

ART. LIII.—*The Rise of the Mammalia in North America* ;*
by HENRY FAIRFIELD OSBORN, Columbia College, New
York.

[Vice-Presidential address before the American Association for the Advancement
of Science, Section of Zoölogy, Madison, Wisc., August 17th, 1893.]

TWENTY years ago an era opened in the mammalian paleontology of Europe and America. Partly inspired by the *Odontographie* of Rüttimeyer, Kowalevsky completed and published in 1873 his four remarkable memoirs upon the hoofed mammals. He wrote these four hundred and fifty quarto pages in three languages not his own, in French upon *Anchitherium* and the ancestry of the horses, in English upon the

* Some passages in this address have been omitted as indicated by dotted lines. The address will be printed in full in the Biological Studies of Columbia College, Part I.

Hyopotamidae, in German upon *Gelocus*, *Anthracotherium* and *Entelodon* including the first attempt at an arrangement of a great group of mammals upon the basis of the descent theory. These memoirs swept aside all the dry traditional fossil lore of Europe; they breathed the new spirit of Darwin, to whom the chief one was dedicated, making principles of descent of more importance than new genera and species. Kowalevsky thus summed up the contemporary paleontology:

“After the splendid osteological investigations of Cuvier had revealed to science a glimpse of a new mammalian world of wonderful richness, his successors have been bent rather upon multiplying the diversity of this extinct creation, than on diligently studying the organization of the fossil forms that successively turned up under the zeal of amateurs and collectors. . . . With the exception of England (referring to Owen, Huxley, Falconer, and others), where the study of fossil mammalia was founded on a sound basis, and some glorious exceptions on the continent (referring to Rüttimeyer, Gaudry, Fraas, Milne-Edwards), we have very few good paleontological memoirs in which the osteology of extinct mammals has been treated with sufficient detail and discrimination; and things have come to such a pass, that we know far better the osteology of South American, Australian, and Asiatic genera of fossil mammals than of those found in Europe.”

At the same time, between 1869 and 1873, the pioneers of American paleontology, Leidy, Marsh, and Cope began the exploration of our ancient lake basins rich in life. The first ten years of their work not only revolutionized our ideas of mammalian descent, but brought together the data for the generalizations of the second decade; for Marsh's demonstration of the laws of brain evolution in relation to survival; for Cope's proof of ungulate derivation from types with the simple foot resting upon the sole, and with the conic or bunodont ancestral molar tooth; and finally for Cope's demonstration of the tritubercular molar as the central type in all the mammalia. These four generalizations furnished a new working basis for morphology and phylogeny.

In these twenty years, thanks to energetic field work, we have accumulated vast materials for the history of the rise of the mammalia, enough for ten students where there is one, and the question arises: how shall we take best advantage of it, what methods shall we adopt? In this address, besides bringing before you the more recent achievements of exploration and research, I will try to illustrate the advances already made in lines of thought, observation and system in paleontology and indicate other advances which seem to me still desirable. In the problem of how to think and work most

effectively, and with most permanent results, all the sciences meet on common ground.

Advances in Method.

It is to the renown of the veteran Rüttimeyer and of Kowalevsky, so soon unfortunately deceased, that, while their main inductions suffer by American discoveries, their methods of thought have not been displaced. It matters little that their theory, that ungulate molars sprang from lophodont or crested forms, has been disproved; that Kowalevsky's tables of descent are full of errors; that his main generalization as to the persistence of adaptive and extinction of inadapative foot types does not hold good; that the horses and Anchitherium spring not from Paleotherium as he supposed, but from *Pachynolophus* and *Hyracotherium*, types which he carefully studied and yet omitted from the horse line! It is the right system of thought which is most essential to progress; better in the end wrong results such as the above, reached by the right method, than right results reached hap-hazard by a vicious method. If a student asks me how to study paleontology, I can do no better than direct him to the *Versuch einer natürlichen Classification der fossilen Hufthiere*, out of date in its facts, thoroughly modern in its approach to ancient nature. This work is a model union of the detailed study of form and function with theory and the working hypothesis. It regards the fossil not as a petrified skeleton, but as moving and feeding; every joint and facet has a meaning, each cusp a certain significance. Rising to the philosophy of the matter, it brings the mechanical perfection and adaptiveness of different types into relation with environment, the change of herbage, the introduction of grasses. In this competition it speculates upon the causes of the rise, spread and extinction of each animal group. In other words the fossil quadrupeds are treated *biologically*—so far as possible in the obscurity of the past. From such models and from our own experience we learn to feel free to abandon traditions in the use of the tools of science, such as mere methods of description and classification, and to regard priority in nomenclature only.

New discoveries continually produce new conditions; there is nothing more obstructive than the reverence for old ideas and systems which have outlived their usefulness. In observation, an old principle was *de minimis non curat lex*; now, we cannot be too exact. Every cusp and facet has its value, not as a sign-post for a new species, but as suggestive of some function or relationship. Bird's-eye methods of comparison, which, for example, find no difference between a rhinoceros and a lophiodon molar, are of no service now that we are

called upon to distinguish between so many lines of ancient mammals crowding in among the ancestors of existing mammals. Again, paleontology is not a science apart; it has always gone hand in hand with recent osteology; it must now keep abreast with the embryology of the teeth and skeleton; with the animal mechanics of Marey, Allen, and Muybridge; with paleobotany, geology, and historical physical geography. In these points we cannot be too broad. All structures should be considered as to their homologies, their mechanics, which throw such a brilliant light upon their evolution; their relations to the food and soil, and to other parts. This brings us to the animal as a whole—its tendencies, its place in the system of descent, its relations to its contemporaries, the causes of its progression or retrogression; finally, into pure speculation. Here I am reminded of a critical saying by the late Professor v. Gudden, the distinguished neurologist: "Ein Steinchen der Wahrheit hat mehr Werth als ein grosser Schwindelbau;" it was in allusion to the temporary character of the great nerve-tract systems of Meynert and Flechsig. The great 'Schwindelbau,' literally the 'disappearing structure' of paleontology, is the phyletic tree which adorns the end of many good as well as superficial papers; and recently, because of its extremely brief life, has fallen somewhat into disfavor. I do not think the present reaction against these 'trees' is a wise one; we must remember they are the working hypotheses of our branch of science and serve to most clearly express present knowledge.

To illustrate some of these principles of modern methods, let us first look at the evolution of the teeth in the rise of the mammalia. The teeth and the feet are the foci of mammalian evolution, the only direct points of contact with food and the earth. Their combined use in phylogeny has increased in interest, because their evolution has proved to be wholly independent. We recall Cuvier's famous law which Balzac said at the time: "Rebuilt like Cadmus cities, from a tooth."

No generalization has been more thoroughly routed than that of a necessary law of correlation between tooth and foot structure. Besides the orthodox clawed carnivores and hoofed pachyderms of the great French anatomist, we have discovered hoofed carnivores such as *Mesonyx*, and clawed pachyderms such as *Chalicotherium*. Even the apparently lasting barriers of correlation, which Owen raised between the even and odd-toed ungulates, have broken down by Ameghino's discovery of a Litoptern odd-toed horse with an even-toed type of astragalus. Not only is there no correlation of type, but none in the rate of evolution. *Hipparion*, the most progressive horse in tooth-structure, probably owed its extinction to its conser-

vative preservation of its ancestral three toes. For these reasons the teeth and feet, owing to the frequent parallels of adaptation, may wholly mislead us if taken alone; while, if considered together, they give us a sure key; for no case of exact parallelism in both teeth and feet between two unrelated types has yet been found, or is likely to be. This, I believe, is the one lesson of later work which reverts to older methods; we should not base either classification or descent upon the teeth or feet alone. Every additional character diminishes the chances of error.

The evolution of foot structure has now become a science and advances have been made in the principles of progression from the plantigrade, pentadactyl serial types to the unguligrade, monodactyl alternating types which are of the greatest importance in classification and phylogeny. It is surprising how little attention was given to ungulate foot structure between the time of Cuvier and Kowalevsky. Owen's generalization as to the Artiodactyl and Perissodactyl pes formed the one bright exception. Kowalevsky first directed attention to the importance of the more median metacarpals displacing or spreading to gain a stronger foothold upon the carpals as the lateral toes disappeared. Ryder also worked out the laws of reduction. The discovery of *Phenacodus* led Cope to the final generalization that the primitive ungulates were not only plantigrade but had some of their carpals and tarsals in vertical rows like bricks clumsily set with unstruck joints—and that one great law of evolution towards digitigradism was to produce diarthry or alternating joints. As he found this alternation differed both in degree and kind in different groups, he revived the comprehensive "Ungulata," of Linnæus and divided all hoofed mammals exclusively upon their foot structure into five great orders.

Rütimeyer and myself have shown that however successful and convenient this system appears, Cope's lines of division ignore the fundamentally different modes of evolution of the fore and hind feet; an animal may be a taxepod in front and a diarth behind or *vice versa*. Numerous exceptions to Cope's definitions are also found. The discovery of the aberrant ungulate foot types of South America further invalidates Cope's system and sustains the principle that to be permanent classification must be based upon at least two entirely diverse sets of characters. This does not diminish the importance of the primitive taxepod plantigrade type as one great key to the still unsolved problems of the primary relationships of the Condylarthra, Hyracoidea, Amblypoda, Proboscidea, Toxodontia, Litopterna, Artiodactyla and Perissodactyla. All these orders still stand apart in the dim past like so many mile-posts.

While Cope overestimates the feet in these larger divisions, many writers in Europe still depend wholly upon the teeth and ignore the wide degrees of divergence such as are indicated in the Perissodactyla for example in functional tetra-, tri- and mono-dactylism. By "functional" we refer to *tendencies* which are not expressed in the bare digital formulas—and which have the same relation to the feet that the dental curve has to the teeth. The evolution of a monodactyl tendency is not the work of a century but of a geological period, a principle which we wholly ignore when we place the monodactyl *Anchitheres* with the tridactyl *Palæotheres*, on the ground that their dental type and digital formulæ are identical. How many toes an animal has is of far less importance than how these toes are being displaced and reduced.

Lower Mesozoic Pro-Mammalia.

With the exception of the triassic *Theriodesmus* of Seelye, no mammal is known by its limbs or skeleton until we reach the basal Eocene; in studying the first steps in the rise of the mammalia, we are thus practically driven to the teeth and jaws alone. In these straits of the fossil-hunter, embryology has lately come famously to aid.

Assuming their remote reptilian origin, agreeing with Baur and Kükenthal that the theromorph reptiles were parallel with rather than ancestral to the mammals, and therefore placing before both groups the hypothetical *Sauro-mammals* in or below the Permian, we come to the old question which Huxley discussed in his famous anniversary address: "Was there a succession between Monotremes, Marsupials, and Placentals, or a parallel development from a common pro-mammalian type?" Then we look to the newer questions, "When were the Edentates and Cetaceans given off?"

Modern tooth-science springs first from the recent demonstration of Rüttimeyer's hypothesis of 1869, that the teeth of all the mammals center around a single reptile-derived type. With a single exception, which I believe can be disposed of, various stages of trituberculism or a three-cusped condition have become the standard for the teeth, as pentadactyly has long been for the feet, except that this is developed within the mammalian stem, while our five fingers are a reptilian legacy. Second, it springs from the recent thorough exploration of the youngest jaws for evidences as to the primitive form and succession of the teeth. This also supports the reptile theory of tooth descent by proving, what has been in considerable doubt, that the Pro-mammalia had a multiple succession of teeth like the reptiles, and that even some of the modern mammals retain dim traces of four series of teeth.

The brilliant discoveries of Kükenthal, Leche, and Röse begin to show how in various ways the mammals early modified the regular succession of all the teeth by suppression of parts of the multiple series; this is the first thing to consider. The next is how heterodontism arose, how the conic rows of teeth were specialized in different parts of the jaw for three or four functions; as a certain number of teeth took up each function, the question arises whether this number or dental formula was ever the same in all the mammals, for we know it is very different now. After the teeth were thus divided, some functions became more important than others, and established a monopoly, causing first a marked difference in the relative development of the series, which we may express in a dental curve, resulting finally in a loss of certain teeth. In the meantime began the special evolution of the form of the back teeth, or molars. Was this alike in all mammals, was it tritubercular? It is surprising how many problems of early relationship are at stake in these simple processes.

Primitive Diphyodontism.

What does *succession* really consist in? It now appears that Baume was right in denying that the first tooth is the mother of the second; for the teeth of the lower as well as the upper series, spring from the common epithelial dental fold (Schmelzleiste) which dips down from the surface and extends the whole length of the jaw; at intervals it buds off the dental caps (Schmelzkeim) of the first series: after these are separated off, the dental fold sinks and buds off the dental caps of the second series, always below and inside the first; thus the fold is the mother and the caps are sisters, twins, or triplets, according to the number of the series. In all young mammals, including the traditional monophyodont Cetaceans and Edentates, and excepting only the still unexplored Monotreme embryos, traces of two series of teeth have been found. Both Leche and Röse have detected evidence that the dental fold sometimes buds off parts of a third series, thus explaining the occasional reversion of supernumerary teeth on the inner side of the second series, and Leche has seen traces of budding preceding the first series—thus giving us vestiges of four successions!

All our perplexities as to the relations of the milk and permanent teeth, and the ingenious but mistaken hypotheses of Baume, Flower, Wortman, have sprung from our want of evidence of the regular and complete diphyodontism of the stem mammals. The solution in brief is that the "milk teeth" and the "true molars" are descended from the first series, while

the second series is represented by the "permanent incisors canines, and premolars" and rudiments of dental caps beneath the true molars. The mammals early began to diverge from this primitive diphyodontism in many ways; apparently adapting the first and second series, respectively, to their infant and mature feeding habits: losing parts or all of one series or the other, and in some cases pushing teeth of the second series in among the first; this intercalation has been a most confusing factor to us.

In the Marsupials (Kükenthal) almost the entire first series became permanent; thus from the Jurassic period to the present time only a solitary fourth premolar of the second series has pushed out its elder-sister tooth, and Röse has observed that an outer upper-incisor also pushes up from the second series; the remainder of the second series still persist as rudimental dental caps beneath the first, even beneath the first and second molars! There are wide variations among the Placentals; thus in the lowest existing forms, the Insectivora, Leche finds that in the Shrew (*Sorex*) the second series is suppressed entirely, while in the Hedgehog (*Erinaceus*) of the twelve permanent teeth in the anterior part of the jaws five belong to the first series and seven to the second. We thus meet with the paradox, that among the "primitive" Marsupials and Insectivores the regular reptilian succession was early interrupted, while in all the "higher" mammals the reptilian succession of two series was retained in the anterior part of the jaw. Beneath the posterior highly specialized molar teeth of both Marsupials and Placentals, the second teeth were early suppressed, although in the Edentates, which also originally had specialized molars, there is a typical succession of seven teeth behind the canine. These discoveries prove that the whale teeth, like their paddles, have acquired a secondary adaptive resemblance to those of the Ichthyosaurs. How did the single and simple teeth of the Edentates and Cetaceans develop? Clearly by retrogression. As Leche points out in the aquatic Carnivora, in which the first series are degenerating, the single-series condition (monophyodontism) advances step by step with retrogressive simplification of the tooth form (homodontism): thus in the true seals, the eared seals and the walruses, as the permanent teeth become simpler, the milk teeth become smaller. The Edentates, so widely separated genetically, parallel the seals in tending to suppress the first series of teeth and simplify the crowns of the second series at the same time. We might jump to the conclusion that this gives us an explanation of the homodont and apparently monophyodont condition of the toothed whales, especially as it has been supposed they sprang from aquatic Carnivora, but in this

order matters were reversed, for the first series persisted and the second series were suppressed and persist as a rudimental row of tooth caps buried in the jaw.

Each dental series has an adaptive evolution of its own, in Erinaceus the first series has an ancient and the second a modern form; in Ericulus both series are alike; in the Bats the first series is homodont the second is heterodont (Leche); in the Edentates the first series is ancient and heterodont the second is modern and homodont (Thomas, Rheinhardt): so among the Cetacea and Ungulata.

What deep and ancient clefts the different laws of succession mark between the Marsupials and these three Placental groups.

Primitive Heterodontism and Formula.

Now that all mammals are led back to a distant diphyodont stem, it is also true that the further we go back both in palinogenesis and embryogenesis, the more widespread heterodontism is—all modern homodontism proving to be secondary. The simple conic teeth of the porpoise, for example, bear a misleading resemblance to those of a reptile. Flower, Weber, Julin, and Kükenthal agree that the ancestral whales and edentates were heterodont and had a smaller number of teeth than the existing forms.

Heterodontism is then the second problem. When did the division of the teeth into incisors, premolars, and molars occur, before or after the Monotremes, Marsupials, and Placentals separated? It is well settled that the canine was the first maxillary tooth, and developed from the most anterior bifanged premolar; also, from the discovery of complete succession, we must now define the first molar as the most anterior specialized or triconid tooth, not as the most anterior permanent tooth. It seems to me we now find strong evidence that the stem mammals had a uniform number of each kind of teeth; in other words, a uniform dental formula. The Monotremes are most in doubt as the existing forms point only to primitive heterodontism. It will be a great step forward when we learn whether or not the Multituberculates are Monotremes—the resemblance of their molars to those of the Duckbill is very superficial, for the Duckbill upper molars lack the intermediate row of tubercles universally seen in the Multituberculates, and look to me rather like degenerate Trituberculate teeth. Cope has recently found in the Cretaceous rocks a remarkable Trituberculate, which he names *Thlaeodon*; the jaw of this animal is neither Placental nor Marsupial: it is like that of the Multituberculates—and both resemble re-

motely the degenerate modern Monotreme jaw. All we can say, therefore, is that the Multituberculates are an archaic group, highly specialized even in the Trias, that they were *probably* Monotremes, and neither structurally nor functionally akin to the Diprotodont Marsupials (Owen) nor to the Microbiotheridæ (Ameghino). With a dental mechanism and a condyle exactly like that of the rodents, they show no trace of canines, and the mode of evolution of their peculiar molars was probably paralleled later in the rodents. They present vestiges of a primitive dental formula, like this: $I3C?P4.M4+$. *Thlaeodon* shows $C1, P4, M3$. Thus, so far as this doubtful paleontological evidence goes, the Monotremes had a typical formula.

Our next step is to unify the typical 5, 1, 3, 4 of recent Marsupials with the 3, 1, 4, 3 of higher Placentals. Thomas has shown in his studies of recent Marsupials that they have probably lost one of the four typical premolars (*pm. 2*); this observation, fortunately, is partly confirmed by Röse's finding an embryonic germ of this tooth. Ignoring the incisors of the Jurassic Marsupials, Thomas raised the number of ancestral incisors to five, the highest number known among recent Marsupials; Röse therefore made another step towards uniformity when he showed that the Marsupial *i. 5* is probably a member of the second series of incisors, and should not be reckoned with the first. Now, if we suppose that the Placentals have lost one incisor, and one molar (abundant evidence of which is found in *Otocyon*, *Centetes* and *Homo*), we derive as the ancestral formula of both orders:

Incisors, 4; Canines and Premolars, 5; Molars, 4.

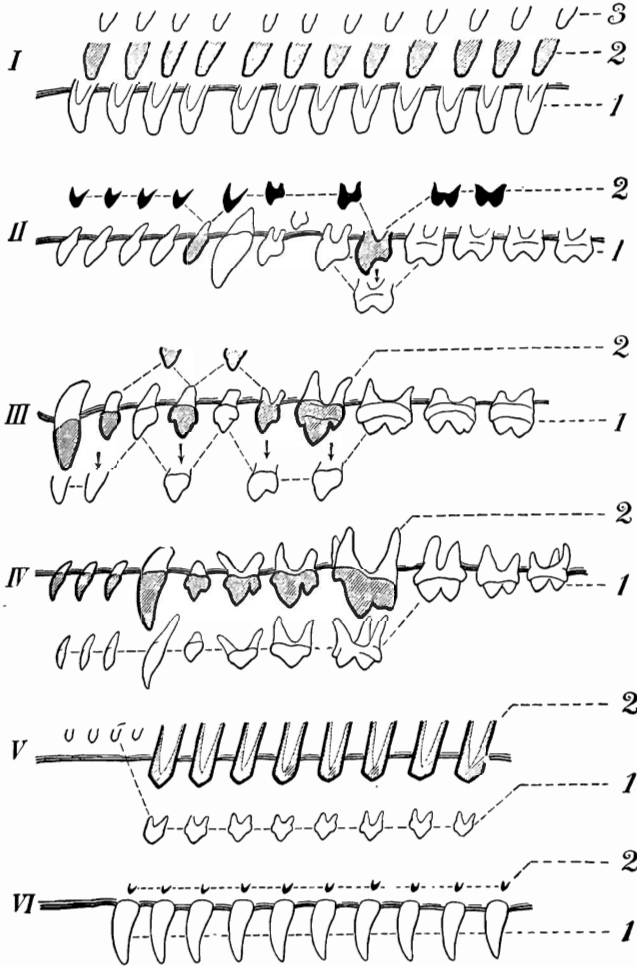
The aberrant placental Cetacea point in the same direction as we read in the conclusion of Weber's fine memoir: "All the Cetacea sprang from a stem with a heterodont, but only partly specialized dentition (something like that of *Zeuglodon*, 3, 1, *p* & *m*: 7), . . . not direct from Carnivores or Ungulates, but from a generalized mammalian type of the Mesozoic period, with some affinities with the Carnivora. . . . *Zeuglodon* itself branched off extremely early from the primitive line, and the heterodont *Squalodon* (mark its formula, 3, 1, 4, 7), "branched off later from the toothed whale line, after the teeth had begun to increase in number and before homodontism had set in." It would be easier for us while speculating to take *Squalodon* and the *Odontocetes* directly from the Jurassic mammalian formula (3, 1, 4, 8). As for the multiplication of this formula, we have found the way, says Kükenthal, by which numerous homodont teeth have arisen from a few heterodont molars, *it is by the splitting up of the numerous triconid molars of Jurassic ancestors into three*. He substitutes this hypothesis

for the one advocated by Baume, Julin, Weber, and Winge, that the multiple cetacean teeth represent the intercalation or joint appearance of both the first and second series of teeth, owing to the elongation of the jaw—a view which is now disproved by Kükenthal's discovery of the second row beneath the first. Since even by Kükenthal's hypothesis the typical Mesozoic mammals could not furnish as many teeth as are found in some of the dolphins, a likelier explanation than his seems to be that as the jaws were elongated the dental fold was carried back and the dental caps were multiplied.

The Edentates, like the Cetaceans, point back to heterodontism, and somewhat less clearly to a typical dental formula. We are here indebted to Flower, Rheinhardt, Thomas, Kükenthal, and Röse. It is their rudimental and useless first series which gives the evidence of heterodontism, while the second series has become adaptively rootless and homodont. The especially aberrant feature is that a double succession exists in the typical "true molar" region. The adult nine-banded Armadillo presents only eight maxillary teeth, seven of which are preceded by two-rooted milk teeth (Tomes); in the embryo *Leche* finds fifteen dental caps, of which only thirteen are calcified; this number probably includes the four rudimentary incisors observed by Rheinhardt. In the aberrant *Ocyteropus* (*Aard-Vark*), with ten adult teeth, Thomas finds seven milk teeth behind the maxillary suture (thus taking us into the molar region of the typical heterodonts). The last of these milk teeth is large, and two-rooted; behind this are three large permanent posterior teeth, apparently belonging to the first series. The large lateral tooth of *Bradypus* is suggestive of a canine. From this rapidly accumulating evidence it appears probable that the ancestral Edentates had four incisors, a canine and eight or more teeth behind it, the double succession extending well back so that the first series did not become permanent at the fifth tooth behind the canine as in the Marsupials and higher Placentals. If these are primitive conditions, as seems probable from comparison with fossil Edentates, they carry the divergence of the Edentates, like that of the Cetaceans, back into the Mesozoic period. Comparative anatomy and embryology thus point back to highly varied branches of a generalized placental heterodont stem in the Mesozoic, and a much earlier divergence than we formerly imagined. Now let us see what the early Mesozoic mammals point forward to.

There are three distinct and contemporary Jurassic types, the Multituberculates, the Triconodonts, and the Trituberculates. Are not these the representatives of the Prototheria, Metatheria, and Eutheria? In the archaic Multituberculates we have seen a monotreme type of jaw and vestiges of a

typical ancestral formula. The Triconodonts are a newer group, perhaps derived from the Dromotheriidae (incipient Triconodonts) of the Trias although these appear to be aberrant; the typical forms extend from Amphilestes to Triconodont,



and exhibit the first stages of development of the inflected Marsupial jaw. The Trituberculates include the Amphitheriidae and Amblotheriidae with true tuberculo-sectorial lower molars, like those of modern Insectivores; they alone exhibit the typical angular placental jaw,—no reason can be assigned for calling them Marsupials, excepting the traditional

reverence for the Marsupial stem theory. Now, it is very significant that the average dentition of these old but highly diverse forms, namely, Multituberculates, 3?, 4, 6, Triconodonts, 4, 1, 4, 7, Trituberculates, 4, 1, 4-5, 8, is also the dentition to which the existing mammals apparently revert.

Thus, the tendency of late research is to show that all stem mammals were related in their double succession, in their dental formula, and in their primitive molar form. These features point, not to a succession, but to a unity of ancestry of the Monotremes, Marsupials, and Placentals.

Divergence of the three Groups.

The discovery of the complete double series seems to have removed the last straw from the theory of the Marsupial ancestry of the placentals, for the peculiar mode of suppression of the second series in the Marsupials has been constant since the Purbeck; this difficulty is added to the structure of the jaw, the epipubic bones, the profoundly different mode of foetal nutrition. None the less, any conclusion we can draw now as to the primary relations of the three great groups is more or less of a "Schwindelbau," and I put together the results of these later discoveries with a full realization of the temporary character of present conclusions.

The Permian Sauro-Mammalia (Baur) with a multiple succession of simple conical teeth divided into: A, Theromorpha, which lost the succession and in some lines acquired a heterodont dentition and triconid single-fanged molars; B, Promammalia.

The hypothetical lower Triassic Promammalia retained a double succession of the teeth; they became heterodont, with incipient triconid double-fanged molars; dental formula approximating 4, 1, 4-5, 8. They gave rise to three groups: I. The Prototheria which passed rapidly through the tritubercular into the multitubercular molars in the line of Multituberculates, and more slowly into tritubercular and its later stages in the line of Monotremes. II. The Metatheria or Marsupials tended to suppress the second series of teeth, except those intercalated with the first; by this and by reduction the formula became 5, 1, 3, 4-6; the molars passed slowly through the triconodont into the typical tritubercular type. III. The Eutheria or Placentals divided early into a number of branches, in which there was heterodontism, but no uniform modification of succession, namely: A, forms suppressing the second series in the molar region only, and acquiring a typical Eutherian dentition, 3, 1, 4, 3-4. 1. The Insectivores tended to partly

suppress the anterior teeth of the second series or intercalate them with teeth of the first series; the molars became tritubercular. 2. The higher Placentals retained the succession of the first and second series as far back as the first molar; the molars entered rapidly into trituberculy and its higher stages. B, forms retaining the double succession in part of the molar region, and retaining more of the primitive dentition, 4, 1, 4, 8. 3. The Edentates branched off from an early triconodont or tritubercular diphyodont stage, with numerous molars, and secondarily suppressed the first heterodont series, and established a numerous homodont second series. 4. The Cetacea also branched off from a diphyodont, heterodont stage, and secondarily established a numerous homodont first series, and suppressed the second series.

[To be continued.]