, the antlers do not reach full size before mineralizing and shedding their velvet.

PHOTO BY JIM HEFFELFINGER

As the amount of time for each antler cycle was reduced to two months, a point was reached where it is impossible to produce even a small set of antlers and the deer default to a near normal cycle. This is fascinating, because it is not clear how deer held under the two-month photoperiod cycle are able to revert back to a normal timing without the normal photoperiod stimulus. Antler research is full of surprises and unanswered questions.

Less frequent photoperiod cycles

Taking the opposite approach, deer have also been subjected to manipulations that simulated one annual photoperiod cycle in a two-year period. In this case, yearling bucks and adult bucks produced different results. In yearlings, the antlers grew normally but when they reached full size they stayed in velvet for another two months rather than shedding their velvet right away. Then the velvet dried and was stripped off and the bucks held their antlers for more than a year until finally shedding them a full two years after they shed their last set. Despite the two-year antler cycle, the bucks grew antlers no bigger than normal.

Adults held under the same conditions somehow stayed on a normal 12-month antler cycle. It is possible that their prior exposure to normal photoperiod cycles allowed them to produce antlers on nearly the same schedule as deer exposed to natural cycles. However, Harry Jacobson reported that a whitetail born without eyes in Mississippi still produced antlers on a cycle of averaging 375 days. There must be an internal clock of some kind that can be defaulted to under extreme circumstances.

Fawns born at the wrong time of year without adequate cover and nutrition do not last long and through time, Mother Nature makes adjustments to maximize survival and all other biological processes fall into place to support that timing.

PHOTO BY AZGFD

Equator deer

In the southern latitudes of the United States there is a much weaker relationship between photoperiod and the fawning season than you see in the north with their harsh winters. Deer in the warmer latitudes have a bigger margin of "error" in the timing of the fawn drop because fawns born over a wider range of dates in the spring and summer still survive in the milder climate. The "alarm clock" for rut in Arizona Coues' white-tailed deer is set for January so that fawns are born in August. A fawn born in August in Wisconsin would not survive because it wouldn't have enough time to grow big enough and store enough fat to survive the harsh winter. Yet for the Coues' whitetails, being born in August coincides with the period of lush forage growth following the summer monsoons and the 70-degree days though January pose no threat to their survival.

Further south, near the equator, the fawning period and other life events are not driven by photoperiod at all because it never changes from 12 hours each of daylight and dark. Because of this, breeding of some individual deer is occurring year-round. Populations of deer near the equator contain bucks in all stages of antler development in any given month of the year. Some bucks will be in velvet, some in hardened antler, and some freshly shed. Remarkably, each buck is on his own 12-month cycle, they are just not all synchronized as they are in the northern latitudes.

Where on the calendar each deer is with his own 12-month cycle depends mostly on what time of year it was born. Without natural selection eliminating the fawns with certain birth dates, the population develops as a mixture of deer genetically programmed to give birth during all months of the year. When these equatorial deer are moved to zoos in northern areas they still retain their odd timing of birth and antler cycles. Their cycles are running on the local photoperiod clock, but their alarm is still set by genetic adaptations from their past.

Normally, bucks are not fertile during the period they are in velvet antler, but with females going into estrus in all months of the calendar it would be advantageous for these males to always be ready. That, apparently, is the case near the equator, as Mother Nature has once again solved that problem with males producing sperm and fertile year round. It remains a mystery how deer in this situation stay on a 12-month cycle without the benefit of photoperiod that has been shown to be so important in deer most other places. This is just one of several pieces of evidence for the existence of some sort of internal clock that deer can sometimes fall back to. The antler cycle has many areas of research just waiting for graduate students and money.

Deer and Daylight

The deer family has such a wide latitudinal range with the familiar and widespread white-tailed deer occupying habitats from near the Arctic Circle in the Yukon to the Amazon in South America. This widespread distribution on several continents and manipulations in captivity have allowed researchers to observe, compare and experiment with how photoperiod affects the antler cycle. The highly-adaptable deer family around the world has adjusted the timing their fawning period to the period that offers the greatest chance of survival under local conditions. That timing then drives the rest of the reproductive cycle from when antlers must be hard to when females come into estrus. To establish these processes at the correct time for local conditions, there must be a universal clock they use to "tell time" throughout the year and photoperiod changes provide that clock.

These whitetails in New Zealand carry out their breeding and antler cycles exactly six months out of sync from their North American counterparts.

PHOTO BY P. PEYCHERS

The annual growth, death and regeneration of antlers is unique to the deer family and unprecedented in the animal kingdom. No other mammal regenerates lost appendages.

Every time we conduct structured research on antlers we learn a little more about the process, but also uncover a few results that are difficult to explain or just don't make sense. Past and present research on antlers provides a model for the study of cancer, osteoporosis, hormone changes, bone growth, and, of course, photoperiodism. As with other wildlife and medical research, we will continue to learn more and start to fill in additional pieces of this puzzle, revealing a more-complete picture of this amazing process.