tion of arithmetical repetitions of a fundamental wave-length, which is harmonically related to cosmical nodes.

The third order is the one which first attracted my attention,* consisting of groups of wave-lengths which are in harmonic instead of geometric progression, and indicating, like the first order, a want of complete homogeneity.

These three orders are variously blended in the spectra of so-called chemical elements. The character of the blending may, perhaps, serve as a guide towards the resolution of the spectra into simpler constituents.

44. *Æther, Corona, Hydrogen.*

In a communication to the Society, on the 18th of December, 1868, I showed that there is some elastic influence between Sun and Earth, which enables us to form approximate estimates of Sun's mass and distance. At the close of the communication was the following paragraph.†

"The revolution of the Sun around the great Central Sun must also cause barometric fluctuations that may possibly be measured by delicate instruments and long and patient observations. The Torricellian column may thus become a valuable auxiliary in verifying or rectifying our estimates of the distances and masses of the principal heavenly bodies."

In various subsequent communications I have shown that electricity, magnetism, solar gravitation and rotation, planetary and stellar positions, spectral lines, chemical affinity, thermal energy, and other physical manifestations,‡ furnish marked indications of an all-pervading elastic medium, vibrating with the velocity of light, and subject to the same laws of harmonic nodal action as have been found to influence the air and other elastic bodies.

The observations upon the solar eclipse of 1869, by Morton, Winlock Young, Pickering, Harkness and others, disclosed an important line in the solar spectrum, which corresponds very nearly to 1474 of Kirchhoff's scale, and is now styled 1474 K, or "the corona line." Father Secchi attributed the line to hydrogen; Dr. Gould thought it identical with the auroral line, and therefore due to some substance which, as stated by Lockyer,§ "may possibly be present in the higher regions of our own atmosphere."

Lockyer‖ considers the observations as indicating "an enormous envelope of hydrogen, probably in the average twelve minutes high," as well as "the existence of some unknown element extending further from the photosphere even than hydrogen." In the eclipse of 1870, "at the same time that this line was observed to extend to a distance of 20′ from the Sun, the lines of hydrogen were observed eight minutes above the Sun." Here are, therefore, probable evidences of two successive stages of æthereal condensation. It has "been shown by Salet, Schuster and others, that" all the hy-

* Ib., xvii, 109-12, 297-301.

† Ante, ix., 288; Phil. Mag. [4], xxviii, 59.

‡ Ante, ix, xiv; xvi, sqq.: P. Mag. [4], vols. 30, 32, 34, 35, 50; [5], 1-6, 10, 11.

§ Solar Physics, p. 269.

‖ Ib. p. 413.

drogen lines but F are "due to impurities," * so that the hydrogen spectrum is harmonically connected with the corona line.

It may be well to recapitulate, in this connection, some of the simple equations which serve to connect the energies of solar and terrestrial rotation, planetary revolution, atmospheric limitation, molecular oscillation, cosmical aggregation, and æthereal action:

1. $M : \pi r :: v_\lambda : v_r$ — Note 34.
2. $v_r = p\, v_h$ — Note 34.
3. $v_\lambda = \left(\frac{gt}{2}\right)_0$ — Notes 33, 37.
4. $v_0 = p \left(\frac{gt}{2}\right)_3$ — Note 17.

See, also, Proc. Am. Phil. Soc., xii, 392–4; xix, 21–5, and Note 16.

45. *Cosmical Significance of the Corona Line.*

Earth being the centre of density in the solar system, its nascent locus should have a time of revolution π times as great as its own, with a semi-axis major of $\pi^{\frac{2}{3}} \times 214.45 = 460.002$ solar semi-diameters. The corresponding wave-length (Note 37,) is 5321.35, as is shown by the following proportion:

$$\log. 6441.4 : \log. 460.002 :: 7612 : 5321.35.$$

This differs by less than $\frac{1}{132}$ of one per cent. from the geometric wave-length (Note 41), and by less than $\frac{1}{80}$ of one per cent. from Gibbs's measurement of the corona line.

The Systematic Arrangement of the Order Perissodactyla. By E. D. Cope.

(*Read before the American Philosophical Society, April* 15, 1881.)

PERISSODACTYLA.

This, the second great order of the ungulate Mammalia, naturally occupies a position between the *Amblypoda* and the *Artiodactyla*. Its lower forms are more specialized in the structure of the feet than the *Amblypoda*, while its highest types do not reach the perfection of structure seen in the *Artiodactyla*. This is particularly indicated by the form of the astragalus, which has but one, the tibial trochlea, and never displays the distal one characteristic of the cloven-footed families. The *Perissodactyla* occupy, as regards their dentition, a position parallel with the *Artiodactyla*. They are always superior in dental complication to the *Proboscidia* and the suilline *Artiodactyla*, but only one series, that of the horses, reaches the com-

* Ib. p. 530, foot-note.

plexity of molars general in the *Ruminantia*. The dentition of the mass of the *Perissodactyla* might be described as intermediate between that of the *Proboscidia* and the lowest selenodont *Artiodactyla*.

The families of this order form a closely connected series, and the division of them into three divisions, the "Pachydermata," "Solipeda" and *Perissodactyla*, has no warrant in nature. Especially unnatural is the conjunction of the genera included under the first name, with the *Proboscidia* and certain suilline *Artiodactyla*, in a single order, as was proposed by Cuvier. The modifications of dentition from the simple type seen in *Menodus*, to the most complex, as in *Equus*, are close and consecutive. So, also, the gradual diminution in the number of digits from 5–4 to 1–1 can be traced through all the intervening stages.

The following definitions of families are applicable in the present stage of knowledge. Those of all but three were published in the Bulletin of the U. S. Geological Survey of the Territories, 1879, p. 228. A modification in the diagnoses of the families *Chalicotheriidæ* and *Palæotheriidæ* is now introduced:

I. Anterior exterior crescent of superior molars shortened, not distinguished from the posterior by external ridge; inferior molars with cross-crests; premolars different from molars.

1. Toes 4–3 .... *Lophiodontidæ*.
2. Toes 3–3 .... *Triplopodidæ*.

II. Exterior crescents of superior molars as in I; inferior molars with cross-crests; superior molars and premolars alike, with cross-crests.

3. Mastoid bone forming part of the external wall of the skull .... *Hyracodontidæ*.
4. Mastoid bone excluded from the walls of the skull by the contact of the occipital and squamosal .... *Rhinoceridæ*.

III. Exterior crescentoid crests of superior molars subequal, distinct; inferior molars with cross-crests.

5. Superior molars and premolars alike and with cross-crests; toes 4–3. *Tapiridæ*.

IV. The external crescentoid crests of the superior molars subequal, separated by an external ridge; inferior molars with crescents.

A. Superior premolars different from molars; with only one internal cusp.

6. Toes 4–3; a vertebrarterial canal .... *Chalicotheriidæ*.
7. Toes 3–3; no vertebrarterial canal .... *Macraucheniidæ*.

AA. Premolars like molars, with two internal lobes above.

8. Toes with digits, 4–3 .... *Menodontidæ*.
9. Toes with digits, 3–3 .... *Palæotheriidæ*.
10. Toes with digits, 1–1 .... *Equidæ*.

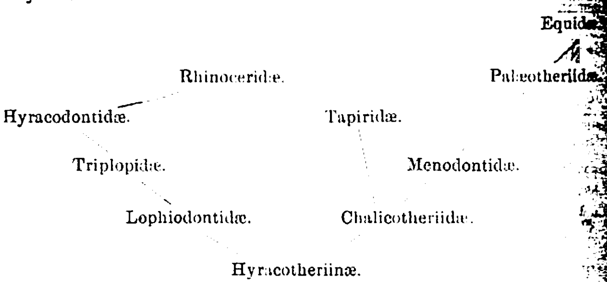
The genera included in these families are the following. The table shows their geological distribution:

	Eocene.		Miocene.			Pliocene.	Recent.
	Lower	Upper	Lower	Middle	Upper		
Lophiodontidæ.							
Hyracotherium Ow.	12						
Pliolophus Ow.	4	2					
? Lophiotherium Gerv.		1					
Pachynolophus Pom.	3	3					
Helaletes Marsh		3					
Lophiodon Cuv.	2	11					
Hyrachyus Leidy		9					
Colonoceras Marsh		1					
Triplopidæ.							
Triplopus Cope		2					
Hyracodontidæ.							
Hyracodon Leidy			2				
Rhinocerontidæ.							
Aceratherium Kaup			3				
Cœnopus Cope			2				
Diceratherium Marsh				3			
Zalabis Cope							
Aphelops Cope					4		
Ceratorhinus Gray				1	2		2
Rhinoceros Linn.					4		2
Peraceras Cope					2		
Atelodus Pom.					2	1	2
Cœlodonta Bronn						3	
Tapiridæ.							
Listriodon Gerv.				? 3			
Tapirus Linn.						6	5
Elasmognathus Gill							1
Chalicotheriidæ.							
Rhagatherium Pict.	1						
Leurocephalus S. S. and O.		1					
Palæosyops Leidy	1	5					
Limnohyus Leidy		3					
Lambdotherium Cope	2	1					
Propalæotherium Gerv.	1	2					
Chalicotherium Kaup		3					
Nestoritherium Kaup				?1			
Meniscotherium Cope	1						
Macraucheniidæ.							
Macrauchenia Ow.					2		

	EOCENE. Lower	EOCENE. Upper	MIOCENE. Lower	MIOCENE. Middle	MIOCENE. Upper	PLIOCENE.	RECENT.
Menodontidæ.							
Acoëssus Cope	1						
Diplacodon Marsh		1					
Menodus Pom			2				
Symborodon Cope			6				
Dæodon Cope				1			
Palæotheriidæ.							
Anchilophus Gerv		2					
Paloplotherium Ow		6					
Palæotherium Cuv		3					
Mesohippus Marsh			2				
Anchitherium Kaup			2	4			
Anchippus Leidy				1	1		
Hippotherium Kaup					8	1	
Protohippus Leidy					5	1	
Equidæ.							
Hippidium Owen					2	3	
Equus Linn						5	7

Total number of well determined species, one hundred and eighty-nine.

From the preceding table it can be readily seen that this order was abundantly represented during the Eocene period, and that the recent species are comparatively few. It may also be 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 types of the *Lophiodontidæ* and *Chalicotheriidæ* differ only in the two

points of the separation, or non-separation, of the exterior crescents of the superior molars, as already pointed out. That no great modification of known forms (as *Lambdotherium* in the *Chalicotheriidæ*, and *Hyracotherium* in the *Lophiodontidæ*) would be necessary to obliterate this difference, is quite clear. The parent types of the order, which present the most generalized dentition, *Hyracotherium*, *Rhagatherium*, and *Acoëssus*, were cotemporaries of the Lower Eocene epoch.

LOPHIODONTIDÆ.

This family embraces 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 diastema behind first premolar.

a. Third and fourth inferior premolar like the first true molar.

Last inferior molar with five lobes .... *Lophiotherium.*

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.*

aa. Last inferior premolar like first true molar;

True molars as in *Hyracotherium* .... *Pliolophus.*

II. External lobes of superior molars flat, not well distinguished. (*Lophiodontinæ.*)

"*A.* No diastema in lower jaw.

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

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 .... *Pachynolophus.*

Superior molars 6;

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

Last lower molar without heels, no horns .... *Hyrachyus.*

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

The geographical range of these genera is as follows :—

North America only .... *Helaletes, Colonoceras.*

lengths. The median ridge is rather wide; the inner malleolus is narrow, has no distal facets and no distinct tendinous grooves externally.

The posterior foot is both relatively and absolutely smaller than that of *Hyrachyus eximius*. The trochlea of the astragalus is narrower and more deeply grooved. The crests are obtuse, and not so narrowed as in *Mesohippus bairdi*, nor are the malleolar facets of the astragalus so sharply defined as in the latter species. The external ligamentous fossa is, however, deep, and is bounded anteriorly by a low trihedral tuberosity not found in the *M. bairdi*. The head of the astragalus is not sessile as in *M. bairdi*, and has rather the proportions of *H. eximius*. The cuboid facet is a bevel of the external side of the distal extremity, as in *H. eximius*, and is not on a produced ledge, as in *M. bairdi*. The internal tuberosity of the head is not as much developed as in either of the species named. The navicular face of the astragalus is horizontally divided by a shallow ligamentous fossa. The calcaneum is much like that of *Hyrachyus eximius*. The cuboid face is less oblique than in that species, in the anteroposterior direction, and is less crescentic in outline than in *M. bairdi*. The sustentaculum is rather more extended transversely than in *H. eximius*, but resembles that species more than the *M. bairdi*, in wanting the deep groove at its base on the inferior side, which cuts it off from the rest of the calcaneum. The remainder of the inferior surface is flat, and not grooved for a tendon as in *H. eximius*.

The remainder of the tarsus includes the usual five bones, the three cuneiforms being present. They are in general a good deal like the corresponding bone of *Hyrachyus eximius*. The navicular differs in having a low transverse ridge on its proximal face, which fits the groove of the astragalus already mentioned. The hook of the cuboid is large. The external (anterior) face of the mesocuneiform has one-third the superficial area of the anterior face of the ectocuneiform. The entocuneiform is rather large, and is flat and subsemicircular. Its position is externo-posterior. The ectocuneiform presents facets to both the second and fourth metatarsals, that with the latter the largest. The distal halves of the metatarsals are lost. At their proximal portions they are of subequal width, as in *Hyrachyus eximius*, but the lateral ones are rather narrower at the middles of the shafts.

Measurements.	M.
Width of distal extremity of tibia	.029
" astragalar face "	.019
Length of inner malleolus	.007
" astragalus on inner side	.030
Depth of trochlea " "	.017
" head " "	.0145
Width of trochlea	.015
" navicular facet	.0195
Length of head from inner crest of trochlea	.005
" calcaneum	.058

Measurements.		M.
Length of free part of calcaneum		.037
Distal depth of the calcaneum		.016
Diameters cuboid face calcaneum	anteroposterior	.0145
	transverse	.0145
Length of navicular		.008
" cuboid		.0145
Transverse proximal width of three metatarsals		.027
Diameters of second metatarsal	anteroposterior	.014
	transverse	.007
Antero-posterior diameter of third metatarsal		.0145
Diameters of fourth metatarsal	anteroposterior	.014
	transverse	.012

This species was obtained in 1873 from the bad lands of South Bitter creek, Wyoming, from the Washakie basin of the Bridger formation. The locality is the same as that which furnished the *Triplopus cubitalis*, the *Achænodon insolens*, etc.

HYRACODONTIDÆ.

This family, which I characterized in 1879, includes, so far as yet known, the single genus *Hyracodon*, which is found in the Oligocene White river formation of North America. According to Marsh, the digits of this genus number three on both anterior and posterior limbs. It has a full series of incisor teeth in both jaws.

RHINOCERIDÆ.

This extensive family has left representatives in all parts of the Northern Hemisphere, and species still exist in the Old World. From the following table the range of variation of its genera can be readily seen:

I. Four anterior digits.

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

II. Three anterior digits.

a. Posttympanic process not coössified with postglenoid.

Incisors $\frac{2}{1}$; canines $\frac{0}{1}$; no dermal horn . . . . *Cœnopus*.
Incisors $\frac{1}{1}$; canines $\frac{0}{1}$; no dermal horn . . . . *Aphelops*.
Incisors $\frac{0}{1}$; canines $\frac{0}{1}$; no dermal horn . . . . *Peraceras*.
Incisors $\frac{1}{1}$; canines $\frac{0}{1}$; a tuberosity for a dermal horn on each nasal bone. *Diceratherium*.
Incisors $\frac{1}{1}$; canines $\frac{0}{1}$; a median dermal nasal horn . . . . *Ceratorhinus*.
Incisors $\frac{3}{2}$; canines $\frac{0}{1}$ . . . . *Zalabis*.
Incisors $\frac{0}{0}$; canines $\frac{0}{0}$; dermal horn median; no osseous nasal septum . . . . *Atelodus*.

aa. Posttympanic process coössified with postglenoid;

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

It can readily be seen that the genera above defined form a graduated series, the steps of which are measured principally by successive modifications of four different parts of the skeleton. These are, first, the reduction of the number of the toes of the anterior foot; second, the reduction in the number and development of the canine and incisor teeth; third, the degree of closure of the meatus auditorius externus below; and, fourth, in the development of the dermal horns of the nose and its supports. While these characters have that tangible and measurable quantity which renders them available for generic diagnosis, there are others which possess a similar significance, and which I have noticed in an article published in the bulletin of the U. S. Geological Survey of the Territories for September 1879.

This series may be represented in genealogical relation, as follows:*

Cœlodonta.

Rhinocerus. *Atelodus.*

Ceratorhinus. *Peraceras.*

Aphelops.

Zalabis. *Cænopus.* *Diceratherium.*

The early type, which corresponds most nearly with *Cænopus*, and which preceded both it and the *Aceratheria* in time, is the genus *Triplopus* Cope, which has left a species in the Upper Bridger of Wyoming. Here the incisors are probably $\frac{3}{3}$ and the canines $\frac{1}{1}$. This formula is that of the Eocene tapirs, where the normal numbers $\frac{3}{3}$ $\frac{1}{1}$ prevail. *Triplopus* further differs in the primitive condition of the premolars above, which, as in the *Lophiodontidæ*, differ from the molars in their greater simplicity. Thus it is probable that tapiroids, probably *Lophiodontidæ*, gave origin to the *Rhinoceridæ*, as Marsh has suggested. And it is further altogether probable that the general type of dentition presented by the *Rhinoceridæ*, *Lophiodontidæ*, etc., which I have named the palæotheriodont, took its origin from the type which is intermediate between it and the bunodont, viz, the symborodont, as I have pointed out in an essay on this subject.

The first appearance of dermal horns was apparently in a pair placed transversely on the nasal bones, in species of Eocene *Lophiodontidæ* of the genus *Colonoceras*. The same character has been observed by Marsh in species of the Lower Miocene, which probably belong to the true *Rhinoceridæ*, and which he has called *Diceratherium*. This genus appears to have terminated the line exhibiting this structure, and the family in North America remained without horn. As we have seen, the types possessing the median horn arose in Europe, in the *Ceratorhinus schleiermacheri* of the Middle Miocene, and still survives.

*See American Naturalist, 1880, p. 611.

It may be observed in conclusion that a successive increase of size in the species of this line has taken place in North America with the advance of geologic time. Thus, their probable ancestors of the genus *Triplopus* were the least of all. The *Cænopoda* of the White River formation were larger; the oldest *C. mite*, being the smallest. The *Aphelopes* of the Loup River or Upper Miocene formation were all larger, and were nearly equal to the large existing species.

TAPIRIDÆ.

The genera of this family are not numerous as yet. The oldest, *Listriodon*, appears in the Middle Miocene (Gers, France), and *Tapirus* is first found in the Upper Miocene (Epplesheim). The recent species of the family belong to *Tapirus* L., and *Elasmognathus* (Gill). A small species, the *Tapirulus hyracinus* Gerv., is from a bed at Perreal, France, which Pictet has identified with the gypsum of Paris (Oligocene). It is sometimes referred to this family, but is not sufficiently well known to determine its position. In America, *Listriodon*, or a genus which has not yet been distinguished from it, is found in the Miocenes.

The three genera are distinguished as follows:

Three anterior premolars different from fourth premolar and true molars; last inferior molar with heel........ *Listriodon.*

One superior premolar different from true molars; no heel of third inferior molar; nasal septum cartilaginous. .. *Tapirus.*

Like *Tapirus*, but nasal septum osseous.................. *Elasmognathus.*

CHALICOTHERIIDÆ.

Gill; Cope, American Naturalist, 1881, p. 340.

This family had numerous representatives during Eocene time, and a few species of *Chalicotherium* extended into Miocene time. The boundaries which separate the family from the *Lophiodontidæ* on the one hand and the *Menodontidæ* on the other, are not always easy to determine. From the former the symmetrically developed external Vs of the superior molars, and the double Vs of the inferior molars distinguish it. Yet in *Rhagatherium* the external Vs are not so well distinguished as in other *Chalicotheriidæ*; and in *Propalæotherium*, the anterior cingular cusp produces a part of the assymmetry found in the *Lophiodontidæ*. The character of the double inner cusps of the superior premolars, which distinguish the *Menodontidæ*, is only applicable to the last premolar in *Diplacodon* of the latter, while a trace of the additional cusp of this tooth is found in the Chalicotheroid *Nestoritherium*.

In using the following table it must be borne in mind that the number of the toes has been determined in a very few of the genera. Should any of them prove to have but three digits on the anterior foot, such genera must be referred to a new family intermediate between this one and the *Palæotheriidæ*.