

PALEONTOLOGY

# The Cloven Hoof

## "A Classic of Science"

### The Cloven Hoof Resulted From Loss of Three Toes, and The Solid Hoof of the Horse From Loss of Four Toes

ON THE ORIGIN OF THE FOOT STRUCTURES OF THE UNGULATES. By E. D. Cope. In *The American Naturalist*, Vol. XV. Philadelphia, McCalla & Staveland, 1881. This is an exact reprint of the original publication.

THE FOLLOWING considerations have been suggested by a study of the primitive types of the odd and even-toed ungulates. I first, in 1874, recorded the opinion that the *Mammalia* with a reduced number of digits were derived from pentadactyle plantigrade types. The ungulate order which fulfills this requirement is the *Amblypoda*, and from them, I doubt not, both the *Perissodactyla* and *Artiodactyla* have arisen, although not from any of the genera now known. Both of these great orders display a regular diminution in the number of the digits; in the former, by reduction and extinction on each side of the third digit; in the latter, by reduction and extinction on each side of the third and fourth digits. Mr. John A. Ryder has pointed out that reduction in digits is probably directly related to strains and impacts. He reminds us that the anterior digits are reduced in *Mammalia* of unusual scansorial or fossorial powers; while in forms which display powers of running, the reduction is seen first in the posterior feet, which propel the body much more than the fore feet. This view is well illustrated in the *Perissodactyle* families, the majority of which have the digital formula 4-3.

No reason has ever been suggested, so far as I am aware, in explanation of the fact that one series of ungulates has retained two digits, and the other only one; that is, why there should have been two kinds of digital reduction instead of one kind. In seeking for an explanation, we will remember that the tarsus

*Amblypoda*=animals with diminished feet.  
*Artiodactyla*=animals with an even number of toes.  
*Perissodactyla*=animals with an odd number of toes.

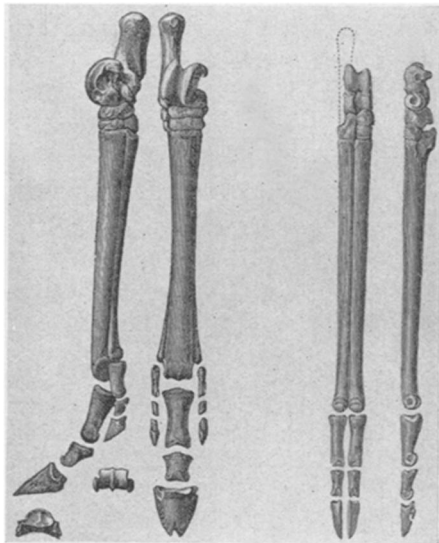
in the odd or single-toed line, is bound together by fixed articulations, while in the cloven footed line it is interrupted by the hinge between the first (astragalus), and second rows of bones. The hinge-joint being more liable to luxation than the fixed articulation, requires a wider basis of support, such as would be furnished by two divergent digits, rather than by a single central one.

In the early types, where the median digits are slender, the mechanical advantage in favor of the bidigital over the unidigital arrangement is much more obvious than in modern genera. Late in time, the horse developed the middle digit to such a width as to form almost as good a support as the bidigital structure. In the Eocene genera, the slender median digit could not have sustained the weight on a hinge, without great risk of dislocation. This explanation it can be said, applies only to the posterior foot. The posterior foot has, however, led the way in the evolution of *Ungulata*, and the fore foot may have followed in accordance with the law of antero-posterior symmetry in growth. A curiously malformed deer from Mendocino county, Cal., throws some light on this subject. It has apparently a single functional digit on each foot. Examination shows that the posterior foot is bidigital, but that the phalanges are fused; while the anterior foot is perissodactyle, all the digits but the third being rudimental! Similar evidence is furnished by the genus *Eurytherium* of the French Eocene. Its posterior foot is modified artiodactyle, while the anterior is modified perissodactyle. We may assume from these facts, that the posterior foot is more subject to the influences which tend to produce the bidigital structure than is the anterior limb.

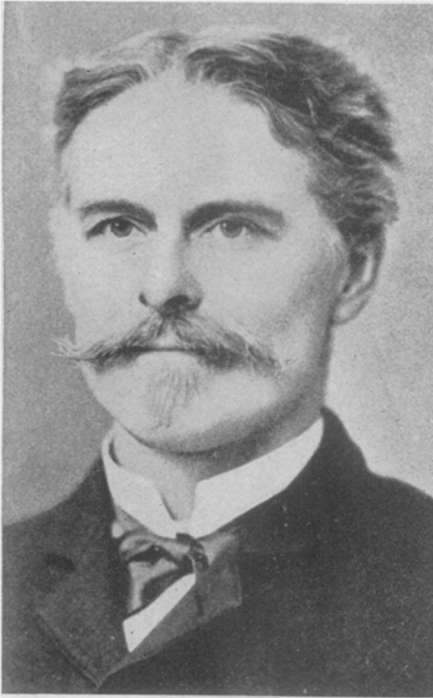
I suspect that the production of a ginglymus in the middle of the tarsus, has been due to the use of the posterior limb in soft swampy ground. In the absence of this condition, as in a life on harder ground than swamp, no gingly-

mus would be formed. The action of an ungulate in walking through deep mud is very suggestive. The posterior foot is bent on the leg, and the antero-posterior strain of the weight or propulsive force, is transverse to its long axis. In progression on dry land, the impact is in the direction of the length or axis of the foot. The obvious effect of a cross strain is to produce by degrees greater and greater mobility of some articulation. The one which has yielded is that between the two tarsal rows. Another effect of walking in swampy ground is to spread the digits apart. As the first digit of both feet is always of reduced size, there are practically but four digits to be considered. The weight falling nearly medially on these, would tend to spread them equally, two on each side. Thus the same cause may have been effective in producing both the artiodactyle structures. The perissodactyle structure, so soon as the lateral digits are much reduced, ceases to be favorable for progression in soft ground, owing to the liability of the lateral digits to injury, in following the principal one into the yielding material, filled with sticks and other hard débris.

The lowest existing forms of the *Artiodactyla*, the *Omnivora*, are univer-



**SOLID HOOF AND SPLIT HOOF**  
 showing the modification of the leg and foot bones as one or two toes predominate.



**EDWARD DRINKER COPE, 1840-1897**  
*Professor of geology and paleontology at the University of Pennsylvania. He studied many North American fossils, particularly those of reptiles, amphibians, and the hoofed mammals.*

sally swamp lovers and livers. So we are told are the lower existing *Perissodactyla*, the tapirs and rhinoceroses. The higher types of both orders are dwellers on plains and in forests. We do not know the habits of the Eocene *Perissodactyla*, but I doubt their having inhabited muddy ground to the same extent as the hogs and hippopotami, the lowest of the *Artiodactyla*. Now in progression on dry land, any preëxistent inequality in the length of the digits would tend to become exaggerated. Such an inequality exists in the *Amblypoda*, the third digit being a little the longer. In rapid movement on hard ground the longest toe receives the greatest part of the impact, even if its excess of length is but little. The harder the ground the larger the proportion of impact it will receive.

The fact that the *Perissodactyla* did not develop the solid ungulate or equine foot, until a late geological period, or in other words, that the orders so long retained the digital formula 4-3, would indicate that it did not adopt a habitat which required great speed as a condition of safety, so early as the *Artiodactyla*.

*Science News Letter, May 6, 1933*

PHYSICS—PHYSIOLOGY

## Muscular Physiology Studied By "Artificial Rainbow"

**B**EAMS of white light have been broken up into their many-hued spectra, or "artificial rainbows" by shining them on the surface of a frog's leg-muscle, and something learned of the physiology of muscular contraction by this unique means. Researches in which striated muscle tissues have been used as diffraction gratings were reported to the American Physical Society by Arthur Adel and David M. Dennison of the University of Michigan.

It has long been known that white light reflected from a finely ruled metal or glass surface would break into its constituent colors, or spectrum, just as though it were projected through a triangular glass prism. The alternating fine bands of dark and light markings that characterize ordinary body muscles have been found to act in the same way. These lines number about ten thousand to the inch.

The two Michigan physicists found that when muscle is lengthened by stretching, or shortened by stimulating

it to contract, the width of the bands changes by the same percentage as the change in total length of the muscle. A study of the spectral changes in light reflected from muscle stimulated to contract but prevented from contracting indicated that the region of active contraction in striated muscle is situated in the dark bands.

At the same session, Miss Rachel Franklin, A. J. Allen and Dr. Ellice MacDonald of the Cancer Research Laboratory of the University of Pennsylvania reported their observations on the effects of ultraviolet light on living protozoa, one-celled primitive animals. Ultraviolet radiation beyond a certain wavelength causes immediate cessation of all motion, followed by marked internal changes and in some cases a complete breakdown of the cellular structure. The researchers photographed these phenomena through a microscope equipped with all-quartz lenses to permit the passage of the short-wave radiations to which glass is opaque.

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ENDOCRINOLOGY

## Few Drops of Extract Gives Goiter to 200 Guinea Pigs

**T**HE "CHEMICAL DISSECTION" of a gland has been reported by Drs. J. B. Collip, D. L. Thomson, H. Selye and E. M. Anderson of McGill University at a recent meeting.

The gland is the pituitary, located at the base of the brain, and apparently possessed of far greater powers than hitherto supposed. This gland secretes a number of hormones, powerful chemical regulators of body activity.

One investigator estimated that twenty-two pituitary hormones had been reported by various investigators. Dr. Collip and associates are working to get clean hormone extracts from this gland, each separate from the other, and to determine the exact effect of each on the human body.

In his pocket, Dr. Collip carried a

tiny bottle containing a clear, colorless fluid. One cubic centimeter, or about 20 drops of this particular pituitary hormone is sufficiently powerful to produce exophthalmic goiter in two hundred guinea pigs, Dr. Collip said.

The fact that a substance secreted by the pituitary gland can produce this disease of thyroid gland over-activity is the latest discovery of scientists both in America and Europe.

Animals lacking a pituitary gland and suffering from under-activity of the thyroid gland are restored to normal by doses of this potent new pituitary hormone. Other hormones which scientists are extracting from the pituitary gland affect the sex glands while still others affect the adrenal gland, Dr. Collip said.

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