acts from being put through them. The experiments indicate the presence of mental images. Miss Isabel McCracken, in studying "The Egg-laying Apparatus in the Silkworm (*Bombyx mori*) as a Reflex Apparatus," performed various operations on the nervous system to learn the localization of function in the egg-laying reflexes. The posterior abdominal ganglion is the controlling center and exhibits a high degree of independent activity. The vitality of the silkworm moth, as measured by length of life and capacity of the reproductive system to function, is not impaired by removal of the head. The exact influence upon the reproductive function of the cerebral, thoracic and the several abdominal ganglia was experimentally determined. "A Study of the Choroid Plexus," by Walter J. Meek, adds confirmatory evidence to the conclusion that the plexuses are concerned in the secretion of the cerebro-spinal fluid.

SOCIETIES AND ACADEMIES

THE ST. LOUIS CHEMICAL SOCIETY

At the meeting of the St. Louis Chemical Society, held June 10, three papers were presented on the general subject "The Fixation of Atmospheric Nitrogen."

1. "By Plants," J. Arthur Harris, of the Missouri Botanical Gardens.

2. "By Direct Oxidation," Carl Hambuechen.

3. "As Ammonia and Cyanides," Dr. F. W. Frerichs.

The speakers presented the general history of the several processes, and the methods employed, together with an account of the present status of the subject. Dr. F. W. Frerichs concluded that even if the Chilean sources of combined nitrogen should be exhausted within twenty-five years, and even if the low nitrogen content of mineral coal (about 2 per cent.) excluded this as a source of combined nitrogen, except in the few cases in which this nitrogen can be obtained as a by-product, still, chemistry will be quite able to supply all the combined nitrogen that shall be required.

C. J. Borgmeyer,
Corresponding Secretary

DISCUSSION AND CORRESPONDENCE

DR. EASTMAN'S RECENT PAPERS ON THE KINSHIP OF THE ARTHRODIRES[1]

Every one who labors with the time-honored problem of vertebrate descent must consider, sooner or later, the arthrodiran "fishes," for these, with forms similar but even more puzzling, were the most conspicuous and diversified of earliest chordates. They are first known in the upper Silurian, run their gamut of evolutional prosperity in the middle Devonian, and become extinct in the early Carboniferous: the earlier forms were small with tubercle-like teeth, the later, often of considerable size, with many types of dentition, tubercular, trenchant, or crushing. Unhappily, however, the various forms of arthrodires are known only imperfectly, and the fact that various writers have considered them as related to almost every and widely separated groups of living fishes is enough to indicate how little is known of their anatomy.

Among the latest contributions to this unsatisfactory theme are three papers by Dr. C. R. Eastman, and these contain such reactionary views as to the kinship of arthrodires that they merit a somewhat extended review. For, in the matter of vertebrate descent, there should, I think, be entered a friendly protest against Eastman's conclusions—all the more necessary on account of his deservedly high authority in matters of palæichthyology—and the reasons should be summarized for regarding his arguments inadequate. On the other hand, I do not believe that this is the place to support in detail a rival theory—it is rather to show the intricacy of the materials involved and the limitations to which our conclusions must be subject.

Eastman brings out in his papers three essential theses. He aims to demonstrate: (1) That arthrodires are specialized lung-fishes, principally on the evidence of dental plates and

[1] "Dipnoan Affinities of Arthrodires," *Am. Jour. Sci.*, Vol. XXI., February, 1906. "Structure and Relations of Mylostoma," *Bull. Mus. Comp. Zool.*, Vol. L., No. I., pp. 1–34, pls. 1–5, May, 1906. "Mylostomid Dentition," *ibid.*, Vol. L., No. 7, pp. 211–229, 1 pl., February, 1907.

the arrangement of the bones of the head-roof. (2) That the living types of lung-fishes, particularly the Australian *Neoceratodus,* show the closest affinities with Devonian arthrodires—especially with *Mylostoma,* the form which has pavement-like dental plates. (3) And that he has discovered the way in which the dental plates of *Mylostoma* were originally arranged. These theses may now be examined; but for convenience, they will be taken up in an inverted order.

I. *As to the dental apparatus of Mylostoma.*

In various forms of arthrodires there were present at least three pairs of dental plates;—there was possibly a greater number of these plates, in pairs or azygous, but the proof is still imperfect. In the case of *Mylostoma,* the three pairs of plates occur in a single well-preserved specimen which was first described by the reviewer (*Mem. N. Y. Acad. Sci.,* 1901), who endeavored to show that these plates corresponded to the "premaxillary," "maxillary" and "mandibular" plates of other arthrodires, and that they were arranged in the mouth in a similar manner—the smallest plate, sharply triangular, becoming the "pre-maxillary," and the medium sized, ovoidal one, the "maxillary." In the fossil, moreover, the normal position of the plates in the mouth indicated, since two of the plates, "maxillary" and "premaxillary," are preserved side by side, in singularly perfect contact. These conditions, then, become the point of departure for Eastman's detailed studies, which involve, by the way, over two-score octavo pages. Thus: taking a large series of detached dental plates (which, we infer, may well have belonged to different individuals, species and probably even genera), Eastman places them together, *secundum artem,* until their grinding surfaces fit, and thus obtains their "true arrangement." By this mode of procedure, he first of all changes the relative position of the "maxillaries," as given by Dean, and figures a pair of new elements, "vomerines," lying crosswise in the front of the mouth. This arrangement, however, does not give permanent satisfaction to its author, for in his third paper, the vomerine plates are withdrawn from the complex, and in this process each of these elements is rotated 90°, changed sides, transferred from the upper to the lower jaw, and described as having belonged to a new mylostomid. This change, however, does not deter the author from still insisting upon the actuality of vomerine plates. On the evidence of a new arthrodire, *Dinomylostoma,* in which he describes three pairs of dental plates, he argues, again from their needs in fitting together, that there must have been still another (*i. e.,* a fourth) pair of plates. Indeed, he declares confidently that, "unacquainted though we be with actual specimens, the existence of vomerine teeth in *Mylostoma,* real or potential, is an assured fact"! That this may be so one will readily admit, but it is not quite obvious from Eastman's argument, especially when it entails the corollary that the two well-known pairs of upper dental plates of *Mylostoma* are the homologue of the single pair of "shear teeth" of a closely similar arthrodire (*Dinichthys*). For we can not understand why we should be asked to believe that two arthrodires, similar to each other in a host of characters, should be so distinct in this important particular? Nor does it make the argument quite convincing when Eastman points out that the "palatine" plate in the young lung-fish, *Neoceratodus,* passes through a stage in which it shows traces of subdivision (= a "*Mylostoma* stage"), for this implies a finished perfection of the embryological record, which would hardly have been assumed by even Haeckel in his palmiest days.

In short, I can not feel that the work of Eastman on mylostomid dental plates is convincing. He has not demonstrated that the plates in *Mylostoma* were more numerous than those well known in other arthrodires, nor has he modified satisfactorily our views as to their relative arrangement. The evidence of the first specimen, which shows two of the dental plates in closely fitted contact, is still, I believe, better evidence in the matter of mylostomid dentition than that obtained by elaborate fittings of detached and possibly (bear witness Eastman's "vomerines")

unrelated dental plates. The chances are infinitely small that in the fossil in question two such plates, if once separated, could have accidentally come to lie in such accurate apposition. And until more perfect material is forthcoming, the present specimen remains of paramount value, none the less so since, as the writer pointed out, the faceted surface of these combined plates corresponds to the indented area of the "mandibular," which is present in the same fossil and must have apposed them. By this view, also, the dentition of one arthrodire can best be explained in terms of another, the smaller, more irregular "premaxillary" of *Mylostoma* becoming the homologue of the smaller and more irregular "premaxillary" of *Dinichthys,* and the longer oblong "maxillary" to the long "shear tooth" of the latter form. It is not necessary, therefore, to go afield and postulate a closer affinity of the Devonian arthrodire *Mylostoma* to a recent lung-fish when a comparison can readily be made with a contemporary form (*Dinichthys*), to which in many regards it is closely akin.

II. *As to the very primitive characters of Ceratodus which ally it to Mylostoma and separate it widely from known Paleozoic Lung-fishes.*

Eastman expresses his view as to the relationship of lung-fishes and arthrodires thus: A primitive ceratodont (from which descend directly *Ceratodus* and *Neoceratodus*) was the progenitor of two side lines of fishes, one giving rise to more and more specialized lung-fishes, the other to more and more specialized arthrodires. Before the specialized line of lung-fishes became extinct it gave rise successively to such forms as *Dipterus, Scaumenacia, Phaneropleuron, Uronemus* and *Ctenodus:* before the arthrodire line died out it passed through phases represented in the order *Macropetalichthys, Homosteus, Mylostoma, Dinomylostoma, Coccosteus, Dinichthys, Titanichthys.* The fact that in all of the mass of Paleozoic lung-fishes there is not a suggestion of the hypothetical *Ceratodus* is easily waived aside as due to the imperfection of the geological record. And thus are rejected Dollo's illuminating researches as to the descent of the dipnoans.

We may query, accordingly, the reasons why the modern *Ceratodus* (*Neoceratodus*) is assumed to be the primitive dipnoan—to say nothing, for the present, of its kinship to the arthrodira. And here Eastman's studies do not appear adequate: *Ceratodus,* he points out, has a cutting type of dental plates, it has a diphycercal tail (rather than heterocercal), and it has fewer dermal head-plates. He does not suggest, however, that we have at the present time a fairly rich material of fossil dipnoans, and he fails to indicate that in the ceratodonts many characters common to the early forms do not appear; in a word, Eastman does not explain clearly his paradox—that we are to believe that these earliest dipnoan characters should be regarded as more modified than the structures of the modern *Neoceratodus.* Indeed, the skeptical reader remembers, on the contrary, that in the earlier fishes the teeth are in the form of tubercles, more or less shagreen-like in form and arrangement; that in all the earliest groups of true fishes, sharks, dipnoans, crossopterygians, actinopterygians, there occur no shear-like dental plates; that in the series of definitely known lung-fishes beginning with those in the Devonian, the tubercular teeth are reduced gradually, and that only with the development of their basal supports do there come to be formed cutting dental plates. Moreover, that this mode of evolution is the true one is confirmed with singular clearness in the general plan of the development of the teeth of *Neoceratodus* itself—a great number of tubercular denticles preceding the solidification of their basal supports and the growth of bony cutting ridges. In short, there is every reason to conclude that the dental plates of *Ceratodus* are derived from dental plates of dipnoans of the paleozoic type, and there is no tangible evidence that the dental plates of the recent dipnoan picture the ancestral condition.

Again, who can doubt that the descent lines of the dipnoans and the ganoids converge very closely in the earlier paleozoic times? One

may even be doubtful whether certain of these genera were ganoids rather than lung-fishes, and close examination of the known structures of these forms has led every observer, as far as I am aware, to postulate the closest kinship between the two groups. From these early types, upward, one may trace in the fossil lung-fishes the dermal plates of the head-roof becoming less numerous, lighter in texture, and deeper in position, losing completely their primitive tubercle-studded surface. From *Ceratodus* (as Teller's figures indicate) to *Neoceratodus* there is a marked step in this direction, and from such a condition only can one understand the curiously reduced dermal head-roof of *Protopterus* and *Lepidosiren*. Why, accordingly, should we believe, in the face of this kind of evidence, that the condition of the head-roof of *Ceratodus* is more primitive than that of the early ganoids and dipnoans conjoined? There is certainly adduced no concrete evidence for such a reactionary view. Eastman's final evidence as to the ancestral nature of *Neoceratodus*, as far as I am able to find, is in the shape of its caudal fin: it is diphycercal rather than heterocercal. Dollo has shown, on the other hand, that the earliest dipnoans (ganoids and sharks as well) are heterocercal, and that it was only through the paleontological series, which he carefully depicts, that diphycercy was attained in the modern lung-fishes, as an eel-like adaptation to living in a muddy bottom—an evolution in the process of which the dorsal and anal fins became merged with the caudal. This conclusion of Dollo is based upon such strong testimony that it can hardly be disproved merely by the assumption that *à priori* a diphycercal caudal fin is more primitive than a heterocercal one! In short, we can find in Eastman's studies no ground for making the stock of *Neoceratodus* an ancestral one; there is, indeed, no reason evident why it should not have descended from an ancestor resembling *Uronemus* or *Phaneropleuron*.

III. *Mylostoma as a Primitive Arthrodire, related to a Ceratodont Lung-fish.*

Mylostoma differed little from its contemporary arthrodires. In its gnathal plates, however, it had evolved restricted crushing surfaces instead of the long tubercle-studded jaw-rims of *Diplognathus, Trachosteus, Selenosteus* or *Coccosteus*. *Dinichthys*, indeed, shows transitional characters, for the tubercles of the anterior reaches of the jaws are ground away when the jaws attain a shear-like action, and the gnathals of *Dinomylostoma* show a still nearer approach to the pavement-like surfaces of *Mylostoma*. In short, there is evidence that the arthrodira during their extraordinary evolution gave rise to a series of forms whose dental characters ranged from tuberculate to pavement-like—a line of evolution which, it will be recalled, is paralleled in other groups of fishes—sharks, ganoids, teleosts, and, as above noted, dipnoi. Now since the time of the classical studies of O. Hertwig (1876) on the origin of the bony plates of fishes, there has been found no good reason to doubt that the tuberculate condition was the ancestral one, and it follows, therefore, that until strong reasons to the contrary be adduced, we can safely assume that the same law of development holds true in the case of the arthrodira. That is to say, that the crushing plates of *Mylostoma* are secondary, not primitive. Eastman, however, contends that since *Mylostoma* resembles *Ceratodus*, it is therefore primitive. But if, as we have indicated above, there is little reason to regard *Ceratodus* as primitive, it is clear that the affinities of *Mylostoma* must be determined by comparison with kindred arthrodira. It might be pointed out, finally, that the great majority (possibly eight out of ten) of the genera of which jaw plates are known, bear tuberculated dental plates, including the earliest known arthrodires. And this is naturally interpreted in favor of the modified nature of *Mylostoma*, for thus historical evidence supports the findings of comparative anatomy.

If, now, the foregoing objections to Eastman's conclusions are valid, it is quite clear that the general question of the affinities of the arthrodira is just as doubtful as ever. Eastman, emphasizing the dipnoan characters

of the arthrodira, points out similarities in *dental plates,* but these might ally them as well to chimæroids as to dipnoi—in the *shape of the caudal fin* and its supports, which are scarcely more dipnoan than shark-like (pleuracanth) or ganoidean—in *persistent notochord,* which might be as well shark-like, dipnoan or chimæroid,—in *punctation of dental plates,* which is a character by no means exclusively dipnoan. So that one may, I feel, hardly conclude with Eastman that the lung-fish (*Neoceratodus*) recalls "in its entire organization, save for the absence of dermal trunk-armoring, the principal features of the arthrodires," or that there are present between the modern lung-fish and the ancient arthrodire, "such intimate structural resemblances [that they] can not be explained by parallelism but point plainly to common descent." Eastman is willing to admit, on the other hand, that the evidence is questionable that arthrodires had a vestige of ventral limbs, and that they are unlike dipnoans in possessing a shoulder- and ventral-armoring. But even if we can picture such a *paleozoic descendant* of primitive lung-fishes, can we still imagine one which lacks also pectoral limbs, and opercular bones, and which possessed on the other hand shoulder joints rendering possible a curious dorso-ventral movement of the head?[2] Certain it is that the resurrected doctrine of the kinship of arthrodira and lung-fishes finds little support in the recent studies of Hussakof and others, which have shown that the gap between the arthrodira and the pterichthyids is by no means as wide as we have hitherto taught.

[2] Eastman can answer these objections only by minimizing their value, as when he maintains that the operculum is represented in the rudimentary spine of *Dinichthys,* and that the movable attachment of the rib to the cranium in *Neoceratodus* is comparable to the intermovement of head and trunk in the arthrodira. In his comparison of the gnathals of arthrodira with the splenial of dipnoans, he calls attention to a fleck of cartilage fossilized on the outer (*ectal*) face of a gnathal of *Dinomylostoma* as evidence of its attachment to a meckelian cartilage; but this evidence, even if accepted, would be as readily ganoidean as dipnoan. It may be remarked, however, that the structure in question is too obscure to warrant a definite judgment as to its nature, and the fact that the ectal surface of such a plate is sometimes known to bear tubercles quite like those of the usual head plates does not make the assumption probable that the gnathal plates were placed far from the surface of the head.

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Evolution Theories: Static, Determinant, Kinetic

In Science for December 7, 1906, Dr. Ortmann presents another of his series of reports upon the kinetic conception of evolutionary processes. It is very gratifying, of course, that my suggestions are receiving so much valuable time and attention, and the more to be regretted that unfortunate methods of study still interfere with the success of so persistent an inquiry.

Would it not be better, for example, to simplify the issues by omitting the discussion of the novelty or antiquity of the ideas, or at least by postponing it until the ideas themselves have been clearly perceived? It will then become evident to Dr. Ortmann that Darwin and many others have entertained kinetic views of evolution, though not bringing them to the point of definite formulation.

In estimating the value of an interpretation which differs from our own it is well to suspend or lay aside temporarily the opinions we have been entertaining, in order to see how the alternative theory accommodates the facts. But instead of making a personal inspection of the kinetic premises, Dr. Ortmann ties himself fast by italics of certitude to his static dogma: "*If the environment remains uniform, perfect uniformity of individuals will result.*" This keeps him far outside of the subject upon which he continues to inform the readers of Science.

Viewed at the long range imposed by this fictitious barrier, many things look quite the same which would be found very different on closer inspection. Thus it appears to Dr. Ortmann that symbasis is the same as amphimixis, whereas the two processes are on distinct lines and work in different directions.