The horse-bean is called, in France, *feverole;* in Germany, *pferde oder feld bohne;* in Italy, *fava cavallina.*[1]

EVENING PRIMROSE.   *Œnothera biennis* L.

The roots may be used as Scorsonera, but it is cultivated in France only as a curiosity.[2]   It is said by Loudon[3] to be cultivated in Germany, and in Carniola the roots are eaten in salad.[4] It was once under English culture.[5]   A native of Northern America, it first reached Europe in 1614.[6]   It is given by Burr[7] for American gardens in 1863, under the name *German Rampion.*

It is called, in France, *Œnothere bisannuelle, onagre, herbe aux anes, jambon, jambon des jardiniers, jambon de St. Antoine, lysimachie jaune, lysimachie jaune cornu, mache rouge;* in Germany, *rapuntica;* in Flanders, *ezelskruid;* in Italy, *rapontica, rapunzia;* in Norway, *natlys.*[8]

(To be continued.)

THE PERISSODACTYLA.

BY E. D. COPE.

DIPLARTHRA.

IT is to the order Diplarthra that the greater number of existing species of hoofed mammals belong.   It is represented by two sub-orders, which have the following definitions:

Astragalus truncate distally; the median toe the largest ;...............*Perissodactyla.*
Astragalus with the distal end convex anteroposteriorly, forming a
  ginglymus (hinge-joint); number of toes generally even, the median two the largest ;..*Artiodactyla.*

[1] NOTE.—The references in the list are to Bridgeman, Young Gard. Assist., N. Y., 1832; Bryant, Fl. Dict., Lond., 1783; Fessenden, New Am. Gard., 1828; Loudon, Hort. Lond., 1860; McMahon, Am. Gard. Kal., Phila., 1806; Mawe, Univ. Gard., Lond., 1778; Noisette, Man., Brussels, 1829; Stevenson, New and Comp. Gard. Kal., Dublin, 1765; Thorburn, Gent. and Gard. Kal., N. Y., 1821; Thorburn's seed-catalogues, 1828, 1884; Townsend, Comp. Seedsman, Lond., 1726; Vilmorin, Les Pl. Pot., Paris, 1883.

[2] Vilmorin, Les Pl. Pot., 202.   [3] Loudon, The Horticult., 1860, 653.
[4] Flore Nat. et Econ., Pt. 2, p. 398.   [5] Johnson, Useful Pl. of Gt. Brit., 104.
[6] Linnæus, Sp., 1763, 492.   [7] Burr, Field and Gard. Veg., 1863, 35.
[8] Schubeler, Culturpflanz de Norv., 118.

No undoubted connecting forms between these sub-orders have been discovered, although they approximate at various points. Thus, in the genus Menodus there are but four toes in the anterior foot, and the median two do not differ much in length. In the same genus the distal extremity of the astragalus is somewhat convex, and the facet for the cuboid bone is large, somewhat as in the hippopotamus; but the angle separating the two facets is diagonal, and not transverse; so that the astragalus cannot move on the cuboid and navicular bones and form a ginglymus, as it does in the Artiodactyla. In a few instances some Artiodactyla have teeth which resemble those of the Perissodactyla; for instance, the genus Listriodon. Both sub-orders probably arose from an undiscovered common ancestor, which was a member of the order Amblypoda. It was probably a type with tubercular molars, and belonged to the Puerco epoch. An approach to this theoretical type is made by the Pantolestidæ, whose molars are bunodont, the superior molars being tritubercular (with two intermediates); but the form of the extremities (the posterior only is known) is that of the Diplarthra. The hypothetical Amblypoda with bunodont molars I have regarded as a sub-order, and have named the Hyodonta.[1]

The opinion has been expressed by Schlosser that the evolution of the Diplarthra, or alternate-wrist-and-ankle-jointed ungulates, has been directly from the Taxeopoda, or straight-rowed-wrist-and-ankle-jointed Ungulata, without intervention of the Amblypoda. The Periptychidæ have been cited as the probable ancestors of the Artiodactyla, and the Phenacodontidæ as ancestors of the Perissodactyla. I do not agree with this view, and for the following reasons:

The conversion of a taxeopod into a diplarthrous ungulate has been accomplished by the rotation outwards of the lower leg with the first row of the carpus and tarsus, on the second row, or by the rotation inwards of the second row on the first, in both the fore and hind feet. This rotation has resulted sooner or later in the loss of the internal digit (thumb and great toe) from both extremities. In the history of this sliding outwards of the first row, the outside element of the row has always preceded in time the inside element. The Amblypoda (Fig. 2)

show this clearly.   The lunar bone has extended outwards so as to rest on the outside bone of the second row (unciform) in part, as well as the one on which it properly rests (magnum). But the scaphoid has not slipped outwards so as to rest on the magnum of the second row.   That continues to rest on its proper successors below, the trapezoïdes and the trapezium, the latter taking half the burden.   This structure (Fig. 2) is absolutely intermediate between that of the Taxeopoda (Fig. 1) and that of the Diplarthra (Fig. 3), and I imagine that all ungulates, in passing from the taxeopodous to the diplarthrous stages, traversed
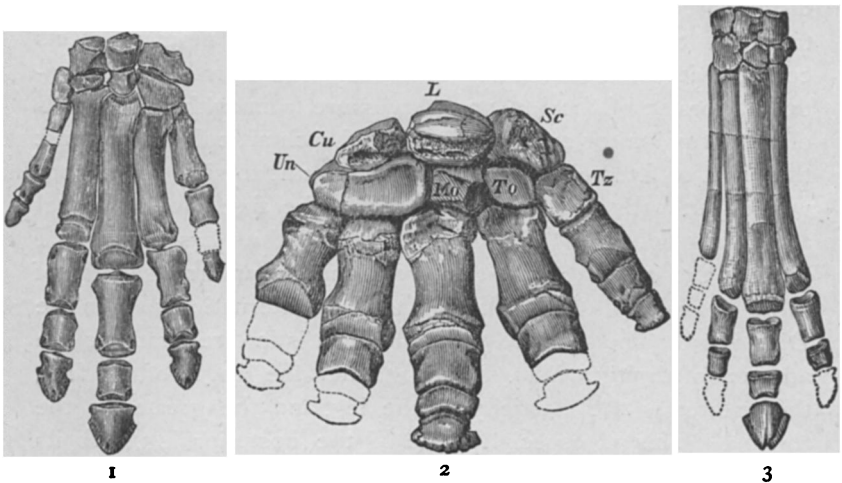

FIG. 1. *Phenacodus primævus*, left manus, one-third natural size.   Original.
FIG. 2. *Coryphodon elephantopus*, right fore-foot, one-third natural size.   Original.
FIG. 3. *Hyracotherium venticolum*, right fore-foot, two-thirds natural size.   Original.

the amblypodous.   The only other conceivable path would have been through a type in which the scaphoid had extended over the magnum, while the lunar did not pass outwards beyond the limits of the magnum.   No such type has been found.   On the other hand, I have shown that the Oredontidæ[1] have pushed the transposition of the bones of the first carpal row to such an extreme that the magnum has gotten entirely under the scaphoid, while the unciform supports the lunar completely.   Thus the alternating position, with its useful mechanical consequence, has been lost to this group, the effect produced being exactly that

[1] Proceeds. Amer. Philosoph. Society, 1884, pp. 503–9.

seen in the Amblypoda. This may have had something to do with the extinction of the Oreodontidæ.

The cause of this rotation of the first on the second rows of carpal and tarsal bones may be now referred to. Mammals, except those which are completely plantigrade (as the bear), turn the toes out in walking.[1] In the Ungulata, the toes of the posterior foot are more strongly turned outwards than those of the anterior foot. In the digitigrade Carnivora, which represent the highest type of the Unguiculata, the movement is reversed, the anterior toes being turned outwards more than the posterior. As the foot is descending towards the ground, it is, with the distal part of the leg, rotated from within outwards. The rotation of the foot is promptly arrested at the moment of its contact with the ground, and the effect of this arrest is to produce a torsion of the leg, and a pressure from within outwards of the proximal or moving element of each articulation, against the distal or fixed element. Thus a constant torsion strain from within outwards has been exerted by the first row of carpal and tarsal bones, on the second row, and thus has arisen, as I believe, the gradual transition from the linear arrangement of those bones of the Condylarthra to their alternation seen in the Diplarthra. The advance of diplarthrism is in direct ratio to the advance of digitigradism, for the greater the length of the foot, the greater is the elasticity of the leg, and the greater is the torsion. This is especially true of the posterior leg, with its prominent heel; and thus is explained the fact that diplarthrism appears in that foot before it does in the fore foot, as in the Proboscidia. (Plate XXIX.)

To the same exterior torsion is to be ascribed the early extension of the radius and tibia over the first row of carpals, and the almost exclusion of the ulna and fibula from the articulation.

This reasoning when applied to the Unguiculate series is modified by other circumstances. In the Carnivora the weight of the body does not rest on the ungues as in the Ungulata, but on the pads of connective tissue beneath the digits. Consequently on the application of the foot to the ground the distal bones in the carpal and tarsal articulations do not present the rigid resistance seen in the Ungulata, but yield more or less to the tor-

[1] Familiar exception to this rule is seen in some horses; but the ass turns the toes out, and the tapir, which represents the horse's ancestors, turns the toes out also.

sion. Hence no alternation of these bones takes place in the hind foot of the Carnivora, where the eversion of the digits is moderate. In the case of the fore foot, the eversion and consequent torsion are so great that the alternation is produced (Plate XXVIII.). In the manus of the plantigrade bear the alternation is almost *nil*.

It may be here objected that the camel walks upon elastic pads as do the Carnivora, and yet the alternation does really take place. It is on this account (as I have maintained) that the distal metapodial tongue-keels were never completed in these animals. But if the camel does not rest on the ungues sufficiently to resist torsion, as in the Carnivora, this was not the case in the ancestors of the camels, the Poëbrotheriidæ, where the contact with the ground was much as in other Diplarthra. But there is little impact in the step such as occurs in other Ungulata, hence the failure to complete the keels.

Our zoological gardens furnish excellent opportunities for the verification of all these observations on the progression of Mammalia.

I. PERISSODACTYLA.

The modifications of structure seen in the evolution of this sub-order are principally those of the feet, teeth, and vertebræ. As already remarked, the changes in the feet consist in the gradual reduction of the number of the digits from four, or perhaps five, to one. In the teeth the changes consist in the conversion of tubercular, or bunodont, into crested, or lophodont, molars, and in the increase in the complexity of the premolars, so that, instead of possessing a distinct and simple character of their own, they come to resemble the true molars; also in the reduction in the dimensions and numbers of the canine and incisor teeth in some lines. The modification of the vertebræ consists in the conversion of a flat zygapophysial articulation into a concavo-convex or embracing structure. This modification is similar to what is seen in some of the Artiodactyla, but the change is carried further, and the structure becomes more complex in the latter suborder.[1] In the teeth the change pursues two paths, both different from that seen in the Artiodactyla. The modifi-

[1] See "Systematic Arrangement and Phylogeny of Artiodactyla," in Proceeds. Amer. Philos. Society, September, 1887.

cation of the feet is of a different type, as already stated in the definitions of the two orders.

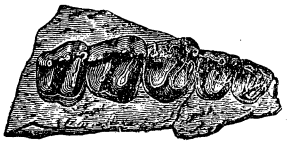The first step in dental modification in the superior series is the flattening of the external tubercles, and their connection with each other at the base. The beginning of this process is seen in *Heptodon singularis* (Fig. 4) and its allies of the Hyracotheriinæ.[1] A concomitant change is the confluence of the internal cusps with the intermediate ones into crests or ridges, which may be transverse or oblique (Figs. 4, 12, and 15), or may be otherwise varied, as in the equine line. In the lower jaw two lines of change have developed. In the one the tubercles of the crown have been opposite, and have become joined in pairs by transverse ridges or crests (Fig. 12); while in the other the cusps have become alternate, so that the ridges which joined them have been oblique, each tubercle giving origin to two crests extending in divergent directions,—that is, to the cusps with which it alternates. The result has been a W-shaped crest or line of crests (Figs. 26 *b*, 28).

FIG. 4. Part of right maxillary bone of *Heptodon singularis* Cope; from the Wasatch beds of New Mexico. From Captain Wheeler's report, iv., ii. Pl. LXVI.

Ryder has pointed out that the rhinoceros masticates its food by the movement of the mandibular ramus from without inwards on the upper jaw. The same is true of the species of Equus (*E. montanus, E. asinus, E. caballus*). The same author points out that the masticatory movement in the selenodont Artiodactyla is in the opposite direction, from within outwards.[2] It appears to me probable that many of the primitive Perissodactyla had the same movement as the latter. They, however, present a remarkable difference from the selenodont Artiodactyla in another respect. The mandibular condyle in Hyracotherium,

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[1] These are frequently accompanied by an additional external cusp, which springs from the anterior external angle of the crown. (See Figs. 4, 8, 10)

[2] Proceedings Academy Philada., 1878, p. 45. Although Professor Ryder afterwards gave up this view, and concluded that the Artiodactyla had the same movement as in the Rhinoceros (l. c., 1879, 47), his first opinion was undoubtedly the correct one.

Symborodon, etc., is strongly convex upwards, so that a lateral twist of the entire lower jaw in mastication becomes possible. The result of this has been to throw the masticating function almost entirely on the external cusps of the molars in both jaws. Thus is explained the fact that in this order the external cusps of the molars in both jaws only are modified, while the internal remain of relatively small dimensions, and often primitive form. In the tapir, where the movement in mastication is almost vertical, neither set of tubercles attains a remarkable specialization.

For the three modes of mastication mentioned the following terms are proposed: Vertical movement (Carnivora, Bunodonta), Orthal; from within outwards, Ental; from without inwards, Ectal (from ἀλειν, to grind).

The three lines which originated from the Lophiodontidæ are those which terminated in the Equidæ, the Tapiridæ, and the Rhinocerontidæ. They differ in the characters of the superior molar teeth as below pointed out. The mechanical cause of these peculiarities is not far to seek. In the Equine line mastication has been effected on that side of the mouth where the lower jaw, in its transverse motion across the superior molars, was moving from the inside outwards, as in the selenodont Artiodactyla (ruminants). In the Tapiroid line there has been little transverse movement of the lower jaw, so that V's have not been developed in the molars of either series. In the Rhinocerontine line mastication has been performed on that side of the mouth where the lower jaw was passing from the outside inwards. This is the method of mastication of the Rhinoceros to-day, as observed by Professor Ryder.[1] The effects of these distinct kinds of mastication are seen in different forms of the external walls of the superior molars. In the Equine line (Chalicotheriidæ, Menodontidæ, and Palæotheriidæ) the edges of the external cusps have been drawn externally by the ental movement of the lower jaw, thus producing the legs of the two V's. In the Rhinocerontine line the branches of the single large anterior V have

[1] Proceeds. Academy Philadelphia, 1879, p. 49. In this paper Professor Ryder recedes from his position that the V's of the selenodont superior molar have been produced by the ental movement, and endeavors to demonstrate that they have arisen by pressure on the cusps by an ectal movement. This view is negatived by the fact that it is not the apices of the cusps which are engaged in primitive mastication, but their sides and lateral ridges. The former fall between the cusps of the opposite jaw.

been drawn inwards by the ectal movement of the lower jaw, so that the external wall slopes inwards at the point where it forms in the horse line a V-with the angle outwards.   In some of the genera (as Isectolophus) a median, inwardly-directed V is developed at this point.   The posterior end of the wall is turned a little outwards in some forms of this series, but this is due to a return or ental movement of the lower molar, of short duration, which has also drawn out externally the external end of the anterior cingulum.   The two lines of development are also indicated in the lower molars.   The one has V's on the lower molars, and the other has cross-crests.   The development of V's is due to the development of intermediate tubercles of the superior molars.   These cause the crown of the inferior molar to pursue a curved path across the upper, so that when the external cusp of the inferior molar is deflected forwards by the intermediate cusp of the superior, the inner cusp of the former must alternate with the external of the same, in order to pass between the internal cusps of the superior molar.[1]

With these preliminary remarks, I give the following synopsis of the families:[2]

I. No $\wedge$-shaped space with the apex external between cusps of superior molars. Inferior molars with cross-crests.
  A. Premolars different from molars.
    a. Superior canine teeth present.
  1. Toes 4–3; ....*Lophiodontidæ.*
  2. Toes 3–3; ....*Triplopodidæ.*
    aa. No superior canine teeth.
  3. Mastoid bone not exposed in external wall of skull;............*Cænopodidæ.*
    AA. Superior molars and premolars alike, with cross-crests.
    a. External cusps of superior molars fused into a wall.
  4. Mastoid bone forming part of the external wall of the skull; superior canines present;......................................*Hyracodontidæ.*
  5. Mastoid bone excluded from the walls of the skull by the contact of the occipital and squamosal; no superior canines;...*Rhinoceridæ.*
    aa. Exterior cusps of superior molars subequal, distinct.
  6. Superior molars and premolars alike, and with cross-crests; toes 4–3;...*Tapiridæ.*

II. The external cusps of the superior molars subequal, separated by an $\wedge$-shaped space, with the apex external; inferior molars with crescents.
  A. Superior premolars different from molars; with only one internal cusp.
  7. Toes 4–3; a vertebrarterial canal;.............................*Chalicotheriidæ.*

[1] These relations will be more fully discussed and illustrated in an article shortly to appear.

[2] Modified from that published in the Proceeds. Amer. Philos. Soc., 1881, p. 378.

8. Toes 3–3; no vertebrarterial canal;...............................,......*Macraucheniidæ.*
    AA. Premolars like molars, with two internal lobes above.
9. Toes with digits 4–3;...*Menodontidæ.*
10. Toes with digits 3–3;...:.............*Palæotheriidæ.*
11. Toes with digits 1–1;...*Equidæ.*

The total number of well-determined species of this order is about two hundred. It was abundantly represented during the Eocene period, and the recent species are comparatively few. It may be also observed that certain families predominated during certain periods. Thus the prevalent *Perissodactyla* of the Eocene are *Lophiodontidæ* and *Chalicotheriidæ;* those of the Miocene are *Rhinocerontidæ* and *Palæotheriidæ.* The *Tapiridæ* and *Equidæ* characterize the latest tertiary epochs. A genealogical tree of the order may be constructed as follows :
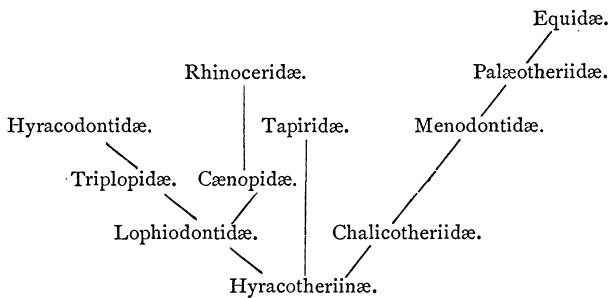
The leading types of the order, divisions I. and II., differ only in the two points of the separation or non-separation of the exterior cusps of the superior molars by a V-shaped interspace, and the transverse or oblique crests of the inferior molars. That no great modification of known forms (as *Lambdotherium* in the *Chalicotheriidæ*, and *Hyracotherium* in the *Lophidontidæ*) would be necessary to obliterate this difference is quite clear. How readily the transverse-crested lower molar can be modified into the V-bearing type may be seen by comparing the inferior molars of *Hyracotherium* with those of a rhinoceros.

The LOPHIODONTIDÆ includes a larger number of known species than any of the others of the order. With one exception, all the species belong to the Eocene period. They range from the size of a rabbit to that of an ox. They resembled most, among living animals, the tapirs.

The genera are characterized as follows :

I. External lobes of superior molars well separated and little flattened; lobes of inferior molars scarcely united (*Hyracotheriinæ*).

A. No diastemata.

a. Fourth inferior premolar unlike the first true molar.

Last inferior molar with five lobes; superior premolars four;.. ....*Systemodon* Cope.

AA. A diastema behind the first premolar in both jaws.

a. Last inferior premolar different from first true molar.

Last inferior molar with heel; cross-crests of superior molars interrupted;...*Hyracotherium* Owen.

aa. Last inferior premolar like first true molar.

Dentition generally as in Hyracotherium.......................*Pliolophus* Owen.

II. External lobes of superior molars well separated and little flattened; inferior molars with perfect cross-crests (*Protapirinæ*).

Last inferior molar with heel; ? four premolars;..............*Isectolophus* S. and O.

Last inferior molar without heel; inferior premolars three;..*Protapirus* Filh.

III. External lobes of superior molars flat, not well distinguished, forming a wall. Inferior molars with perfect cross-crests (*Lophiodontinæ*).

" A. No diastema in lower jaw.

Last inferior molar with third lobe;..............................*Helaletes*" Marsh.

AA. Lower jaw with diastema.

* No diastema behind first premolar.

a. No inferior premolars like the true molars.

Superior molars 7.

Last inferior molar with heel;......................................*Heptodon* Cope.

Last inferior molar without heel;..................................*Hyrachyus* Leidy.

Superior molars 6.

Last inferior molar with heel;......................................*Lophiodon* Cuv.

Last lower molar without heels, no horns;.....................*Dilophodon* Scott.

Last lower molar?; " an attachment for a dermal horn on each nasal bone;"...*Colonoceras* Marsh.

The above table shows that the modification which this family has undergone in its superior molars, has consisted in the confluence of the external tubercles into a more or less irregular external wall to the crown, and the confluence of the intermediate and internal tubercles into cross-crests. In the lower molars cross-crests have been formed. It is impossible to separate the Hyracotheriine sub-family as a family from the Lophiodontine, since the characters grade into each other completely. But it has been from the Hyracotheriine sub-family that the horse line was derived; the Protapirinæ gave origin to the Tapiridæ; while the rhinoceroses have descended from the Lophiodontinæ.

Among Hyracotheriinæ the genus Systemodon (Cope) holds the lowest place on account of the entire absence of diastemata from the dental series. It is as old as any of the genera, occur-

PLATE XXX.
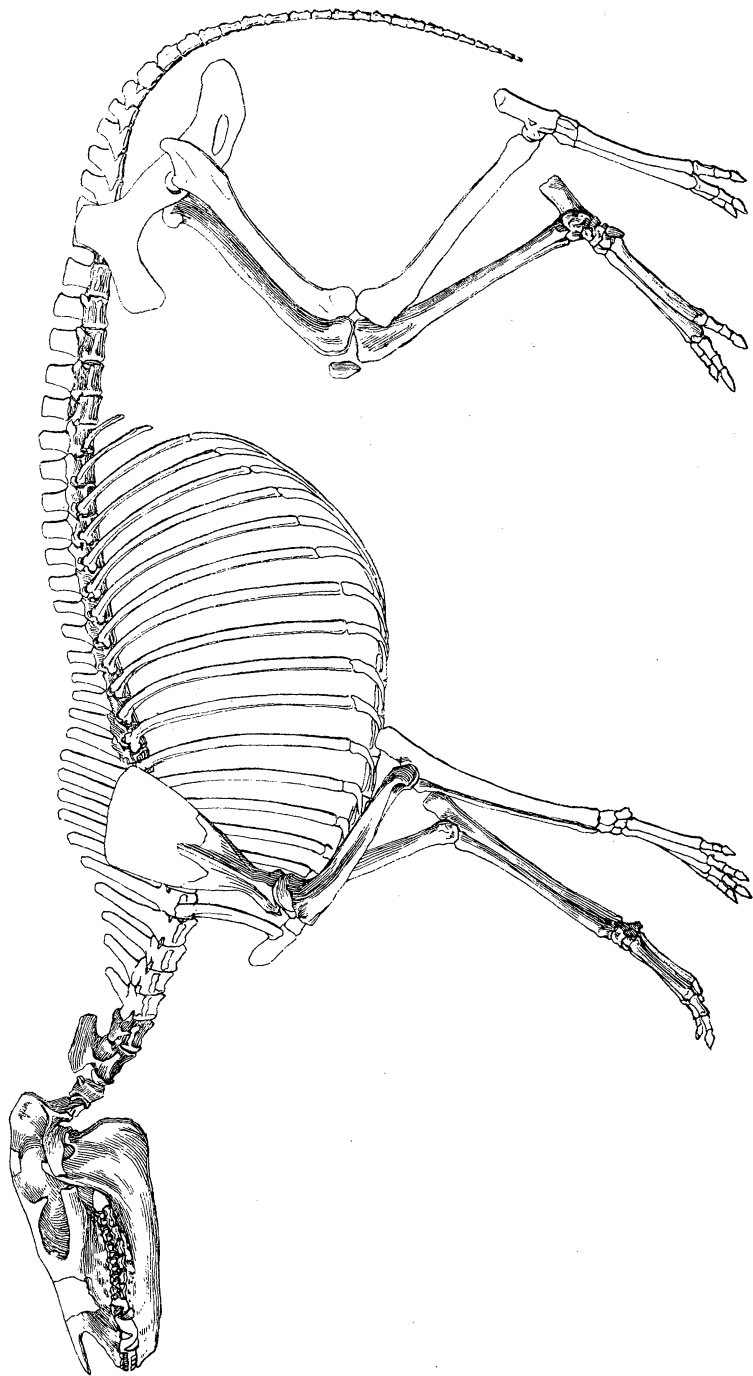
Hyracotherium venticolum, Cope, skeleton restored, one-third natural size; from the Wasatch beds of Wyoming, N. A. Original except ribs, which are after Osborn. Unshaded portions not preserved in specimen, which is in Coll. E. D. Cope.

ring in the Wasatch (or Suessonian) epoch.   A common ancestor
gave origin to Systemodon and Hyracotherium.   It resembled
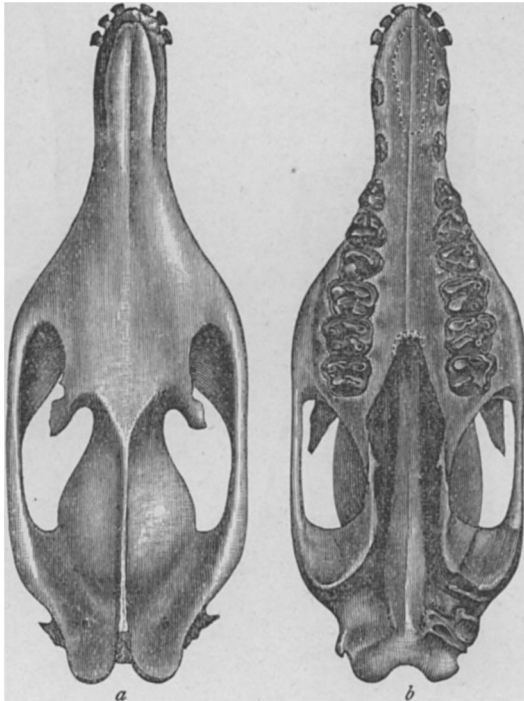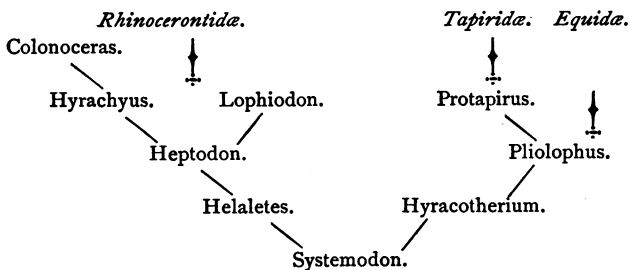the former in the absence of diastemata, and the latter in the

FIG. 5. Skull of *Hyracotherium venticolum* Cope, three-quarters natural size;
from Wind River Eocene of Wyoming.   Original.   Fig. *a* from above; *b* from
below.

greater distinctness of the cusps of its molars.   The succession
of the genera may be represented somewhat as follows:

In the Lophiodontine line we have Helaletes (Marsh) without diastema, like Systemodon. In Heptodon the diastema appears,
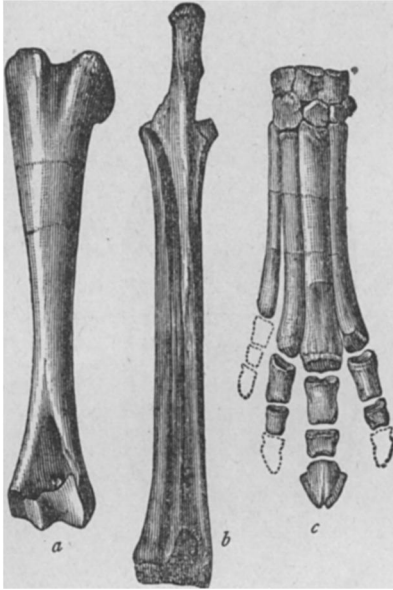
FIG. 6. Fore-leg and foot of *Hyraco-therium venticolum* Cope, two-thirds nat-ural size; from Eocene beds of Wind River, Wyoming. Original, from "Report U. S. Geol. Surv. Terrs.," iii. Fig. *a*, humerus from front; *b*, ulna and radius from be-hind; *c*, anterior foot from before.
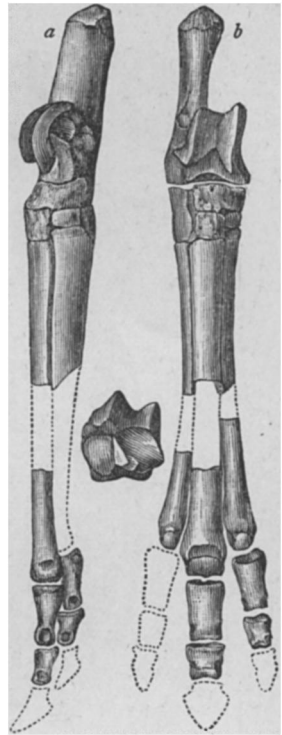
FIG. 7. Posterior foot of specimen of *Hyracotherium venticolum* already figured; *a*, left side; *b*, from front; *c*, distal end of astragalus and calcaneum.

and in the succeeding genera the first premolars are lost. In Hyrachyus the heel of the last inferior molar vanishes, while the nasal bones bear traces of dermal horns in Colonoceras (Marsh). The transition from Hyrachyus to the Rhinocerontid series is not difficult. The nearest form is Cænopus of the Cænopodidæ, which only differs from Hyrachyus in the lack of the canine teeth above, and of the middle incisors. The passage to the Tapiridæ is equally easy, through the close resemblance of Protapirus (Filh.) to Tapiravus (Marsh) of the

latter family. The latter only differs from the former in the increased complexity of the premolars. The passage to the horse line is suggested by the resemblance of Pliolophus
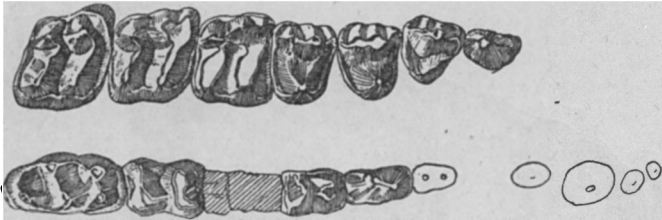

FIG. 8. *Systemodon tapirinus* Cope, dentition; upper figure, right superior molars from below; lower figure, left inferior molars from above; natural size. Original; from Wasatch bed of Wyoming.
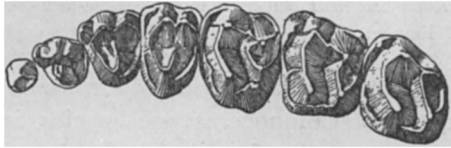

FIG. 9. *Heptodon ventorum* Cope, superior molars of left side, natural size. Original; from Wind River beds of Wyoming. From "Report U. S. Geol. Surv. Terrs.," F. V. Hayden, vol. iii.

(= Orohippus Marsh) to Anchitherium of the family of the Palæotheriidæ. The transition is seen in some genera of the intermediate family of the Chalicotheriidæ, beginning with Ectocium (Cope).
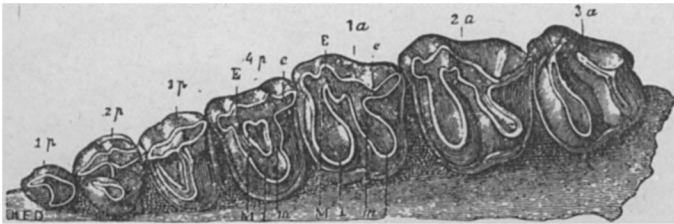

FIG. 10. *Hyrachyus agrarius* Leidy, superior molar teeth, natural size; from Bridger bed of Wyoming. From Leidy, "Report U. S. Geol. Surv. Terrs.," F. V. Hayden, vol. i.

Three species of Systemodon are known, all from the Wasatch Eocene. The largest, *S. tapirinus* Cope, was equal to a large ram. A dozen species of Hyracotherium are known from the Eocene of Europe and North America, which range in size

from that of a sheep to that of a kit-fox. Several species of Helaletes have been described from the Bridger Eocene. The species of Hyrachyus are rather numerous, and range through
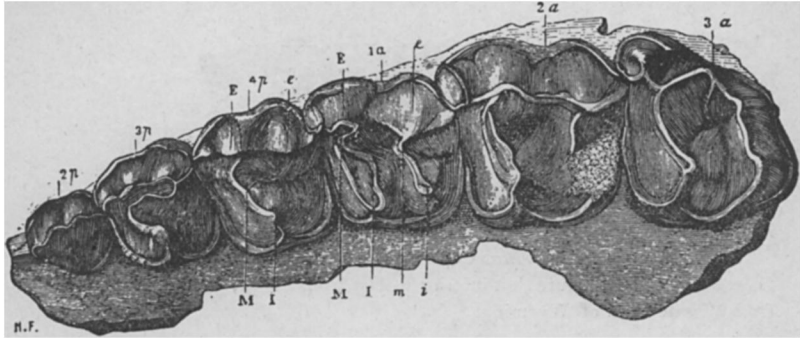

FIG. 11. *Lophiodon isselensis,* superior molars three-fifths natural size; from Middle Eocene of France. From Gaudry, " Enchainements du Régne Animal."

the Wind River, Bridger, and Diplacodon beds. Dilophodon has two species and Colonoceras one species, in the Bridger. Lophiodon is, so far as yet known, confined to Europe. One of its species, *L. rhinoceroides,* was as large as a medium-sized rhinoceros, and several species ranged in dimensions to those of a sheep. They appear in the Bruxellian, and range upwards through the Bartonian. Heptodon is, so far, only American; two species, a large and a small, are found in the Wasatch formation, and two, of intermediate size, in the Wind River.
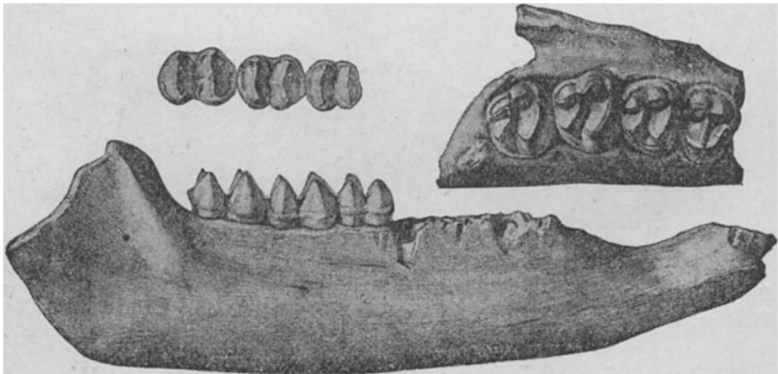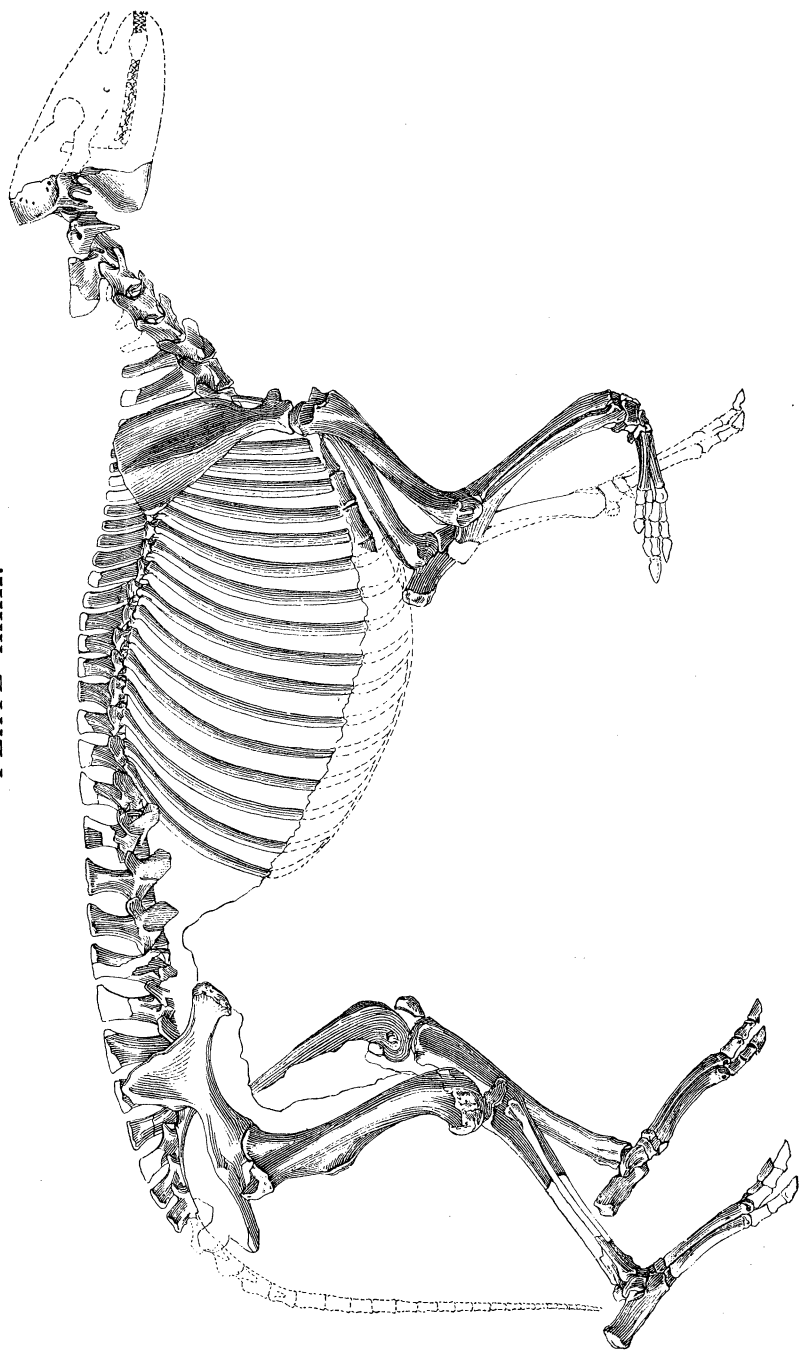

FIG. 12. *Protapirus priscus* Filh., Phosporites of Quercy, France, three-fourths natural size. From Filhol.

Protapirus is from the Phosphorites of France; and Isecto-

PLATE XXXI.

Hyrachyus agrestis, Leidy, $\frac{2}{15}$ natural size; from Bridger bed of Wyoming. Unshaded portions not preserved. Original, from specimen in Coll. E. D. Cope.

lophus is from the summit of the Eocene in North America, or from the Diplacodon beds.

As but one genus of TRIPLOPODIDÆ is known, its origin and probable descendants only can be referred to. It may very readily have been derived from Heptodon, with which it agrees in dental formula. The loss of the heel of the last inferior molar and of the fifth anterior digit would metamorphose Heptodon into Triplopus. Two species are known, both from the upper division of the Bridger Eocene. A possible third species is from the Diplacodon bed (*Prothyracodon* S. and O.).
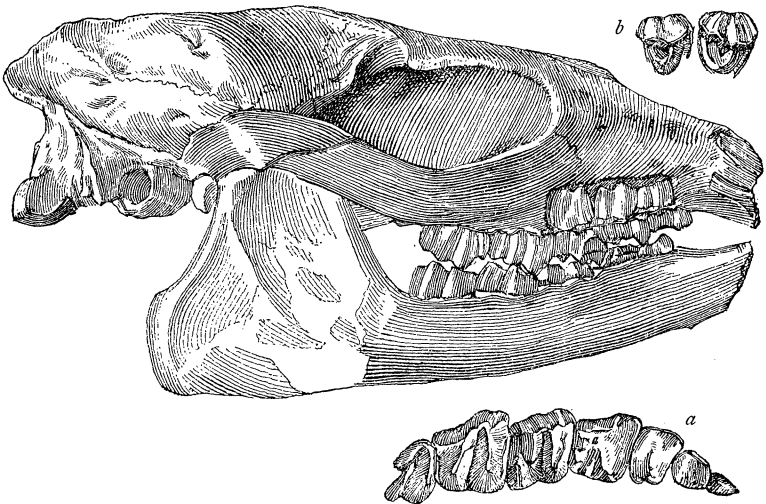

FIG. 13. Skull of *Triplopus cubitalis* Cope, from the Bridger Eocene of Wyoming, three-quarters natural size; right side. Original; from the " Report U. S. Geol. Surv. Terrs.," vol. iii. Fig. *a*, superior molars with deciduous premolars; *b*, third and fourth superior premolars.

The CÆNOPIDÆ include genera which have lost the superior canine teeth, and have thus come to resemble the rhinoceroses. The known genera resemble these animals also in the reduction in the number of the incisors, and in one genus at least a dermal horn was present. The two genera known differ as follows:

No dermal horn;..*Cænopus* Cope.
A dermal frontal horn;.....................................*Dihoplus* Brandt.

This family constitutes the transition between the Lophiodontine group of the Lophiodontidæ by Heptodon or Hyrachyus,

and the Rhinocerontidæ. Cænopus embraces, as yet, only American species, of moderate and small size; the *C. occidentalis* Leidy had four toes in front and three behind, representing the type which is the phylogenetic ancestor of the lowest and only four-fingered genus of Rhinocerontidæ, Aceratherium. A cusp is sometimes present within the inner extremity of the incurved, transverse crest of the premolars in Cænopus. Fusion of this with the transverse crest has produced the double transverse crests of the premolars of the Rhinocerontidæ. Dihoplus must be regarded as a collateral outgrowth from Cænopus. It is represented by one European species, the *D. schleiermacheri*, which is of larger size than either of the known species of Cænopus.

FIG. 14. *Cænopus occidentalis* Leidy; cranium, one-fourth natural size, from below; from the White River Miocene of Nebraska. From Leidy, "Ancient Fauna of Nebraska."

In the HYRACODONTIDÆ we have a direct descendant from the Lophiodontidæ, but presenting a modification quite different from the Cænopidæ. In that family the canines were lost and the simple premolars retained; in the present family the canines are retained and the premolars become complex, as in the rhinoceroses. Three, perhaps four, genera are known:

> I. Canines very distinct from incisors.
> Premolars $\frac{4}{4}$;..*Amynodon* Marsh.
> Premolars $\frac{3}{3}$;...*Metamynodon* S. and O.
>
> II. Canines small, similar to incisors.
> Premolars $\frac{4}{4}$;..*Hyracodon* Leidy.

These genera are all hornless.

Amynodon is the oldest and ancestral genus; its two species belong, one in the Diplacodon formation, and the other in the Bridger. Desmatotherium (Scott) belongs here, but I do not

know how to separate it from Amynodon. Metamynodon and Hyracodon are from the White River Miocene. The family is not yet known from higher formations, and appears to have died out. Why such a robust and well-defended type as Meta-mynodon should have disappeared, and the comparatively weak and entirely unarmed Cænopus should have survived, is not easy to understand. In Hyracodon we observe a degeneracy of the anterior dentition of both jaws. According to Scott, *Hyracodon nebrascensis* was "a slender, long-limbed, and slightly-built ani-mal, with a long neck." Three or four species only are known. The entire family is, so far, only known from North America. The phylogeny may be thus represented:
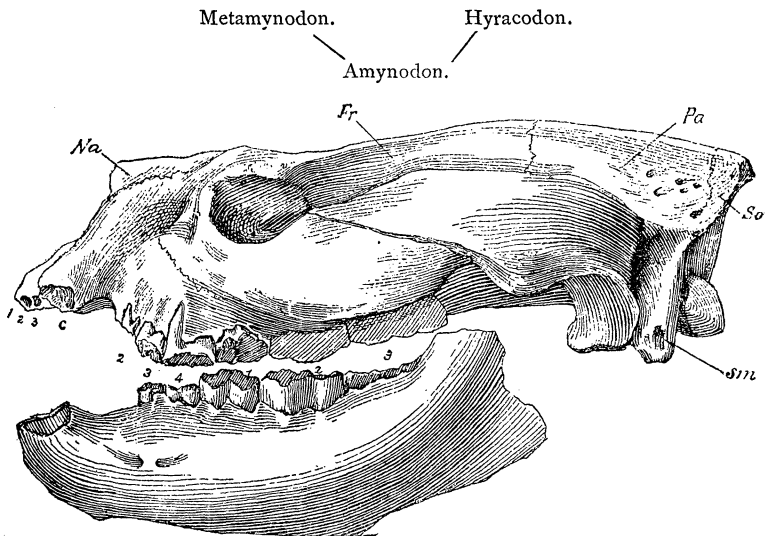

FIG. 15. *Metamynodon planifrons* S. and O.; skull, one-sixth natural size; left side. From Scott and Osborn, in "Bulletin of Mus. Compar. Zoölogy Cambridge."

The RHINOCERONTIDÆ came into existence in the Miocene of Europe, in a genus nearer to the Cænopidæ than any other of the family. This approximation is shown in the persistence of the external or fifth digit of the anterior foot in the genus Aceratherium (Kaup.). In this form all the superior premolars have the structure of the true molars; so that it enters the pres-ent family. The general relation of the component parts of the true molars in the rhinoceros family is that of the Lophiodon-tidæ in all important respects. The external ends of the cross-

crests of the inferior true molars are generally turned forwards
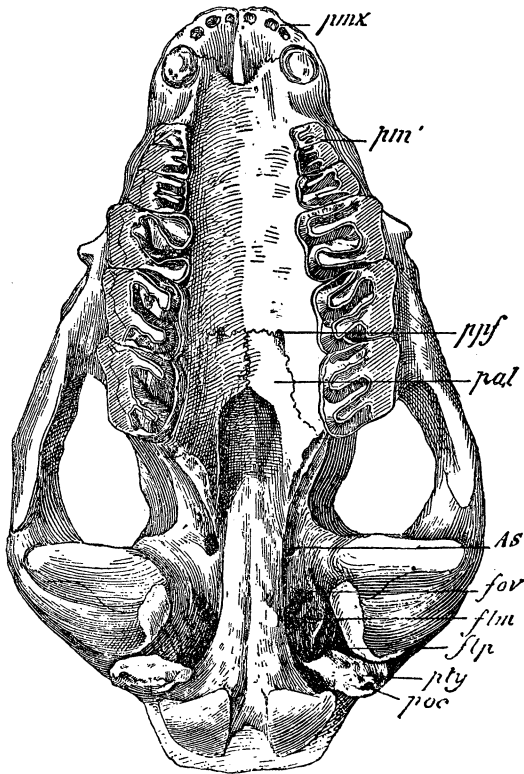and inwards, showing a tendency to the formation of V's.

FIG. 16. *Metamynodon planifrons* S. and O.; the same cranium from below; from
White River bed of Nebraska.   From Scott and Osborn, in " Bulletin of Mus. Compar.
Zoölogy Cambridge."

The changes in the structure of the genera of this family are
seen in the loss of incisor teeth, of the fifth digit from the an-
terior foot, and in the greater co-ossification of various bones of
the skull,—among them of the nasal bones,—to support the
offensive dermal horns.   In Cœlodonta and Elasmotherium the
nasal bones are further supported by the ossified nasal septum,
and the last-named genus adds an osseous basis or even core
for a horn on the frontal bone.   In most of the genera the
cross-crests of the superior molars are comparatively simple,
but in Atelodus and Cœlodonta they display projecting angles,
which, on wearing, join each other.   In this way the valleys
become surrounded or enclosed.   This is especially the case

with the extinct genera of the Old World, Cœlodonta and Elasmotherium. In the latter the molars became prismatic, and the vertical enamel-plates vertically plicate.
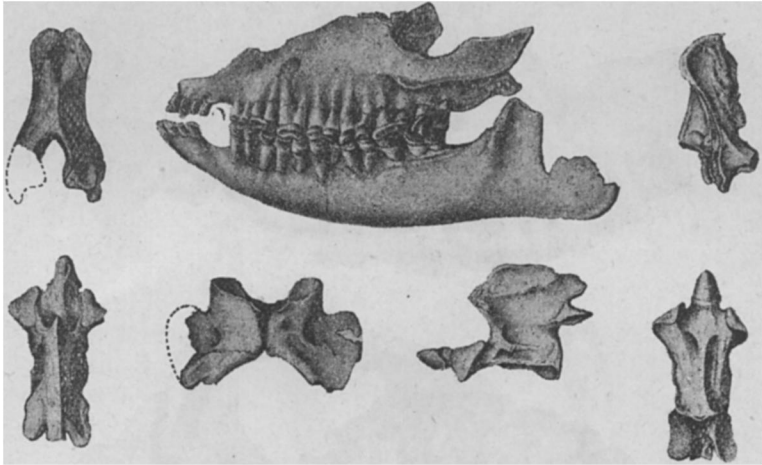

FIG. 17. *Hyracodon nebrascensis* Leidy, cranium, four-fifteenths natural size; left side of facial region and lower jaw; occipital and mastoid regions from behind and from side; and atlas and axis, the latter from above, side, and below; from White River Miocene of Colorado. Original.

This line first appears in Europe, and in Europe, Asia, and Africa it reached its highest specialization and force, in two lines. The one terminated in the genus Rhinocerus, of which two species now exist in Asia. The other line first appeared in the upper Miocene of Europe and India, in the genus Atelodus, of which two species still exist in Africa. From this the genus Cœlodonta took its origin, and peopled the temperate and cold regions of Europe and Asia. This form gave rise to Elasmotherium, which was the largest and most remarkable of all the Rhinocerotidæ. Its only known species, *E. typum*, dwelt in the cold regions of Europe and Asia.

In North America it developed only two genera, Aphelops[1] and Diceratherium, the former in the Loup Fork, the latter in the John Day, Miocene ages. Both were numerous in individuals. Aphelops did not develop a horn. Diceratherium developed two opposite tuberosities on the nasal bones, which probably supported dermal callosities.

[1] For an illustrated account of this genus, see NATURALIST, 1879, p. 771, *a.*
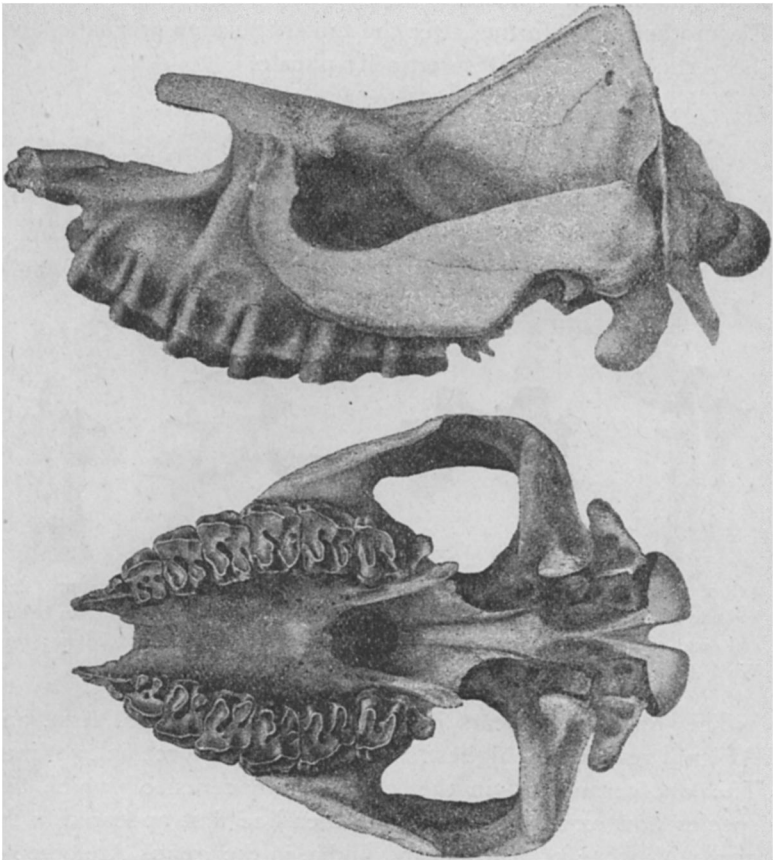
FIG. 18. *Peraceras superciliosus* Cope, about one-sixth natural size; from Loup Fork bed of Nebraska. Original. Fig. *a*, left side; *b*, from below.

A. Four anterior digits.

Incisors $\frac{2}{2}$; canine $\frac{0}{1}$; no horn; posttympanic bone distinct;..*Aceratherium* Kaup.

  AA. Three anterior digits.

    a. Posttympanic process not coossified with postglenoid.

Incisors $\frac{1}{1}$; canines $\frac{0}{1}$; no dermal horn; ....*Aphelops* Cope.

Incisors $\frac{0}{1}$; canines $\frac{0}{1}$; no dermal horn; ....*Peraceras* Cope.

Incisors $\frac{1}{1}$; canines $\frac{0}{1}$; a tuberosity for a dermal thickening on
    each nasal bone;...*Diceratherium* Marsh.

Incisors $\frac{1}{1}$; canines $\frac{0}{1}$; a median dermal nasal horn;............*Ceratorhinus* Gray.

Incisors $\frac{0}{0}$; canines $\frac{0}{0}$; dermal horn median; no osseous nasal
    septum;...*Atelodus* Pomel.

    aa. Posttympanic process coossified with postglenoid;

      β. No median frontal horn-core.

Incisors $\frac{1}{1}$; canines $\frac{0}{1}$; dermal horn median; nasal septum
    not ossified;..*Rhinocerus* Linn.

Incisors $\frac{0}{0}$; canines $\frac{0}{0}$; dermal horn median; nasal septum
    ossified;..*Cœlodonta* Bronn.
 $\beta\beta$. A frontal median horn-core.
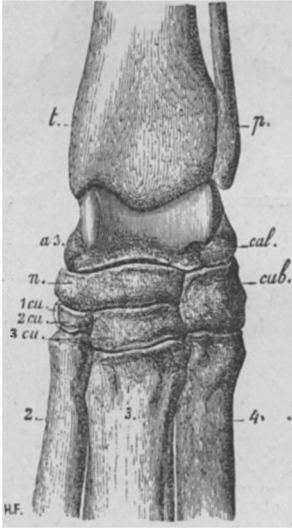Molars prismatic;...*Elasmotherium* Cuv.

FIG. 19. *Atelodus pachygnathus*
   Wagn., left tarsus, one-fourth
   natural size, showing three
   posterior digits; from the Up-
   per Miocene of Greece. From
   Gaudry.

FIG. 20. *Aceratherium tetradactylum*
   Lart., anterior foot minus the first row
   of carpal bones, one-fourth natural
   size, front; from Miocene of Sansan,
   France. After Gaudry; in Les En-
   chainements du Régne Animal.

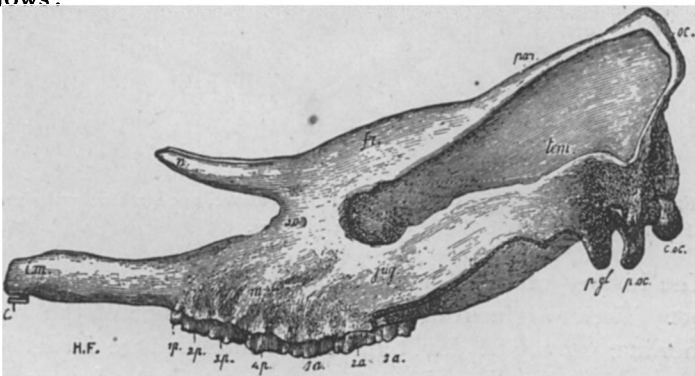The phylogeny of the rhinoceroses may be represented as follows:

FIG. 21. *Aceratherium incisivum* Cuv., skull, one-seventh natural size; from the
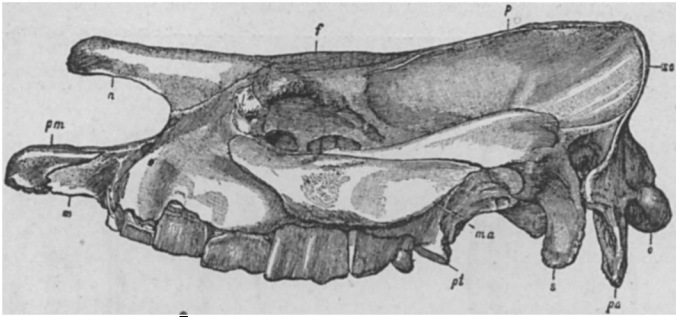Miocene of Epplesheim, Germany. From Gaudry, after Kaup.

FIG. 22. *Aphelops fossiger* Cope, skull, one-fifth natural size, from side and below; from Loup Fork beds of Kansas. From Marsh.
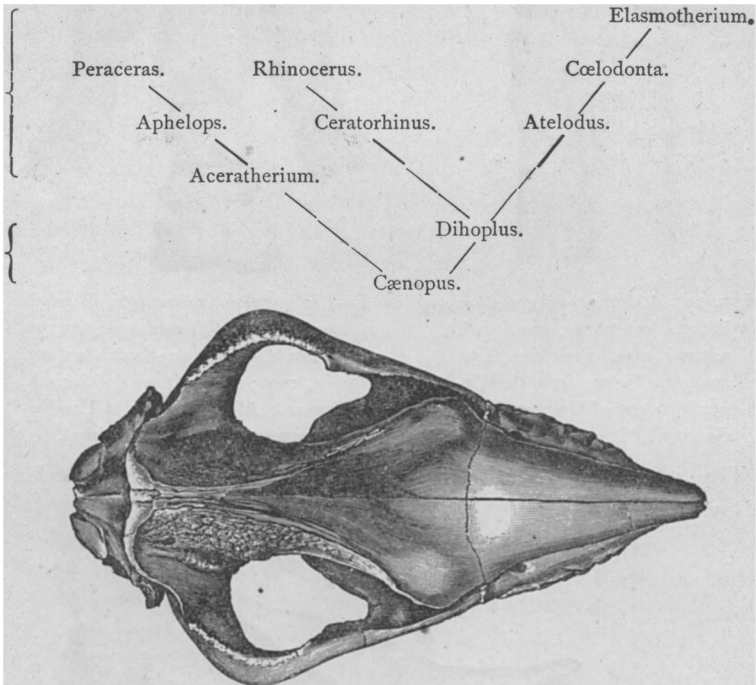

FIG. 23. *Aphelops megalodus* Cope, skull from above, one-sixth natural size. From the Loup Fork bed of Colorado; original.

The history of the TAPIRIDÆ has been mainly unravelled by Scott. Their origin from the Protapirine division of the Hyracotheriinæ cannot be doubted, but the intermediate forms have been mostly lost. The oldest genus appears in the Lower Miocene of North America (White River), and it is followed by

Tapiravus (Marsh) of the Upper Miocene. Tapirus is first found in the Upper Miocene of Germany (Epplesheim). The recent species of the family belong to Tapirus L., and Elasmognathus (Gill).

The three genera are distinguished as follows:

Two superior premolars different from true molars;.. *Tapiravus* Marsh.
One superior premolar different from true molars;
   no heel of third inferior molar; nasal septum
   cartilaginous;.. *Tapirus* L.
Like *Tapirus*, but nasal septum osseous;.............. *Elasmognathus* Gill.

The order in which these genera stand above, represents their phylogenetic as well as their taxonomic relations, the oldest genus standing first.

(To be concluded.)

EDITORS' TABLE.

EDITORS: E. D. COPE AND J. S. KINGSLEY.

To discover the relation of mind to matter is the goal of scientific research, and every addition to knowledge may be regarded as a contribution to this subject. The advent of Neo-Lamarkianism brings the question immediately within the view of the student of natural history, where it belongs, and brings it out of the metaphysical limbo, where it has so long lain neglected by science. The evidence that the environment is not the only factor in evolution is abundant enough, and the attempt to restrict the remaining factors to "heredity" has not long satisfied the mind of science. The evidence that the movements of animal organs and tissues is the other factor, constituting the source of heredity, is becoming clearer and clearer. The relation of sensation (consciousness or mind) to motion, is supposed to be well known, so that the direct dependence of evolution on the former seems to be an inference fully justified by the knowledge now in our possession.

But every step in this logical succession is, and ought to be, contested. It is denied by some that animal movements do materially affect animal structures. It is further denied that such