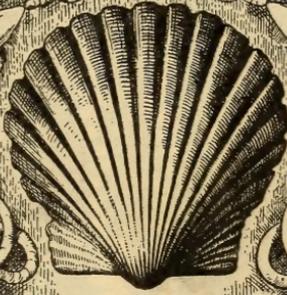




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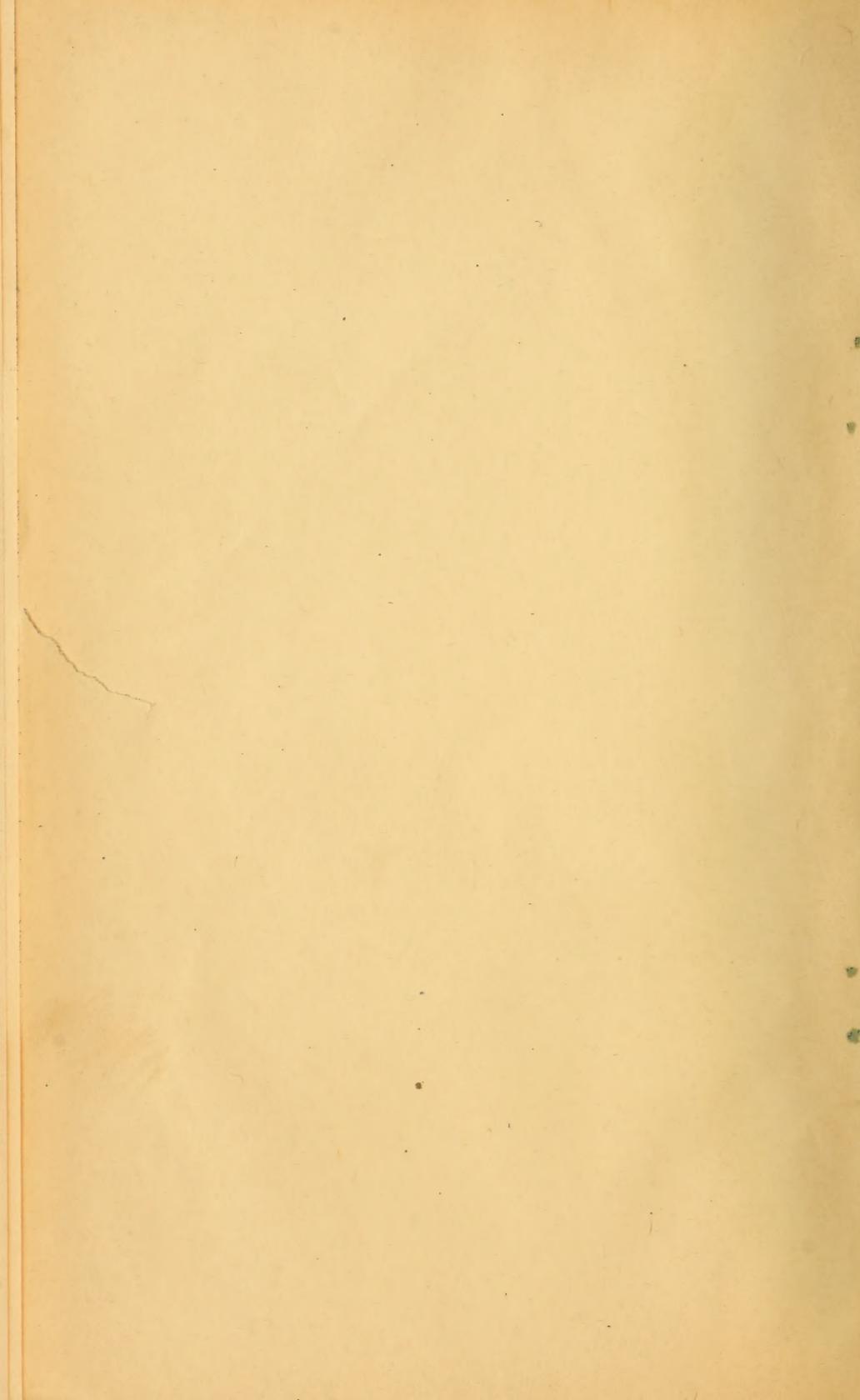


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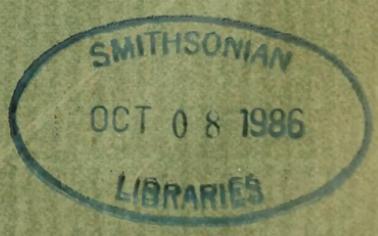
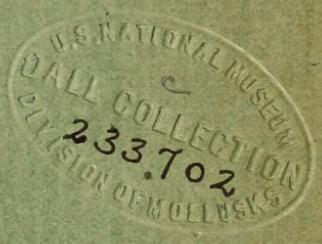
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# Phylogeny

....OF AN....

# Acquired Characteristic.

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HYATT. 1894





PHYLOGENY  
OF AN...  
ACQUIRED CHARACTERISTIC.

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BY ALPHEUS HYATT.

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Extracted from Proceedings American Philosophical Society,  
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PREFACE.

This memoir was first given as a short address before the American Philosophical Society of Philadelphia, at the celebration of the one hundred and fiftieth anniversary of the foundation of that illustrious body. A short preliminary abstract was subsequently published in their *Proceedings* and in the *American Naturalist* for October, 1893, with one diagrammatic plate. The statements made in these two preliminary papers before all the facts were brought together and correlated were true, in the main, but necessarily defective and have been put into more correct shape in the following pages.

INTRODUCTION.

The nature of the evidence afforded by fossil shells is even at the present time very little understood. They have been so often spoken

of slightly, as a sort of jacket, an unimportant part, etc., that all conclusions arrived at by their study alone are considered as peculiarly liable to error.

A shell, to begin with, ranks as a primary, essential part arising in an early stage of development from the shell gland common to the embryos of all forms of Mollusca. Subsequently, by its mode of growth it becomes a model of the external form, and at the same time a mould of the outlines of the internal soft parts to an extent which has not been fully appreciated. The shell is often, also, a permanent record of the series of changes which the form has undergone, from the time it first began to enclose the embryo until the death of the soft parts, since it retains the young shell and all the later stages of growth. Among Nautiloids and Ammonoids, it also contains the calcareous tube or so-called siphuncle, which exhibits remarkable and significant changes of structure and position following upon the development of the animal. This siphuncle connects the septa or horizontal partitions, which with their sutures vary with the age of the animal constituting a third record of changes and structural modifications.

All these parts, the shell proper, the siphuncle, the septa and the sutures are in correlation with each other and together make an index to the life history of the individual, which is unequaled in some respects among other existing or extinct animals.

A single shell, either from a living or fossil form, may present accurately the general history of the development of the young, the stages of the adult and old age. The results of heredity and of the action of endemic or traumatic diseases may also be detected, if one knows how to study and compare the remarkable and distinct series of metamorphoses displayed by this external or protective skeleton with those of congeneric forms. This can be done even when the young is not visible externally by breaking down or dissecting a well-preserved fossil and thus following the history of the shell backwards through all of its stages to the embryo.

The researches of Beecher, Schuchert and Clarke among Brachiopoda have demonstrated that the shell and the internal brachial armature of these forms possesses similar life histories to those here described for the external and internal skeletons of the Cephalopoda. Jackson has demonstrated similar phenomena among Pelecypoda and Beecher among corals.

The vertebrate skeleton has long been considered a standard,

and the evidence afforded by its fossil remains is very important and convincing. The series made in the case of the horses found by Marsh and Cope and those described by Gaudry are universally quoted as the strongest proofs of evolution. This evidence is considered complete, because naturalists understand and have thoroughly studied the skeleton, and because it is internal and has been assumed to be more invariable than the shell. All of these arguments have their due weight, but there are no examples of greater invariability than exist between the shells of the *Nautilus* now existing and those of *Barrandoceras* (*Nautilus*) of the Cambrian, or the Triassic and Silurian *Orthoceras*, or of the *Prodissoconch* stage in the young of *Pelecypoda* as demonstrated by Jackson, or of the *Protegulum* among *Brachiopoda* as shown by Beecher. The *Prodissoconch* and *Protegulum* are embryonic shells that have persisted from the earliest horizons of geologic time and are still to be found in living shells attached to their apices.

The conclusions arrived at by the study of the vertebrate skeleton are reliable, but they are neither more conclusive nor important in theoretical meaning than any other series of equally well-understood hard parts in any other branch of the animal kingdom found as fossils when traced out in the same thorough and careful manner.

How unreasonable it would seem to a student of fossil *Mammalia*, if he were requested to do what it would be appropriate to require from a student of the fossil *Cephalopoda*, viz., to describe from the investigation of a single perfect fossil skeleton of an adult, not only the characteristics of the skeleton at the stage of growth at which the animal died, but the developmental stages of this same skeleton, and in case it were the remains of an old, outgrown animal, also, the retrograde metamorphoses through which it had passed during its last stages of decline. It might require a life time to make out the stages of a single species of mammal satisfactorily from the isolated specimens which would be found and the attempt would be hopeless for all the youngest stages of growth, while the bones were still cartilaginous.

This kind of evidence, however, is readily obtainable among fossil *Cephalopods* with relation to the shell and other hard parts as among living animals, and it can be obtained in good collections everywhere, whether "in situ" or in museums. Thus it

is possible to study the relations of these fossil forms very minutely and with a certainty of possessing a clue to their true relations, which is rarely obtainable even among existing animals. For among these we have only the embryos and young of contemporaneous forms and necessarily lose all relations of succession in time, unless the investigation embraces a prolonged series of experiments or is more or less historical, and even then the facts cannot have a very wide chronological range.

The class of Cephalopoda has two subclasses, Tetrabranchiata and Dibranchiata. These were established by Richard Owen as orders—a purely technical difference, which does not change in any way the value of the structural distinctions as given by this eminent naturalist. The Tetrabranchiata are shell-covered; and they are represented by the modern *Nautilus*, the only existing genus. The Dibranchiata are descendants of the former, but enclosed the shell, and resorbed it in many forms, so that they appear as naked animals. The cuttlefishes, squid, devil-fishes, etc., are existing types. In studying these types, the author has been led to adopt a new method of characterizing the divisions, and besides the old structural distinctions, which are still available, to apply the correlations of habit and structure to the elucidation of some of the ordinal characters.

The classification adopted is as follows :

- Class Cephalopoda.
- Subclass I, Tetrabranchiata.
- Order, Nautiloidea.
- “ Ammonoidea.
- Subclass II, Dibranchiata.
- Order, Belemnoidea.
- “ Sepioidea.

These four orders converge to one type by intermediate forms, by embryology and development of the shells and internal hard parts, by their morphology and by the possession of a similar embryonic shell, the protoconch, or the cicatrix which is a remnant of the aperture of this stage on the apex of the true shell or conch.

The class is composed of exclusively aquatic and marine animals, and consequently they breathe with gills. The structures of the orders mentioned coincide with the distinct habitats they respectively occupy.

The animal of the Nautilus has a large mantle or fleshy sac enclosing the internal organs, which can be opened around the margin, or closed, at the will of the animal. Admitting the water around the margin they fill their mantle cavity with fluid, and then constricting the margin and compressing the mantle-sac, force it out with violence through a fleshy pipe, which is exclusively used for that purpose, and always situated on the ventral side. The reaction of the stream is sufficiently powerful to drive the body of the animal with varying degrees of swiftness backwards. The fleshy pipe is therefore an ambulatory pipe or *hyponome*; and it is advantageous to replace the old and confusing terms by this name.

The Dibranchiata change the external shell, which they inherit from the Nautiloids, into an internal organ, and by suitable modifications of shape and also taking advantage of the powerful hydraulic apparatus, which they also inherit, and increasing its efficiency, become exclusively swimmers.

The hyponome of the Nautilus causes a corresponding depression or sinus to occur in the aperture of the shell on the same side, and its effect is also to be seen in the striæ of growth on this side; so that we know, from these indications in any fossil, what was the comparative size of the pipe, and whether the animal was more or less powerful as a swimmer.

Other indications, such as the openness or contracted form of the various apertures of different genera, exhibit with equal clearness what they could do in the way of crawling. The wide-open apertures indicate powerful arms, capable of carrying and easily balancing the large spire of the shell above; the narrow contracted aperture shows that the arms were small, and that the animal could not so efficiently balance or carry the shell in an upright position, and was therefore, according to the amount and style of the contraction, more or less inefficient as a crawler.

In studying the different types of the Tetrabranchiata, we find that there are two orders as first defined by Prof. Louis Agassiz—the Nautiloidea and the Ammonoidea—and, further, that these divisions coincide with differences in the outlines of the ambulatory sinuses which indicate distinctions of habit general in the normal forms of each order.

The extinct Nautiloidea had large ambulatory sinuses, and were evidently capable, like the modern Nautilus, of rising to the sur-

face, and swimming with a jerky motion ; though their open apertures, as a rule, show their normal condition to have been reptant, or bottom-crawling. The exceptional shells, which depart from the typical form in the sinus and apertures, exhibit their peculiarities in the adults, but not, as a rule, in the young, except in cases

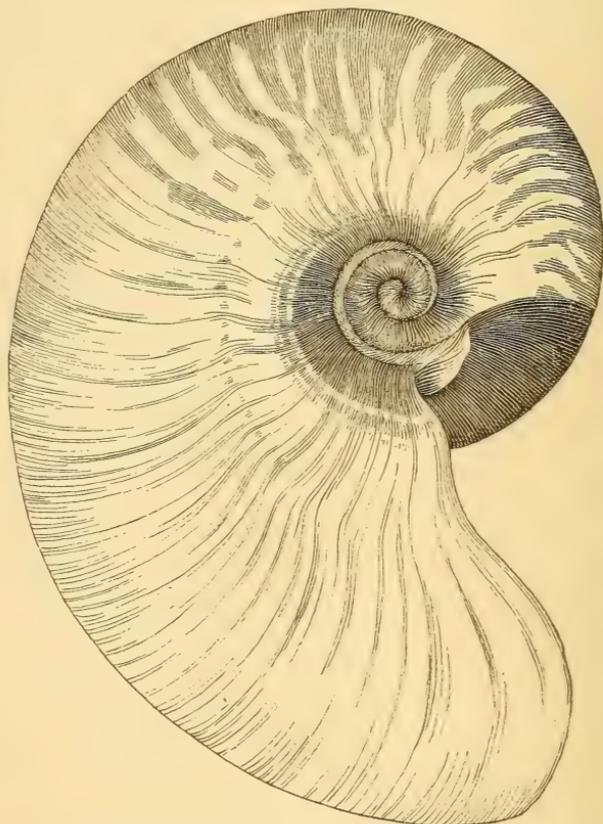


FIG. 1.—*Nautilus umbilicatus*.

where direct inheritance has occasioned the exception, and these are, in fact, the most conclusive proofs of the power of the habitat to produce permanent changes in the apertures.

The orthoceratitic shells of this order are straight cones, with internal septa dividing them into air-chambers, connected by a tube passing through all the air-chambers, and opening into the body of the animal itself, which occupied a large terminal chamber,

which however was a small part only of the whole length of the cone. This is the simplest form: and others are, the bent or arcuate, cyrtoceratitic; the loosely coiled, but with whorls not in contact, gyroceratitic; the closely coiled, with whorls in contact, nautilian; and the still more closely coiled or involute shells, the involute nautilian, in which the outer whorls may simply overlap the inner, or entirely conceal them by their excessive growth, as in *Nautilus pompilius*.

The Ammonoidea in the earlier forms, the Goniatitinæ of the Silurian,\* had apertures with well-marked ambulatory sinuses sufficient to show that they must have had considerable powers of rising or leaping in the water, if not swimming, like the Nautilus. In the later forms of the same suborder and in the Ceratitinæ, Ammonitinæ and Lytoceratinæ the ambulatory sinus is absent; and in its place a projecting crest or rostrum was developed indicating reduction in size and disuse of the hyponome. This and the generally open apertures enable us to see that they were more exclusively bottom-crawlers than the Nautiloidea.

The most interesting of the facts in this order lies among the exceptional shells, some of which must have been sedentary, and could neither have crawled nor moved about with any ease; but none of these, so far as we know, seems to have exhibited a type of aperture which indicated transition to an exclusively swimming habit. These shells appear in our subsequent remarks among phylogerontic and pathologic types.

The Belemnoidea of the Jura had a solid cylindrical body, called the guard, attached to the cone-like internal shell, and partly enclosing it. Aulacoceras of the Trias, as described by Branco, is a transitional form with an imperfect guard, which frequently contains fragments of other shells and foreign matter. This demonstrates that this guard could only have been built by some external flap or inclosing sac, independent of the true mantle. This false mantle must have inclosed both the shell and the guard, and must have been at the same time open, so as to admit the foreign materials which Branco found built into the substance of the guard. One of the straight shells of the Silurian Nautiloidea, *Orthoceras truncatus*, regularly breaks off the cone of its shell, and then mends the mutilated apex with a plug. This plug, we are able to

\* See Plate ii.

say, is the precise homologue, in position and in structure, of the guard of the Belemnite.

Barrande endeavored to show this plug to have been secreted by external organs, as he supposed—two arms stretching back from the aperture like those of *Argonauta*, and reaching beyond the broken apex. The dorsal fold of *Nautilus* is, however, a secreting organ stretching back over the shell; and, as the probable homologue of the plug-secreting organ of the *Orthoceratites* and the guard-building organ of the *Belemnoidea*, it enables us at once to explain how the *Belemnoidea* arose from the *Orthoceratites*, and why *Aulacoceras* had an imperfect mantle. This fold, which was far larger among the ancient *Orthoceratites*, would have been necessarily open on the ventral side, then more but not completely closed in *Aulacoceras*, and finally completely closed in the later *Belemnoidea*, and able to construct a guard as perfect as that which they carry.

The solid guard of these animals, a compact cylindrical body such as they were known to possess, could have been only a heavy burden to a swimming animal. The *Belemnoidea*, therefore, were not purely natatory; but for these and other reasons, which we cannot here discuss, they were evidently ground-swimmers, probably boring into the mud for shelter, or as a means of concealing themselves while lying in wait for their prey.

The old view, that the guard could have been in any sense a "guard" against collisions with rocks, etc., in their wild leaps backwards, is inadmissible for many reasons. The most obvious are its position as an internal organ, its solid structure, and its weight. I think it more reasonable to suppose that it might have increased the liability to injury from collisions. In tracing the *Belemnoidea* to the *Orthoceratites* I have simply continued the labors and carried out more fully the sagacious inferences of Quenstedt and Von Ihering.

The modern *Sepioidea* are known to be almost exclusively swimmers; and the more ancient, normal, flattened forms, and their descendants, the cuttle fishes, have very light, flattened, internal shells, in which the striæ of growth are remarkable for their forward inflection on the dorsal aspect, due to the immense comparative length of this side of the aperture.

The enclosure and suppression of the shell was predicted, with a sagacity which commands our highest admiration, by Lankester,

from studies of the embryo of *Loligo*; and these facts carry out his conclusions, substituting, however, the hood for the two mantle-flaps which were imagined by him as the organs which inclosed the shell and formed the shell-sac.

Most paleontologists have considered the Sepioidea and Belemnoidea as more closely allied; but they appear to us as two orders, certainly as distinct as, and perhaps even more widely divergent than, the Nautiloidea and Ammonoidea.

Among these two orders we recognize many exceptional forms—

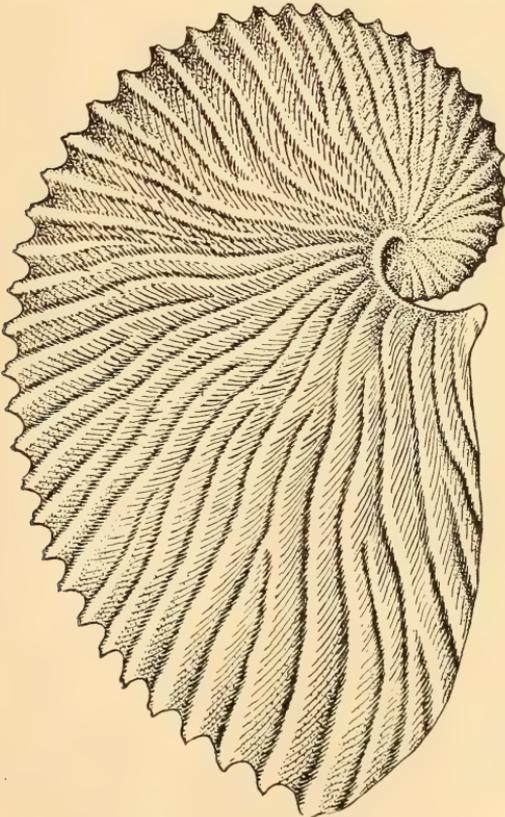


FIG. 2.—*Argonauta* sp. ?

such as the *Spirula* among Belemnoidea, and among Sepioidea the octopods; and we think they all prove our position, that the habitat so closely accords with the structural changes of the type that its purely physical agency must be regarded as the efficient

and direct cause of the correlated changes of structure which distinguish the different orders and suborders, and often of the exceptional genera and species.

We will mention but one of these exceptional cases, in some respects the most pertinent—the existing Argonauta, or paper nautilus (Fig. 2, p. 357). Here a thin shell secreted by the mantle, by the edge of the mantle, and by the two pairs of long dorsal arms, encloses completely the animal of the female alone, the male being naked. As a sexual organ for the protection of the eggs; as an adolescent and adult structure, originating at a late stage in the life of the individual, and not in the shell gland of the embryo; and in its microscopical structure—it is not a true shell, or similar to any true shell among Cephalopoda. Still, in form and position, and as built in part by the mantle, it is analogous to a true shell, and has in part also the functions of a true external shell, and ought therefore to support or refute the hypothesis maintained above. It belongs to a swimming animal, and should therefore have the hyponomic sinus in the aperture and striæ of growth as in Nautiloidea; and these it certainly has. Compare the side view of *Nautilus umbilicatus* (p. 354, Fig. 1), with the Argonauta and it will be seen that the lines of growth agree in both and that both possess the hyponomic sinus on the outer side. One can appeal to this example as a most convincing exception to prove the rule that the shell is a true index of the most remarkable adaptive structures, and, among the fossils, can give us exact information of important similarities or differences in structure and habits.

The *efforts* of the Orthoceratite to adapt itself fully to the requirements of a mixed habitat of swimming and crawling gave rise to the Nautiloidea; the *efforts* of the same type to become completely a littoral crawler evolved the Ammonoidea. The successive forms of the Belemnoida arose in the same way. But here the ground-swimming habitat and complete fitness for that was the object. The Sepioidea, on the other hand, represent the highest aims as well as the highest attainments of the Cephalopods in their evolution into surface-swimming and rapacious forms. We cannot seriously imagine these changes to have resulted from intelligent effort; but we can with Lamarck and Cope picture them as due to efforts on the part of the animal to take up new quarters in its environment and thus acquire habits and structures suitable to the

changed physical requirements of its surroundings and this position is better supported by facts than any other hypothesis.

Confining the discussion to the Tetrabranchiata, which are the most favorable for the present purposes, the next problem presenting itself is whether the two orders, Nautiloidea and Ammonoidea, have had a common origin, or whether they bear internal evidence of having sprung from different ancestors.

The embryo of all Ammonoidea, as shown by the author in his *Embryology of the Fossil Cephalopods of the Museum of Comparative Zoölogy*, and since confirmed by the more extensive researches of Dr. Branco, is the little bag-like shell first discovered by Saemann. This is attached to the apex of the secondary shell. The embryonic bag has been called the *protoconch* by Owen; and the secondary or true shell, the *conch*.

There is no protoconch in most Nautiloidea, as first shown by Saemann, then by Barrande, and subsequently by the author and Branco; but where it ought to have been attached on the apex of the conch, there is a scar, first demonstrated by Barrande. The view brought forward by the author, that this scar indicated the former existence of a protoconch in the Nautiloidea, has been opposed by Barrande, Branco, and several authors, on the ground that the cicatrix demonstrated the existence of a distinct embryonic form. Therefore, according to Barrande, the Nautiloidea were not similar to the Ammonoidea in their earliest stages of growth, and must have been equally distinct in origin.

I have found the protoconch in several forms of Orthoceratites, the figures being reproduced here, Figs. 3-7, and, further, it can probably be found on the apex of all of the so-called perfect shells, which have no scar or cicatrix. These, when described by DeKoninck, were supposed by him, in his "Calcaire carbonifere" (*Ann. du mus. roy. de Belgique*), to be fatal to this conclusion. Having no scar, they could not possibly, according to DeKoninck, have had a protoconch. When the so-called perfect apex is broken off, the observer will probably find that this apex was the shriveled remains of a protoconch which concealed the cicatrix underneath, as in Fig. 4.

There is therefore no essential difference between the embryos of the Ammonoidea and those of the Nautiloidea. There are some of minor importance which we cannot discuss here. These, however, do not interfere with the facts of general agreement; and there is

great probability that the shell-covered forms of all kinds which have the protoconch—namely, the ancient and modern Gastropoda, Tentaculites, and the ancient Pteropoda, and all the radical

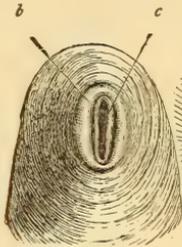


FIG. 3.

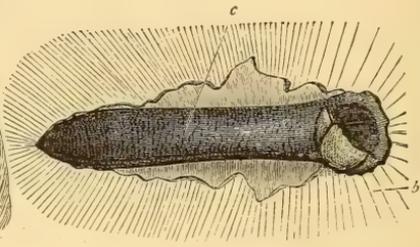


FIG. 4.

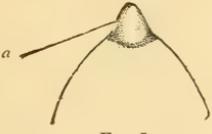


FIG. 5.

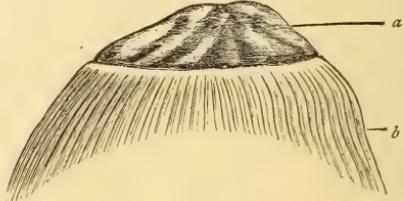


FIG. 6.

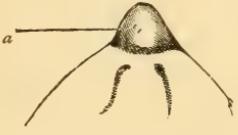


FIG. 8.

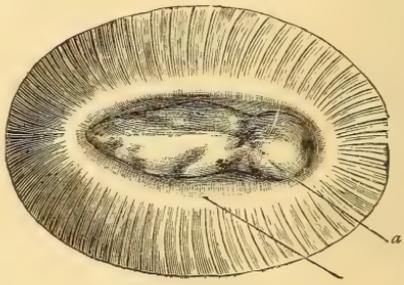


FIG. 7.

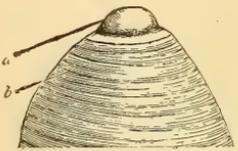


FIG. 9.

Fig. 3.—Aspect of the apex of the conch in *Orth. wuguis* Phill., after the protoconch has been shed in the usual manner. *b*, conch or shell of the apex; *c*, cicatrix.

Fig. 4.—Aspect of the apex, after the protoconch has been accidentally broken off, fracturing the outer shell, and exposing the cicatrix. *b c*, as before.

Figs. 5-7.—Apex and protoconch of *Orth. elegans* Munst. from the front, side and above. *a*, protoconch; *b*, shell of apex.

Figs. 8, 9.—Another individual, said to be of the same species, less magnified. *a b*, as before. The author has also, in *Spy. crotakum*, traced the striæ of the outer shell on the protoconch itself, showing the continuity of the shell over this part (*a*), and completing the evidence that it must have been the shell which enclosed the embryo, and could not have been a mere plug, as asserted by Barrande (*Syst. sil.*, pl. 488). (See Figs. 10 and 11, p. 361).

forms of Cephalopoda—had a common origin, probably in some chamberless and septaless form similar to the protoconch.

Clarke has recently shown that a straight, Orthoceras-like shell may have a complete egg-shaped protoconch like that of Bactrites.\* His form certainly has the characters of an Orthoceras, but the protoconch is large and like that of the Ammonoidea. The shell may be transitional from Orthoceras to Bactrites, but is probably not a typical form of Orthoceras.

The young of the simplest and earliest of Ammonoidea, the Nautilinidæ, have in varieties of two species, as shown by Barrande, a straight apex, like the adult shell of such forms as Bactrites † and that described by Clarke. I have already claimed that this fact was sufficient to prove the high probability of a common origin from a straight shell like Orthoceras for both of the orders. *Mimoceras compressum*, sp. Beyrich (Figs. 1-6, 20, Pl. ii), is a shell which differs from all other Ammonoidea in an essential and highly important character. The septa have no inner lobe. The V-shaped annular lobe, which occurs in all the Ammonoidea except the Nautilinidæ, is also absent in this species. What is more to the point, some species have the sutures of a true nautiloid, since they have

\* "The Protoconch of Orthoceras," *Am. Geol.*, xii, Aug., 1893. See also Figs. 28, 29, Pl. ii.

† A straight form of Goniattinæ (see Figs. 30, 31, Pl. ii).

\*Prof. Hall, in his *Paleontology of New York*, described a young specimen of *Spyroceras* (*Orthoceras*) *crotalum*, sp. Hall, which he subsequently loaned me for further study. Upon developing the specimen, I found the beautifully preserved apex shown in Figs. 10-12. This shows the shriveled protoconch with striations passing on to its surface from the conch, which are made somewhat more prominent in the figures than in nature, in order to demonstrate this connection. The ananepionic substage is smooth and distinctly marked off from the succeeding, probably metanepionic substage, which shows both longitudinal ridges and transverse bands of growth. The metanepionic substage is marked off below by a more prominent band of growth, probably indicating the aperture of this substage. The paranepionic substage below this changes in the form of the cone and in the character of the ridges and bands of growth. The absence of a hyponomic sinus in the young, of straight as well as of nautilian shells, shows that they were not active swimmers in these earlier nepionic substages, and that the hyponome was acquired or at any rate large and functionally active only at a comparatively late age of the ontogeny.

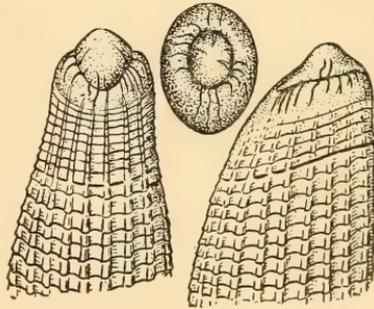


FIG. 10.

FIG. 11.

FIGS. 10-12, SPYRO CERAS CROTALUM.

dorsal saddles in place of dorsal lobes, as in the sutures of their nearest allies among the Nautilini and all of the remaining Ammonoidea. *Mimoceras ambigena* Barr., of the Silurian (Figs. 7, 8, Pl. ii), is a close ally of this Devonian species, and with *Mimoceras* (Gon.) *lituum* (sp. Barr.) Hyatt (Figs. 40-42, Pl. viii), are the only ammonoids which are not involute-nautilian in form. The whorls are in contact; but there is no impressed zone, and no sutural lobes on the dorsum, as in true nautilian shells. On the contrary, they are purely gyroceran forms, with rounded dorsum and sutural saddles on this side in place of lobes. All of the Nautilinidæ also have the septa concave, as in the Nautiloidea, in place of the invariably convex character of the septa in later Ammonoidea, as shown in Pl. x. As doubts may disturb the mind as to whether *M. compressum* is an ammonoid, we recommend a comparison of this shell with the young of an undoubted species of Goniatitinæ, *Agoniatites fecundus* of Barrande, which is a miniature copy made by heredity (Figs. 9-11, Pl. ii).

Bactrites is a perfectly straight form, similar to the members of the Goniatitinæ in all important characteristics, especially the siphuncle and septa, and it also has, like the young shell described by Clarke and all the coiled Ammonoidea, a comparatively large protoconch, as demonstrated by Branco, whose figure has been reproduced on Pl. 2 of this paper. This same genus includes straight cones like *Bactrites* (*Orthoceras*) *pleurotomus* Bar. (*Syst. sil.*, Pl. 296), which are undeniably transitions to true *Orthoceras* in their striæ of growth and position of siphuncle. There is, therefore, convincing evidence in the structures of these Silurian shells that the Ammonoidea, with their distinct embryos, arose from the orthoceran stock, and passed through a series of forms, in times, perhaps, preceding the Silurian, which were parallel to those characteristic of a number of genetic series among Nautiloidea, viz., straight, arcuate, gyroceran, and nautilian.

In *Science* (Vol. iii, No. 52, February, 1884, p. 127), an article written by the author closed with the following words: "The study of the tetrabranchs teaches us that, when we first meet with reliable records of their existence, they are already a highly organized and very varied type, with many genera, and that there was a protozoic period; and the tetrabranchs, like their successors, certainly must have had ancestors which preceded and generated them in this period, but of which we are at present necessarily ignorant. What-

ever the future may have in store for us we cannot now predict ; but at present the search for the actual ancestral form, though necessary, is nevertheless not hopeful. We can, however, rely upon the facts of embryology, and predict without fear of failure that, when our knowledge makes this prototypical form known, it will have a decided resemblance in structure and in aspect to the earlier stages of the shell as observed in the fossil cephalopods."

At the time this was written I had in my possession two fossils which I had collected myself in the lowest Calciferous of Newfound-

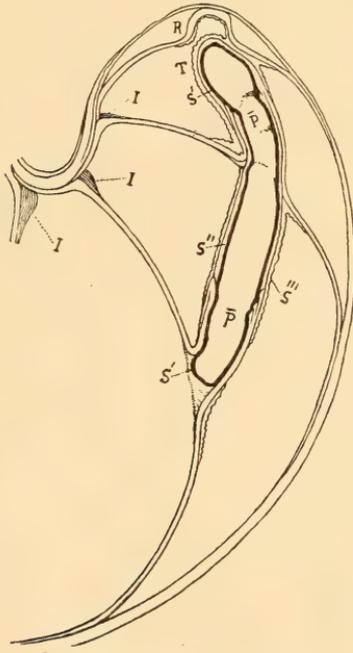


FIG. 13.—*Nautilus pompilius*.  
[Contributed by Henry Brooks.]

land. I was aware that they presented peculiar and apparently septate siphuncles, but in the field had supposed this to be due to an accident that not infrequently happens, viz., the intrusion of Orthoceratites of small size into the open upper parts of the large siphuncles of the Endoceras. When an opportunity finally arose, through Dr. C. S. Minot, Secretary of the Thompson Science Fund, to illustrate and publish these forms, I found that this was not the case, but that their siphuncles were truly septate and completely

closed to within a certain distance from the living chamber by a series of partitions occurring at regular intervals. These forms I shall describe under the name of *Diphragmoceras* in the *Proceedings of the Boston Society of Natural History*, and I shall endeavor to show that this genus is one of the distal ancestors of the Nautiloidea. This conclusion is based largely upon comparison with the apical, metanepionic substage of development in the shell of the modern *Nautilus*. The first septum of the shells has appended to it a closed cæcum or bag, the metanepionic representative of the siphuncle, and the second septum is prolonged apically into a closed tube, the end of which fits into this bag and usually lines it with a second or internal layer. In some cases (Fig. 13, p. 363), probably through the displacement of the second septum, this closed termination is carried forward and is then clearly seen to be a closed tube extending into the siphuncle. The bottom of this tube, in fact, forms a septum in the siphuncle, and the resemblance of this early stage to the adult structures of *Diphragmoceras* becomes perfectly clear. *Diphragmoceras* had a closed tubular prolongation of the base of the mantle like that of the metanepionic septa of *Nautilus* and also more remotely similar to that which occurs in *Endoceratidæ*. But it does not diminish in size towards the apex, hanging like a cone in the middle of the siphuncle; nor does it, as in that genus, also fill the siphuncle below its own extremity with a continuous mass of calcareous matter having a cone in cone structure, nor has it any endosiphuncle. The sheath fits the siphuncle closely and rises step by step with the body, its end forming septa across the siphuncle at the resting stages of this process corresponding in number to those of the shell, but not corresponding in position, each septum being situated just in the interval between two septa, or opposite each air chamber of the conch. Thus the siphuncle becomes divided into air chambers like those of the surrounding shell, but these partitions are not pierced by any endosiphuncle, as are the endocones formed by the sheath in the *Endoceratidæ* and the solid deposits and peculiar rosettes of the *Actinoceratidæ*.\*

Dr. Charles E. Beecher has been fortunately able to lay hands upon the primitive radical of all of the Brachiopoda through the study of the early stages of the shell and has shown that the common embryonic shell or *protegulum* of recent and fossil Brachiopoda is represented by one of the earliest occurring forms, *Paterina*. Dr.

\* "Genera of Fossil Cephalopods," *Proc. Bost. Soc. Nat. History*, xxii, 1831, p. 272.

R. T. Jackson has accomplished the same result for the Pelecypoda by following the same mode of analysis, and shown that *Nucula* was the common form to which all bivalve shells can be traced. Among corals, as shown by Beecher, there are satisfactory indications that there is a common ancestral form of at least a large proportion of that class, and the labors of Barrande, Mathews, Walcott and Beecher are leading to similar conclusions for the Trilobites. The theory of monogenesis, or origin of similar forms from one form, is in other words now rapidly passing from the condition of a reasonable inference from the facts of development and evolution, in which it has stood since the time of Von Baer, to that of a demonstrated law of general application.

The individual coiled shell of every nautiloid may be said to pass through the stages of the protoconch and point of the apex, when it is nearly straight;\* then it becomes slightly curved or gyroceran, and then through a more completely curved or gyroceran stage, in which the first volution of the spiral is completed. After this it continues the spiral, commonly revolving in the same plane and becomes truly nautilian, the whorls on the outside touching the exterior of the inner ones, and spreading so rapidly by growth as to begin to envelop them, and in extreme cases, as in *Nautilus pompilius*, completely covers them up.

The natural inference from these facts would be, that there was a similar succession of forms in past times—the straight in the most remote, the arcuate and the gyroceran in succeeding periods, and the nautilian only in comparatively modern times. This would be a perfectly clear and legitimate mental conception. The structural relations of the adult shells appeared also to demand the same solution, as shown by the researches of Quenstedt, Bronn and Barrande, and later of Gaudry. Barrande's researches, however, demonstrated that this idea could not be maintained, and that there were no such serial relations in time, but that the whole series of forms from the straight to the nautilian were present in the earliest period, and occurred side by side in each Paleozoic formation.

This great author's conclusions have had a curious effect upon

\*It is to be noted in this connection that the earliest nepionic substages do not have equal circular bands of growth, even in true Orthoceras, and are never quite symmetrical on the dorsum and venter. In other words, the descriptive term, straight, is only applicable in a general way. The youngest stages of the conch having differentiated venter and dorsum and a compressed elliptical outline which is similar to that of the radical ancestral form *Diphragmoceras*. See Figs. 10-12, p. 361.

paleontologists. It has been hastily assumed by some, Barrande himself leading in this respect, that the mental conception was more than could be realized in nature; and that the imperfection of the recorded succession was an obvious refutation of the doctrine of evolution, and all pursuit of a solution unworthy of serious attention.

Statistically, the logical picture coincides with the observed succession in time. The straight cones predominate in the Silurian and earlier periods; while the loosely coiled are much less numerous, and the close coiled and involute, though present, are also rare. The close coiled, or nautilian shells, gain in numbers in the Carboniferous, and the involute—meaning by this those that envelop more or less the inner and younger whorls—are much more numerous than in the Silurian; while, in the later times of the Jura, all disappear except the involute.

But suppose we reverse the course of nature and follow back the diminishing number of nautilian and gyroceran shells. We then see, upon arriving at the Silurian, that the vanishing point of these shells, although not traceable on account of the lost records of Protozoic time, could not have been far distant, while the increasing number and varied forms of the straight cones indicates for them a more remote focus in time and consequently a more ancient origin. Thus we are able to see, that antecedent to the Silurian, in the Protozoic, there must have been a time when the straight cones or their immediate ancestors predominated, to the exclusion of the coiled and perhaps even of the arcuate types.

The involute shells of the earliest geological times were, therefore, probably evolved from the straight cones in regular succession; and we may, perhaps, hope to eventually get the evidence of this succession in the fossils themselves. The exact counterpart of our logical picture, as Barrande has truly stated, does not, however, exist in the known geological records of later periods. Judged by the common classification, by the prevalent ideas about the affinities of adult structures, and by the modes of occurrence of fossils in the rocks, the forms seem to be without law or order in their succession, and that eminent author's objections to the theory of evolution have never been fairly met and refuted by any modern writer.

But let us imagine, during the Paleozoic, a different condition of affairs from what is now the general rule. Let us suppose such a thing possible as the quick evolution of forms and structure, and

that in these ancient periods, near their points of origin, animals found the earth comparatively unoccupied, and were not only able, but in fact forced, to migrate in every direction into different habitats, and to make perpetual efforts to readjust their inherited structures to the new requirements demanded by these comparatively unoccupied fields. Food and opportunity would have acted, in such localities, as stimulants to new efforts for the attainment of more perfect adaptation and for changes of structure useful to that end. We can neither imagine the effort to change of habitat and consequently change of habits, without their cause the primary physical stimulant of change in the environment, nor the changes of structure, except as results of efforts on the part of the organism to meet the physical requirements of the surroundings. That this process should end in the production of structures suited to the environment is inevitable. *With these factors at work, both without and within the organism, the evolution of their structures obey a physical law which acts amid a thousand disturbing forces perhaps, but nevertheless must act with predominating force in one mean path or direction, the resultant determined by the environment and the inherited structures of the organism.*

One can compare the changes taking place during the whole of Paleozoic time with those known to have occurred in certain isolated cases in more recent times; such, for example, as that of Steinheim, where a single species, finding itself in an unoccupied field, proceeded with unexampled rapidity to fill it by the evolution of new series and many species, all differing from each other, but all referable, by intermediate varieties, to the original form—in this example, a single species, the well-known *Planorbis æquimbilicatus*.\*

The rapid evolution of the entire family of the Arietidæ can also be used to illustrate this point. This family originates from one ancestral species and yet the process is so rapid that eleven distinct series and seven genera arise, culminate and disappear within the limits of a single age of geologic history, the Lower Lias of Europe, South America and North America.†

There are a number of other well-known cases, which could be cited, illustrating the quick evolution of species in locations which

\* "Genesis of Tertiary Species of *Planorbis* at Steinheim," by Alpheus Hyatt, *Memoirs 50 Year Anniv. Bost. Soc. Nat. Hist.*

† "Genesis of the Arietidæ," by A. Hyatt, *Smithson. Contrib. No. 673, Mem. Mus. Comp. Zool.*

were obviously free when they first entered them. If we admit such possibilities, and then find similar phenomena in the Paleozoic epoch, we shall no longer need our first picture, but can construct a far more natural one.

The Nautiloidea will not then present themselves as a simple chain of being, but as they really were—several distinct stocks or grand series, arising from a common stock or radical, and each of these grand series divisible into many parallel lines of genetically connected forms. In the Lower Silurian, some of these do not have close-coiled forms at all; some of them have: but all, except the most primitive series, which are composed wholly of straight or arcuate forms, have some close-coiled species. These we can often trace directly with the greatest exactness, both by their development and by the gradations of the adult forms, to corresponding species among the straight shells.

The series we have described above, from the straight *Bactrites* to *Goniatites*, compares closely with any single genetic series of the Nautiloidea, and shows that this last arose very suddenly in the Protozoic, and evolved true nautilian shells in the Calciferous and Quebec groups on the earliest fossiliferous level known positively to contain the remains of Cephalopoda.

The genera of Ammonoidea evolved in the Silurian and Devonian are structurally much more distinct from each other than any groups of the same value (*i. e.*, genera) in the succeeding formations, and thus, in different but equally plain characters, teach us that they also had a quicker evolution within those periods than in the later formations. Either this was the case, or else the Ammonoidea were created in full possession of an organization only attained by similar parallel series of congeneric, close-coiled nautiloids, after passing through all the intermediate transformations above described.

These comparisons bring out other curious results. Thus although both are orders and taxonomically equal, we cannot compare the whole of the Ammonoidea with the whole of the Nautiloidea, but only with a more or less perfect single series of that order.

The radicals of the Nautiloidea, *Diphragmoceras*, *Endoceras*, *Orthoceras* and *Cyrtoceras*, evolve through time as an organic trunk giving off an indefinite number of small branches in Paleozoic time, each branch complete in itself and composed of successive species becoming more arcuate, coiled and closer coiled and finally involute. In the Trias the trunk comes to an end, but a small

number of branches composed entirely of close-coiled forms continue the existence of the order.

The Ammonoids have similar straight radicals, but these are few in number, dying out in the Devonian, leaving in that period a number of branches of closely coiled and involute forms, the *Goniatitinæ*. These immediately manifest a capacity for expansion and become the radicals of other involute and more modified involute series which expand in the Trias and Jura, becoming less numerous and degenerate in the Cretaceous and cease to exist with that period or soon afterwards. The history of the Ammonoidea so far as the succession of different forms is concerned is as a whole like that of a single series of the Nautiloidea which can be traced back to a primary straight radical and which has a complete history of modifications, but which necessarily occupies much less space chronologically, evolving and disappearing within perhaps the limits of a single epoch of geologic time.

The trunk of the Nautiloidea is in other words a huge cone-like trunk, clothed with branches but topped only by a few straggling persistent survivors shooting up through time and reaching the present surface with the tip of a single twig. The trunk of the Ammonoidea is only a slender short branch, springing from the Nautiloid trunk, but spreading out and splitting up into many smaller branches. Like a climbing vine of huge proportions it ascends through geologic history, resting upon the level of each age or epoch as upon a horizontal trellis and spreading into great masses of branches at each of these resting places. It shows throughout its evolution less power to resist the action of the surroundings both in the number and high specialization of the forms produced with every change in geologic history, but also in the more rapid and earlier disappearance of each type, and finally in the total disappearance of the entire order.

This comparison fully accords with the true picture of the genetic relations. The remarkably sudden appearance and fully developed structures of these earlier ammonoids finely illustrates the fan-like character of the evolution of forms from centres of distribution, and the quickness with which they must have spread and filled up the unoccupied habitats.

The contemplation of the wonderful phenomena presented by these series has finally led the author to the conclusion that the

phenomena of evolution in the Paleozoic were distinct from those of later periods, having taken place with a rapidity paralleled only in later times in unoccupied fields, like Steinheim.

The hypothesis of Wagner, that an unoccupied field is essential for the evolution of new forms, gains immensely in importance, if it is practicable to apply it to the explanation of the morphic phenomena that have been observed. Every naturalist must see at once, by his own special studies, that this is a reasonable explanation of the rapid development of types in new formations and of the sudden appearance of so many of the different types of invertebrates in the Paleozoic.

Newberry's theory of cycles of sedimentation shows that the sudden appearance of types is inexplicable, except upon the supposition that their ancestors retired with the sea between each period of deposit, and again returning after long intervals of absence made their appearance for the first time in a given littoral fauna bearing changed characteristics and different structures acquired by the migrations of their own stock in unknown seas.

With this explanation and that of Wagner the facts that have been observed fully coincide, and amply explain the phenomena, both of sudden appearance in the first deposits of formations, and subsequent quick development in the necessarily unoccupied habitats. The researches of Barrande, Alexander Agassiz, Bigsby, Gaudry and many others, show us that this must have been especially true of the Paleozoic as compared with subsequent periods.

In order to make a logical and generalized picture of correspondence between all the changes in the life of a nautilian close-coiled shell and the life of its own group accord exactly with the facts, care must be taken to limit it to groups quickly evolved, and these exclusively Paleozoic. Among Nautiloidea there are no series traceable directly to arcuate forms after the expiration of the Carboniferous. This is the common story, and we can see that the series must have risen very rapidly during the Paleozoic, branching out on every side from the common ascending trunk of the straight and arcuate forms. The same is true of the Ammonoidea in the Silurian, but only one short series, the Nautilinidæ, arises from the common trunk of straight cones. The close-coiled shells of this one family became the stock form for the whole of the Ammonoidea.

The Nautiloidea of the Mesozoic are all nautilian forms, and their genetic series do not present the rapid changes of form

observed in the Paleozoic; they are all close coiled and have, as observed by M. Barrande, small umbilical perforations. This same statement applies also to the Ammonoidea; when near their point of origin in the Silurian their forms are very quickly evolved, but are much less quickly evolved after this period. The smaller genetic groups in the Paleozoic are distinguished by differences between the sutures, which are decided indications of structural distinctions. Thus the groups of Clymeninæ and Goniatitinæ differ widely in their sutures and position of siphuncle, and smaller groups have also decided structural differences. In later times the families and, in fact, the whole of the Ammonitinae are more alike. There are many genetic series in the Jura which can be distinguished by the minor details of the ornaments and outlines of the sutures, the differences being less structurally than in the Paleozoic. In other words, the field of variation is structurally decidedly narrower in the Mesozoic than in Paleozoic, whether we consider the Nautiloidea or Ammonoidea.

I have observed the same phenomena repeated in each period and in the mode of appearance of the genera and families in lesser divisions of geologic time. Groups originate suddenly and spread out with great rapidity and often, as in the Arietidæ of the Lower Lias, are traceable to an origin in one well-defined species which occurs in close proximity to the whole group in the lowest bed of the same formation. These facts and the acknowledged sudden appearance of the greater part of all the distinct types of Invertebrata and Vertebrata in the Paleozoic speak strongly for the quicker evolution of forms in that time and indicate a general law of evolution. This has, in former publications, been formulated as follows: *Types are evolved more quickly and there are greater structural differences between genetic groups of the same stock while still near the point of origin than appear subsequently. The variations or differences take place quickly in fundamental structural characteristic, and even the embryos may become different when in the earliest period of evolution, but subsequently only more superficial structures become subject to great variations.*

This law applies only to the epacme or rise and acme, not to the paracme or decline of the same genetic groups or stocks. These last will be shown further on to reverse this law of progressive evolution.

The degraded uncoiled forms of the Nautiloidea and Ammonoi-

dea, wherever they occur, whether in the Silurian or in the Cretaceous, invariably have coiled young, showing that they were the offspring of coiled or nautilian shells, that is, of progressive forms which have themselves been evolved from a series of straight arcuate and gyroceran predecessors. Their uncoiling is a truly retrogressive character, and this tendency is inherited in successive forms in several series, and thus the whole structure is finally affected, the whorl reduced in size, and the complication of the sutures and shells at all stages of growth is degraded until, in the development of the individual, only the close-coiled young remain to testify to their exalted ancestry. In other words, the forms really inherit degraded characteristics at such an early stage that it affects their whole life except the earlier stages.\*

If we examine any of the progressive series we find that characteristic modifications or variations tend to appear first in the later stages of growth and, as a rule, in adults, then in successive forms of the same genetic series they tend to appear at earlier stages of the ontogeny and finally often disappear altogether or become embryonic, and this is the case also with the degraded characteristics. This is clearly shown in the illustrations given on Pls. ii, iii, iv, especially in the history of the development of the sutures among Ammonitinæ. The simpler sutures of the Nautilinidæ of the Silurian and Devonian have undivided ventral lobes and broad lateral lobes. The more specialized forms of the same suborder in the Devonian have the ventral lobes divided, prominent saddles are also introduced, and the lateral sutures become more sinuous. These characters, especially the division of the ventral lobes, occur in these forms (as in Fig. 17, Pl. 2) in an early neanic substage, having replaced the hereditary undivided ventral of the adults of the Nautilinidæ and forced this characteristic back until it is repeated only in the earlier or paranepionic sutures. In the Ammonitinæ of the Trias and Jura this process is carried still farther. The repetition of the undivided ventral of the Nautilinidæ is confined to the earlier septa, which show sinuous lateral outlines (as in Figs. 2, 3, Pl. 4) and these septa become immediately convex, the

\* Several examples are given of such forms among Nautiloidea in the text and the similar uncoiling of the gerontic or senile stage is shown in the ontogeny of a number of species in the plates, notably *Eurystomites kelloggi* (Pl. iv, Fig. 1). Among Ammonitinæ see young of *Crioc. studeri* (Pl. iii, Figs. 11, 12), *Crioc. studeri*, after Barrande (Pl. ii, Fig. 40), *Ancylloc. calloviense*, after Barrande (Pl. ii, Fig. 41), and *Baculites*, after Brown (Pl. iii, Fig. 13).

first one alone being concave, the divided ventral is introduced earlier in the ontogeny and, finally, the division of the outlines by digitations occurs in the earliest neanic substage, replacing the simpler sinuous outlines of the preceding suborders.

In the evolution of a series heredity therefore acts according to a definite law of replacement. *The ancestral characters are brought into contact with new adaptive characteristics, which are being continually introduced into the adult and adolescent stages of ontogeny, and these eventually replace the former which are crowded back to make room for them into earlier stages than those at which they first appeared, and in many cases the latter are resorbed and disappear during this process.*

It is a fact, as shown by the writer and especially by Barrande and Dr. Branco, that the embryonic shell has varied comparatively little throughout time in the Ammonoidea, Nautiloidea, Belemnoidea and Sepioidea. But these statements do not apply to the earliest times in evolution of these types, when they branched off from the common stock. The embryos of the Ammonoidea and Nautiloidea become quite different from each other, the embryos of the Belemnoids remained like those of the Ammonoids, almost exactly similar to those of the Nautilinidæ as shown by Chalmers and Branco, and finally in the Sepioidea, the protoconch or embryonic shells changed more completely and soon disappeared. Attention has been already called to this remarkable fact in the history of the evolution of these forms, that the separation of the orders took place rapidly, and in the embryos as well as in the adults near the origin of the orders, and that the comparative invariability of the embryo was confined to the subsequent history of these types after separation. There is also considerable ground for the conclusion that the young, not the earliest stages of shell, are more variable among the degraded types than among progressive forms. The facts already stated with regard to the young of Baculites and some crioceran forms show this.

This paper cannot be devoted to the discussion of the apparent reasons for these changes, but we have been able to explain the mode in which they take place. *The mode in each case is the earlier or accelerated development of ancestral characters, which as we have said follow the same law, whether progressive and tending to preserve the characters of the type, or retrogressive and tending to destroy the characters of the type.*

Attention is given to the acceleration of development because it will be used in this paper and also because in looking at the young in the usual haphazard way, naturalists often do not find the strong marks of affinity which the ordinary modes of studying lead them to anticipate. The law of acceleration explains the disappearance of important characteristics which often occur even in short and comparatively small series. It acts frequently within a small group like the Arietidæ, so that the later larval and adolescent stages are unlike the same stages in very nearly related species in the same family. Unless investigators are willing to take a small well-characterized group and follow out all its transformations they cannot hope even to understand the remarkable phenomena which are shown more or less in the history of every complete genetic series.

Embryologists generally consider it essential to associate all forms having similar embryos, and to place widely apart in classification all forms having different embryos. As a matter of experience that is correct, but it does not apply to the earliest times in the evolution of types and the surest guides of affinity are sometimes the adult gradations of forms. These show that the Nautiloidea and Ammonoidea with comparatively distinct embryos are nevertheless more closely related than the Belemnoidea and Ammonoidea which have precisely similar embryos, and Sepioidea and Belemnoidea which have very distinct embryos must also be affiliated.

The embryos of all these must have been precisely similar at their origin, but they afterward became varied in the different orders, and we cannot lay down any hard and fast rule by which the embryo becomes an invariable criterion of affinity. We think there is ample reason in the structures of these shells themselves to account for the embryonic differences, and that it is possible to reconcile them with the affinities indicated by the gradations observed between the adults. These reasons which we have only space to allude to here consist in tracing the gradations of adult structures and in a series of correlations which are plainly apparent between the adult structures, and the habits of the animals, and the power which habits in conjunction with effort have to change the adult structures, and then by the action of the law of acceleration in heredity to change even the embryos, either quickly, when the habits are widely changed, or more slowly when they vary but slightly with the progress of time.

Evolution is apparently a mechanical process in which the action

of the habitat is the working agent of all the major changes; first taking effect as a rule upon the adult stages, and then through heredity upon the earlier stages in successive generations. Thus in the open fields of the periods of their origin they expanded into their different habitats, varying to accomplish this purpose with great rapidity, but once in their appropriate habitat, inducements to change or open fields became rarer and we get as a result comparative invariability. As time rolled on and the earth became more crowded, the variability was reduced to less and less important structural changes, except in the retrogressive types. These exceptions are our best proofs of the action of the habitat. The changes in these retrograde forms are again remarkable for the rapidity in which they take place, and some of these types, at least, can be shown to have occupied free fields where they met with new conditions, and to have changed their habits and structures rapidly to accord with these new conditions.

In 1843 Auguste Quenstedt began researches which ought long ago to have led to this solution. He demonstrated by repeated examples, that among diseased types the most extensive changes of form and structure might take place in a single species, and within the narrowest limits of time and surface distribution. Quenstedt was thus the first to show that in diseased forms the shell had the inherent habit of reversing the process of growth and evolution, and of becoming more and more uncoiled by successive retrograde steps. Von Buch and Quenstedt, master and disciple, and the author independently of either of these predecessors, in three successive researches, have arrived at the identical conclusion, that these uncoiled shells are truly distorted, or, as we may more accurately express it, pathological forms. They are not, however, rare or exceptional, as one might at first suppose, but occur in numbers and in every grade, from those that differ but little from the normal forms, to those that differ greatly; from those that are exceedingly confined in distribution, to those which lived through greater lengths of time. But in all cases they exhibit degradation, and are expiring types. The author has repeatedly traced series of them, and studied their young, partly in Quenstedt's own collection. In all cases they show us that great changes of form and structure may take place suddenly; and this lesson could have been learned from Quenstedt's work and example as well forty years since as now.

When we attempt to understand these pathologic uncoiled series and forms, which show by their close-coiled young that they were descended from close-coiled shells, we find ourselves without comparisons or standards in the early life of the individual. The laws of geratology—that the old age of the individual shows degradation in the same direction as, and with similar changes to those which take place in successive species or groups of any affiliated series of uncoiled and degraded forms—here come into use, and serve to explain the phenomena. This correspondence is shown in the uncoiling of the whorls, loss of size, the succession in which the ornaments and parts are resorbed or lost, the approximations of the septa, and position of the siphuncle. It is quite true, as first stated by Quenstedt and also by D'Orbigny, that every shell, when outgrown, shows its approaching death in the closer approximation of the last sutures, the smoothness of the shell, the decrease in size, etc.; but, in order to realize that these transformations mean the same thing as those which take place in any series of truly retrogressive forms, we have to return to the types in which unfavorable surroundings have produced distortions or effects akin to what physicians would term pathological.

This frequently happens in small series of Nautiloidea; and, if we confine ourselves to these, we can make very accurate comparisons: or, on the other hand, in the case of the Ammonoidea, we may trace the death of an entire order, and show that it takes place in accordance with the laws of geratology. Such series, among the Nautiloidea, are abundant in the earlier formations; but they have not the general significance of the similar forms among the Ammonoidea, and can be neglected in this article. There are no known cases of degraded series of uncoiled forms among the ammonoids of the earlier or Paleozoic periods; they may have occurred, but they must have been excessively rare.

In the Trias and early Jura, pathologic uncoiled forms are rare among ammonoids, but in the Middle and Upper Jura they increase largely; and finally, in the Upper Cretaceous they outnumber the normal involute shells, and the whole order ceases to exist. Neumayer has shown, that a similar degradation occurs in all of the normal ammonoids of the Cretaceous, and that their sutures are less complicated than those of their immediate ancestors in the Jura. This proves conclusively, that the degeneration was general, and affected all forms of Ammonoidea at this time; since the uncoiled

forms are not confined to special localities, as in the Jura, but are found in all faunas so far as known.

The facts show that some general physical cause acted simultaneously, or nearly so, over the whole of the known area of the world during the Cretaceous period, and produced precisely similar effects upon the whole type as had here and there been noticeable only within limited localities and upon single species or small numbers of species during the previous periods. This general cause, whatever it may have been, affected the type so as to cause the successive generations of the larger part of the shells to become distorted, smaller and more cylindrical in their whorls, smoother and to lose their impressed zones and their complicated foliated sutures. In extreme cases they became again, with the exception of the earliest stages which are usually broken off and lost, perfectly straight cones, like the orthoceratitic radicals. So much alike are they, that it is quite common for those who are not students of this group to mistake the degraded *Baculites* for the radical *Orthoceras*. This decrease in size, increasing smoothness, and uncoiling, is precisely parallel with the similar transformations taking place during old age in the normal involute shells of the Jura, which, when old enough, also depart from the spiral, or tend to straighten out, and always lose their ornaments, decrease in size, and so on.

The universal action of the surroundings, as we now know them, is certainly not exclusively favorable to the continuance of life, and may be wholly more or less unfavorable. It certainly perpetually excites the animal to new and more powerful exertions, and, like perpetual friction, wears out its structures by the efforts which it obliges it to make for the support of the structures in doing work. At first this leads to development, the supply being greater than the demand; but sooner or later, and with unvarying certainty, the demand exceeds the powers of supply, and old age sets in, either prematurely, or at the termination of the usual developmental periods. The remarkable and at present unique example of the *Ammonoidea* places us in a position where we can see the same process taking place in the whole of a large group, with attendant phenomena similar in every respect to those which we have observed in individual shells of the same order.

In numbers of species and genera, and in the complication of the internal structures and the production of the external ornaments on

the shells, the order reaches what appears to be the acme of evolution in the Jura ; then retrogression begins, and, steadily gaining, finally affects all forms of the type, and it becomes extinct. Smaller series of the Ammonoidea and Nautiloidea go through the same process within their more restricted time-limits, and in the same way, but can be compared with the individual much more accurately and closely. It is evident, then, that the comparison of the life of an individual with that of its immediate series or group reaches a high degree of exactitude, and that the observed phenomena of the life of an individual should enable us to explain, in some measure, the equivalent phenomena of the life of the group ; and we are unavoidably led to entertain the expectation that it does explain it.

The evidence is very strong that there is a limit to the progressive complications which may take place in any type, beyond which it can only proceed by reversing the process, and retrograding. At the same time, however, the evidence is equally strong that there are such things as types which remain comparatively simple, or do not progress to the same degree as others of their own group. Among Nautiloidea and Ammonoidea these are the radical or generator types. No case has yet been found of a highly complicated, specialized type, with a long line of descendants traceable to it as the radical, except the progressive : and all our examples of radicals are taken from lower, simpler forms ; and these radical types are longer-lived, more persistent and less changeable in time than their descendants.

We find the radicals of the Nautiloidea living throughout the Paleozoic, and perpetually evolving new types in all directions ; then this process ceases, and the primary radicals themselves die out. But they leave shells, which are in that stage of progression which I have called the nautilian. These, the more direct descendants of the radicals, become secondary radicals and generate series having more involute shells. These, in turn, as secondary radicals, exhibit a greater chronological distribution than their descendant involute forms. The same story may be told of the Ammonoidea, but substituting at once the close-coiled shell (the secondary radicals) for the primary radicals of the Nautiloidea, even as far back as the Devonian.

This is the essential element of difference between the life of the whole order and that of the individual. One can accurately compare the rise and fall of the individual and its cycle of transforma-

tions with that of any of the single series or branches of the same stock which become highly specialized and then degenerate; but, when an attempt to go farther is made, similar difficulties arise to those encountered in tracing the progress of types and orders. The radical and persistent types are still present, and teach us that, as long as they exist sufficiently unchanged, new types are a possibility. I have traced a number of these in the two orders, and have found that they change and became more complicated, and that probably a purely persistent or entirely unprogressive type does not exist among the fossil Cephalopoda.

The most celebrated example of unchanging persistency has been, and is now supposed to be, the modern *Nautilus*. The similarities of this shell to some of the Silurian coiled forms—which have caused Barrande and others to suppose that it might be transferred to the same fauna without creating confusion—belong to the category known to the naturalist as representative. It is similar in form, and even in structure, in the adults, but has young with entirely distinct earlier stages of development, and belongs to distinct genetic series. The young of the existing *Nautilus pompilius*, shown on Pl. i, can be easily compared with those of their supposed nearest congeneric shells, *Barrandoceras* of the Silurian given on Pl. v, Figs. 6–10.

Comparative invariability or persistency is common to all radicals; and they force us to recognize the fact that the orders could have produced new series, as long as they were present, if it had not been for the direct unfavorable action of the physical changes which took place, so far as we now know, over the whole earth. Thus, in making comparisons between the life of the individual and the life of the group, one cannot say that the causes which produced old age and those which produced retrogressive types were identical: it can only be said that they produced similar effects in changing the structures of the individual and of the progressive types, and were therefore unfavorable to the farther development and complication of these types. In their effects they were certainly similar; but in themselves they might have been, and probably were, quite different, agreeing only in belonging to that class of causes usually described as pathological, or those whose nature can be generally summed up as essentially unfavorable to the progress, and even to the existence, of the organism.

In order to understand the meaning of these evidently degraded

structures, we must turn back to the first remarks upon the order. The apertures and forms of the retrogressive shells all show that they were exceptional, that they had neither well-developed arms for crawling nor powerful hyponomes for swimming; that, in other words, they could not have carried their spires in any of the ordinary ways. Their habits, therefore, must have been more or less sedentary; and like the sedentary Gastropoda, Fissurella, Patella, etc., as compared with the locomotive forms, they presented degeneration of the form and structure of their more complicated ancestors. Their habits did not require the progressive grades of structure, and they dispensed with or lost them; and in many cases this took place very rapidly. This retrogression was in itself unfavorable to a prolonged existence; and the phylogerontic nature of the changes tells the same story, and one can attribute their extinction to the unfavorable nature of their new habitats, and also call them pathologic types without fear of misrepresenting their true relations to other forms.

## II. PRINCIPLES OF BIOPLASTOLOGY.

Relying upon the results of such researches as are described above and especially upon those of Cope, Ryder and Packard, I have in a former publication used the name Bioplastology to designate that branch of research which deals especially with the characteristics of development and decline in the life of an individual and endeavored to show that correlations exist between these and the life history of the group to which the individual belongs. In order to classify this branch of research properly it is necessary to separate it from other allied modes of studying organic phenomena.\*

### AUXOLOGY OR BATHMOLOGY.†

Mr. Buckman and Bather, both well known for their original and instructive researches on Paleozoölogy in England, have recently, in a joint paper under the title of "The Terms of Auxology,"‡ criticised the nomenclature employed in my papers to designate the stages of growth and decline in the individual. They have also

\* The author has given a synopsis of the facts that seem to characterize the different branches of research and their relations to Bioplastology in a paper entitled, "Bioplastology and the Related Branches of Biologic Research," *Proc. Bos. Soc. Nat. Hist.*, xxvi, pp. 59-125; and a brief preliminary abstract appeared in *Zool. Anzeiger*, Nos. 426, 427, 1893.

† Cope, *Proceedings Phil. Soc.*, Phila., Dec., 1871, and *Origin of the Fittest*, p. viii, etc.

‡ *Zool. Anz.*, Nos. 405, 406, 1892.

proposed in view of the correlations which have been shown to exist between the transformations that occur in the stages of development and decline in the individual and those that characterize the evolution of the group to which it may belong, to designate the study of these correlations by the new term "Auxology." This term is open to the objection that it is derived from  $\alpha\upsilon\tilde{\xi}\eta$ , meaning simply progressive growth up to and including the adult stages, and, although in common with others I have felt that it has claims to be retained, there are good reasons why it should be restricted in application, if adopted, to researches upon growth. I have placed alternative terms at the head of this abstract, because one or the other is likely soon to be adopted and I hardly feel competent to arrive at a decision myself without further study of the facts.

Cope in his "Method of Creation of Organic Forms," used the term Bathmism from *Bαθμός*, meaning a step or threshold, to designate growth force, and it is therefore questionable whether the term Bathmology should not be substituted for Auxology in order to give uniformity to the nomenclature.

Dr. C. S. Minot, who has given the first demonstration of the fundamental law of growth, has shown that the common notions with regard to the action of this force in organisms are erroneous. His plotted curves of the actual additions in bulk to the body by growth during equal intervals of time in guinea pigs show that these increments are in steadily decreasing ratio to the increase of weight of the animal from a very early age. He was so much impressed by these facts that he characterized the whole life of the individual as a process of senescence or growing old.

This law is applicable also to the growth of the body as measured by the ratio of the increase of the shell in all its diameters and by the distance apart of the septa with relation to the ratio of increase of the transverse diameters of the volution. The great rapidity of the growth starting from the apex of the conch is obvious and can be observed in all the figures of the young given in this paper which spread out suddenly in the building of this part of the skeleton. The septa mark successive arrests in this process of construction, and it can be readily seen that the first septa are wider apart in proportion to the diameters of the volution in the nepionic (larval) stage than in the early part of the neanic (adolescent) stage and that more uniformity in the distance apart occurs in the ephebic (adult) stages until the last of the gerontic (senile) stage is reached.

Then the septa alter in this respect and finally in extreme parage-rotic substage the approach of extinction is heralded by the close approximation of several septa, as has already been stated above. The greater number of these that show this change indicate that the species possess great vital power and has a prolonged old age changing slowly, and the small number show that senility is a more rapid process. In the higher, more specialized Nautiloids and Ammonoids there are usually only two or three approximate septa in old age; in *Endoceras*, a radical type, there may be as many as twenty-two which show degeneration in the rate of growth. There are other phenomena of a similar character which might be noticed in this connection, but must be deferred to future publications.

Naturalists have as a rule understood the differences between the organic molecular increase that takes place within cells which is the simplest form of growth, and that which follows this and builds up the tissues of the body by the division of cells. Both of these processes, although distinct from each other, result in additions to the bulk of the whole body of the organism and come properly under the head of growth. But while both are thus constructive so far as the body is concerned, only one can be considered constructive or anabolic while the other is essentially destructive or catabolic so far as the cell itself is concerned.

The function of nutrition and the nature of the organic structure are the two essential factors of growth, and this term, *i. e.*, growth, also obviously applies to the morphology of metabolism, consisting of intracellular increase, or anabolism, and cellular development, or catabolism, and the phenomena resulting from the alternating action of these in ontogeny. This at once shows that growth is not simply progressive addition to the bulk of the body, since the multiplication of cells by fission is in itself catabolic or developmental so far as the cells are concerned. Further than this the ultimate results of catabolism are of the nature of reductions as is shown by Minot's law,\* and also by Maupas' observation † on the old age of the agamic cycle in Infusoria and the results of late researches on amitosis in cellular fission. These and the actual reduction of the body taking place in extreme senility show that the term growth

\* "Senescence and Rejuvenation," *Journ. Phys.*, xii, No. 2, 1891, and address on "Cert. Phen. of Growing Old," *Am. Assoc. Adv. of Sc.*, xxxix, Aug., 1890.

† "Recherches expérimentales sur la multiplication des Infusoires ciliés," *Arch. de Zool. experim. et gén.*, Sr. 2, vi, pp. 165-277, et *ibid.*, vii, pp. 149-517.

covers decrease in bulk due to development and use as well as increase.

When one passes beyond this and attempts to deal with the characteristics of ontogeny or phylogeny he at once finds himself in the presence of other forces, such as heredity and other processes, namely, the acquisition of new characters and the renewal of the powers of growth in nuclear substances by means of conjugation.

The manifestation of growth energy, in brief, arises from two factors, or, at any rate, is always found associated with two, a living organism and assimilation of nutritive matter, and is an obvious result of their union.

#### GENESIOLOGY.

The term heredity has been used in two senses, one expressing the results of the action of an unknown force which guides the genesis of one organism from another and a second in which it implies the force itself. Clearness of statement demands that some other term than heredity should be used, and I have consequently proposed to designate the study of the phenomena by the term Genesiology, from *Γένεσις*, meaning that which is derived from birth or descent, this force itself as genetic force, and the principle of heredity thus becomes genism.

The continuity of the same element in the agamic division of unicellular bodies, as in Protozoa, makes it comparatively easy to explain the transmission of likeness, but this is growth of the ontogenic cycle. Maupas shows this clearly and continually speaks of the growth, full-grown virility, and senility of his generations of unicellular, agamic protozoans. In fact they are obviously in a disunited form the equivalent of the colony of protozoans, and secondarily, although more remotely, the equivalent of the single metazoan, or individual, which is essentially a cycle of agamic cells reproducing by fission.

While this likeness of agamic daughter cells to the original agamic mother cell which has disappeared in them may be considered a manifestation of heredity, it is also a form of growth and readily separable from the more complicated relations of organism produced by conjugation of two forms. When the transmission of likeness is complicated with the effects of conjugation the difficulties increase until finally, in the bodies of the Metazoa, they culminate in a problem of surpassing difficulty. Heredity is as plainly

written in the life history of the Protozoan and in the growth of cells, in the tissues in the budding of the Metazoa and parthenogenesis as in these more complicated forms, but the phenomena of transmission occurring after conjugation can be separated from growth and considered upon entirely distinct lines.

The theories offered show this. Thus the corpuscular theories, whether gemmules or biophors or pangenes are assumed, assert the need of minute bodies for the transmission of characters, while on the other hand the dynamic theories, maintained principally by American authors, are more in accord with physical phenomena in assuming that there is a transmission of molecular energy, and some of these views support Hering's theory of what may be called mne-megensis, namely, that heredity is a form of unconscious organic memory, and this, from my point of view, is the only satisfactory one yet brought forward.

Heredity is obviously manifested, for the most part, in the developmental results of growth and appears chiefly in the cytoplasmic structures which Dr. Minot so clearly places before us as constantly increasing with age while the comparative size of the nucleus which represents the power of growth force decreases. Whether this be granted or not, it can hardly be denied that, in describing the development of organisms along ontogenetic and their evolution along phylogenetic lines we are dealing with cycles of progression and retrogression which are quite distinct from the growth of the body as determined by the laws that govern its increase and reduction in bulk, and that one cannot describe the study of both series of phenomena under the same general term without danger of confusion.

Genism, in brief, is the transmission of likeness from one ontogenic cycle to another of the same species. It appears to be due to the same factors as the perpetuation and rejuvenescence of the cycles themselves, namely the union of two distinct forms of the same species or kind.

#### CTETOLOGY.\*

Weismann and his supporters deny that ctetetic or acquired characters are inheritable, but it is safe to make the assertion that this will not be maintained by the students of Bioplastology. Within the limits of my own experience in tracing the genetic relations of varieties and species of fossils Cephalopods and other

\* *Κτητός*, something acquired.

groups through geologic time, although I have tried to analyze the behavior of all kinds of characteristics, I have failed to find any such distinctions. If Weismann's theory is true, it ought to be practicable to isolate in each type some class or classes of modifications that would be distinguished by the fact that they were not inherited.

It is practicable to isolate inherited characters from new variations which have not become fixed in any phylum. It is also practicable to point out characters which are transient in various ways appearing in individuals but not in varieties, in species but not in genera, and so on. When one has by this system of exclusion arrived at the end of the list, he finds that there is no class of characteristics which may be described as non-inheritable. The new variations of any one horizon which can be isolated from inherited ones are not distinguishable in any way from others which occurred previously. Later in time these new variations in their turn become incorporated with the younger stages of descendants. The transient characters of the zoön also do not differ in any way from others that are inherited in allied species, genera, etc. For example, the position of the siphuncle is very variable in some species of Nautiloidea, in others of the same order it is invariable within a certain range, and finally, in other species and genera it is invariable. In the Ammonoidea, derived from the same common stock as the Nautiloidea, this organ attains a fixed structure and is invariably ventral from the Devonian to the end of the Cretaceous, although in number of forms and genera the ammonoids far exceed the nautiloids. All characteristics, even those observable in some groups only in old age, are found in the adults of other groups, and finally in the young of the descendants of these, according to the law of tachygenesis. Everything is inherited or is inheritable, so far as can be judged by the behavior of characteristics. Cope has ably sustained this opinion in all his writings and has called it the theory of "diplogensis" in allusion to the essentially double nature of the characteristics first etetic and then genic.

It is probable that what has been called effort is the principal internal agent of organic changes as first stated by Lamarck, and subsequently rediscovered and first maintained by Cope and subsequently by others in this country. The modern school of dynamical evolution, or the Neolamarckian school, which has adopted this

theory as a working hypothesis, regards effort as an internal energy, capable of responding to external stimuli. They include under this name both the purely mechanical or involuntary, as well as the voluntary reactions of organisms, whether these are simply plasmic, or cellular, or occur in the more highly differentiated form of nervous action.

The word "effort" has mental connections with conscious endeavor, and when we enlarge the definition so as to include purely mechanical organic reactions, this obliges every one to make an effort to rid himself of old habits of associating it with psychic phenomena. It not only imperfectly explains what is meant, but it does not of itself fully convey the idea of a force capable of molding the parts of the body into new forms, and cannot be used at all for the characteristics which originate through its action.

No apology is therefore needed for the use of Entergogenism for the popular term effort derived from *ἐντός*, meaning within, and *ἔργον*, meaning work or energy. This term does not interfere with the name given to the general theory by Prof. Cope—kinetogenesis, in allusion to its dynamical character as a theory of genesis—but is supplementary to this more general title. It is also quite distinct from his neurism or nerve force, and phrenism or thought force, although both of these, if we rightly understand him, are certain forms of entergogenism.

Dr. John A. Ryder\* has discussed in one of his profound essays the relations of the statical and dynamical phenomena of development and evolution, using the terms ergogeny and ergogenetic for all the modifications produced by organic energy, and he considers kinetogenesis and statogenesis as divisions of the first named. These instructive speculations and observations were written to show that the changes of form produced by motion, and those modifications or conditions which may be properly considered as due to the conditions of equilibrium, are often reached, as is claimed by Ryder, as the result of Cope's law of kinetogenesis and are considered by him as statogenetic. These are interesting in connection with the above, and support the remarks made elsewhere with reference to the use of terms like "avolution," and are substantially in agreement with the general views taken in this paper, although taking up a side of the mechanics of evolution not specifically discussed here.

\* "Energy as a Factor in Organic Evolution," *Proc. Amer. Philos. Soc.*, Phila., xxxi, 1893.

The part enterogenic energy or enterogenesis has played in the production of normal reactions, hypertrophy, etc., is well known, and the fact that an organism cannot move or respond to external stimuli without its aid needs no illustration. It seems equally plain that modifications of structure and form follow as the results of such repeated actions developing into habits, and this process necessarily ends in the permanent establishment or fixing of these modifications in varieties and species.

This theory accounts satisfactorily for the so-called mysterious suitability of organic structures for the work they have to do. Such a force, capable of producing changes of structure and sensitive to the impinging action of external physical conditions, must work in directions determined by these two factors, *i. e.*, the structures already existent in the organism and the external forces themselves. It is obvious that these actions and reactions must, as has been already stated above, produce habits and changes of structure which are direct responses to the environment.

If one uses the Darwinian phraseology, one can say that the variations thus produced are natural selections, and I have called them in other publications *physical selections*, although it is likely that the use of the word selection in any way may convey an erroneous idea of my meaning. Selection implies the choice of some characters or tendencies out of a number of others, and in the minds of most naturalists it also implies the survival of the fittest chosen by the working of the struggle for existence in two directions, in one direction between contending organisms, and in the other between the same organisms and their surroundings. According to the opinions maintained in this paper, however, the organism has no such power of choosing, in the evolution of its characteristics. It is driven along certain paths and the influence of the struggle for existence and survival of the fittest is, if it has any influence at all, a perturbing force which has to be accounted for but does not seriously affect characteristics until after they originate. Characteristics, therefore, are not evolved fortuitously and in indefinite numbers for the animal to select out those that are favorable and perpetuate only those, but according to the definite law of variation of Lamarck and Cope.

The dynamical school does not reject the Darwinian doctrine, but it uses this hypothesis in its proper applications as a secondary law explanatory of certain phenomena of survival and perpetuation of

characteristics after they have originated through the action of this law.

According to my own view of the facts, often published elsewhere, its use is unnecessary for the explanation of the quick evolution of series in the early periods of their evolution near the origin of types, also for the elucidation of the pathologic phenomena in the quick evolution of phylogerontic forms and series.

It can also not be applied to the explanation of experimental results, as is admitted by all experimenters and most Darwinists, in cases where modifications have been produced by the artificial application of physical agencies, of which there are now so many on record in both the animal and vegetable kingdoms.

It is plainly, as Dr. A. S. Packard has pointed out, a doctrine derived from the study of the results of evolution and cannot be applied to the more general and fundamental phenomena of the origin of types, the building up of series or the origin of characteristics. My own experience leads substantially to the same opinion, and I find its use unnecessary except for the explanation of the perpetuation of some characteristics that occur during the acme of the evolution of species. The perpetuation of many characteristics which are fundamental to the organism and species is necessarily provided for by agencies which originated them and by heredity as soon as they become fixed in the organism. I think there is good ground for the statement that in many cases these are plainly not advantageous.

Weismann and his supporters are necessarily Darwinians. No one denies that cletic characters arise through the action of the surroundings. If these are perpetuated through heredity, evolution is an undeniable corollary and it must follow the path defined by the dynamical school. If, however, cletic characteristics may originate at the bidding of the surroundings and persist in the successive members of the same genetic series only while the surroundings are comparatively unchanged, or in other words sufficiently alike to continue to force their reappearance, then it must be admitted that the law of the survival of the fittest through the action of the struggle for existence is probably a fundamental law of evolution in organism.

In other words, the battle of the two contending theories is being fought in the domains of cletology and it is hoped that this paper may be a definite contribution to the Neolamarckian side of the con-

troversy. I cannot give further space here to theoretical discussions of this sort and am obliged to refer any persons interested to my other works, especially "The Genesis of the Arietidæ" and the "Bioplastology, the related Branches of Research,"\* in which I have more fully given my own views.

The exclusive Darwinians are, according to the views of the Neolamarckians, as much out of the true path in one direction as are the empiricists in the other in appealing exclusively, as they often do, to the action of the surroundings in accounting for observed modifications.

It is certainly not a very acute analysis of the facts which attributes to external causes exclusive power in producing modifications in many cases as has been largely done by experimental zoölogists. For example, Brauer and the author have both pointed out this defect in the accepted explanations of the famous Schmankeiwitsch experiments upon *Artemia*, and the same may be said of the explanations of all experimenters who do not take into account the internal reactions of the organisms themselves.

The physical forces of the surroundings must act through medium of entergogenic movements, and this is shown clearly in the nature of modifications produced which are extra growths, substitutions of characteristics due to changes of functions, etc., or partial or absolute obliteration of these due to the failure of genetic force to repeat characteristics in the presence of opposing influences and superimposed characteristics as in accelerated development.

Ctetology should also, however, include the study of the action of physical forces when they either actually do produce direct effects upon organisms or may be assumed to act in this way. Changes in light, food, heat and moisture may cause modifications that cannot be included under the head of entergogenic reactions without danger or confusion.

Maupas gives exceedingly instructive examples of this class, and quotes other authorities who have investigated these effects in Protozoa.

Beddard gives a number of examples of such modifications in his *Animal Coloration*, and Semper has also discussed the same subject more extensively in his *Natürlichen Existenzbedingungen der Thiere*.†

\* *Smithsonian Contributions*, No. 73, and *Proc. Bost. Soc. Nat. Hist.*, xxvi.

† Translation by Minot, Macmillan, 1892.

The use of the term entergogenesis makes it practicable to indicate the essential distinction existing between the modifications produced through the mediation of internal forces and those arising as the direct results of the action of external forces by means of the term ectergogenesis and ectergogenic.

These explanatory remarks serve to show that Ctetology is a branch of research which needs to be isolated from researches upon growth and Genesiology, since it is devoted to the study of the origin of acquired characteristics, and therefore necessarily considers all of the internal reactions of the organisms in response to the action of physical forces, as well as the more obscure reactions of structures which are produced solely by (or supposed to be produced by) the direct physical or chemical action of external physical forces.

#### BIOPLASTOLOGY.

The separation of Auxology or Bathmology, Genesiology and Ctetology show also that the study of the correlations of ontogeny and phylogeny to be distinct from either of these, and this branch of research can be designated by the term Bioplastology from *Bίος*, life, and *Πλαστός*, meaning molded or formed.\*

To sum up in a few words the rather ambitious aims of this comparatively new recruit in the army of investigation, it aspires to show that the phenomena of individual life are parallel with those of its own phylum and that both follow the same law of morpho-

\* Bioplasm, bioplast, bioplastic have already been used by Beale and others for the living cell and its contents, but the term "Bioplastology" has not been used, nor have the names proposed by Beale been generally adopted. If they were, Bioplasmology would cover the requirements of students of such phenomena, and there is already in use Plasmology with about the same meaning, and Histology for the descriptive side of the study of cellular structures.

Biogeny has been used in extra scientific literature by Fiske with the same meaning as Bioplastology, and Haeckel has named the law of embryonic and ancestral correlation the law of biogenesis, but there is a strong objection to both of these. Biogenesis is the name given to the theory of the origin or genesis of life from life in contradistinction to the assumption of spontaneous generation or abiogenesis and has a well-established place in scientific literature. Therefore, while the law of correlation of the stages of development and those of the evolution of the phylum may, if one chooses, be called a law of biogenesis, it is more accurate to consider it a law of correlation in Bioplastology, or better still, the law of palingenesis or regular repetition of ancestral characters which very nearly expresses what the discoverer, Louis Agassiz, saw and described. The fact that Agassiz was wrong in his theory, not believing in evolution and not recognizing the meaning of his law in this sense, does not absolve those who profit by his labors from recognizing his discovery of the facts and his obviously full acquaintance with the law and its applications to the explanation of the relations of organisms. It is Agassiz' law, not Haeckel's.

genesis, that not only can one indicate the past history of groups from the study of the young, and obviously the present or existing progression or retrogression of the type by means of the adult characters of any one organism, but that it is also possible to prophecy what is to happen in the future history of the type from the study of the corresponding paraplasic phenomena in the development of the individual.

Whether these claims are well founded or not the nomenclature to be employed is a matter of importance and should be accurate, appropriate and convenient for those who are interested in this work.

ONTOGENY. TABLE I.

| CONDITIONS. | STAGES.                                   | STAGES.       | SUBSTAGES  | SUBSTAGES.        |
|-------------|---|---------------|--|-------------------|
| Anaplasis.  | { Embryonic.<br>Larval<br>or<br>Young.    | 1. Embryonic. | Several.*  | No popular names. |
|             |   | 2. Nepionic.  | { Ananepionic.<br>Metanepionic.<br>Paranepionic. |                   |
|             |   | 3. Neanic.    | { Ananeanic.<br>Metaneanic.<br>Paraneanic.       |                   |
| Metaplasis. | { Immature<br>or<br>Adolescent.<br>Mature | 4. Ephebic.   | { Anephebic.<br>Metephebic.<br>Parephebic.       |                   |
|             |   | 5. Gerontic.  | { Anagerontic.<br>Metagerontic.<br>Paragerontic. |                   |
| Paraplasis. | { or<br>Senile<br>or<br>Old.              |               |  |                   |

Recent researches have, in my opinion, clearly demonstrated that all the stages of development like the embryonic will have to be subdivided in studying many groups. These subdivisions are also relatively important and their differences are often well defined.

The ovum and the extreme degraded substage of the senile period represent the widest departures structurally and physiologically from the adult, one being at the commencement and the other the termination of ontogenesis. Departing from the ephebic stage in either direction towards these extremes one finds the same law. *Contiguous substages of development, when considered in sequence, differ less from each other and from the adult the nearer they are to the ephebic stage, and they differ, on the other hand, more from the adult and from each other in structure and form the nearer they are to the*

\*These stages were enumerated and more or less described under the names of Prot-embryo, Mesembryo, Metembryo, Neoembryo, Typembryo in my paper on "Values in Classification," etc., and to these Jackson added Phylembryo in his *Phylogeny of the Pelycypoda*, p. 289.

*two extremes of the ontogeny.* This is an evident corollary from the phenomena of the ontogenetic cycle and need not be dwelt upon here.

The terminology of the different departments of research which come properly under the head of bioplastology is recognized at present only in the case of embryology, but it is obvious to the student of epembryonic development that similar terms for the study of other stages and periods will in course of time be needed, and in fact the old terms—nealogy, ephebology, and geratology—are cited in that sense in the *Century Dictionary*, and may introduce some confusion. It is not now necessary to discuss this question, but only to draw attention to the facts. I therefore pass on to the consideration of the term epembryonic.

Among fossil nautiloids it is rarely practicable, on account of the frequent destruction of the protoconch, to find an embryonic stage. My last work on Carboniferous cephalopods contains descriptions of the entire ontogeny of a number of species, with the exception of the embryonic stages. In such cases the fact that the embryology is wholly omitted can be pointed out by the use of the term "epembryonic stages," and this has already been found useful above. \*It only remains to add that the same prefix is also useful in designating the exclusion of other stages—thus one can speak also of the "epinepionic" or "epineanic" stages in this same way without danger of confusion with any other term.\*

It is often possible to employ a more specific and characteristic designation than epembryonic. Thus among shell-bearing forms one can distinguish between the embryonic shell and the true shell; for example, the protegulum and tegulum of Brachiopoda as defined by Beecher, the prodissoconch and the dissoconch of Pelecypoda as defined by Jackson, the periconch and conch of Scaphopoda, the protoconch and conch of Cephalopoda. In all of these forms it is practicable to speak of tegular, dissoconchial, or conchial stages or periods, meaning thereby all of the epembryonic stages of these types.

Haeckel, in his *Morphologie der Organismen*, sketched the physiology of ontogeny and phylogeny and gave the general correlations of the two series of phenomena, together with an appropriate

\* Postembryonic is in use for the young stages among embryologists, and is equivalent to the term nepionic, but it is not consistent with the other terms of bioplastology, and is a hybrid.

nomenclature which has been here adopted, with some necessary changes.

The dynamical relations of three great phases of evolution in the phylum were designated by Haeckel\* as the *epacme*, including the rise of the type from its origin, the *acme*, meaning the period of its greatest expansion in members and forms, and the *paracme*, or decline towards extinction, and these phenomena were correlated with the similar physiological phenomena of the ontogeny, and these appear in the table of phyletic terms given below.

Previous to this, in the same volume (p. 76), Haeckel gives his classification of the development of the individual under three headings: "Anaplasis oder Aufbildung (evolutio)," meaning thereby to include the physiological phenomena of all of the stages developed in the four earlier stages of the individual. This is certainly a useful term for the entire series of transformations from the fertilization of the ovum until the progressive stages are all passed through. It does not express nor can it be used for cases of retrogression in which degenerative characters are introduced at such an early age that progression is limited to the embryonic, or to that stage and a part or the whole of the nepionic stage. There are also some examples among parasites in which progression seems to have been reduced so much that one can say it is practically eliminated from all stages succeeding some of the earliest embryonic. For such forms as these the proper term would be Paraplasis, from *παρα πλάσσω*, meaning to change the form for the worse, to deform. Thus the stages of such forms could be collectively spoken of as paraplasic with relation to the ontogeny of others of their own type or allied types, whereas they could not be described as anaplastic.

The explanatory word "evolutio" is here used by Haeckel in a confined and erroneous sense. Evolution really means continuity in time invariably accompanied by change, but whether the modification be progressive or retrogressive, or a combination of progression and retrogression, is immaterial. It is obviously better not to use these terms for ontogenic phenomena. There are sufficient terms in "development," "differentiation of characteristics," "rise," and one has always a slight mental reservation in employing this word for the growth and development of an individual or isolated zoön.

\* *Morphologie der Organismen*, Vol. ii, pp. 320-366.

“Metaplasis oder Umbildung (transvolutio)” is used by the same eminent authority for the adult period in a general sense, and it appears to the writer to have useful function as a descriptive term especially, since it is uniform with anaplasia and paraplasia. Thus one can describe the metaplastic phenomena or characteristics of the ephelic stage in any form as metaplasia, and also speak of the general meaning of metaplasia without referring to that stage of ontogeny in any special form. The use of “transvolutio” is obviously objectionable, since it introduces confusion and conflicts with the proper definition of “evolutio” or evolution as given above.

“Cataplasia oder Rückbildung (involutio),” used by Haeckel for the senile stage, is open to the objection that there is no corresponding Greek word, and also that *καταπλάσσω*, the only Greek verb to which this term can be referred, means to spread over or plaster. Paraplasia, derived from *παρα πλάσσω*, meaning to change the form for the worse or deform, is an obviously preferable designation. Thus the paraplasia or paraplastic phenomena of all the periods of development or only of the paragerontic substage in ontogeny may be spoken of and correctly described under this term.

The use of “involutio” as a descriptive term is objectionable, not only on the grounds given above, but because “involution” and “volutio” are both in common use as descriptive terms for the peculiarities of the whorls of Gasteropoda and Cephalopoda. Any modification of evolution is objectionable because it is misleading. For example, the word “avolution,” supposed to mean things that do not evolve or have not been evolved, represents an unnatural condition. One can, of course, conceive of matter in a state of more or less stable equilibrium, but there are other words than “avolution” in habitual use to express this conception. It is also to be regretted that it has been applied by several eminent writers to ontogeny, and is probably fairly established in this application. The growth and development of the tissues is in a general way evolution, as much so as that of a colony of Protozoa. But it is also obvious that the product of the development by division of a single autotemnon, which forms a cycle, or when held together so as to form a colony, and the product of the division of an ovum in Metazoa held together more compactly so as to build up an individual or zoön, are not the same as the product of the evolution of an ancestor into a phylum through successive independent forms or

ontogenic cycles. One cannot accurately speak of the "growth" of a phylum, nor ought the word "development" to be used for the phylum. Development should be restricted to the zoön or individual or its morphic equivalent among Protozoa, since it expresses more clearly the differences that exist between ontogeny and phylogeny than their similarities, and for the same reason it is advantageous to use evolution for the phylum alone in the sense in which it is commonly employed. The necessity of subdividing the embryonic stage is admitted, and in all probability this really includes several stages with their own substages, but the discussion of this problem must be left to the future.

The paragerontic stage is in no sense "atavistic" or "reversionary," as it is defined by Buckman and Bather. Reversions are the returns or recurrence of ancestral characteristics in genetically connected organisms which have been for a time latent in intermediate forms. I do not think that we can include in this category purely morphic characteristics which habitually recur in the same individual as the result of paraplasia, or which occur in the paracme of a type more or less invariably. In the individual the resemblance of the smooth round shell of the whorl of the paragerontic ammonoid after it has lost the progressive characteristic of the ephebic stage cannot be considered as a reversion. It is simply analogy of form, not structural similarity of characteristics. A better known and more easily understood case is the resemblance of the lower jaw of the infant before it has acquired teeth and that of the extremely old human subject in which these parts have been lost and the alveoli and upper parts of the bony mandible have disappeared through resorption. The forms are alike, but no one would venture to consider the infant's cartilaginous jaw and that of the old man as similar in structure.

The best example of similar phenomena in the phylum known to me is the close resemblance of form between the straight *Baculites* of the Cretaceous or Jura and *Orthoceras* of the Paleozoic, which has been described above, and is figured further on. One occurs in the paracme and the other in the early epacme of the group of chambered shells. They are widely distinct in their structural characteristics, and these differences are greater in the young than at any subsequent stage of their ontogeny, *Baculites* having a close-coiled shell in the nepionic stage, and *Orthoceras* is straight from the earliest stage. The return of a similar form in *Baculites* in the

epinepionic periods of development in obedience to the law of the cycle does not carry the structure back with it to a repetition of the orthoceran siphuncle and sutures.

The structure of an individual during its development might be represented graphically by an irregular spiral of one incomplete revolution which describes a curve, continually increasing its distance from the point of departure until the meridian of the epebic stage is reached, and then beginning to return. Such a curve would always as a spiral rise more or less vertically, and consequently, even if it completed the revolution, must terminate in space. It might, perhaps, reach nearly to the same imaginary vertical plane, but never to any point approximate to that of its departure. Structure separates the extremes of life, as widely as possible, and does not permit us to regard them as approximate, nor can one regard old age, however complete its return in external form, as a reversion.

One of the most noteworthy contributions of bioplastology is that it gives proper values to this class of analogies and shows them to be constantly recurring in the individual and in the phylum in obedience to well-ascertained laws of morphogenesis.

The different stages have been described by Dr. Beecher among Brachiopoda, Dr. Jackson among Pelecypoda, and the author among Cephalopoda; and Buckman and Bather and also Blake\* in England, and Würtenberger in Germany have admitted their existence, and the last redescribed them. Würtenberger has admirably described the phenomena of bioplastology as they occur among Ammonitinæ, and correctly interpreted the law of tachygenesis and its action in these forms, but failed to quote either Prof. Cope or the author. This omission was not so remarkable as the fact that Neumayr and some other investigators, after they had received the printed records of the work done in the same direction in this country, continued to quote Würtenberger as the sole discoverer of these phenomena and of the law of tachygenesis. Würtenberger's work was apparently independent, and it has higher value on that account, but it needs rectification from a historical point of view.

Buckman and Bather propose to use the prefix "phyl" for forms occurring in the phylum which represent in their adult characters stages in the evolution of the phylum corresponding with those in the development of the ontogeny, and give an instructive table in

\* "Evolution and Classification of Cephalopoda," *Proc. Geol. Assoc. Lond.*, Vol. xii, pp. 276-295, 1892.

which Haeckel's physiologic terms are placed side by side with those proposed for the morphic phenomena. In following out the same ideas the following table has been constructed, which differs from theirs in the use of nepionic, as stated above, and also in the use of phylanaplasia, phylometaplasia and phyloparaplasia as correspondents of the similar ontogenetic terms :

SUMMARY, TABLE II.

| ONTOGENY.  |                                      | PHYLOGENY.      |  |
|------------|--------------------------------------|-----------------|--|
| Anaplasia  | { Embryonic.<br>Nepionic.<br>Neanic. | Phylanaplasia   | { Phylembryonic.<br>Phylonepionic.<br>Phyloneanic. } Epacme. |
| Metaplasia | { Ephebic.                           | Phylometaplasia | { Phylephebic. } Acme.                                       |
| Paraplasia | { Gerontic.                          | Phyloparaplasia | { Phylogerontic. } Paracme.                                  |

Buckman and Bather gave the following appropriate example from Beecher's and my own researches :

“Thus we would say that the Productidæ attained their paracme in the Permian, when they were represented by the phylogerontic Strophalosia and Aulosteges; that the characters of the neanic and ephebic stages of *Coroniceras trigonatum* are phylocabatic” (here phylanagerontic). While granting the need of using this distinctive prefix for the periods of evolution in the phylum one is likely to become confused unless he fully understands the use of the word “phylum” as applicable to all grades of genetic series. Thus, in ordinary acceptance of the term, a phylum may be the entire class or any subdivision of it, even a single genus, provided the forms can be shown to be genetically connected. It has been employed in this way several times in this text after the names, species, genus, family, etc., the ammonoidal phylum or ordinal phylum, phylum of the Goniatitinae or subordinal phylum, family phylum, and even a phylum of varieties and individuals.

#### THE CYCLE.

Phylum expresses genetic connection, cycle the totality of the phenomena, whether morphic or physiologic, which are exhibited by ontogeny or phylogeny. Thus, one can describe the cycle of the phylum in its rise and decline, the epacme, acme and paracme as purely dynamical phenomena exhibited by the increase in numbers of forms, etc., or the cycle of the ontogeny as shown by the in-

creasing complexity of the development and its decline, the anaplasia, metaplasia and paraplasia of the individual; or one may describe the cycle as exhibited by the embryonic, nepionic, neanic, ephebic and gerontic stages, or the cycle of the phylogeny as exhibited by the corresponding phylostages\* of evolution designated by their appropriate prefix "phyl."

There appears to be real need of two terms under the head of cycle, one for ontogeny and the other for phylogeny. It is proposed to use in this way ontocycle or ontocyclon for the ontogeny, meaning the cycle of the individual, and phylcycle or phylcyclon for that of the phylum. This will make it practicable to use the terms monocyclon or monocyclic, polycyclon or polycyclic, etc., to describe the number of cycles observed. Thus the ammonoids are polycyclic, the Arietidæ are decacyclic, the genus *Coroniceras* is an incomplete monocycle.

It is not necessary to defend these terms before students of bioplastology; they will be tested, and, if convenient, adopted. For the benefit of others it may be mentioned that the cycle is of all degrees of development in ontogeny. Thus, *Insecta* are apt to stop at the ephebic stage and in many other animals there is a similar limitation. On the other hand, there may be the most unexpected development of the cycle. Thus, *Podocoryne* starting from the hydroid stage passes through a permanent colonial stage built up by budding which gives rise by secondary buds to independent medusæ. The life of an independent medusoid bud ends with a paragerontic substage in which the veil is destroyed, the bell is partially resorbed and turned back together with the tentacles, and the proboscis is left naked and projecting. In this condition the old of *Podocoryne* is similar to the hydroid with which the colony began. This gerontic transformation has been observed by Dujardin in *Cladonema* and *Syncoryne*, by Hincks in *Podocoryne* and *Syncoryne*, and by Gosse in *Turris*.†

Man is not completely ontocyclic, but makes a close approach to this in the loss of the hair, teeth and proportions and shape of the body; and certainly in some parts, as in the mandible described above, there is sometimes a completed cycle.

\*This word is a fearful hybrid, and I beg pardon of my classical friends in advance of their merited wrath.

†Dujardin, *Ann. Sci. Nat.*, Series 3, Vol. iv, pp. 257-281, 1845; Hincks, *British Hydroid Zoöphytes*, Vol. i, p. xxviii, 1868.

What the limits of the ontocycle may be has not yet been ascertained, but so far as the facts are known it would appear to be coincident with the limits of agamic reproduction, or, in other words, with the limits of the growth of one autotemnon or of one ovum after conjugation by fission, and includes all agamic generations produced by division or by budding.

The act of self-fission is similar whether it takes place for a certain cycle among Protozoa or Metazoa under purely organic conditions or follows upon the conjugation of two zoöns, and is due to the rejuvenation caused by the union of the nuclear elements of their bodies as among Protozoa, or the more differentiated generative cells of the Metazoa. Under all conditions the cells divide in obedience to the laws of growth, and whether the resulting daughter cells remain fastened together forming colonies as in Protozoa or masses of tissue as in Metazoa, or whether they separate and become distinct autotemnons or distinct zoöns the action is the same.

The product of this autotemnic function in single cells has, as shown by the researches of Maupas, a cycle of transformations which are like those of an individual among Metazoa, although they may reach in some forms over six hundred so-called generations and therefore include thousands of distinct protozoans. It is obvious to the student of bioplastology in reading Maupas' researches\* that this cycle among Protozoa Ciliata is the equivalent of the cycle of the individual among Metazoa. Although he uses the word individual for the autotemnon he does not speak of the successive forms as generations but as partitions, "bipartitions" being his usual term, showing clearly that he recognizes these are not generations like those of distinct successive zoöns in Metazoa.

Maupas' researches show, as in fact he himself states, that there is a cycle of partitions produced from one autotemnon after conjugation, when isolated and allowed to propagate by fission without the renewed stimulus of conjugation with others of different broods. The earlier successive partitions are incapable or at any rate do not show any desire to conjugate with their fellows. Each of his cultures of isolated autotemnons passed through these youthful or anaplastic stages, and then a series of metaplastic partitions was developed in which the micronuclei became more numerous and

\*"Recherches expérimentales multiplication des infusoires ciliés," *Archiv. de zool. expér. et gén.*, Sér. 2, Vol. vi, pp. 165-277; *ibid.*, Vol. vii, pp. 149-517.

conjugation with other broods took place whenever it was permitted by the experimenter.

In the generations immediately succeeding these, degenerative changes, both structural and physiological, took place in the partitions which were distinctly paraplasic, although the cultures were maintained under conditions which precluded the supposition that these changes could have resulted from unfavorable, abnormal surroundings. The successive partitions then had gerontic transformations, lost their micronuclei, became much reduced in size and unable to conjugate with others with the usual normal results, and finally the external buccal apparatus was affected, reduced, or obliterated, and so on. These changes were termed senile by Maupas, who explains the entire phenomena as a cycle comparable with that of the individual among Metazoa.

One is, of course, at this incipient stage of bioplastology, confused by many apparently inexplicable phenomena. When, however, one contemplates the confusion of the most eminent authorities with regard to the relations of the autotemnon among Protozoa and Metazoa, shown by the use of the same term for the autotemnon, the individual, and the zoon, and also the prevalent confusion with relation to the morphology of forms designated as colonies—some regarding the whole product of one egg as an individual and others considering each bud or independent zooid as properly designated by that term and defining the colony as an aggregate of more or less connected individuals—it is surprising that there should not be more difficulties in the path of this new branch of research.

Those who try to find the cycle of metamorphoses in their own special branches of research will be often disappointed and probably deny that it exists at all. Thus, in my own case, I for some time could not find any evidence of its existence among certain cephalopods, notably those having a primitive organization like *Endoceras* and *Orthoceras*; but I have since seen well-marked senile stages in these shells. Undoubtedly there is as great distinction between the paraplasic and anaplasic periods, and between phyloparaplasia and phylanaplasia everywhere, as there is between the correlations of the corresponding periods at the extremes of the ontogeny and phylogeny.

Paraplasia essentially differs from anaplasia, as has been described above in treating of relations of analogy between the gerontic and

the nepionic stages. The earlier characteristics of the ontogeny are, as the author has striven to explain in several publications, essentially distinct, being in large part in most animals and in some cases almost wholly genetic. In considering the simplest manifestations of the cycle, palingenesis accompanied always by tachygenesis must be taken into account, and also cenogenesis in groups like Lepidoptera, Hymenoptera, most Echinodermata, many Vermes, where a supposed ancient and regular palingenetic record is assumed to have been disturbed by etetic characters acquired by the larvæ.\*

The gerontic characters, on the other hand, and all paraplastic, as well as their corresponding phyloparaplastic characters belong to the category of analogies in so far as they are purely morphic resemblances or equivalents. This is clearly shown in the physiology of all the parts and organs in the anaplastic and paraplastic periods, the former being full of hereditary and perhaps, also, acquired power, and the latter more or less weakened and reduced or worn out by the exercise of those powers and the constant wear and tear of the surroundings.

Retrogressive reductions in every form, although often indicating and accompanying a high degree of specialization, partake more or less of the same nature when considered with reference to their morphic and accompanying functional attributes, and one cannot study such bioplastic phenomena as if they were of the same nature and subject to exactly the same laws as progressive genetic and etetic characters. As I have pointed out above, and in several other publications, there are all degrees of completeness in the evolution of the cycle, and it is dependent upon a variety of causes whether occurring in the ontogeny or phylogeny. If it were constant and invariable and independent of the surroundings in the

\* Such examples are, correctly speaking, not disarrangements of palingenesis, although so translated by Haeckel, if I rightly understand his ideas of a confused record. Cenogenism does occur in such examples in obedience to the same law that governs palingenesis, but it occurs through the introduction of etetic characters during the larval instead of in the neanic or ephebic stages, and the crowding back of these upon the nepionic and embryonic stages. The use of terms indicating that nature has confused or destroyed its own ontogenic records of the transmission of characters in certain cases assumes (1) that these are exceptional cases, (2) that cenogenesis is not the normal mode of transmission in certain types in which it occurs, (3) that both of these modes of transmission are not affected by tachygenesis, all of these implications being erroneous according to the opinions expressed above. One can assume a disturbance or perturbation, or decided change of mode according to law, but "destruction," "confusion," or "falsification" are subjective terms inapplicable to the objective character of the phenomena to which they are applied, appropriate in metaphysics, perhaps, but entirely out of place in natural science.

phylum, it would not be so closely parallel to the ontogenic cycle, which we know to be subject to great variations in accordance with the surroundings of the individual or species.

The standard of reference in bioplastology is the ontogenic cycle, and this should be studied first in every group. Without a full knowledge of this, the morphology of the group cannot be properly translated, nor can the forms be taxonomically treated with reference to their natural relations. This branch of research aims to complete Von Baer's law and Louis Agassiz's great discovery of the correlations of palingenesis and phylogenesis, and it, therefore, asserts an equal utility for the metamorphoses of the nepionic, neanic, ephelic, and gerontic stages, provided these be applied in each group according to the ontogenetic development of the cycle in the zoön and its phylogenetic evolution in the same group.

### III. ONTOGENETIC STAGES.

My own researches have led me to the conviction that subdivision of the developmental phenomena of the nepionic, neanic and ephelic stages are necessary, and for obvious reasons I shall take my illustrations wholly from the shell-covered Cephalopoda.

Those who do not believe that there was a protoconch in nautiloids will have to reconstruct this part of the nomenclature in accordance with their own views. Having been reproached by Prof. Blake in his address before the Geologists' Association in 1892 in London for holding to this opinion, it is only necessary for me to point again to the new evidence with regard to the existence of the protoconch given in the Introduction to this memoir.

Granting, therefore, that the conch begins with the nepionic stage, the first part of this period is the ananepionic substage. This substage is more or less similar in all the nautiloids on account of the existence of the cicatrix on the point of the apex of the conch and the surrounding comparatively smooth area which is, as a rule, elliptical, the apex being in most forms of Nautiloidea, when seen from the side, like a broad cup, and in section a laterally compressed ellipse, the vertical or ventro-dorsal diameter being the longest.

This substage is frequently figured in the plates of this memoir, and has been well shown in figures of several species, in the *Genesis of the Arietidæ*, pp. 10, 11, and in *Nautilus pompilius* in *Fossil*

*Cephalopods of the Museum of Comparative Zoölogy*, "Embryology," Vol. iii, Pl. iii, Fig. 1, and in a number of figures of Barrande in his *Système Silurien*, Pls. 487, 488, a few of which were drawn and given to Barrande by the author. I first described this substage among the nautiloids under the descriptive name of the "asiphonula," but have since substituted the term, Protosiphonula. Among ammonoids this substage has been forced back into the embryonic stage and has practically disappeared from the conch, probably through the action of tachygenesis. The tendency of the embryo to build a solid calcareous protoconch of imbricated structure may be attributed to the earlier inheritance of the characteristics of the calcareous, apical conch of its nautiloid ancestor.

This explanation has been supposed by Prof. Blake to show that the protoconch of ammonoids was necessarily identical with the apex of the shell or early part of the ananepionic substage, protosiphonula, of nautiloids. It would have such a meaning, perhaps, if there were a cicatrix on the protoconch of ammonoids and if there were not more or less rugose lumps, supposed to be the remnants of protoconchs, covering up the cicatrices of the apices of the conch in some nautiloids as figured above on page 360 of the Introduction. These facts must be reinvestigated by the opponents of this view, and it lies with them to prove that the latter are not the remnants of shriveled, horny protoconchs, and that the cicatrix was not a passageway from the embryo into the shell or at any rate an aperture through which the animal of the protosiphonula communicated with the protoconch, before one can consider the facts in a different light or admit any other hypothetical explanation.

It will be seen below that I have altered my view in so far as the primary origin and nature of the cæcum is concerned. Barrande imagined that my view necessarily implied the passage of the embryo bodily out of the protoconch into the conch, but this was a mistake arising probably from inadequate statements. The young, when it had passed by growth out of the protoconch, or as the anterior parts of the embryo grew out of the protoconch into this position, began to build the shell, and finally at the end of the protosiphonula stage rested in the apex, which was then aseptate and was the first living chamber. The structure of the apex in *Endoceras*, *Piloceras* and *Actinoceras* indicates large and direct, open, tubular connection between the protoconch and the animal when in this first chamber through which the endosiphuncle in the

generalized nautiloids, Endosiphonoidea, opened into the protoconch.

The tubular opening of the apex in *Endoceras*, *Piloceras* and *Actinoceras* and other genera having a marked endosiphuncle, is not closed by the cæcum of the siphuncle as was formerly supposed. It is, on the contrary, directly continuous with the endosiphuncle, as was first pointed out by Foord in his *Catalogue of British Cephalopoda*. This is an attenuated, central, more or less irregular tube or axis formed by the extension of the points of successive endocones or sheaths. It is more or less interrupted by pseudosepta, and is a separate and distinct part occupying the axis of the large siphuncle. This organ is continuous with some corresponding part in the embryo which existed in the protoconch. On the other hand, the true siphuncle, including the cæcum of the first air chamber, is a secondary organ formed by the funnels of the septa. The living apical chamber was, as said above, a shallow cup, and its limit in the living animal was probably as indicated by Henry Brooks in the drawings given on Pl. i of this paper. At any rate, his conclusions with regard to the probable situation of the aperture of this stage seem to me to be sustained by observation.

The next substage is indicated by the presence of the cæcum lying within the apex, and this is formed by the funnel of the first septum and in association with the first septum is universal among Cephalopoda, with the exception of some sepioids, so far as the internal structures are concerned. It has been descriptively named the cæcosiphonula. This may be considered as a part of the metanepionic substage in nautiloids, but among ammonoids and belemnoids it is forced back according to the law of tachygenesis into the calcareous apex of the ancestral shell, being consolidated with and disappearing in the aperture of the calcareous protoconch. The limit of the living chamber which rested upon this first septum has been determined in existing form of *Nautilus pompilius* by Mr. Brooks and is shown in his drawings on Pl. i.

In a general way it may be also said that the external characteristics of this age are characteristic of the entire order of Nautiloidea.

Among Nautiloidea the shell of this substage grows less rapidly in all its diameters and may either remain smooth and approximately retain the earlier form, becoming, however, more compressed, or it may become more rapidly altered to a depressed ellipse. That

is to say, one with the transverse axis longer than the dorso-ventral and is apt to be ornamented with coarse ridges, whether the shell is subsequently smooth or remains ridged. The septum succeeding the first septum among nautiloids and also belonging to the metanepionic substage has a large siphuncle compared with the ventro-dorsal axis, and this has been called the "macrosiphonula." The remarkable observations of Henry Brooks have amply sustained these statements made in previous publications, as may be seen in diagram Fig. 11, Pl. i.

The macrosiphonula brings before the observer certain internal characteristics which, although much altered, appear to have been derived from the earliest ancestors of the nautiloids, *Diphragmocerat*. The metanepionic substage is therefore in part in all forms very primitive, in spite of the fact that in highly accelerated nautilian shells it is very much modified and also that some of its external characteristics are derived from the more recent ancestors of its own ordinal or subordinal phylum.

The paranepionic substage begins with the third septum and its accompanying living chamber and, so far as I know, it does not carry any external characteristics derived from a very remote ancestry but usually in nautilian shells points very definitely to some known or unknown gyroceran ancestor. This is broadly shown in the fact that in the greater number of the more generalized forms of nautilian shells the three parts of the nepionic stage occur before the whorls touch. The external characteristics and form of the metanepionic and paranepionic substage have been largely derived from the immediate ancestors of the species. They often have their corresponding phyletic forms within their own genetic group or family, whereas the characteristics of the ananepionic substage are, in large part at least, derived from remote ancestors.

Thus by the aid of direct observation it is not difficult to see *that the substages of development in ontogeny are the bearers of distal ancestral characters in inverse proportion and of proximal ancestral characters in direct proportion to their removal in time and position from the protoconch or last embryonic substage.* It is already generally admitted that this law is true of the embryonic stages themselves with reference to the protembryo, although most observers would hardly dare state this in the same positive terms as here employed because they are confused by what they call abbreviated development. They have not traced the systematic regu-

larity with which the law of tachygenesis works in producing the replacement of hereditary characters in every series of forms, and do not trust or know how to use this law.

The paranepionic substage is consequently among Nautiloids as among Ammonoids of longer duration than either of the preceding substages and of more variable limits. The siphuncle has acquired its ephebic aspect and characters, but it is very often in a different position from that which it subsequently assumes, as it is in *Nautilus pompilius* and other forms figured in this memoir. I have hitherto considered that it included the latter part of the cyrtoceran volution, but it now seems more natural to limit it to that portion of the whorl which assumes the gyroceran curve or, in other words, turns sharply away from the straighter cone of the preceding substages on its return curve towards the apex. This is well shown in Mr. Brooks' drawings and also in the other forms of nautilian shells, especially those of *Barrandeoceras tyrannum* and *Sacheri* of the Silurian. At or near the end of the paranepionic substage in *Nautilus umbilicatus* and *pompilius* there is in almost every shell a more or less sharply defined constriction which marks a permanent aperture. The limits of both substages are subject to variations that will be noticed in the succeeding descriptions, but it suffices here to note the fact that the upper limits of the paranepionic substage are in a general way definable by the limits of the gyroceran form in close-coiled nautilian shells. That is to say, this substage, as a general rule, approaches its end and neanic characteristics begin to appear at or near the completion of the first volution, when growth brings the whorl in contact with the apex or dorsal side of the conch. Tachygenic forms are often notable exceptions to this definition and introduce modifications that have to be studied in each separate series.

The transformations that distinguish the subdivisions of the neanic stage are very well marked in some forms and less distinctly in others, but I have constantly found the need of defining two stages. Ananeanic is a suitable term for the first substage, which is usually well marked in nautilian\* shells by the first appearance of

\*In my *Genera of Fossil Cephalopods* nautilian forms have been defined as those having the whorls in such close contact that the dorsum of the enveloping or later formed whorl is modified, either flattened or bent inwardly along the area of contact, and has what is called an "impressed zone." There are, however, some shells that are difficult to classify. These have the volutions in contact but do not have an impressed zone. Most of them are transitional between gyroceran and nautilian forms and may be placed in either category.

the impressed zone. This is the name I have given to the area on the dorsum affected by the contact of the dorsum of the growing whorl with the venter of the already formed whorl of the next inner volution. This is either flat, gibbous, or indented in accordance with the form of the venter of the whorl it touches or envelopes, but it is usually indented more or less deeply.

There is a notable exception to this rule when in highly tachygenic shells the zone of impression is inherited and the dorsum becomes furrowed before the first whorl bends. This is one of the most complete demonstrations of the probable inheritance of acquired characters that I know, and an excellent illustration of the law of tachygenesis. It occurs in some groups of nautilian shells of the Carboniferous and also in the Jura, Cretaceous and Tertiary, as well as in the existing species of *Nautilus* early in the nepionic substage, as may be seen in the drawings of Henry Brooks (Pl. i).

In tracing out the distinct phyla to which different nautilian forms belong, it can be shown that the impressed zone is invariably consequent upon close coiling, never appearing in ancestral forms in the nepionic stage unless through this agency. As a rule, it comes in the ontogeny after this stage, usually in the ananeanic substage of more generalized and less closely coiled shells, but when one ascends in the same genetic series to the more specialized nautilian involved shells this purely acquired character becomes, through the action of tachygenesis, forced back, appearing as a rule in the nepionic stage before the whorls touch. It is therefore in these forms entirely independent of the mechanical cause, the pressure of one whorl upon another, which first originated it. One need only to add that this configuration of the dorsum is never found in adults of any ancient and normally uncoiled shells, so far as I know, nor so far as they have been figured. I have so far found only one form—*Cranoceras* of the Devonian—in which there is apparently a slight dorsal impression, which may have arisen independently of close coiling.

There are apparent exceptions to this rule in some of the extremely close-coiled forms of nautilian shells of the Calciferous and Quebec faunas (some of which are figured in the plates of this memoir), but in these the first whorl bends so abruptly and enlarges with such extreme rapidity that the inflection of the dorsal side before the whorls touch can be attributed to mechanical effects of

three factors, viz., rapid spreading of the whorl, the abrupt curvature and contact or close proximity of the paranepionic stage to the apical part of the conch. Even, however, if this conclusion be doubted and if, in a few forms of extremely specialized nautilian shells of these early periods of geologic history, it can be asserted that the impressed zone has really become inheritable; the position assumed in this paper, that the impressed zone is mechanically generated in the later stages of growth and becomes an inheritable characteristic only in forms with accelerated development, is positively strengthened. The whole argument being based upon morphology, it makes no essential difference how early the impressed zone appears or in what form it appears, provided the shells in which it is characteristic of the first volution before contact are the descendants of those in which this character is transient and obviously due to the moulding during growth of one volution over the next inner volution.

My experience, however, in writing this paper has led me to distinguish two kinds of impressed zones; that which occurs on the free dorsal sides of the young and that which occurs as the direct result of contact. I propose therefore to call the former the *dorsal furrow* and the latter the *contact furrow*.

The aneanic substage among Carboniferous cephalopods is not only marked by the beginning of the contact furrow but also, as a rule, by the introduction of correlative changes in the form of the whorl. Thus the tetragonal whorl, with an outline similar to that of an inverted trapezoid in section, and consequently an obvious repetition of the ephelic whorl of *Temnocheilus*, and with sutures also like those of the adults of that genus, appears at this stage in Carboniferous cephalopods of several different genera, showing their immediate descent from Devonian *Temnocheili*.

The first appearance of the dorsal lobe in the sutures is correlated with closer coiling and is apt to make its first appearance in primitive nautilian shells at this stage in the contact furrow. This lobe however, occurs also before the whorls touch in a number of forms, notably *Barrandoceras* of the Silurian, and in one of these, *Barrandoceras Sternbergi*, it occurs in the ephelic stage, although this is a gyroceran form and no contact furrow is formed. There is also another smaller lobe which appears in the centre of this, the annular lobe. These are not strictly correlative with the impressed zone, since a dorsal lobe appears in some cyrtoceran

shells which do not have an impressed zone at any stage in *Barandeoceeras* while the dorsum is still convex, and in *Nautilus aratus* it and the annular lobe is found beginning, in the third septum, and similar observations have been made on a few other species in the descriptive part of this memoir. The characteristics of the ananeanic substage of *N. pompilius* show how distinct this substage is in existing nautilus from the preceding and succeeding substages. The longitudinal ridges disappear during this substage, and the broad transverse bands of growth become in consequence for a time more prominent. The uniform brown of the paranepionic may begin to be striped on the sides in the latter part of the same substage, but this is often delayed until the ananeanic substage and always become more definite at this time.

In the metaneanic substage the shell becomes smooth, the brown striping extends on to the venter, and the markings become more distinct and more widely separated. The whorl which, during the preceding substage, had lost the subtrigonal outline of the paranepionic and become kidney-shaped in outline, with a deep impressed zone, now acquires a deeper impressed zone and slightly flattened sides and venter, thus forming lateral zones, as in *Nautilus umbilicatus*, and repeating at this stage the form of whorl characteristics of that species. During the paranepionic substage the deposits of porcellanous matter in the umbilical zone begin but do not become a very marked characteristic.

In the ephebic stage these deposits on either side increase and the whorl spreads inwardly closing the umbilici, the whorl in the meantime losing its flattened venter, which again becomes rounded. The metephebic substage begins when the umbilical perforations become obliterated by the ingrowth of the umbilical zones.

The paraphebic substage is definable externally only by the cessation of the coloration. This may be due either to the fact that senility is not marked by any peculiar structural changes, as happens often in other highly involute species of Nautiloids and even in many Ammonoids with smooth shells, or because no very large old specimens have been collected.

These remarks do not represent fairly all the ontogenic changes in existing Nautili, which will be treated in another essay, but they suffice for the purposes of this paper and serve, with other facts cited, to show the applications of the nomenclature used in the following pages.

In general terms transition to the ephebic stage takes place in the paranecanic substage or near its termination, and characteristics derived from the ephebic stages of immediate ancestors in the same phylum, such as the trapezoidal whorl of *Temnocheilus* mentioned above, are completely replaced by characteristics peculiar to the genus and species. While there are often marked distinctions between this and the ananeanic substage, the differences are much less obvious between this and the ephebic stage except in those shells in which this period has degenerate characteristics. In these phylogerontic forms marked distinctions are likely to make their appearance owing to the disappearance of hereditary external ornaments and markings which have been present until near the end of the neanic stage.

The ephebic stage has not been so fully studied among the nautiloids or ammonoids, and in both of these orders it might be considered questionable whether any subdivisions were essential. But I have found it convenient to subdivide this stage in some of the descriptions given in this memoir, and since this stage is much prolonged in some forms of Ammonitinae, especially those with numerous whorls like the shells of *Caloceras*, *Vermiceras* and the like, it is probable that when its characteristics have received more attention subdivisions will be found to be as necessary as in other stages. The gerontic stage has been described above and is necessarily illustrated in the text which follows, and the subdivision of this stage into two or more according to the species is convenient in order to distinguish the well-marked substages of decline.

The limits of the earlier epembryonic stages are somewhat more difficult to define among Ammonoidea than Nautiloidea, because the shells of the former are the bearers of a larger number of hereditary characters, and being more highly specialized descendants of the latter, the history of these stages is more complicated by the intrusion of new modifications through the action of the law of tachygenesis.

The protoconch, with a large aperture connecting with the opening of the conch, is plainly seen in the figures of *Mimoceras compressus* and others on Pl. ii, of this paper, and also in Sandberger's figures of species of Goniatitinae on the same plate. This is very distinct from the aspect of the apex of the conch in Nautiloidea. In that order the neck of the protoconch must have been at least as narrow from side to side as the scar on the outer surface of the

apex, and at least as long ventro-dorsally as the same. In other words, the aperture of the protoconch in Nautiloidea was narrow and elongated vertically, while that of the Ammonoidea in all having cylindrical, straight or loosely coiled young shells, was an open tube, as happens in Clarke's Orthoceran form, in *Bactrites* and in a number of *Goniatitinæ* as shown in the figures.

In most groups of *Goniatitinæ* and the other suborders of Ammonoidea which, as a rule, have invariably closely-coiled first whorls, the effect of contact is to produce immediately a deep, contact furrow and an almost entire obliteration of the umbilical perforation between the neck of the protoconch and the nepionic volution. Two funnel-shaped openings are left on either side, as shown in figures on Pl. ii, and these represent the more complete perforation present in all Nautiloidea and in the earliest forms of *Goniatitinæ* among Ammonoidea. The probable position of the aperture of the protoconch has been indicated in *Embryology of Fossil Cephalopods*, p. 110, and in Pl. iv, Fig. 1, and this information, gathered from sections, agrees well with the figure given by Dr. Brown of the supposed aperture of *Baculites* which is reproduced in outline, Fig. 17, Pl. ii.\*

The growth of this form out of the protoconch, as in *Bactrites*, must have been quite different from that of the true Nautiloidea. Nevertheless it is obvious that as the animal grew outside of the limits of the protoconchial aperture, it began to build the shell of the apex of the conch and the first living chamber. This was the anepionic substage and it in part more or less resembled in some of its essential characteristics and for a short time, the aseptate, apical living chamber of the Nautiloid, but this resemblance must have been transient and much accelerated.

After or during the building of this external skeletal tube it became practicable for the animal to lift itself, or, more properly speaking, to progress by growth out of the protoconch, and the next step can be seen in Branco's Fig. 10, Pl. iii, and the details in my Fig. 7, Pl. iii, both of which, and others also given, show that the bottom of the cæcum occupied the aperture of the protoconch and is formed, as in Nautiloids, of the closed funnel of the first septum. It is therefore inherited earlier, according to the law of tachygenesis, since the first septum and the cæcum occupy the same position with relation to the protoconch as the scar or cicatrix in

\* *Proc. Acad. Sci. Phil.*, 1892, Pl. ix, Figs. 5 and 10, 11.

the apex of the shell in Nautiloidea. This and the fact that the protoconch is calcareous are in favor of the opinion that the characteristics of the ananepionic substage of the ancestral nautiloids appeared in combination with the protoconchial stage in ammonoids. Thus the first septum and cæcum in this order is the floor of the first living chamber of the apex of the conch and is one substage earlier in this order than in nautiloids, and should be called ananepionic.

The figures, so far as the shell is concerned, also seem to demonstrate that the cæcum at this substage probably represents some embryonic structure. This is Zittel's explanation of the origin of the siphuncle, it being as stated by him obviously traceable to the cæcum, and this in turn being probably formed out of a part of the body or the shrunken mantle of the embryo, since it lies in the Ammonoidea directly in the aperture of the protoconch.

While, however, this organ fills the diameter of the apex in the median plane, it is narrower laterally, and one feels that this supposition is open to certain objections that will be discussed more fully in a paper now in preparation on the Endoceratidæ. It may be mentioned here, however, that in these ancient forms of the Nautiloidea the opening from the siphuncle into the protoconchial shell is closed in a different way from what it is in the normal Nautiloidea, and in the protosiphonula the endosiphuncle communicated with the protoconchial shell, passing through the bottom of the cæcum and apex. The elements of the walls of the siphuncle surrounding the endosiphuncle in these forms are, however, similar to what they are in the Nautiloids of less primitive organization, and it becomes probable that the cæcum was formed in the metanepionic substage in Nautiloidea as a secondary epembryonic organ, and that this has been crowded out of the metanepionic into the ananepionic in Ammonoids. In other words, like some other characters it was acquired in the epembryonic stages of *Diphragmocerat* and like these has been inherited earlier in descendants.

One naturally, if disposed to adopt the theories of genesiology as a working hypothesis, looks for the largest representation of ancestral characters in the earliest and most generalized forms. Thus the *Goniatitinæ* of the Silurian, which belong in all except the terminal members of series like *Pinnacites* and *Celcerat* to this category, one ought to find the transitions to *Bactrites*, or, failing these, indications in the young of the less specialized forms of the

Silurian of their immediate derivation from Nautiloid ancestors. This is precisely what actually occurred and in the Nautiloidea such evidence is easily obtained as has already been stated above in the pages of the Introduction and other publications.

It also follows, if the theories advanced by the author are true, that the Nautilinidæ among Goniatitinæ, as ancestors of the Ammonoidea, and especially the genus *Mimoceras* as the centre of derivation, should also show more prolonged retention of nautiloid characters in their ontogeny than is usual in their supposed descendants. The researches of Sandberger, Barrande, Branco and the author show this to be a fact. The figures of Pl. ii copied from Barrande and Branco exhibit this in *Mimoceras compressum*, *ambigena* and the whole of the Nautilinidæ of the Silurian, and the essential distinctive characteristic of this family is the nautiloid form of the septa and lateral sutures. The shells of this genus also do not possess a contact furrow, as noted above, and have no annular lobes on the dorsum.

The first suture of *Mimoceras compressum*, Figs. 3, 4, Pl. ii, and in some other allied species of the Devonian is bent into a slight lobe on the venter, which is a purely nautiloid character, and not to be confounded with the ammonoidal lobe in the same situation in the third suture that follows this. This is shown by the occurrence of similar lobes in the Endoceratidæ and some cyrtoceran forms of Nautiloidea and in figures of sutures of *Nautilus deslongchampseanus* and *clementinus* of the Cretaceous, also copied from Branco, which have similar first and second sutures. The aselate first septum is in *M. compressum*, followed on the second septum by a broad, almost imperceptible saddle, also considered aselate by Branco, but which is obviously a transition to the latisellate, or broad-saddle type of suture in the more specialized forms. The limits of the ananepionic substage in this form, which, as said above, is directly transitional to Bactrites, is therefore that part of the whorl which is represented by these two septa and the living chamber in which the animal rested while constructing the second one.

The characters of these two septa, however, are not repeated in the closer-coiled forms of the Nautilinidæ and Primordialidæ. In these the repetition of the outline of the second suture may be entirely omitted, the shell passing immediately in the second septum to the repetition of the peculiar undivided ventral of the

Nautilinidæ, obliterating the primitive characteristics of the second septum and substituting the more advanced characteristics of the Nautilinidæ as is plainly demonstrated in Fig. 16, Pl. ii, of *Anarcestes* (*Goniatites*) *lateseptatus* and in the Primordialidæ in *Gephuroceras* (*Goniat*) *serratum*, Fig. 17 of same plate. In the Ammonitinæ and Lytoceratinæ, and probably in the Ceratitinæ, as in most of the Goniatitinæ, this substage is obviously limited to the first septum and the corresponding living chamber. The limits of this living chamber in one form may possibly be indicated by the transverse imbricated line between the third and fourth septa in my Fig. 1, Pl. iv, of *Embryology of Fossil Cephalopods*. This line seems to demonstrate an arrest of growth at this time in the calcareous deposits corresponding to that indicated in Fig. 11 of the same plate which is probably due to a former aperture.

The metanepionic substage must obviously begin with the advent of the characteristics of the tubular microsiphuncle and the ventral lobe in sutures, whether this occurs in the second or third septum or later.

It is limited in duration to the repetition of the characteristics of the Nautilinidæ in certain of the Goniatitinæ. Thus that family of the Silurian and Devonian is phylo-metanepionic, or corresponds in the phylum in its ephebic characters to the metanepionic substage of its descendants. The closely allied family of the Primordialidæ, for example, as shown in Fig. 17, Pl. ii, has several septa with this character appearing in the metanepionic substage, the construction of the divided ventral lobe so characteristic of all normal forms of Ammonoidea not taking place until the shell is nearly or about 3 mm. in diameter in one species, according to Branco's figures, and still later in some other species.

In the Ceratitinæ of the Trias this substage is in many species, as shown by Branco's drawings, prolonged through several septa and there are decided indications that it is subdivisible into two parts, one characterized by the purely nautilinian ventral lobe and lateral sutures with only one broad lobe, and a second older portion having the undivided ventral lobes and lateral sutures of other radical forms among Goniatitinæ, ex. Prolecanites.

In *Trachyceras Munsteri* the eighth suture, according to Branco, is still undivided or nautilinian, and *Tropites*, according to the same author's figures, has this substage still more prolonged. In *Megaphyllites*, *Pinnacoceras*, etc., all more highly specialized forms

of the Trias, it is apparently shorter in duration than in the generalized and less complex organization of Tirolites if one can judge by the simple characters of the ephebic stage.

In the Jura and Cretaceous, among the Ammonitinae and Lytoceratinae, typical Ammonoids with more highly specialized structures than any Triassic shells, the primitive characters of this substage are, as one can read in Branco's drawings and to a less extent in mine, still more limited in extent, being confined as a rule to a few sutures or to one, and finally, in many forms they are obliterated altogether. That is to say, the divided ventral lobe encroaches upon and finally obliterates the intermediate stage so that the metanepionic substage, which begins with the third septum and microsiphon, is wholly changed in the aspect of the sutures. In other words, the undivided ventral lobe of the Nautilinidae has been replaced in this substage by the divided ventral of the Primordialiidae which appears in the suture of the second septum.

This is also, like the preceding, an excellent example of what is meant by the law of tachygenesis, the earlier inheritance through the crowding back and replacement of distal by proximal genetic characteristics.

Fig. 3, Pl. iv, shows the prolonged duration of the nautilian characteristics in this substage in second, third and fourth septa of *Vermiceras* (*Arietites*) *spiratissimum* of the Lower Lias, the decided change to a divided ventral and two lateral lobes not coming in until the seventh suture.

Fig. 7, Pl. iii, shows the section of *Deroceras planicosta* of the Lower Lias and the delayed approximation of the siphuncle to the ventral side. Fig. 7 shows the primitive structure of this organ in the earlier substages, and the figures from Branco show the duration of characteristics to be in correlation with these primitive characteristics.

Fig. 7, Pl. iii, shows the structure of the siphuncle in the metanepionic substage. The transitional aspect of the second septum can be observed in Figs. 6 and 7 of the same plate. This is a direct reference, as I shall show in another paper, to the similar structure of the ephebic siphuncle, and also the swollen aspect of the early stages of the siphuncle in the Endoceratidae, although in some species of this family as many as six funnels may take part in the construction of the swollen apical end of this organ. These facts are also in direct correlation with the more specialized and

complicated structure of Ammonoidea. They show that these forms do not retain the tendency to form a cæcum with double walls as in Nautiloidea, and such an example as that figured in *Nautilus pompilius*, in which a misplaced second septum necessarily shows a long tubular cæcum like that of the living chamber of *Diphragmoceras*, probably does not occur. In other words, one of the most persistent of the nepionic characteristics of Nautiloidea does not exist in the more specialized shells of Ammonoidea so far as known.

It is obvious from the preceding that the paranepionic substage begins in most forms of this order with the first appearance of the divided ventral lobe, or what I have called the siphonal saddle and it is limited in extent by the duration of the simple entire goniatitic outlines of the sutures which accompany all the substages of the nepionic stage in all the suborders of Ammonitinæ, except, of course, the stock in which they originated, the *Goniatitinæ*.

In the *Ceratitinæ*, *Ammonitinæ* and *Lytoceratinæ* it is generally true that this occurs, and the ananeanic substage begins with subdivision of the lobes and saddles into minor lobes and saddles or digitations, and this is often also accompanied by the advent of a minute siphonal lobe in the apex of the siphonal saddle. It is not essential here to discuss the limits of the neanic stage and its substages. They vary so much with the condition of development and the position of each species in its own series or genus and of each series or genus in its own group, that it is impracticable to define them except in very comprehensive terms.

Thus one may say the limit of the neanic stage is reached when the specific characteristics begin to appear in normal progressive forms. But there are exceptions to this in some highly tachygenic species, as in *Oxynoticeras oxynotum*, for example, and many others in which certain characteristics are carried back to earlier substages. Still, as a rule, this definition does good service if the occurrence of exceptions are constantly anticipated.

The limits of the substages can be obtained in some species of each series, and are quite distinct in the external characteristics of the form of the whorl and of the ornamentation. The sutures of the ananeanic substage are different from those of the metaneanic since they are much simpler and less completely digitated, but there is, as a rule, but slight, if any, differences between the sutures of the metaneanic and paraneanic or ephebic sutures. These

substages have been described, although not defined according to the nomenclature used in these pages, by Würtenburger in his essay referred to above; by S. S. Buckman in his extensive and monumental work published by the Paleontographical Society in their volume for 1891 on the "Ammonites of the Oölite," and by the author in the *Genesis of the Arietidæ*.

The gerontic stage has also been fully described and separated into two subdivisions by Mr. Buckman and the author, and is easily distinguished from the epebic by the external characters, and as stated above the septa become more or less approximated in the paragerontic substage and there is often slight but perceptible degeneration in the sutures.

All of the remarks made above apply well enough in a general sense to the progressive series of the Ammonoidea, but although we know the younger stages of only a few species of the retrogressive species, there are indications that they will require modifications to be true also for the phylogerontic forms.

Thus *Choristoceras* (of) *Henseli*, as figured by Branco,\* has apparently a considerable number of sutures having the undivided ventral lobe. These are less in number than in some progressive forms like *Tropites subullatus*, figured on the same plate, but unluckily the immediate ancestors of this species are unknown and exact comparisons cannot be made.

The young of the uncoiled forms of the Ammonoidea show however, in all their characters that the early inheritance of gerontic tendencies interferes with and delays the development of the progressive, more complicated structures of the forms from which they must have been derived. This is admirably shown in the drawings of Dr. Brown, some of which are reproduced on Pl. iii.

Fig. 13 shows a complete young shell which is in the neanic stage of growth. Fig. 17 is a restored side view of the protoconchial stage and ananepionic substage with aperture. Fig. 16 gives front view of the first volution in the paranepionic substage which begins at the fourth septum, and Fig. 18 side view at the sixth septum. Fig. 1, Pl. iv, shows the sutures for the same age.

Figs. 14-16 show the gradual diminution of the area of the contact furrow and the decrease in lateral diameters of the volution

\* *Op. cit.*, *Paleontogr.*, xxvi, Pl. v.

while the shell is still in the nepionic stage and as it approaches the point of departure from the spiral and the subsequent loss of the contact furrow. Dr. Brown records that the spacing of the septa increases after the deposition of the twelfth septum, and that these partitions are more widely separated. This correlates with a corresponding increase in the lateral diameters and together indicate an increased rate of growth. Nevertheless there is no quickening in the processes of development nor any resumption of progressive characters. The shell becomes a compressed ellipse in section, loses the contact furrow, and the straightened cone does not acquire the digitate sutures and pass into the neanic stage of the Ammonitinae until after it has departed from the spiral.\*

It is clear from this and other examples taken from later stages of growth that these are tachygenetic forms so far as the early inheritance of gerontic characters is concerned. Correlating with this, or in consequence of this, the inheritance of progressive characters in the sutures is delayed, and these parts change more slowly in these phyloparaplastic shells than in the phylometaplastic forms of the same order. The internal structures and the shell itself also, as previously stated, never attains even in the stage of epehebic development characteristics comparable to those of phylometaplastic species.

It follows upon the preceding remarks that the characters of these stages have different duration in different members of the same genetic series, being more prolonged in the more primitive and shortened up through the action of tachygenesis in the more specialized shells of the same series. It is also obvious that the limits of each substage must be defined differently according to the position of the animal in time and in the evolution of its own special series.

There are theoretically no exceptions to this law in its broadest acceptance, but in its practical applications this is not the case.

Thus the protoconchial stage is so nearly invariable in each order that it is characteristic of all Nautiloidea and all Ammonoidea, having peculiar characters in each of these orders, but this comparative invariability is less apparent in the characters of the ananepionic, metanepionic and paranepionic substages, and especially in the neanic stage, which are not as constant. The tendency to change

\*Having received specimens of these precious fossils through the kindness of Dr. Brown, I am able to confirm his observations, although I have not yet had proper opportunity to go over all the material and study every detail of the development.

along certain lines of modification in accordance with definite genetic laws becomes, in other words, more apparent in the later than in the earlier substages of the ontogeny.\*

In order to give a clear and comprehensible example of the general application of these laws I have quoted below several pages from Buckman's interesting and instructive paper on "Some Laws of Heredity and their Application to Man." †

#### HOW THE TRANSMISSION OF VARIATION WOULD AFFECT THE ORIGIN OF SPECIES.

"It is not difficult to understand the origin of species if the surmises that I have submitted, concerning the transmission of developmental variation, are correct. The greater and greater elaboration of any particular features in, say, an adult male, as functional modification necessitated by environment, are transmitted to the male sex alone, and appear earlier and earlier in that sex. The greater and greater elaboration of these features results in the course of time in the formation of a marked and distinguishing character in the male sex; and this character being transmitted in accordance with the law of earlier inheritance ultimately appears early in life in the male. Then the character tends to appear in the female sex also, though why it does so is not clear. By such process, however, there arise both males and females which possess characters different to those which their ancestors possessed.

"By the time that this character, influenced by the law of earlier inheritance, appears at an age early enough to be transferred to the female, the male has probably either further elaborated this character—which further elaboration is at first transmitted to the males only—or he has elaborated something else so much that it seems like a new character which is transmitted in the same way. In course of time this further elaboration, or this new character as the case may be, is transmitted also to the females; and so it becomes plain how, merely by the gradual transmission of developmental variations, both sexes of what may be called an incipient species, beginning with a slight variation in one sex alone, are able to diverge wider and wider from the original stock.

"The same laws of transmission would of course hold good if

\*The application of this law, however, to the gerontic substages demands a longer discussion than can be given here, and must be deferred to future publications.

† *Proc. Cotteswold Natur. Field Club*, Vol. x, Pt. iii, pp. 258-322, 1891-1892.

the developmental variation arose in the female in response to changes of environment; while if both sexes were exposed to the same changes of environment necessitating the same functional modifications to be acquired to bring them into better adaptation with their surroundings, it is reasonable to conclude that the result would be the production of a greater difference in a shorter space of time.

“Thus it is clear that the gradual accumulation of slight developmental variations transmitted in accordance with the law of earlier inheritance would be sufficient to cause the origin of various species; and at the same time there can be little doubt that this cause has also been assisted by both Natural and Sexual Selection in the production of diverse species from one original stock. I am inclined to think that developmental variation has been more important in the origin of species than has abnormal, or as Darwin calls it, ‘spontaneous,’ variation. The transmission of such abnormal variations as supernumerary digits seems to be so much more uncertain than the transmission of developmental variation, while practically speaking the origin of Ammonite species seems to be almost entirely attributable to developmental variation.

“Specialized structures like the long neck of the giraffe and the proboscis of the elephant, to take familiar instances, are, in my opinion, developmental variations. They did not arise, in the first place, in certain members of the pregiraffian or preëlephantine species as abnormal or ‘spontaneous’ variations which gave their possessors such great superiority over their fellows in the struggle for existence that those possessors survived by the law of Natural Selection. These features began imperceptibly—the neck and the nose grew more in proportion to other features during the lives of the individuals on account of the habits of the animals, and they may be compared in this respect to the enlarging skull of civilized Man.

“As the features of the adult become in course of time the features of the adolescent by the law of earlier inheritance, the elongation of nose and neck would become exaggerated from one generation to another. I do not see any reason to suppose, at any rate at first, that the giraffian or elephantine ancestors were the favored individuals of the community, and that the other members died out because they did not possess elongated necks or noses. I do not suppose that all the members of the species possessed

these features in the same degree, but I do imagine that a gradually increasing elongation was more or less common to all the members of the pregiraffian or preëlephantine species as a result of their habits.

“To take the case of the giraffe alone, for the sake of clearness—it is hardly necessary to suppose occasional droughts during which those members of the community with the longest necks would survive, while others starved because they were not able to reach such high branches as their longer-necked fellows. An extra inch or so of neck could not make so much difference as this.\*

“I do not say that the giraffe or its ancestors have not had the best of it when there was a struggle for existence, and that natural selection has not played its part; the fact of the giraffe’s existence is proof enough that it was better adapted to its environment than some of its competitors; and the longer the neck grew doubtless the greater superiority the animal would possess.

“As to the short-necked forms which would connect the present giraffe with the stock from which it originally came, their dying out is not difficult to explain. The law of earlier inheritance allows us to imagine a small beginning becoming more accentuated in all members of a species as time goes on, and as the shorter-necked forms were really the parents of the longer-necked forms, the disappearance of the former would be due, as the lawyers say of a lease, to effluxion of time.

“Arising from and coëxisting with developmental variation there seems to be another factor important in differentiating species, and this is the time when the offspring is produced.

“Offspring produced early and offspring produced late in the life of a parent shewing considerable developmental changes between early and late maturity, or between early maturity and senility, would in all probability differ to a certain extent. It is, I think, reasonable to suppose that if there were, say, a decline of vigor after a certain period of the parent’s life, the offspring produced after this time would be more likely not only to be somewhat less vigorous altogether, but would probably exhibit declining vigor at an earlier age than those produced before any decline of vigor set in.

\*“The adults would have the best of it in a drought on account of their larger size. Therefore if there were a long-necked ‘sport’ among the young pregiraffes it would have no chance against the adults unless its neck were of a preternatural length.”

“This seems to be a reasonable deduction from what is observed in phylogenetic series of Ammonites, where from the same stock arise one series which continues to progress, another series which retrogrades, though both lived together and were presumably subject to the same environment.

“More marked still would be the effects if from any cause there arose a difference among members of a species as to the time in their lives when offspring were produced. There is the case in Man—the professional classes defer marriage till late in life, agricultural laborers marry very early.

“These surmises illustrate what may be supposed to be accomplished in the differentiation of species by the transmission of developmental variations in accordance with the law of earlier inheritance. Further consideration will shew that, if some members of a species acquire, on account of environment, habits necessitating the increased use of one part, and other members acquire other habits with different results, and so on, there would, in course of time, arise from one original stock two or more species very different from each other or to the parent form—simply because their small initial differences had been constantly increased by the action of the law of earlier inheritance.”

#### IV. DESCRIPTIVE TERMS.\*

Before attempting to enter upon the descriptive part of this essay it is essential to define, as briefly as possible, the meaning of the terms which are constantly employed in the descriptions of the different forms. The term “coil” has been applied solely to the whole shell, while “whorl” and “volution” have been used when in the singular or when numbered only for a particular whorl or volution. Thus the first whorl or first volution is the first completed revolution of the shell, and so on. I have also been obliged to use volution for parts of a single whorl in describing substages.

In describing the aperture I have used the terms “crest” for projecting parts and “sinus” for inflections of the outline to distinguish them from the saddles and lobes of the sutures. The ventral sinus of the aperture and lines of growth is here called the “hyponomic sinus,” it being due to the large size of the hypnome or

\*Special students of Cephalopoda will, it is thought, be grateful for this chapter. Other classes of readers, if there be one who gets so far and has the courage to go farther, can skip and refer to it in connection with the descriptions which follow.

motor organ usually called "fleshy funnel" in the modern nautilus, as has been explained above.

It is useless to discuss the terms "ventral" and "dorsal." There can be no debate on their application, unless it is based upon new anatomical information. The fact is obvious, so far as now known, that in *Nautilus pompilius*, and all other Nautiloids, the outer side of the whorl is ventral and the inner side is dorsal. Whenever, even in straight shells, Orthoceras, etc., the lines of growth can be seen, the ventral side is indicated by the "hyponomic sinus," and in nautilian or coiled shells it is invariably on the outer side.

The term "depressed" is used for the flattening of the whorls, which affects the abdomen and dorsum and acts at right angles to the transverse diameter of the coil; "compressed" for the similar effect on the sides, which acts in the plane of the transverse diameters and at right angles to the plane of coiling. When the sides, lateral zone, or faces are inclined inwardly towards the umbilici, the term "divergent" is applied, and when they incline outwardly towards the abdomen the term "convergent" has been used.

The adoption of these terms has been found to give clearer ideas of the development and true importance to the different characters of the volutions. The term "sides" is used in a general way, and distinguishes the whole of the lateral aspect of the whorl at any stage. The "lateral zones" and lateral faces, etc., as will be seen in the descriptions, are developed as modifications out of the sides of the young and immature whorls. The outer angles occurring on either side in the young or in the biangular forms are in the text named "lateral angles," being really on the sides of the whorl and distinct from the angles arising later in the life of the individual, and later in the evolution of the group. The junction of the "lateral faces" and abdomen are the "abdominal angles," and those of the "lateral faces" and inner faces of the mature whorls are called the "umbilical shoulders," and the inner surfaces are the "umbilical zones." All of these parts are developed in succession and in various combinations, from a round or elliptical form of whorl, having the vertical or ventro-dorsal diameter longer than the transverse, both in the individual and in the evolution of the group.

The venter is the area between the outer angles, whether they be the "lateral" or "abdominal" angles, on the outer part of the whorl, and the "dorsum" is the corresponding part on the inner

part of the same, between the "lateral angles" or the "umbilical shoulders." The "zone of impression," or "impressed zone," is the area on the dorsum, which is concave, and lies between the "umbilical zones." The impressed zone may appear independently as a "dorsal furrow," or, after contact, as a "contact furrow." The "zone of inclusion" or "included zone" is the covered area corresponding to this on the venter. The term "zones of involution" or "area of involution" can be used for both of these when the whorls are not separated or it is desired to speak of the two together. The "lines of involution" are the outer boundaries of the "zone of impression" on the dorsum, and the "lines of inclusion" the corresponding lines on the venter.

The terms "involved" and "involution" should be limited to whorls having a "zone of impression" or "impressed zone," that is, to "nautilian" shells. "Coiled" can be applied to all shells that have the gyroceran curve and even to shells with the whorls in contact. Nevertheless these sometimes have closer affinity with nautilian shells of a given series than with the gyroceran shells of the same series.

Whorls with only two surfaces and angles are "digonal;" three surfaces and angles "trigonal;" four surfaces and angles "tetragonal," and when the abdomen is much broader than any other side "trapezoidal;" five surfaces and angles "pentagonal;" six surfaces and angles "hexagonal;" seven surfaces and angles "heptagonal;" eight surfaces and angles "octagonal;" nine surfaces and angles "enneagonal;" ten surfaces and angles "decagonal."

The outlines on the Diagram Plate, opposite, page 425, will be found to explain these terms more fully.

#### EXPLANATION OF DIAGRAM PLATE.

*Diagram A.*—Section of compressed elliptical whorl with primitive regions indicated, ananepionic substage of nautilian shells and ephebic stage of many primitive orthoceran and cyrtoceran forms.

*Diagram B'.*—Section of depressed elliptical whorl occurring older in the ontogeny or correspondingly later in the phylogeny than A.

*Diagram B''.*—Section of a reniform whorl with a contact furrow. This may be evolved from B' by the growth and involution



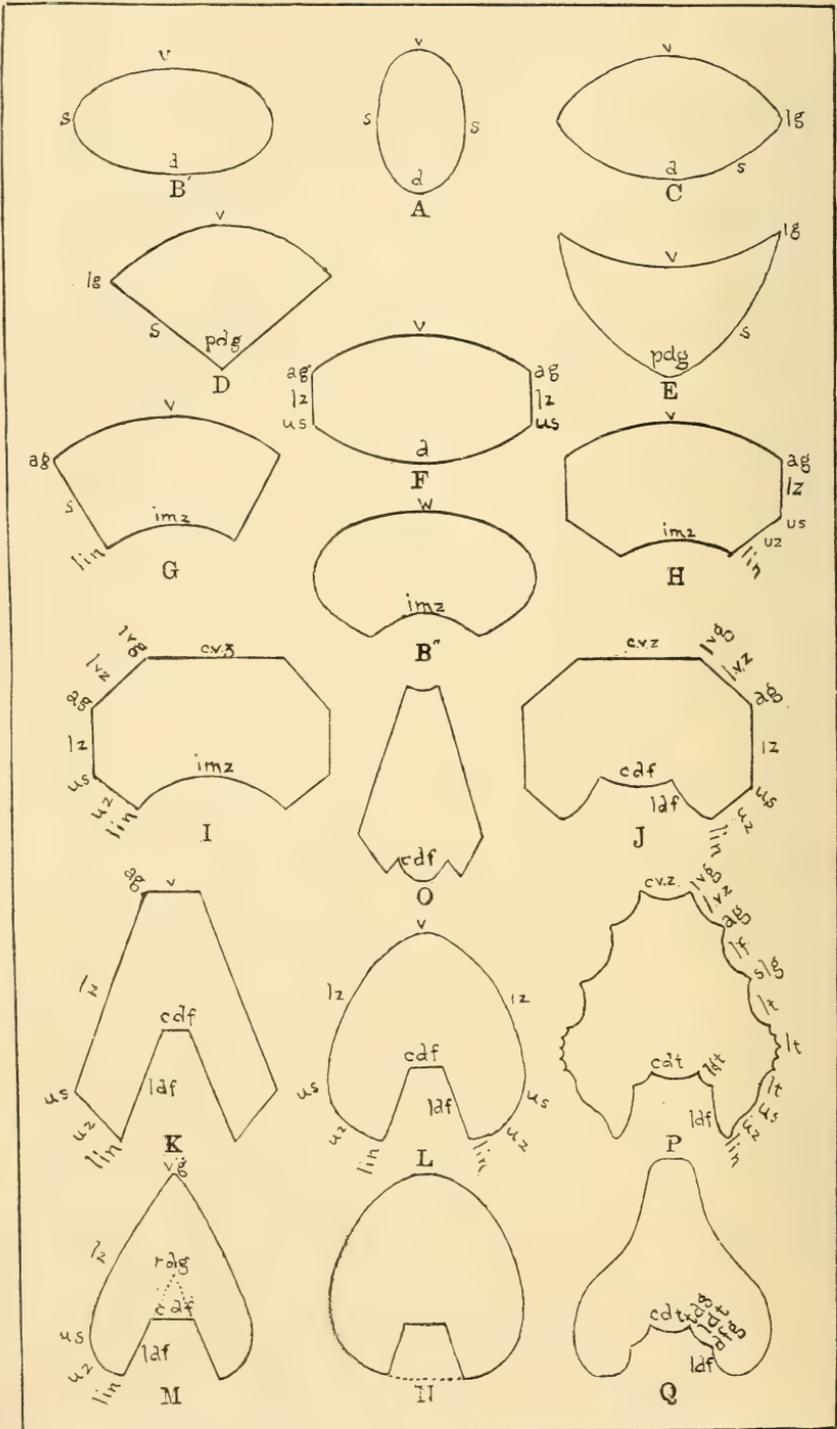


Diagram Plate (Hyatt).

of the whorl,\* and may be an intermediate stage leading into a whorl like that shown in H, or it may acquire lateral angles as in C, thus passing into G, or A may pass directly into H.

*Diagram C.*—Section of a digonal whorl with primitive regions and lateral angles, l. g., occurring in the epebic stage of orthoceran and cyrtoceran forms and in the young of nautilian forms, Edaphoceras.

*Diagram D.*—Section of a trigonal whorl with gibbous venter, lateral angles, l. g., and projecting dorsal angle, p. d. g., ex. Trigonoceras.

*Diagram E.*—Section of a trigonal, shield-shaped whorl, with concave venter, lateral angles, l. g., and projecting dorsal angles, p. d. g. Either D or E may evolve into a tetragonal whorl by the appearance of a lateral zone on the outer part of the sides and the rounding off and disappearance of the dorsal angle, ex. Trigonoceras.

*Diagram F.*—Section of a tetragonal whorl with gibbous venter and dorsum and lateral zones, l. z. This may be developed from B'' or from C.

The morphic distribution of these forms is as follows: A, B and C may be Orthoceran, Cyrtoceran or Gyroceran, but are more generally Orthoceran; D may be Orthoceran, but is usually Cyrtoceran and Gyroceran; E and F are almost exclusively Gyroceran. All of the remaining outlines belong to Nautilian forms.

*Diagram G.*—Section of a tetragonal, trapezoidal whorl with a contact furrow nearly as broad as the dorsum, the sides flat and well defined. This may be evolved from C or B'' in development of Nautilian forms. The abdominal angle, a. g., in this form is derived from the lateral angle of forms like C. Sides, s., are still undivided, ex. Temnocheilus.

*Diagram H.*—Section of a hexagonal whorl with lateral zones, l. z., developed between the abdominal shoulders or angles, a. g., and the umbilical shoulders, u. s., and umbilical zones, u. z., developed between the latter and the lines of involution, l. in. The contact furrow remains primitive or undivided. This may be

\*This same diagram can also be used to represent the paragerontic substage of the degeneration. A reniform whorl may result in the gerontic stage from such an epebic whorl as is represented in H, J, K, or P. Q shows an intermediate stage between P and a reniform paragerontic whorl. No confusion need result from this double use of the same outline, since it does not imply identity of structure, but simply the identity of form at the extremes of the ontocycle in the individual and of the phyllocycle in the group.

developed from G or B, or from C, with an intermediate transformation like G, or from B, with an intermediary like B'', and F may give rise to a similar modification when close coiled. A number of Paleozoic forms have this outline, ex. *Metacoceras*.

*Diagram I.*—Section of an octagonal whorl derived from H by the building out of the venter and the formation of a central ventral zone, c. v. z., two lateral ventral angles, l. v. g., and two lateral ventral zones, l. v. z., ex. *Tainoceras*.

*Diagram J.*—Section of a decagonal whorl derived from I by the subdivision of the impressed zone (contact furrow) and the formation of a central dorsal face, c. d. f., and two lateral dorsal faces, l. d. f., ex. some species of *Tainoceras* and *Cœlonautilus*.

In their gerontic substages the whorl of G, H, I and J become more or less rounded and show a tendency to return more or less completely to the outline of B''.

*Diagram K.*—Section of an octagonal, truncated, cuneiform whorl, usually derived from a whorl similar to H by the convergence of the lateral zones and the subdivision of the impressed zone, c. d. f., central dorsal face, l. d. f., lateral dorsal faces.

*Diagram L.*—Section of a gerontic whorl derived from K. By farther degeneration the dorsal angles may disappear and the whorl assume approximately the reniform outline of B.

*Diagram M.*—Section of a heptagonal, cuneiform, anagerontic whorl derived from K. The acute ventral angle, v. g., is formed by the convergence of the lateral zones and the disappearance of the abdominal angles. The dotted lines represent the similar transformation which subsequently takes place in the same form on the dorsum by the convergence of the lateral dorsal faces. The whorl then becomes a hexagonal cuneiform. This outline has been represented with rounded umbilical shoulders, but these have to be considered as equivalent to two angles, and they are often more or less angular.

*Diagram L.*—Section of a metagerontic whorl of K or M; similar forms may also result from the paragerontic degeneration of Q, ex. *Stroboceras sulcifer*, sp. De Koninck.

*Diagram N.*—Section of a paragerontic whorl of L. The dotted line represents the obliteration of the zone of impression which may take place in very old whorls in this substage or in the apertures of the ephebic stages of phyloparagerontic species.

*Diagram O.*—Section of an octagonal, truncated, cuneiform whorl with a concave abdomen in which a gibbous, central, dorsal face is formed and the lateral dorsal faces are excessively narrow. This may be derived from E by involution and the formation of umbilical shoulders and umbilical zones, ex. *Apheloceras*, *Subclymenia*.

*Diagram P.*—Section of a highly complicated fluted whorl with concave abdomen. The venter has become subdivided into a fluted central ventral zone, c. v. z., and two fluted lateral ventral zones, l. v. z., these having become incorporated with the lateral aspect, and the intermediate lateral ventral angles, l. v. g., form the borders of what is usually considered as the sides of the whorl.

The lateral zones lying between the abdominal shoulders, a. g., and the umbilical shoulders, u. s., have become subdivided into two lateral faces, the outer one, l. f., is a broad flute, and the inner one is subdivided into three lateral facets, l. t., two of them, the outer and inner facets, fluted, and one of them, the central one, slightly gibbous and ridged.

The contact furrow has a central dorsal facet, c. d. t., two lateral dorsal facets, l. d. t., and two lateral dorsal faces, l. d. f., the angle between l. d. t. and c. d. t. is the tertiary dorsal angle, t. d. g., but is not lettered, and the angle between l. d. f. and l. d. t. is the dorsal face angle and is also not lettered in this diagram, but these are lettered in Diagram Q. The facets are introduced by the subdivision of the central dorsal face, which is at first flat, as in L.

The secondary lateral angle, s. l. g., is developed between the flute of the lateral face, l. f., and the outer facet of the inner lateral face that extends from s. l. g. to u. s. The lateral facets formed out of the surface of this face are three in number, marked l. t., and the angles between these are the tertiary lateral angles, but are not lettered. The angles on the central gibbous lateral facet are due to longitudinal striæ.

*Diagram Q.*—Section of a gerontic whorl of P. The flutings and other ornaments have been obliterated, but the impressed zone retains its peculiar characteristics. The more advanced paragerontic substage would approximate to Diagram N, but with more depressed venter. *Coloceras* is a phyloparagerontic form, having an almost reniform whorl in the neanic and ephebic stages.

TABLE III.

## LETTERING OF DIAGRAMS TO ILLUSTRATE DESCRIPTIVE TERMS.\*

| PARTS OF THE WHORL.   |  |
|-----------------------|--|
| (1) REGIONS.          | (2) ZONES.   |
| v., venter or abdomen | { c. v. z., central ventral zone<br>l. v. z., lateral ventral zone   |
| s., sides             | l. z., lateral zones   |
| d., dorsum            | { u. z., umbilical zones<br>im. z., impressed zone<br>(in these diagrams always a<br>contact furrow)             |
|                       | ANGLES.  |
|                       | { v. g., ventral angle always central<br>s. v. g., secondary or lateral ventral angles                           |
| l. g., lateral angles | s. l. g., secondary lateral angles   |
|                       | { u. s., umbilical shoulders<br>p. d. g., projecting dorsal angle  |
|                       | (3) FACES.   |
|                       | l. f., lateral faces   |
|                       | u. f., umbilical faces<br>(None figured)   |
|                       | { c. d. f., central dorsal face<br>l. d. f., lateral dorsal faces  |
|                       | (4) FACETS.  |
|                       | l. t., lateral facets  |
|                       | c. d. t., central dorsal facet   |
|                       | l. d. t., lateral dorsal facets  |
|                       | t. v. g., tertiary ventral angles<br>(None figured)  |
|                       | t. l. g., tertiary lateral angles<br>(Occur between the lateral<br>facets of Diagram P,<br>but are not lettered) |
|                       | t. d. g., tertiary dorsal angles   |

\*These terms have been chosen in accordance with the following principles: The Regions of the anapleonic whorl, viz., venter, sides and dorsum, are regarded as primitive, and therefore of the first order. The latter surfaces of the whorl are developed next, and are called Zones, and placed in the second order. The truncations of the angles made by the Zones take place when the Faces are formed, and the last necessarily belong to the third order of modifications, and for similar reasons the Facets, being subdivisions of the Faces, form the fourth order. The angles have been classified according to the same system; those occurring at the intersections of the Regions are of the first order, those made by the Zones are of the second order, and so on.

These diagrams and examples (with the exception of A, B and C) were taken from Carboniferous forms published in the *Fourth Annual Report of the Geological Survey of Texas*, 1892, but they are applicable to all of the Nautiloidea, provided certain distinctions be made. The outline expands by growth from an ananepionic stage, in this case having the approximate outline of A, and may develop into B and C, with decided lateral angles, but in the epebic stage may sometimes return to the form of *Edaphoceras*, C. Species of other groups may pass through B' and, becoming involute, take on the outline of B'', and then, if the shell progresses still more, it may tend towards forms of H.

It must, however, be noticed that fossils of such species occurring in the earliest geologic period have not, as a rule, even approximately well-defined angles, and these being deficient, the zones are not apt to be well differentiated. One can readily see that these shells, even though they may be involute from an early stage, have not the more highly specialized characteristics of the whorl found in some of the Devonian fossils. The latter, in their turn, take rank as a whole below the still more progressive and highly ornamented nautilian shells of the Carboniferous which represent the acme of the order.

The paracme of the order begins in the Trias, and retrogression is plainly manifested in the steady decline of the external ornaments and less angulation of the whorl. The universal absence of all of the third and fourth orders of modifications of the whorl is one of the marked features of this decline, beginning with the Trias and becoming universal in the Jura and other subsequent periods.

The nomenclature of the sutures needs no special description, except with reference to the "annular lobe." This is a small indentation in the sutures, occurring either in the centre of a dorsal saddle or a dorsal lobe. It is pointed or V-shaped. In some forms it may arise before a dorsal lobe is formed in the middle of a primitive but persistent dorsal saddle, or it may arise subsequently in the centre of a broad dorsal lobe. Its development has not been fully described. It is often accompanied by an internal pointed cæcum called the "annular cone," and both are probably connected with the development of the "annular muscle."

It has been usual to measure the distance of the siphuncle and describe its position, with more or less circumlocution, as ventral, dorsal, central, etc., but in these descriptions the following terms

have been employed, which are best explained by the following diagram, Fig. 14.

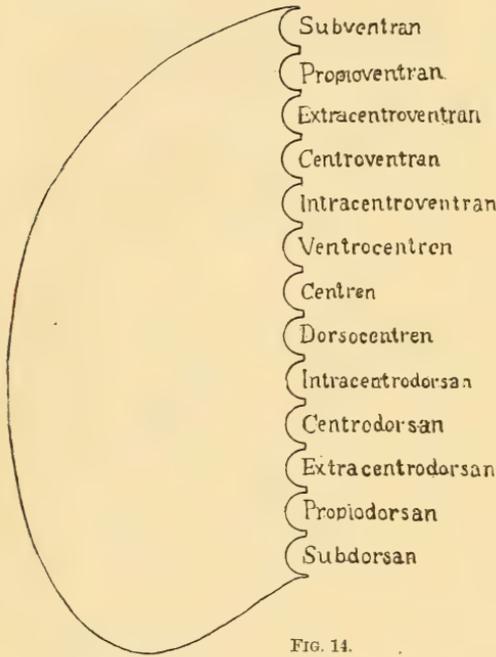


FIG. 14.

Ventran and dorsan express only the position of the shell, this alone being superficial. By using these terms and others, a considerable degree of accuracy can be obtained, and others can also be employed if essentially based on the same system. Thus, for example, proximo-ventran expresses the position of the siphuncle in *Nothoceras* and *Bathmoceras*, where this organ is so close to the shell that its own wall is in part absent and in

part much modified. Subventran is applicable only to those forms in which the wall of the siphuncle is not altered or modified through contact with the shell, although it may lie quite closely against it. The other terms sufficiently explain themselves, except the use of "extra" and "intra." It is not meant to confine these terms to the two where it is used in the diagram. It is obvious that these prefixes may be employed wherever they are needed. Thus one can say "intraventrocentren" for a location between centren and ventrocentren positions.

It would not be proper, however, to use these prefixes on either side of centren for the reason that the comparisons are all made from the centre towards the dorsum, on the one hand, and towards the venter on the other. Thus everything on the dorsal side of this point is not inside of the centre but dorsad of this point or axis, and everything on the ventral side is not outside of the same axis but ventrad of it. I have also used Wilder's term, mesal, for the plane of the siphon, instead of median.

These terms and others of the new descriptive nomenclature, of which only very few will be used in these pages, because I think it will be essential to discuss them further before applying them to the descriptions of cephalopodan shells, have been gradually introduced in consequence of the labors of Wilder and Gage, in this country, and are in a fair way of being adopted in Europe through the effort of Franz Eilhard Schulze and others.\*

Terms like *ventran*, *ventrad*, *ventral*, *dorsan*, *dorsad*, *dorsal*, *centren* and *centran*, and so on, strike one at first as awkward and barbarous, but their utility becomes apparent, as in the case of the siphuncle cited above, as soon as one begins to use them, and they can be made to have an exact meaning which it is not practicable to gain otherwise without the repetition in every description of the same explanatory text.

The shells of *Nautiloidea* and *Ammonoidea* are divided by transverse partitions or septa into what are called "air chambers," and the intersections or lines made by the edges of these when they strike against the inner surfaces of the shell of the whorl are called the sutures. Fig. 15 shows the edges of these septa as they would appear in *Nautilus umbilicatus* (Fig. 1, p. 345) if the shell there figured had been fossilized, the air chambers filled with infiltrations and the outer walls of the last whorl destroyed except in the umbilicus. The outer empty chamber beyond the suture of the last septum is the cast of the living chamber. The sinuous edge of this is the impression left by the edge of the aperture on the right side. This being a cast artificially made, is somewhat more perfect than natural casts of the interiors of such forms in the rocks and the spreading abutments of the septa against the inner wall are broad bands. Usually, in fossils, the upper extremely thin parts of these bands have disappeared, leaving only a line below corresponding to the lower parts of the bands in this figure and more nearly representing the thickness of the internal part of the calcareous septum.

\* See Wilder, *Science*, ii, 1831; Wilder and Gage, *Anatomical Technology*, 1882, and other papers. Also Schulze, *Biologisches Centralblatt*, xiii, Nos. 1, 2, 1893; Hyatt, *ibid.*, Nos. 15, 16; and again, Schulze, *Verh. d. Anat. Gesellech.*, Versam. Göttingen, 1893, p. 104; and reprint of same, *Deutsche Zool. Gesell.*, Göttingen, 1893, p. 6.

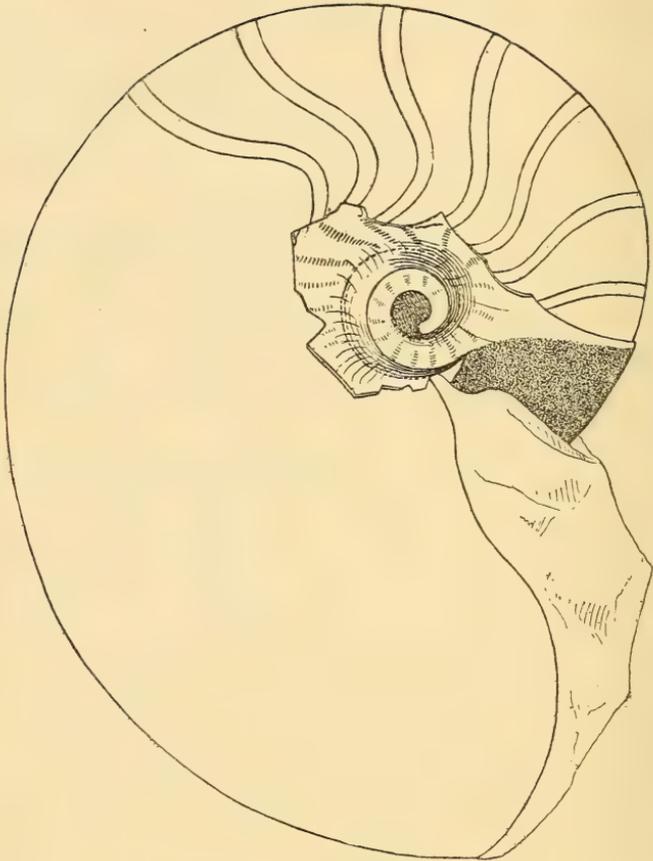


FIG. 15.—*Nautilus umbilicatus*.

#### V. DESCRIPTIONS.

In treating of the history of the impressed zone it has become essential to describe a number of new genera and also new species. The old names—*Gyoceras*, *Lituities*, *Nautilus*, etc.—convey entirely false ideas of affinity and would serve to confuse the student of these fossils, since the new names ignore these groups. Thus it is not at all in contradiction of the nomenclature if I state that the close-coiled *Tarphyceras prematurum* of the earlier Quebec faunas is the last of its phylum and has no descendants in the Upper Silurian or later; but if I call it *Nautilus*, and say that *Nautilus*

*prematurum* had no descendants, even a tyro would begin to wonder why it bore the same generic title as the existing species.

The limits of time and space have not enabled me to follow out each genetic series in this paper, but it will be readily recognized by naturalists that shells having such very different forms in their younger stages must have belonged to different phyla. I have, however, tried in the introduction and in the parts treating of the history of the impressed zone to discuss the facts and arrange them in more intelligible form than is practicable in the following descriptions.

The families into which genera have been assembled are entirely provisional since more information with regard to the genealogy of the forms is needed before any satisfactory results can be reached in defining these larger groups.

## NAUTILOIDEA.

### TARPHYCERATIDÆ.

This family includes shells which had elliptical whorls with gyroceran mode of growth or subquadragonal whorls with nautilian mode of coiling, the venter narrower than the dorsum in most forms. The shells comparatively smooth, the sutures with ventral saddles or only slight lobes, shallow, broad lateral lobes and either saddles or faint lobes on the venter of free whorls. The siphuncle is ventrad of the centre.

The genera are as follows: Tarphyceras, Aphetoceras, Deltoceras, Pyncoceras, found exclusively in the Quebec faunas older than the Chazy; Eurystomites and Barrandeoceras,\* found in both the Quebec faunas and the Lower Silurian; Planctoceras and Falcilitutes, found only in the Lower Silurian.

#### *Tarphyceras*, † n. g.

This genus has heretofore been confounded with Eurystomites by Schröder, the species being found together and resembling each other in general aspect. It differs, however, from that genus in having a more discoidal form, more numerous and more slowly growing whorls, in length of living chamber, in form, aperture, and other characters.

\*In my *Genera of Foss. Ceph.* I included this genus under the title of Nautilidæ.

† *Ταρχύς*, close.

The young become almost as close coiled during the paranepionic substage as in Trocholites, differing in this respect from those of Eurystomites. The dorsal furrow appears in some species, perhaps in all, in the paranepionic substage. This might be considered as due to the quick growth and contiguity of the whorls, the dorsum of the paranepionic substage being brought close to the dorsum of the preceding metanepionic and ananepionic substages of the first whorl. This extraordinary condition of the first whorl obtains also in Trocholites and will be discussed more fully under the heading of *Tarphyceras prematurum* and Trocholites. I do not intend, here or elsewhere, as has been stated in other parts of this paper, to express a positive opinion that the dorsal furrow in any of these nautilian forms was originated in the nepionic stage by the mechanical stress of the metanepionic dorsum even in these very closely coiled shells. The evidence that this may have been the cause is not satisfactory, nor is there any positive evidence of an entirely satisfactory character that the dorsal furrow was genetic.

The siphuncle is centren in the ananepionic substage, but becomes quickly propioventran and continues near the venter for a more or less prolonged period, shifting slowly towards the center. In Eurystomites this shifting usually takes place later, or does not occur at all, and the siphuncle is larger.

The septa are less convex usually than in Eurystomites and, as a rule, more numerous in each volution.

The sutures have well-marked lateral lobes and have broad saddles on the venter. This ventral saddle may be rounded or straight or have a slight shallow depression or lobe in the median line. The sutures, as they approach the lines of involution, are usually more inclined forwards towards the umbilicus than in Eurystomites.

The whorl in section has a flattened venter and frequently slightly flattened zones on the sides, so that there is often a decided approximation to the quadrangular form.

The living chamber is somewhat over one-half of a volution in length. The aperture is like that of Trocholites, with a deep, broad hyponomic sinus encroaching upon the lateral zones, these last being bordered by broad crests, with slight sinuses at the lines of involution. There appears to have been a slight crest on the dorsum. The lines of growth are parallel with the borders of the aperture.

The shell usually has strong striæ of growth externally, but no costations; there are only the broad, slight ridges following the

lines of growth, which are more or less sporadic in shells of this group. These primitive costæ are probably due to the imperfect resorption of the more or less expanded borders of the apertures occurring in some shells but not in others during the progressive stages of development but common in all shells in the gerontic stage.

The shell is very thick on the venter, somewhat thinner, but still thick on the sides and dorsum.

The type is *Tarphyceras prematurum*.

The species of this genus are as follows: \*

*Tarphyceras Aucoini*, Hyatt, Newfoundland.

“ *prematuum*, Hyatt, Newfoundland.

“ *Farnsworthi* (sp. Billings, *pars.*), Phillipsburg. †

“ *Champlainense*, sp. Whitfield, Fort Cassin.

“ *Seeleyi*, sp. Whitfield, Fort Cassin.

“ *extensum*, Hyatt, Newfoundland.

“ *MacDonaldi*, n. s., near Lexington, Va.

This last species has a form and suture like that of *Champlainense*, but the siphuncle is nearer the venter and the young have flatter and more divergent sides and broader abdomen in the neanic stage.

#### TARPHYCERAS AUCOINI, n. s.

Loc., Port au Port.

Pl. iv, Figs. 17-22.

The ananepionic substage seen in the somewhat rough casts is given in Figs. 20-22, Pl. iv, from the side and front. These figures

\* *Nautilus calciferous* of Billings (*Pal. Foss.*, i, p. 258) is probably a species of this genus surviving in the later forms of the Quebec at Port au Choix. The small siphuncle and its position appears to indicate this, but I have no specimens of this species and have not seen any at Ottawa.

† This species has two or more very distinct species. The one referred to above has an elliptical or oval whorl in the ephebic stage, the dorsum a little broader than the venter. There is a contact furrow in the neanic and ephebic stages. The sutures have ventral saddles, with probably slight dorsal lobes in the zone of involution, and a free living chamber over one-half of a volution in length. The siphuncle is subventran in the ananeanic substage, becoming propioventran in the paraneanic and ventrocentren in the metephebic substage. The diameter of the largest specimen, somewhat compressed, was 140 mm. by 146 mm.; the estimated longest diameter of this through the free living chamber was about 160 mm.

The type of *Farnsworthi* is a very distinct species and belongs to another genus and is cited below under the heading of *Aphetoceras*.

show the apex to be blunt and rounded, but this rotundity may be exaggerated in this part which had to be in part restored.

The umbilical perforation is present, but it is very small. The whorl grows very rapidly in all of its diameters and the bending of the shell in the paranepionic substage is very abrupt, bringing the continuation of this substage, the dorsum, in contact with the dorsum of the metanepionic and ananepionic parts of the first volution.

In correlation with this, as in *Trocholites*, a distinct dorsal furrow appears as the shell bends in the first part of the paranepionic substage. The coiling is so close that the slightest variation in the same direction would obliterate the umbilical perforation. The growing mantle while building the shell might have been influenced by the proximity of the metanepionic dorsum and the small diameter of the curve. The dorsal furrow here, as in *Trocholites*, although occurring in the paranepionic substage before the whorls touch, is perhaps due to the close contiguity of the whorls and the rapid ingrowth of the primitive umbilical zones. This process is still apparent in the first part of the second whorl, a section of which is given immediately above the apex in Fig. 20. This is the first of the ananeanic substage, and the siphuncle shifts from its previously subventran position to propioventran. In the metaneanic substage, in the latter half of the second volution, the elongation of the ventro-dorsal diameters is faster, and the tendency to develop lateral zones by the flattening of the sides becomes marked. The sections of the whorls in the upper half of Fig. 20 are slightly distorted by compression, the lower half is in proper proportion. The aspect of the section is better given in the more enlarged Fig. 21, and the decrease in lateral diameters in proportion to the ventro-dorsal is a marked characteristic and continues in the epebic stage.

In some specimens this change is not so marked and the flattening of the sides develops later.

In the later stages the siphuncle is slightly nearer the center as in Fig. 19.

Fig. 17 gives the full-grown epebic stage, and is very close to the original. The section Fig. 19 shows how closely this species resembles *Tarphyceras Champlainense*, differing only in the greater rotundity of the venter and in the position of the siphuncle and in

the possession of very slight folds or nascent costations, which appear in some casts, as in the side view Fig. 17.

These specimens occurred in a dolomitic limestone, on a hill to the west of the inside beach of Port au Port, in the calciferous of Murray and Howley.

TARPHYCERAS PREMATURUM, n. s.

Loc., Port au Port, Newfoundland.

Pl. iv, Figs. 12-16.

This species is apt to be confounded with *Tarphyceras Aucoini*, but the whorls increase faster by growth and are much larger at the same age.

Fig. 14 shows in part the nepionic whorl of this species and the ananeanic substage. The section of the ananeanic whorl above the ananepionic apex is restored, and is probably made too angular and the abdomen too broad. The other parts of the figure are accurate. The side view in Fig. 15 gives the same showing the prominence of the early nepionic substages and the first of the paranepionic. Fig. 16 shows the paranepionic and earlier substages from the front. These figures give satisfactorily the differences between the young of this species and *Tarphyceras Aucoini*.

The presence of a very narrow umbilical perforation is plainly evident in this specimen and this is similar to that of *Aucoini*. The metanepionic dorsum is distinctly separated from the paranepionic dorsum, here shown in outline on the inner edge of the septum, by a narrow, smooth space which curves around between them, but in consequence of its ventral curvature as it crossed between them it cannot be seen in a side view. This perforation or bend is larger and wider than in *Aucoini*, and the involution or ingrowth of the nascent umbilical shoulders is less than in *Aucoini*. It is consequently doubtful whether the abruptness of the curvature and the ingrowth of the umbilical shoulders fully accounts for the presence of the dorsal furrow in the dorsum of this specimen. The condition of the specimen is not wholly satisfactory, otherwise a more definite opinion could probably be given. The inner or dorsal surface of the ananepionic and metanepionic substages has been more or less eroded and it is not practicable to say, as in *Aucoini*, that they might have influenced the formation of the outline of the opposing dorsum of the paranepionic whorl as it was bent around the umbilical perforation.

The shell in its later stages, as shown in Figs. 12 and 13, resem-

bled closely *Aucoini*, but the abdomen becomes more prominent and the contact furrow is deeper and broader in consequence of this and the breadth of the venter.

The siphuncle in the paranepionic substage is subventran, becoming propioventran in the ananeanic as seen in section above in Fig. 14, and extracentroventran in the septum seen below in Fig. 12. The position alters slightly in the succeeding stages.

The living chamber is obviously over one-half of a volution in length and is shown in an incomplete fragmentary condition in the outline on the farther side of Fig. 12; the form in section of the same specimen partly restored is given in Fig. 13, Pl. iv. The depth of the dorsal lobes in the sutures is shown upon the venter of the exposed whorl in the upper part of the section which is still covered by the dorsal layer and the remnants of the septa.

#### TARPHYCERAS EXTENSUM.

Loc., Port au Choix, Newfoundland.

This fossil resembles *Tarphyceras Seeleyi*, but has a shorter living chamber and the living chamber and part of septate whorl are free in gerontic stage. The contact furrow increases in depth with the ephebic stage and then decreases with the approach of the gerontic stage. The ventro-dorsal diameter slightly decreases, as is shown in Fig. 1, Pl. vi, in the paragerontic substage, when the whorl is almost straightened out, and at the same time the impressed zone is found to be wholly lost, as shown in the section, Fig. 2.

In section 4 the inner whorl represents a section of the ephebic stage and the outer whorl is the gerontic stage. The uppermost, with siphuncle nearer the venter and reduced impressed zone, is the anagerontic, and Fig. 2 is the paragerontic substage. The whorls are apparently smooth. The septa are not very concave. The sutures have ventral saddles, dorsal lobes and slight lateral lobes. In the anagerontic substage they are nearly straight on the sides and decidedly inclined forwards.

#### TARPHYCERAS CHAMPLAINENSE.

NAUTILUS CHAMPLAINENSE, Whitfield, (*Bull. Am. Mus.*, New York, Vol. i, Figs. 1, 3, Pl. 31).

Loc., Fort Cassin, Lake Champlain.

Pl. iv, Figs. 4-11.

The nepionic stage of this species, as in others of this group, has

a very small umbilical perforation, the bending of the paranepionic stage taking place with great abruptness. When seen laterally (Fig. 4, Pl. iv) the umbilicus shows a much larger perforation than exists internally. This is due to the curvature of the perforation and its decrease in diameter internally. Starting from either side, it is an unsymmetrical cone with a pear-shaped base, which decreases internally and bends in a bow-like curve as it crosses between the dorsan surfaces of the meta- and paranepionic substages. The external orifices are usually owing to the fact that the matrix is difficult to clean out, apparently broader than they really are. The actual diameter is about 1 mm., diminishing to .5 mm. at the center. In section, however, it may be seen, as in Fig. 9, to have a minute perforation between the metanepionic dorsum at the center below and the paranepionic dorsum just above this. The outline of the section (Fig. 10) probably passed not far from the apex in this specimen, probably through the metanepionic substage, judging from the outline of the section (Fig. 9, and the enlarged outline, Fig. 11), which shows transitional characteristics from the dorsoventrally elongated oval of the whorl of the ananepionic substage common to most Nautiloids and the transverse oval of the earlier paranepionic also found at this substage in a large number of nautilian shells. This outline, Fig. 11, is similar to that of the shells of *Nautilus pompilius* at the same age.

The paranepionic substage of Fig. 9 has also an outline similar to that of *Nautilus pompilius* at the same age, being kidney-shaped, with a broad but well-defined dorsal furrow. The presence of this dorsal furrow, although the whorls do not touch, appears at first to justify the opinion that this is a case in which inheritance may be assumed. The paranepionic dorsum is, however, very closely approximated to the dorsum of the metanepionic substage, and it seems possible that this proximity modified the shape of the secreting edge of the dorsal side of the mantle and caused the corresponding impression shown in the shell. At any rate, it is not safe to assume that this represents any hereditary tendency. The exceedingly quick growth from the apex to the paranepionic and the sudden curvature of the early paranepionic whorls might have produced this also, as pointed out in other similar cases. In making another specimen of this species (Fig. 4, Pl. iv) I was fortunate enough to crack the fossil so as to expose the entire length of the cast of the umbilical perforation. I found this

to be, as stated above, a bow-shaped, dark, smooth filling, as shown in Fig. 5 and more enlarged in Figs. 6 and 7. Fig. 8 is an ideal restoration of a side view of the nepionic stage, and gives the location of sections shown in Figs. 6 and 7. By the aid of Fig. 7 one can see that the furrow which appears in the dorsum of the paranepionic substage is first found just as the whorl makes the sharp turn to form the umbilical perforation. This shows also that its origin may be purely mechanical. The hard wall of the dorsum of the metanepionic was only about .5 mm. distant from the growing pliable edge of the paranepionic as it made the turn, and this pliable border may have been built to conform to the shape of the internal metanepionic dorsum. This becomes possible when one takes into consideration the rapid growth of the whorl in its lateral and ventro-dorsal diameters at this stage. The increase of the former broadening out the volution causes the involution of the apex on the sides when this is reached, and rapid increase of the ventro-dorsal diameters forces the building shell to make this sudden turn, owing to the more rapid building out of the ventral side.

Immediately after passing this point of greatest pressure, as shown in Fig. 6, the zone produced by it begins to decrease in depth and increase in width, but it does not disappear altogether, because the growing shell immediately strikes the dorsal side of the metanepionic and anepionic substages and the true contact furrow appears. This is shown in the truncation of the dorsal corner of the outline in Fig. 8 when it strikes the apex. The centre of Fig. 5 is approximately the same as Fig. 6.

A Trocholites-like outline is assumed in the neanic stage (shown in Fig. 5 in section of second whorl below center) and in the ephebic stage the whorl is apt to become slightly flattened on the venter. The outer whorl of section, Fig. 5, is flattened in this way and represents the anephebic condition of the living chamber.

This shell is smooth until the ananeanic substage, as in Fig. 4, and then becomes costated. These costæ are infrequent, low, broad elevations which become less distinct with the incoming of the anephebic substage and are very often absent in the later ephebic substages, beginning however again in the gerontic stage, but are never so constant or prominent as in the earlier stages.

The siphuncle of the metanepionic whorl, if the mark in the centre of the enlarged outline (Fig. 11, Pl. iv) really represents this organ or its general location, is centren. This, however, is a

mere spot, so that this must be regarded as doubtful. In the later paranepionic it is unquestionably propioventran or subventran. In the neanic stage it approximates to and attains an extracentroventran position, which it retains throughout life. The position in the gerontic stage was, however, not observed.

Having had an opportunity for close study of Whitfield's originals and also the fine collection of Mr. Walcott (now in U. S. National Museum), from same locality, there is but little doubt that the specific name is correct.

TARPHYCERAS (?) CONVOLVENS.

DISCOCERAS CONVOLVENS, Angelin et Lindst. (*Fragm. Sil.*, xvi, Fig. 3; not Pl. x, Fig. 5).

This form has the sutures and similar position of siphuncle and last part of outer whorl free and the lines of growth similar to other species of this genus, as figured on Pl. xvi of Angelin and Lindstrom. The figure in section on Pl. x, Fig. 5, is doubted, because the whorls appear to be closer coiled and the dorso-ventral diameters increase faster than in other specimens figured.

*Eurystomites.*

This genus was first described by Schröder,\* who saw that the *Nautilus Kelloggi* of Whitfield was generically distinct from his genus *Estonioceras*. He also included in the same genus *Nautilus Champlainensis*, but this, with *Seeleyi* and similar discoidal forms, are here placed in the genus *Tarphyceras*.

The siphuncle is subventran in the nepionic and ananeanic sub-stages, becoming extracentroventran in all the later stages of development, or it may remain nearer the venter. The rate of growth of the shell is more rapid than in *Tarphyceras* and there are fewer whorls in the same diameter. The ventro-dorsal diameters are consequently longer in proportion than in *Tarphyceras*. The whorl may be rounded until a late stage of development, but usually acquires a more or less flattened venter and primitive lateral zones and ill-defined umbilical zones like those of some species of *Tarphyceras*. The lateral zones are apt to be more convergent and the abdomen narrower.

\* *Op. cit.*, *Pal. Abh. Dames et Kayser*, V, p. 26.

The umbilical perforation is large and the impressed zone is a contact furrow not generated until the whorls come in contact.

The contact furrow is deeper and the amount of involution slightly greater in the epehebic stage than is usual in *Tarphyceras*. It has been supposed, from the large specimen described by Whitfield, that this shell was close coiled and involute throughout life. There is, however, one large specimen (Fig. 4, Pl. v) in the Walcott collection, U. S. National Museum, which has the entire living chamber and part of the septate whorl free. The living chamber is very variable in length. It is shorter than in *Tarphyceras* in the adult of *Eurystomites Kelloggi*, and in the aged specimen referred to above it was very long. The aperture, as figured by Whitfield, has lateral crests which are most prominent opposite the centres of the lateral zones, receding into sinuses on the umbilical zones.

The sutures may remain throughout life almost straight, with the slightest of lateral lobes and ventral saddles, or they may become quite sinuous, with well-defined lateral lobes and the ventral saddles entire or divided by median lobes. A distinct dorsal lobe makes its appearance in the contact furrow when this is formed and on the gerontic volution this furrow persists as an impressed zone although entirely freed from contact with the inner whorl (Fig. 5, Pl. v). It diminishes slowly in depth and breadth, but its persistence on the dorsum of this very long free gerontic stage shows that it has acquired a strong hold upon the organization of this specimen. Having no other specimens it cannot be said that this persistence is common to all individuals of the species.

#### EURYSTOMITES KELLOGGI.

NAUTILUS KELLOGGI, Whitf., *op. cit.* (*Bull. Am. Mus.*, N. Y., i, No. 8, Pl. xxx; not Pl. xxxi, Figs. 4, 5).

EURYSTOMITES KELLOGGI (?), Schröder, *op. cit.* (*Pal. Abh. Dames et Kayser*, v, hft. 4, p. 26).

Pl. v, Figs. 4, 5.

The figures of Whitfield give an excellent general representation of this species. The young are, however, slightly costated in the neanic stage and there are at least two distinct forms placed by Whitfield under this name.

## EURYSTOMITES ROTUNDUS.

NAUTILUS KELLOGGI, Whitf., *op. cit.* (*Bull. Am. Mus.*, New York, i, Pl. xxxi, Figs. 4, 5; not Pl. xxx).

Loc., Fort Cassin.

Pl. v, Figs. 21-25.

This species increases more rapidly in the growth of the ventro-dorsal diameters than in *Kelloggi* and retains the siphuncle near the venter for a longer time during the growth. This may be due, however, to the differences in the size, and not a matter of age, since in large whorls it assumes a similar position to that of *Kelloggi*. Fig. 21, Pl. v, gives a view of the first two whorls from the side, partly restored from the study of the section, and the dotted lines explain the position of the last section (Fig. 25, Pl. v) of the centre of first volution.

This figure shows the metanepionic above and paranepionic below, just before the paranepionic comes in contact with the apex. This was the last section taken. Fig. 22 shows the first section, secured through the inner dorsal part of the metanepionic substage, and Figs. 23, 24, Pl. v, show the successive sections connecting this with Fig. 25, and thus demonstrating the large size of the umbilical perforation and the correlative rotundity of the dorsi of the meta- and paranepionic substages.

## EURYSTOMITES GIBBOSUM, n. g.

Loc., Port au Port Choix, Schooner Island, Newfoundland.

I mention this new species here without giving figures, because it is important in the consideration of the relations of the dorsal lobe and impressed zone and it is so peculiar that it can be easily recognized.

The general aspect is like that of *Eurystomites Kelloggi*, but the septa are more deeply concave than in any species of these faunas and the lateral sutures run forward on the sides as in *Tarphyceras*. The outlines of the whorls in section at all epinepionic stages is like that of the last whorl of the specimen of *Nautilus Kelloggi*, here *Eurystomites rotundus*, as figured by Whitfield on Pl. xxxi, Fig. 4, and in section the whorls at all stages are ovals similar to the metanepionic substage of *Eurystomites rotundus* (Fig. 25, Pl. v), but the abdomen is rounder. No lateral zones or umbilical zones are differentiated, but there is a faint approximation to the digonal form probably in the early neanic substages. The sides are only

slightly convex and slope evenly and divergently outwards and consequently appear flattened in some specimens.

The envelopment covers the abdomen, which last is prominently convex.

The length of the sub-V-shaped dorsal lobe in the sutures is greater than in any species I have yet seen, and this is very instructive. Occurring as it does in a shell which is not very involute, and with a contact furrow but little exceeding the ordinary dimensions, it shows that the depth of the dorsal lobe in the sutures is not only correlated with the extent and depth of the contact furrow but also largely dependent upon the concavity of the septa. In other words, if this species had had septa of ordinary concavity the dorsal lobes in the sutures would not have been so deep and sub-V-shaped as they are. The sutures have also broad lateral lobes running well forward to sharp saddles at the lines of involution. There are broad saddles at the abdominal angles and shallow ventral lobes or straight sutures across the venter. The siphuncle becomes intracentroventran in the ephebic stage and is very large, as it is in *Eurystomites Kelloggi*. The whorls come in contact in the ananeanic substage. The shell grows quite large, but, so far as I have seen, none have any part of the last whorl free.

#### EURYSTOMITES VIRGINIANA.

NAUTILUS KELLOGGI(?) (*pars*), Whitf. (not figured).

Loc., near Lexington, Va., and Fort Cassin.

This shell had more cylindrical whorls and more numerous and straighter sutures at all stages than in *Kelloggi*. The siphuncle is nearer the venter, and in the type-specimen, which is over 90 mm. in diameter (in collection U. S. National Museum), it is still almost subventran at the entrance into the living chamber. This last is less than one-half of a volution in length. The whorl is almost circular in this specimen at all stages observed, including the neanic stage, and the involution is very slight; the dorsal lobe correlates with this, being correspondingly shallow and narrow. The sutures otherwise resemble those of *Kelloggi*, but are straighter, and the three specimens from Virginia do not show the ventral lobes that often occur in *Kelloggi*.

There is a young specimen in the American Museum under the name of *Kelloggi*, from Fort Cassin, that appears to belong to this species, having similar sutures, form of whorl and involution.

## EURYSTOMITES UNDATUM.

NAUTILUS UNDATUS, Hall (*Pal. New York*, i, p. 52, Pl. xiii and xiii *bis*).

Loc., Poland, Herkimer county, N. Y., Black River Limestone. Pl. v, Figs. 1, 2.

This species has much broader whorls in the young than in *Eurystomites* of the Quebec faunas. The position and size of the siphuncle, the large umbilical perforations and the sutures and the flattened abdomen of the adult stage and comparison with the heavily costated forms like *Discoceras antiquissimum* and others show that this shell is probably a member of the genus *Eurystomites*.

The nepionic stage has a very large umbilical perforation and in correlation with this the whorl has a rounded dorsum at this age. The metanepionic substage has a broadly elliptical form and sub-ventran siphuncle; the paranepionic, on account of the rapid transverse growth, has a subdigonal whorl, as shown in Fig. 2, Pl. v. The shell does not increase so fast transversely in the neanic stage and the whorl becomes rounder, a slight contact furrow appearing when the whorls come in contact, and the living chamber at this age is less than one-half of a volution in length. Light costations also appear in this substage, but the nepionic whorl is smooth with the exception of strong lines of growth. The abdomen becomes flattened in the paraneanic substage, and the sutures show slight, ventral lobes and very slight lateral lobes.

The siphuncle is propioventran in the paranepionic substage and neanic stage. The costations become stronger in the paraneanic substage but are reflected on casts only to a very slight extent.

The young are, however, quite variable, and the figures, Pl. v, give probably an extreme form so far as the retention of the broad subdigonal form is concerned. In other varieties or species, for I think there are several species usually placed under this name, the sides and venter become slightly flattened in the metaneanic substage, or even before this. In the specimen figured this change had not yet taken place, although the shell was in the metaneanic substage.

The aperture in this specimen flared out laterally, but is removed in the section Fig. 2, Pl. v.

Slight, foldlike costæ are better developed in the ephebic stage,

and, although always present, they are only occasionally developed into decided costations even in full-grown specimens.

The shell grows quite large, but so far as I have seen none have any part of the last whorl free. The largest shells often have compressed whorls, with abdomens much narrower and flat, and sides much flatter than in the earlier stages.

*Planctoceras.*

This group was first described by Remelé under the name of *Ægoceras* and subsequently under that of *Tragoceras*, but both of these being preoccupied, Schröder proposed that of *Planctoceras*.\*

Schröder considers it to be a subgenus, and that the only distinction between this and *Estonioceras* lies in the fact that it was probably not close coiled at any stage.

As *Estonioceras* is here limited, however, the sutures are different and have ventral and dorsal saddles with lateral lobes, as in *Falcilituites*. The young and all stages so far as seen have also compressed elliptical instead of depressed whorls. That is to say, they are probably never digonal, and do not resemble those of *Estonioceras* at any stage, unless in the very earliest or nepionic stage which is not known. The whorls, as shown by Schröder in his fine figures, have the dorsum and venter somewhat depressed and very nearly equal and distinct from the side in the young. In other words, there is a faint tendency to form a quadragonal whorl. Later, probably in the ephebic stage, the dorsum may exceed the venter in breadth, and in the gerontic stage the whorl becomes almost circular.

The lines of growth are similar to those of *Falcilituites*, *i. e.*, they have broad ventral sinuses and a broad latero-dorsal crests.

The volutions are attenuated and the living chambers very long.

The siphuncle is small and about twice its own diameter removed from the venter, or, in my nomenclature, is extracentroventran in the neanic and ephebic stages as measured on Schröder's figures.

The only species referred to this genus in Europe is the *Planctoceras* (*Orthoceratites*) *falcatum*, sp. Schlot., which, judging from the figures of Dewitz, Schröder, Quenstedt and Eichwald, probably includes several quite distinct species. *Planctoceras Quenstedi* (Lit., *falcatus*, Quenst.), for example, has distinct sutures and outline

\* Dames et Kayser, *Pal. Abh.*, v, hft. 4, 1891, p. 41.

from the species figured either by Dewitz or Schröder. In fact, the figures show that there are very likely three species under this one name.

This genus is described here partly because it is an excellent illustration of the correlation of the dorsal and ventral saddles with elliptical compressed whorls and gibbous abdomens and gibbous dorsal sides such as occur in many cyrtoceran and gyroceran forms, and also because of its resemblance to *Aphetoceras*.

*Aphetoceras*,\* n. g.

The shells of this genus are remarkable for their resemblances, until a late stage of growth, to the cyrtoceran genus, *Melonoceras*, from which they differ in having open apertures, and in this case they would probably compare more closely in these stages with *Oonoceras*. These shells are, however, coiled with an even gyroceran curvature that does not bring the whorls in contact at any stage.

The form of the whorl in section is compressed elliptical or ovi-form, the venter narrower than the dorsum. This outline is common to all of the epembryonic stages as far as known. The nepionic substage has, however, not been seen as yet.

There is no impressed zone at any stage.

The whorl probably deviates from the spiral in the paragerontic substage, but this has not been observed, unless *Farnsworthi* is a true member of this generic phylum.

The shell is invariably smooth so far as known.

The sutures have very nearly the same form throughout the epembryonic stages, so far as known, having dorsal and ventral saddles and broad lateral lobes in correlation with gyroceran characters of the coil.

The siphuncle is subventran or propioventran and probably does not vary much from these positions in any species.

This genus is separable from *Planctoceras* by the gyroceran mode of coiling, by the form of the whorl in section, by the length of the living chamber and position of the siphuncle.

APHETOCERAS AMERICANUM, n. s. (Pl. vi, Figs. 5-8,  $> \frac{1}{3}$ ).

Loc., Port au Choix, Newfoundland.

This shell has an open gyroceran coil and, so far as could be

\* *Αφετόσς*, free.

seen, it was not in contact at any stage, but the earlier and probably nepionic whorl was not seen.

The whorls increase slowly by growth, especially in the transverse diameters; the ventro-dorsal growth is somewhat more rapid, but not sufficiently so to close up the volutions. In the gerontic stage the living chamber begins to depart slightly from the preceding curve of growth, as shown in the drawing (Fig. 5, Pl. vi).

The shell is probably smooth.

The whorls in section are compressed, the dorsum wider than the venter, and the dorso-ventral diameter much larger than the transverse, especially in the ephebic and gerontic stages. The abdomen becomes more or less flattened in the last two stages, but is rounded in the neanic stage. The dorsum remains rounded and gibbous throughout all the stages so far as known.

The sutures have ventral and dorsal saddles and broad lateral lobes in the neanic stage and probably also in the later nepionic stage. After the abdomen becomes flattened, slight ventral lobes are developed in the sutures of the ephebic and gerontic stages.

The siphuncle is large, propioventran in all the stages observed.

APHETOCERAS BOREALE, n. s. (Pl. v, Figs. 15-17,  $> \frac{1}{3}$ ).

Loc., Schooner Island (on southeast side), Newfoundland.

This resembles *Aphetoceras Americanum*, at the same age, in sutures and form, but the siphuncle is slightly nearer to the venter and the coiling is obviously distinct and the abdomen has not the well-marked, flattened aspect of the former.

It is doubtful, of course, whether the whorl actually does form a coil in the specimens collected; but, if it does, the inner whorls were probably more loosely coiled than in *Aphetoceras Americanum*, since the curvature of this fragment is larger than in any corresponding part of *Americanum*.

APHETOCERAS FARNSWORTHI.

LITUITES FARNSWORTHI, Bill. (*pars.*) (*Geol. Surv. Canada*, Pal. i, p. 21, Fig. 24).

Loc., Phillipsburg.

This species probably belongs to a distinct genus, and is cited here provisionally under this name because it may be merely a highly degenerate species of *Aphetoceras*. It is also coiled in the neanic stage, but apparently the whorls are not in very close contact. There are certainly two species, and probably three, usually

included under this name. One is separated above as *Tarphyceras Farnsworthi* and the other below as *Aphetoceras attenuatum*. The type is that figured by Billings, and this had the living chamber free and deviating strongly from the spiral. It was 91 mm. long on the dorsal surface and more than one-half of a volution in length when this measurement was applied to the coil of the preceding whorls. The siphuncle in the ephebic stage was propioventran and the septa much closer together than is usual in this genus.

APHETOCERAS ATTENUATUM.

LITUITES FARNSWORTHI, Bill. (*pars.*) (*op. cit.*, p. 21).

Loc., Phillipsburg.

This species is founded upon the specimen described by Billings on p. 21 of his *Paleozoic Fossils* as having first two whorls in contact and making a coil an inch across. These whorls are, however, not in contact on his specimen, if my drawing of this is correct. The specimen is of nearly the same size as the type of *Aphetoceras Farnsworthi*, but one and a quarter volutions are free, so as to leave a gap of 8 mm. before the completion of the first quarter of the septate part of the eccentric volution, and at the end of the same this gap has increased to 13 mm., and in the next quarter, at the end of the living chamber, it is 25 mm. The departure of the free whorl of *Farnsworthi* increases, as shown in Billings' drawing, in less than one-half of a volution to 40 mm.

The septate part of the eccentric volution in this specimen is 58 mm. long, the living chamber is 88 mm. long. The former would occupy about three-fourths of a volution if it followed a regular open spiral curve, and the latter would be about one-half of a volution, estimated in the same way.

The septa are similar to those of *Farnsworthi*. The fragment of the siphuncle observable in the neanic stage changes in the length of 10 mm. from nearly subventran to propioventran.

*Deltoceras*,\* *n. g.*

The shells of this group resemble those of *Aphetoceras*, but are just one grade more complicated. The whorls are similar in section, but grow more rapidly in the ventro-dorsal diameters, the siphuncles in some species are very large and ventral. The sutures are simi-

\* Δέλταος, a scroll.

lar to those of *Aphetoceras*, but the whorls are in contact either in the earlier epembryonic stages or throughout the ephebic stage. A departure from the spiral regularly takes place in the gerontic stage or earlier; sometimes the entire ephebic stage is free.

No impressed zone has been found at any stage, although a slight flattening of the dorsum was observed in one species.

This group is represented by several species in the Newfoundland basin of the Quebec fauna, but it is only necessary here to describe one.

*DELTOCERAS PLANUM*, n. s.

Loc., Port au Choix, on north side, Newfoundland.

This fossil is apparently very close to *Barrandeoceras natator*, but it increases more rapidly in the dorso-ventral diameters and has a larger siphuncle, and this is closer to the venter and it differs also in the greater compression of the form.

In the neanic stage it agrees more closely with *natator* in aspect, but the siphuncle is subventran. In the ephebic stage and anagerontic substage it becomes propioventran and increases in size until it becomes 7 mm. in diameter ventro-dorsally where it enters the living chamber. The transverse diameter was not measurable, but it is undoubtedly less than this in correlation with the compressed character of the volution. The ventro-dorsal diameter of the last whorl through the living chamber is 53 mm., the transverse only about 28 mm. to 30 mm., the whole diameter of the coil at this place being 163 mm.

The incomplete living chamber is over one-quarter of a volution and has departed slightly from the closer spiral of the ephebic stage. This departure is very gradual at first until the gerontic stage begins, and then becomes more apparent and widens more rapidly. The whorls are in absolute contact only in the neanic stage. The venter appears to be rounded at all stages of growth.

*Barrandeoceras.*

This genus was described in my *Genera of Fossil Cephalopods* to include shells having large umbilical perforations, compressed slightly costated or smooth whorls. The venter usually narrower than the dorsum, the whorls barely in contact or with very slight contact furrow, siphuncle near but above centre, septa deeply con-

cave, sutures having usually ventral and dorsal saddles and lateral lobes. This last statement is true of all the forms having the gyroceran mode of coiling, but not of those which have the closer nautilian form. In these there is a slight dorsal lobe and a different form of the paranepionic whorl which may eventually lead to their generic separation.

The type is *Barrandeoceras* (Naut.) *natator*, sp. Billings.

BARRANDEOCERAS MINGANENSE.

Loc., Mingan Islands.

There is a specimen from the Chazy limestone of the Mingan Islands in the collection of the Museum of the Geological Survey at Ottawa which has very similar characters to those of *Barrandeoceras natator*, but is distinct in some of its characters. The living chamber is short and, if complete, about a quarter of a revolution in length. It is free and in section is compressed oval, the abdomen broader than the dorsum, but the centro-dorsal diameter is longer than the transverse.

The siphuncle is nearer the centre, being ventrocentren. The neanic, or perhaps an ephebic stage has slight annulations or raised lines of growth, judging from the marks on the section. This is labeled as coming from the white limestone of Large Island.

There is no impressed zone at any stage observed. The ephebic stages have a whorl similar to that of *Barrandeoceras convolvans* in the neanic stage, but the abdomen is broader.

BARRANDEOCERAS CONVOLVANS.

LITUITES CONVOLVANS, Hall (*Pal. of New York*, i, p. 53, Pl. xiii, Fig. 2):

Loc., Watertown, N. Y.

The specimen figured by Hall has in the ephebic stage sutures with slight dorsal lobes. This, however, may have been a mistake in drawing or an abnormal individual variation. A specimen in the Museum of Comparative Zoölogy from the same locality, exhibiting the form of the whorl and the sutures of the ephebic stage, does not have such lobes.

The characteristics otherwise are so close to Hall's description and figure that, in spite of this and the supposition that the siphuncle was ventral, I have referred this and a suite of sections of the same to his species.

The whorls are variable in the coiling, and in some specimens are plainly not in contact at any stage. In others the neanic volu-

tion is in contact, but this is so slight that no contact furrow is formed. The whorls are mostly gyroceran in the character of the coil becoming excentric in the ephebic stage.

The section is a much compressed oval, the ventro dorsal diameter much longer than the transverse, the abdomen narrowly rounded and dorsum broader, but also gibbous. The neanic stage has a more rounded outline in section.

The shell is smooth.

The sutures have ventral and dorsal saddles with broad lateral lobes in the neanic and ephebic stages.

The siphuncle varies from centroventren to intracentroventran in the neanic and ephebic stages.

#### BARRANDEOCERAS NATATOR.

NAUTILUS NATATOR, Bill. (*Can. Nat.* iv, No. 6, 1859).

BARRANDEOCERAS NATATOR, Hyatt (*Gen. Foss. Ceph.*, p. 299).

Loc., Mingan Islands.

This species has volutions compressed oval in section, the dorsum somewhat broader than the venter; siphuncle is extracentroventran, even in the neanic stage; septa deeply concave; sutures with dorsal and ventral saddles and the lateral lobes as in other species of this genus.

The volutions are in contact, but no contact furrow was formed at any age. The contact takes place as in the young of *Estonioceras perforatum*, Fig. 9, Pl. vii, on the venter of the paranepionic volution.

The volution in the neanic stage, dorso-ventral diameter 13 mm., has a much narrower venter in proportion to the dorsum than in the adult. The venter was rounded at all stages and also the dorsum. The ananeanic and nepionic stage were not present in the original specimen in the Museum at Ottawa, but in following out the same lines it is easily ascertained that the umbilical perforation must have been enormous, at least 15-17 mm. in diameter. The living chamber was somewhat over one-fourth of a volution in length. The whole diameter was about 108 mm. It was reported as having been found in the Chazy limestone.

#### BARRANDEOCERAS STERNBERGI.

NAUTILUS STERNBERGI, Barr. (*Syst. Sil.*, Pl. xxxvi, xxxvii).

Loc., Bohemia. Pl. xiv, Figs. 2-5.

This species has, as is usual in transitional species with gyroceran

mode of coiling, very variable aspects, owing to the closer coiling of some specimens than of others.

There is no impressed zone in most specimens at any stage, although there is a slight flattening of the dorsal side and an obvious although very slight modification of the dorsum, which takes place in the most closely coiled shells.

The whorl in section is closely similar to that of *natator* and the siphuncle similarly situated. The sutures are similar, with the exception of a faint dorsal lobe that appears in this species.

The whorls do not touch in some specimens at all (Pl. xiv, Fig. 2); in others they may touch in the neanic and ephebic stages. In some they may become excentric in the gerontic stage, and in others this may occur earlier in the ephebic stage. Very likely there is more than one species included under the name, but it is obvious that they are transitional to *Barrandeoceras Sacheri*.

#### BARRANDEOCERAS SACHERI.

NAUTILUS SACHERI, Barrande (*Syst. Sil.*, Pl. xxxix). Pl. v, Fig.

11-14.

Loc., Bohemia.

The large umbilical perforation is shown and the almost straight form of the ana- and metanepionic substages. The paranepionic substage has sutures with dorsal lobe (Fig. 13) and form with flattened dorsum (Fig. 14), precisely like that of the close-coiled forms of *Sternbergi* in the ephebic stage. In *B. Sacheri*, however, the coiling is not variable and a contact furrow is invariably formed after contact, which takes place always as in Fig. 11, at the apex.

The sutures in the ana- and metanepionic substages have ventral and dorsal saddles and form in section with similar position of siphuncle to *Barrandeoceras natator* of the Chazy and resemble *Sternbergi* only in the paranepionic substage. In the neanic stage, after the impressed zone is generated, the whorls become more compressed and this resemblance is less noticeable.

#### BARRANDEOCERAS TYRANNUM.

NAUTILUS TYRANNUS, Barr. (*Syst. Sil.*, Pl. xxxviii). Pl. v, Fig. 6-10.

Loc., Bohemia.

This species is similar to *Sacheri*, but has a smaller umbilical perforation and is somewhat closer coiled, the contact furrow appearing sooner and the *Sternbergi* stage of the paranepionic is considerably shortened. Its first appearance in the outline of the aperture is shown in Fig. 6 in the paranepionic substage.

Figs. 6-9, Pl. v, show the side and front views of two specimens, the smaller in the metanepionic and part of the paranepionic substages and the other older. These are magnified to show the ananepionic substages, and Figs. 6, 8, and 10 show the cicatrices on the apices of both of these. The longitudinal striæ shown on these are necessarily exaggerated, these markings being perceptible with difficulty under a magnifier. It is interesting to compare these with the young of the existing *Nautilus* on Pl. i, and it is also obvious that if found without their older stages in any locality they would certainly be described as cyrtoceran forms.

BARRANDEOCERAS (?) ELRODI.

GYROCERAS ELRODI, White (*Eleventh Ann. Rep. Geol. Indiana*, p. 356, Pl. xxxvii, Fig. 1).

Loc., Hartsville, Ind.

This species has an oval outline in the full-grown and senile stage figured by White, with siphuncle slightly above centre by description, but slightly below centre in the figure. The living chamber is not quite one-half of a volution in length, but it is very large, and this, together with one-half of the last volution, are free. The younger whorls are closely coiled, but not more than two and a half, if so many, are in contact; the remainder of the third and first quarter of the fourth are free and the last part excentric. Dr. White describes them as rounded outline in section, giving the impression that there was no impressed zone.

The rate of growth in the ventro-dorsal diameters is rapid, and consequently the living chamber on the last of the third and first of the fourth volution is very large, especially in the ventro-dorsal diameters.

The form and sutures are similar to those of *Barrandeoceras Sternbergi*, and the species, if it is a member of this genus, is interesting on account of its appearance in the Niagara group, the close coiling of the young, and the length of the free whorl.

*Pycnoceras*,\* *n. g.*

This genus has shells similar to those of *Aphetoceras* in the nepionic stage, with siphuncle subventran, similar form in section and similar sutures, with ventral and dorsal saddles and shallow lateral lobes. This may be seen by comparing figures of *Apheto-*

\* Πυζνός, close.

ceras (Pl. vi, Fig. 5) with the figure of the young of *Pycnoceras apertum* (Pl. v, Fig. 18). The nepionic stage has rounded dorsum and more rounded venter than appears in the Fig. 19, Pl. vi, because of the presence of a thick band of shell on the venter, consisting of its own shell which is not present on the sides and also of the corresponding part of the shell of the dorsum of the next older whorl that has been broken away. A slight contact furrow is present at the beginning of the ananeanic substage when the whorls come in contact at the point indicated in Fig. 18 by the end of the outline of the restored apex. This zone is further shown by the band of shell left on the venter from the dorsum of the next older whorl, which was the neanic volution. Upon this, also, there are remnants of the septa of this stage, showing that this zone was immediately accompanied by the advent of dorsal lobes in the sutures. These replaced the dorsal saddles of the nepionic stage.

In the epebic stage the siphuncle assumed a propioextraventrans position and retained this until the gerontic stage.

The form of the whorl remains quite similar, the ventro-dorsal diameters being longer than the transverse, but the venter becomes broader in proportion than the dorsum in neanic and epebic stages.

In the gerontic stage the living chamber and part of the septate last whorl alone are free in some species, in others the age at which the whorl becomes free varies greatly.

The type of the genus is the young specimen, Fig. 18, which shows that the young are distinct from those of *Tarphyceras*, being much less closely coiled and having distinct form of whorl and large umbilical perforation.

There are several undescribed species of this genus in the fauna of Newfoundland.

*PYCNOCERAS APERTUM*, n. s. Pl. v, Figs. 18-20.

Loc., Port au Port, Newfoundland.

This single specimen was found in the dolomitic limestone or calciferous in company with the closer coiled young of *Tarphyceras*.

The nepionic stage is prolonged and has the oval form of whorl and sutures of the adults of the cyrtoceran genus, *Melonoceras*, and of the nepionic and neanic stages of the gyroceran form, *Aphetoceras*, its nearest affine, which occurs, however, later in the fauna of the Quebec group.

The characteristics have already been given in the generic descriptions and the presence of the contact furrow in the neanic stage noticed. It only remains to call attention to the fact that this and the dorsal lobes of the sutures are generated together as the whorls come in contact.

PYCNOCERAS CALCIFERIFORME, n. s.

Loc., Port au Choix and Schooner Island, Newfoundland and Phillipsburg, Canada.

This species is sufficiently abundant at Port au Choix, and seems at first identical with *calciferus* of Port au Choix, but the latter is probably a species of *Tarphyceras*, having the small siphuncle of that group.

The shell reaches a considerable size, 128 mm. in the entire diameter. This specimen has a living chamber somewhat over one-half of a volution in length, and a similar living chamber occurs in a younger specimen longer than in *Eurystomites*.

The whorl in section is an oval with evenly rounded sides, no umbilical shoulders, and the abdomen broader than the dorsum, but in the neanic stage, and perhaps in the early part of the ephebic stage, the sides are evenly rounded and very gibbous, and the venter may be narrower than the dorsum, measuring through the thickest inner part of the whorl ventrad of the impressed zone.

The siphuncle is very large, measuring just before entering the living chamber about 7 mm., and is propioventran in position, but less than its own diameter distant from the venter. It has a sub-ventran position in the ananeanic substage, the earliest age observed. Billings described the siphuncle in *Tarphyceras calciferus* as small at the diameter for the whole shell of three inches, and the septa as numbering about twelve to the inch along the venter at the diameter of three inches. At this diameter in *calciferiforme* the septa are six or eight to the inch, and the siphuncle is about 5 mm. in diameter.

The contact furrow is very slight at all stages. The septa are deeply concave, approximating to those of *Eurystomites gibbosus*, but owing to the slight amount of involution the dorsal lobes are shallow; thus showing the dependence of this character upon the amount of involution, as well as the concavity of the septa. There are broad ventral saddles with almost straight suture or slight lobes, broad lateral lobes trending forwards to narrow saddles at the lines of involution.

The shell is smooth except from strong striæ of growth, and occasional folds as in other species of this group, the casts are all perfectly smooth. A specimen from Phillipsburg has identical form and position of siphuncle, and is in collection of Museum of Comp. Zoölogy.

*Falcilituites.*

This genus set apart by Remelé, the type selected being *Lituites Decheni* equal to *Discoceras subcostatum* Ang. et Lindstrom.\* This species has a very close-coiled whorl in the nepionic stage, the umbilical perforation not being figured at all by Angelin and Lindstrom, a fact of essential importance when comparing this type with *Estonioceras*. The coiled volutions are three in number according to their figures, but the centre may be erroneously drawn.

The shell has a decidedly quadragonal whorl like that of some species of *Schroederoceras*, and the abdomen is even slightly concave along the median portion? The lines of growth are strongly marked and have a different aspect from those of *Estonioceras*. The hyponomic sinus is deeper and broader and apparently the lateral lines rise towards the dorsum in crests, but these really join across the dorsum, forming one huge broad, dorsal crest. In other words, if figured correctly, the aperture on the free volution must have had a very deep hyponomic sinus and huge projecting dorso-lateral crests undivided by any dorsal sinus as in *Estonioceras*. The closely coiled volutions may have had lines of growth with dorsal sinuses, but if so these disappeared on the free part of the whorls. These volutions may also have had a contact furrow, but it must have been slight, since it entirely disappears on the early part of the free volution in both of the European species mentioned below.

The sutures have also ventral saddles with deep lateral lobes. Dorsal sutures are not given.

The siphuncle is much smaller than in *Estonioceras* and is nearer the centre, being but little above this point or centroventren. This organ is elliphoanoidal according to Angelin and Lindstrom figures which are very clear and apparently exact.

There are only two species as yet described, *Falcilituites Decheni*

\*I have not been able to obtain from any library in this vicinity Remelé's principal works, but there is no doubt that he selected *Discoceras subcostatum*, as described by Angelin and Lindstrom. His papers were published in the *Festsch. 50 Jahr. Jubelf. d. Forstakad. Eberswalde*, and the *Untersuch. u. d. versteinerngsf. Diluvial.*, etc.

Remelé, sp. Ang. et Lindstrom, and *Facilituites ? Muellaueri*, sp. Dewitz. This last has the ventral saddles and approximately quadrangular form of this genus. The sutures also have dorsal saddles and the siphuncle is small and central. There is a slight contact furrow in the coiled volutions, which is still retained, but shows to a less degree in the free part of the whorl as figured by Dewitz, and the dorsal part of the aperture is flat, not concave. The living chamber was evidently entirely free in these two species when full grown, since in the figures by Angelin and Lindstrom and by Dewitz this is shown. The umbilical perforation in *Muellaueri* is so much larger than in *Decheni* that I refer this species to this genus with considerable doubt. The close-coiled volutions are only two in number.

#### *Trocholitidæ.*

This group was formerly included by the author under the family name of Tainoceratidæ, but was separated in Carboniferous Cephalopods Fourth Ann. Rep. Geol. Surv. Texas, and is here placed under its proper title. The shells are smooth, or with heavy transverse ridges, which are really primitive costations, but are never very prominent. The whorls are nephritic or depressed subquadrangular or trapezoidal, the venter generally broader than the dorsum, and the form is usually nautilian. The sutures as a rule have broad and slight ventral lobes and lateral lobes.

The siphuncle is dorsal of the centre. The genera are as follows: Litoceras and Trocholitoceras confined to the Quebec faunas, Schroederoceras and Trocholites found in both the Quebec faunas and the Lower Silurian.

#### *Schroederoceras.*

This genus has been described by Schroeder and others as Discoceras, and as having close affinity with Trocholites.

The affinity with Discoceras is apparently close, but when one considers the heavily costated shells of that genus and the younger stages of the conch, it becomes obvious that the species having such distinct characters and different modes of development cannot be associated according to the mode of research adopted here.

There are some species like *Schroederoceras Eatoni* and *Eichwaldi*, which approximate in the number and form of the whorls to

Trocholites, but this is not sustained by closer approximation in the early stages. The nepionic stage has whorls which depart more widely from the trocholitean form of the same age than the later stages of growth.

The umbilical perforation is large, the whorls are few in number and increase less rapidly by growth and change more in form than in Trocholites, the sutures are more sinuous, the siphuncle is not so close to the dorsum, the apertures narrower in transverse and longer proportionately in ventro-dorsal diameters and have deeper narrower hyponomic sinuses, the living chambers are much shorter, varying, so far as known, from less than one-fourth of a volution to somewhat more than one-half of a volution, and the size is very much greater at the same age in all dimensions and there are fewer whorls.

The resemblances consist in the surface ornamentation, which, although much coarser, is similar to that of Trocholites.

But even here the deep V-shaped dorsal sinus found in some species is quite distinct. The aspect of the neanic stage before the whorl acquires the flattened abdomen and sides is similar, but this likeness becomes of less importance when the younger nepionic stage is considered. The ananepionic substage may possibly have very fine straight transverse striations, which are not usually visible, but it is apparently smooth as seen in my specimens and in the figures given by others.\* The metanepionic stage has strong transverse bands of growth with finer striæ on the surface of the bands. The borders of the bands are prominent and crenulated, the crenulation being due to short longitudinal depression and intermediate folds that occupy the edges of the bands and are discontinuous between them.

The costations also begin to appear in this substage, and these are in some species apparent as obscure folds on the casts. These are distinct from the bands of growth being less numerous on the surface and more widely separated. The crenulations disappear subsequently probably before the completion of the second whorl, but there are often a few continuous longitudinal raised lines perceptible on the centre of the venter and near the umbilical shoulders. The cyrtoceran form is retained longer in the nepionic stage than in Trocholites and the change to the gyroceran curve that brings

\* See Schroeder's figure of *Schroederoceras* (*Troch.*) *Damesi*, *Pal. Abh.* v, Pl. xxviii, Fig. 2a.

the whorl finally into contact is more gradual, so that the umbilical perforation is larger and the contact occurs in the usual way on the ventral side of the ananepionic substage, instead of on the dorsal side of the metanepionic substage, as in *Trocholites*.

The whorl has short ventro-dorsal and longer transverse diameters, or broad whorls like many species of *Trocholites*, but is like a broad whorled typical nautilian form from the earliest stage and has not the kidney-shaped outline so common in sections, especially of the younger stages of the shell in *Trocholites*.

The modifications of this outline through the flattening of the abdomen and lessening of the gibbosity of the sides occurs doubtless at different stages in different species, but in *Schroederoceras angulatum* and *Saemanni* it is fully developed only in adults.

The contact furrow is well marked in the young and continues in some species to be a well-defined depression throughout life, becoming, however, somewhat less marked in the free part of the whorl or gerontic stage. In some species it is very faintly marked apparently before this stage is reached. It seems to be dependent upon the closeness of the coiling and involution, which is as a rule very slight at all stages in the ontogeny and all stages in the phylogeny. It is consequently somewhat remarkable that this zone should persist upon the dorsum of the shell so long after the whorl becomes free of pressure on that side in the gerontic stage.

The siphuncle does not apparently, so far as is seen, materially change the position it has at the end of the first whorl. It may, as in *Saemanni*, become slightly more removed from the dorsum, but in *angulatum* it is very close to the dorsum, even in the ephelic stage. The walls of this organ are thick, and it is often preserved in the middle of loosely crystalline calcareous deposits under conditions which are not usually considered favorable for the preservation of siphuncles.

#### SCHROEDEROCERAS ANGULATUM.

LITUITES ANGULATUM Saem. (*Palentogr.*, iii, Pl. xxi, Fig. 1a-b; not c-d).

Loc., Brevig, Norway.

The original of the *Lit. angulatus* of Saemann (Fig. 1a-b) is in the Mus. of Comp. Zoölogy. It has a subquadrangular whorl in the ephelic stage with a flattened and slightly concave abdomen. The shape in cross section is peculiar and quite different from that in Fig. 1d. The abdomen on the living chamber is slightly elevated

the flat zone being narrower than the transverse diameters immediately internal to this. This may be due to compression, since on the septate portion the lateral curve from the abdomen to the umbilical shoulders show the somewhat flattened aspect given in Saemann's figure. The umbilical shoulders are rounded. The abdomen not so broad as the dorsum, that is not so broad as the transverse diameter through the umbilical shoulders.

The cast shows faint broad fold-like costations bending apically which were more prominent on the shell, as is shown by other specimens from the same locality. Saemann's figure is correct in outline and proportions, but it is incorrect in that it does not give the sutures which are apparent on the original, and it also brings the cast of the whorls in close contact, whereas these are separated by the thick dorsal and ventral shell layers. The whole surface of the cast is also erroneously given, since it is marked by obscure costations, which must have been more prominent upon the exterior of the shell. These are more prominent in the young than upon the full-grown whorls. The sutures have well-marked ventral and dorsal lobes and lateral lobes with saddles at the abdominal angles and umbilical shoulders. The sutures are numerous and close together as in most species of this group and in *Trocholites*.

The siphuncle is nearer the dorsum than that given in Fig. 1c.

The apex is smaller than in the original of Figs. 1c and 1d, and the umbilical perforation smaller and the rate of increase by growth less, so that the species is smaller than *Saemanni*.

The living chamber in *angulatus* is free as figured by Saemann on the outer part only. In the original of Fig. 1c-d it is free for nearly the entire length.

The prominent costæ of the true *Disc. antiquissimum* are not present in this shell nor in its allies, and the differences in form are supplemented by the close coiling of the living chamber in *antiquissimum*.

Saemann's original is 91 mm. in diameter, and has somewhat more than three and a half volutions. The living chamber measured along the median lateral line is 53 mm. in length from aperture to suture. The transverse diameter of the septal floor is 26.5 mm., the dorso-ventral diameter in median plane is 20.5, both without the shell. The aperture is narrower in proportion to the ventro-dorsal diameter, owing to the flaring of the lips and the slight constriction. Only one-half is preserved and it is slightly distorted; it may be a

little too narrow in the figure on account of the necessary restoration, and the ventral sinus is somewhat too narrow and too deep owing to a mistake of the artist. The impressed zone continues on the free part of the living chamber, but becomes distinctly shallower and is almost obliterated in the dorsal outline of the aperture.

SCHROEDEROCERAS SAEMANNI.

LITUITES ANGULATUS Saem. (*Paleon.*, iii, Pl. xxi, Fig. 1c-d; not Fig. 1a-b).

Loc., Brevig, Norway.

The two specimens used by Saemann, one for his section Fig. 1d, and other for the siphuncle, Fig. 1c, are both in the collection of the Mus. Comp. Zoölogy and cannot be considered identical with *Lituities angulatus* (Figs. 1a-b).

The characteristic differences have been noted under description of that species. The abdomen of the ephebic stage is flat and slightly convex, broader than the dorsum, and the sides are slightly flattened in the full grown as in the Saemann's Fig. 1d, which was taken from the exposed last septum or floor of a living chamber in the metephebic substage on the last quarter of the third volution, a substage preceding that in which the whorl became free, which I have considered as the parephebic substage. The sides incline inwards and the umbilical shoulders are hardly perceptible.

There is an impressed zone broader and deeper than in *Schroederoceras angulatum*. The sutures are similar, but have a broader ventral, dorsal and lateral lobes. The saddles on the abdominal angles and those at the lines of involution are also narrower.

The siphuncle is propiodorsan on the first quarter of the fourth volution, as figured by Saemann. It is nearer the dorsum in the younger whorl, being less than its own diameter distant from that side on the early part of the third quarter of the second whorl.

The sides are gibbous and the abdomen rounded throughout the earlier whorls until the beginning of the third whorl in the anephebic substage.

The ventrodorsal diameters increase by growth more rapidly than in *angulatum*, and the whole shell is consequently larger at corresponding stages of development.

The living chamber is longer as well as in every way larger on the third whorl in the anephebic substage before the free part of the whorl is reached, than it is in *angulatum* at a later age in the early part of the parephebic substage as figured by Saemann. In this

specimen, the original of Fig. 1*d*, it is about 75 mm. in length along the median lateral line from suture to aperture. The transverse diameter of the septal floor of this given by Saemann in Fig. 1*d* is 29 mm., the ventro-dorsal diameter in the median plane being 24 mm.

The aperture at this stage spreads laterally, slightly flaring but without any preceding constriction. The hyponomic sinus of the aperture was not preserved, but judging from the lines of growth in both species it was broader and perhaps shallower than in *angulatum*. In the larger specimen, the original of Fig. 1*c*, the living chamber was measured along the umbilicus, it being incomplete. The whole diameter of this shell, consisting of nearly four and three-fourths volutions, when complete was over 112 mm.

The length of the living chamber measured along the inner part on the umbilical line, corresponding to the line of involution, was about 75 mm. As estimated by measurements corresponding to this along the median lateral line to a point opposite the termination of the inner line of measurement, this living chamber was certainly over 100 mm. in length. The transverse diameter of the venter of this living chamber at 35 mm. beyond (orad) the septal floor was 34 mm. without the shell. The shell would increase this to between 2 and 4 mm., according to the place of measurement, whether between or on the ridges. There are well-marked narrow ridges or costæ at more or less irregular intervals on this shell with coarse lines of growth between them. These ridges are not perceptibly reflected on the cast of the interior as in *angulatum*, even in the young stages of one specimen, but in another they are faintly shown on the cast of the side of part of the third whorl.

I have been entirely unable to find the usual marks on the exterior of the siphuncle of this species, or any other similar form which usually accompanies the short funnels of elliphoanoidal forms, but Holms and Schroeder's statements are specific, and they have had better opportunities for their studies, so that I merely suggest a doubt with regard to the structure of such siphuncles as appear in this species and which have usually been described as annulated. The contact furrow is well marked in the neanic stage and in ephebic and metaphebic substages, but in the paraphebic stage it is perceptibly lessened and shows a decided tendency to disappear on the free whorl. The dorsum was distorted near the apertural end so that the exact amount of this diminution could not

be seen, but it was clear that the impressed zone had become narrower and shallower. The termination of the living chamber being also absent, it could not be ascertained whether it finally disappeared or not on the dorsal rim of the aperture.

SCHROEDEROCERAS TUBULATUM, n. s. Pl. vii, Figs. 1-3, and Pl. xiv, Figs. 6-12, > $\frac{1}{3}$ .

Loc., Brevig, Norway.

This species was included by Saemann under the head of *angulatum*, but it has much broader whorls, increases more slowly in size and the free part of the whorl is longer, not only the living chamber but a considerable portion of the septate whorl being free.

A cast of the latter part of the first or first part of the second whorl is costated, and the narrowness of the side shows that the young whorl was not so broad ventro-dorsally as in *angulatus* at the same stage.

One specimen shows the living chamber in the epehebic stage before the uncoiling begins. This is of about the same age as that figured by Saemann in his *angulatus*, Section 1d. The ventro-dorsal diameter of the septal floor of this is 26 mm., and the transverse about 32 mm. The venter was the broadest part at this stage as it is in the early epehebic stage of *angulatum*. The umbilical shoulders do not exist even in the rounded form that they take on in the adult of *angulatus* and in the epehebic and gerontic whorls of *Saemanni*. The sides incline or diverge outwardly more decidedly and are flatter than in *Saemanni* at the same stage.

The shell has coarse lines of growth upon this living chamber at more or less irregular intervals, with finer lines between them, and at still rarer and less regular intervals there are the usual narrow ridges which are the remains of the costæ of earlier stages. The ventral sinus is broader and deeper than in *angulatus* or *Saemanni* at the same stage, and there is a deep sinus in the impressed zone on the dorsum with a shallow subacute V shape.

The type of the species is the specimen showing the extended last whorl figured in this paper, Pl. vii, Fig. 1.

According to my estimate this specimen must have had at least five complete whorls. The diameter of the coiled part was probably about 118 mm., and this is estimated to contain nearly five volutions, the length of the free part was over 115 mm. measured along the median lateral line, along the dorsal line of this mould of the outer whorl it could be measured more readily as 105 mm.

The incomplete living chamber occupied 75 mm. of this free part as measured above the median lateral line from the broken edge to the imperfect remnant of the septal floor.

The transverse diameter of the termination of the third whorl was 15 mm. without the shell, the breadth of the side 10 mm., the ventro-dorsal diameter in the mesal plane, as estimated, was of about the same length. The transverse diameter about the middle of the last quarter of the fourth whorl was 22 mm., the ventro-dorsal in the mesal plane was 17 mm. both without the shell.

The shape of the living chamber must have been greatly altered near its termination. The fragment of mould of one side and part of the dorsum preserved shows that the impressed zone had become narrowed and disappeared completely. The dorsum remained slightly flattened, but this flattening given in the restored section, Fig. 3, Pl. vii, is probably greater than it was in the fossil. The lines of growth on the dorsum of the first part of the free living chamber have such a faint sinus that they would ordinarily be described as straight, the lateral crests are much reduced, the ventral sinus was not visible, but it also probably became reduced or shallower. The transverse diameters were also much reduced, and aspect of the aperture changes so that the ventro-dorsal diameter is much longer than the transverse. The outline given may be defective in making this diameter somewhat too long and the abdomen not quite flat enough, but certainly there is an entire change in the proportions of the whorl and an approximation to this reconstructed outline.

The sutures do not differ materially, if at all from those of *Saemanni* so far as could be seen. They are visible on the third whorl and had the usual curvatures. The two last on the fifth whorl were visible on the dorsum and partly on the side. These had a deep dorsal lobe, with saddles and lateral lobe as in *Saemanni*, and were very interesting, since they showed that the dorsal sutures had not been immediately affected by separation of the whorls. The last suture is given in Fig. 1, on Pl. vii.

The zone of impression is fainter, but still perceptible in the dorsum of the first part of the living chamber, but has entirely disappeared on the latter part of the same. It is more strongly marked on the dorsum of the third and early part of the fourth whorls than on the latter part of the fourth, but it is broad and still quite dis-

tinct just before the whorl becomes free on the last quarter of the fifth volution (Fig. 2).

The nepionic stage of this species is given in Figs. 6-7, Pl. xiv. The advent of the hyponomic sinus can be seen in the lines of growth of the metanepionic substage in the front view, Fig. 6. The umbilical perforation is larger than it appears to be in the side view, Fig. 7, because it is in part overlapped by the inward growth of the umbilical zones of the paranepionic volution.

The lines of growth are entire and very fine lines on the ananepionic and metanepionic substages, and there are no longitudinal ridges. The sides are convergent and rounded, and the abdomen is rounded and narrower than the dorsum in these substages. At the beginning of the paranepionic the abdomen becomes suddenly flattened, the sides also tending to become flatter and the whorl spreads laterally very fast, the venter becoming wider than the dorsum. Slight crenulations also appear, and in consequence of these faint longitudinal lines may be seen with a magnifier.

Regularly spaced transverse lines are first noticeable in the paranepionic forming the forward edges of broad laminæ on the surface and having finer lines of growth between them, as in Fig. 10, Pl. xiv.

The septa in this substage are deeply concave and have broad ventral saddles divided by narrow V-shaped central ventral lobes, as in Fig. 10, Pl. xiv. There are shallow lateral lobes and dorsal lobes in the contact furrow.

The siphuncle is propiodorsan in this substage as given in Fig. 9, but was not seen in earlier ages. It is slightly nearer the dorsum in the succeeding stages of development of this specimen.

A distinct dorsal furrow appears in this shell in the early part of the paranepionic and deepens until replaced and enlarged by the contact furrow. Contact takes place upon the area of the scar, but not on the dorsal side of this area. I was not able to define the exact line of contact because the apex had been slightly fractured in making the preparation, but it was quite clear that contact did not occur upon the dorsum of the ana- nor metanepionic substages as it does in Trocholites. The involution is greater and the contact furrow deeper in the ananepionic substage, where it begins, than at any subsequent substage, as shown in Fig. 8, Pl. xiv.

In the meta- and paraneanic substages the more prominent lines of growth described above on the edges of the broad bands become

subcostal in aspect, but are somewhat exaggerated in Fig. 11. In the ephelic stages these subcostæ are less prominent and do not have any corresponding ridges on the cast, which is smooth. The venter is also less elevated, the ventro-dorsal being less in proportion to the transverse diameters and the whorl assumes the broad depressed outline in section of this species.

SCHROEDEROCERAS RAROSPIRA.

CLYMENIA RAROSPIRA (*pars*) Eichw. (*Leth. Rossica*, Pl. 1, Fig. 1a-b, Fig. 3; not Fig. 2a-b, nor Fig. 6a, b, c\*).

This species has the aspect of *Schroederoceras Saemanni* on the latter part of the second and third whorl, but the early part of the same whorl in section is rounded and without a zone of impression. The whorls increase faster by growth in the ventro-dorsal diameters than in *Saemanni*. If Eichwald's figures can be relied upon the species are distinct. The distribution of the prominent striæ of the neanic stage is instructive. They occupy all of the first whorl except the apical part and are lost upon the last half of the second whorl, persisting somewhat longer than in *Saemanni* or *angulatum*. The siphuncle is depicted as very large, and according to the figure is nearer the dorsum in the first and second whorl than it is in the same age in *Saemanni*. The faster increase in dorso-ventral diameters makes the adult somewhat larger in diameter of the coil at the same age.

The fact that the last volution is not free at the end shows probably that the specimen figured had not reached the gerontic stage of degeneration. It is of course to be expected that some species of *Schroederoceras* never become uncoiled, and this may be one of these. Eichwald's Fig. 1b also shows that the impressed zone is deeper on the second whorl in the anephebic stage than it is subsequently on the third whorl in the parephebic when a tendency towards uncoiling begins to show itself in this way. The sutures, as shown in Figs. 3a, b, c, are like those of *Saemanni*.

SCHROEDEROCERAS TERES.

LIT. TERES, Eichw. (*Sil. in Esthland*, p. 105).

LIT. TERES, Dewitz (*Schrif. physical-okonon. Gesell.*, Königsberg, xx, Pl. iv, Fig. 4).

LIT. TERES, Schroeder (*ibid.*, xxii, Pl. ii, Fig. 2).

DISCOC. TERES, Schroeder (*ibid.*, xxiii, p. 96).

\*See *Trochilitoceras Eichwaldi*.

LIT. TERES, Holm (*Pal. Abh.*, Dames et Kayser, iii, hft. i, Pl. v, Fig. 5-8).

Loc., Kandel, Esthland.

The smooth whorl has in section an abdomen somewhat broader than the dorsum as figured by Dewitz and the siphuncle closer to the dorsum than in *Odini*. The living chamber is free and the aperture like that of *angulatum*. The impressed zone is continued to the edge of the aperture. It suffers, however, a certain obvious diminution and the dorsal edge of the aperture is merely flattened instead of being concave as is the dorsum at the beginning of the living chamber. This peculiarity is described by Schröder, who gives the best figures.

Holms' figures of the young have been copied in outline on Pl. vi, Fig. 21-27. These sections show how closely the young resemble those of *Schroederoceras Eatonii*, and if correctly identified and drawn indicate considerable variation in the form of the young and the relations of the umbilical perforation. In Fig. 21, it is between the ananepionic and paranepionic; in Fig. 22, it is situated as in *Trocholites*, viz., carried more on to the metanepionic substage, and is differently shaped.

The young (Figs. 23-27) give a rare opportunity for the study of the nepionic stage. The ananepionic substage (Figs. 26-27) is like that of *Eatonii*, and one sees the peculiar shape of the apex and the great comparative depth of the apical chamber. The first septum and cæcum of course belongs to the later metanepionic substage, but the whorl itself is ananepionic, and this a broad elliptical section as seen in the front view of Fig. 26. The dorsum broader than the venter and rounded. The shape is here decidedly cyrtoceran. The first septum and cæcum is seen in this view and the siphuncle is subventran. In the metanepionic it changes as in other forms towards the centre. This is shown by its becoming extracentroventran in the third septum, which belongs to the later age of the paranepionic substage. At the angle of the turn a faint, but plainly marked dorsal furrow appears. The point at which this impression occurs is like that of similar forms of early faunas, and the shape of the whorls show a very rapid increase of the lateral diameters and the usual approximation to the kidney-shaped whorl which characterizes rapidly growing shells of Nautiloids at similar substages. It seems probable, therefore, that this may have been

produced by the mechanical effect of the proximity of the stiff wall of the metanepionic substage. It would be extremely instructive to make a number of such preparations and study comparatively the amount and variability of this characteristic with relation to the size of the umbilical perforation, its position, etc.

SCHROEDEROCERAS? BANDONIS.

SCHROEDEROCERAS? BANDONIS, Rem. (*Unter. verstein. Diluvial-gescheibe*, i, Pl. iii, Fig. 4).

SCHROEDEROCERAS ODINI, Vern. (*Geol. Russia, Pal.*, ii, Pl. xxv, Fig. 8).

This entirely smooth shell has rounded whorls, the ventro-dorsal diameters in adults longer than the transverse. There are deeply sinuous sutures with slight ventral lobes on the abdomen in the neanic stage, and these are replaced by flattened saddles (if correctly figured) in the epebic whorl. It is obviously, if the characters are correctly depicted, quite distinct from *Schroed. teres*. These species agree in general aspect, but not in the form of whorl of the coiled stages of growth, and differ also in the sutures and in position of siphuncle and in the shape of the free whorl.

In *Odini* there is no impressed zone on the free whorl, and probably this was very slight in the neanic stage, as shown by Verneuil's Fig. 8c.

SCHROEDEROCERAS DENCKELMANNI.

LIT. CORNUARIETIS, De Vern. (*Pal. Russia*, Pl. xxv, Fig. 7).

LIT. DENCKELMANNI, Rem.

DISCOCERAS DENCKELMANNI, Rem. (*Zeitsch. deutsch. geol. Gesell.*, xxxviii, 1886, p. 468).

This is a completely smooth shell with rounded and more numerous whorls at the same size than in *Schroederoceras angulatum* and a less deeply marked impressed zone.

SCHROEDEROCERAS DAMESI.

TROCHOLITES DAMESI, Schroeder ("Ceph. d. Untersil.," *Pal. Abh.*, Dames et Kayser, v, Pl. xxviii, Fig. 2).

This shell was erroneously referred to Trocholites by Schröder, if his figure is correct. The young has the large umbilical perforation, the large whorls and rapid increase by growth, as well as the characteristic surface markings of this genus. The last whorl has

also the form common in the neanic stage of species like *Schroederoceras angulatum* and especially *Saemanni*, which it very closely resembles. It is obviously an immature shell of some species of this genus.

SCHROEDEROCERAS EATONI.

LITUITES EATONI, Whitf. (*Bull. Am. Mus.*, New York, i, No. 8, Pl. xxviii (?), Fig. 5-7 et. Pl. xxxii, Fig. 1; not Fig. 2).

DISCOCERAS EATONI, Schröder ("Sil. Ceph.," *Pal. Abh.*, Dames et Kayser, v, p. 22). Pl. vi, Figs. 28-35, and Pl. vii, Figs. 7-8.

Loc., Fort Cassin, Lake Champlain.

Having had the original of this species, I am able to state that the apex or nepionic stage is closely similar to that of Holms' figures of *Schroederoceras* (*Lit.*) *teres*. The single specimen, Fig. 35, Pl. vi, that showed this section has a large apical or air chamber very deep and cap-shaped in outline, with abrupt ventral side, exactly as in Holms' figures, the second chamber being proportionately somewhat less in depth. The umbilical perforation is, however, much larger, as may be seen in this section, and in Fig. 31, Pl. vi.

The septa continue throughout the first and larger part of the second whorl, that is during the nepionic and neanic stages, to be proportionately wider apart on the venter and nearer together on the dorsum until the decrease by growth in the ventro-dorsal diameters in the anephebic stage makes them more equal on the first quarter of the third whorl where they begin to assume the usual depths. The siphuncle begins subventran in the first chamber, inclining centrally in its passage through the first and succeeding septa until near the end of the first whorl, when it becomes centren. It is in other words nearer the venter than the centre during the cyrtoceran or nepionic stage and becomes centren in the ananeanic substage, as in the figure from Whitfield's specimen and in other figures, Pl. vi.

The sutures have the usual broad ventral saddles and lateral lobes in the nepionic stage and probably dorsal saddles, but these last were not distinctly seen.

The siphuncle in the metaneanic and paraneanic substages trends slowly towards the dorsum until the third quarter of the second whorl is reached, and after that the approximation proceeds more

rapidly until it reaches the centrodorsan position in the anepibic substage at the beginning of the third whorl.

The ventro-dorsal diameters also slowly decrease by growth comparatively with this movement, along the mesal plane and proceed with equal steps, correlative with changes in the septa, and relative dimensions and shapes of the air chambers and the shifting of the siphuncle towards the dorsum to the first quarter of the third whorl where they take on the adult proportions and aspect.

These facts are admirably well shown in the figures of *Schroedero-ceras* (*Lit.*) *teres* by Holm, reproduced here if allowance is made for the more cyrtoceran or less involute form of *Eatoni*, which has a larger umbilical perforation. The third septum in both forms, however, comes internally to the same point, the end of the cyrtoceran stage, when the whorl makes a sudden bend and assumes the gyroceran curvature that brings it at the end of the first whorl against apex of the conch. In Figs. 21 and 22, from Holm, this bend is more abrupt and more like that of *Trocholites* than in this species. The dorsal side of the last quarter of the first whorl actually strikes and lies upon the dorsal side of the first air chamber, whereas in this species the contact takes place farther towards the apex. In *teres* also, according to Holm's figures, the approximation of the siphuncle towards the dorsum takes place more rapidly and probably earlier than in *Eatoni*. Holm found no signs of a cicatrix on the apex of *teres*, but no shell is represented in his figures and he describes the whorls as so very closely approximated that there was but one shell wall. The young shell is very thin, and probably this explains the difficulty of separating the whorls. At any rate, the absence of the cicatrix is not established by his observations. I think he must have overlooked the shell wall, this not being absent in any other forms that I have examined.

Fig. 34, Pl. vi, gives the aspect of an accidental section, the location of which is shown by the line through Fig. 35, taken from the center of Whitfield's original of this species. The sections passed subdorsan to the shell, cutting across the two first septa of the metanepionic substage. The peculiar aspect of this part of the section is due to the continuity of the lateral shell lines on either side with those of the paranepionic whorl which is given in section of volution immediately under this. The convex line dividing the metanepionic from the paranepionic volution, the projecting third septum. The reverse, the splinter from which this section was

taken, is given in Fig. 31, Pl. vi. The core of the umbilical perforation was exposed, the metanepionic volution is smaller and younger, the paranepionic section is older and is shown to be convex on the gyroceran turn or curve around the core. The state of the section left this observation open to some doubt owing to the fact that it was slightly clipped on one side, exposing an older part of the same whorl. On wearing this same section down a shade farther the beginning of a dorsal furrow became apparent, and is given in Figs. 32, 33.

It is, however, obvious that the dorsal furrow is very slight and it occurs in the usual place on the paranepionic dorsum; the rotundity and form of the metanepionic whorl was perfectly well defined. The umbilical perforation in this fossil was very small, and the occurrence of a dorsal furrow at the place designated in the drawing could be accounted for as due to the contiguity of the dorsum of the growing whorl of the paranepionic to that of the stiff wall of the metanepionic substage.

The position of the siphuncle in the apex could not be determined, but its place in the other whorls was plainly seen and agrees closely enough with the positions determined by Whitfield in the young of *Eatoni*, with which also the characters of the sutures of the older whorls agreed in this specimen.

The contact furrow is deeper relatively in the neanic stage than it is subsequently, when one takes into account the form of the whorl and the relative extent of the sides covered by involution. It is, however, very well marked in all stages, and its disappearance upon the latter part of the last whorl, as has been shown in Whitfield's figures and those given in this paper, is a significant and instructive fact that has been discussed in other parts of this essay. The aperture of Fig. 7, Pl. vii, was removable, and this being taken off the last vestige of the impressed zone is seen on the dorsal side of the free whorl in the front view of the same specimen, Fig. 8. The portion removed is so short that it is possible it may represent the rim of the aperture itself.

The sutures of the anephebic stages differ considerably from those of the adult, being straighter and more like those of Trocholites, and it may be questioned whether this should not be called the paranepionic substage on account of its close resemblances to Trocholites.

In the full-grown shell of the parephebic and gerontic age, as

shown in Whitfield's figure, Pl. xxxii, and in my figure, the oldest sutures are more sinuous than those of an earlier stage just under the free part of the living chamber, as given in my copy of his figure, with sutures drawn in from the original chambers (Fig. 28, Pl. vi). They have normally in the ephebic stage ventral and dorsal lobes, with lateral lobes and saddles at the abdominal angles and umbilical shoulders.

The length of the living chamber in a full-grown specimen is over one-half a volution, and the latter part is free, as given by Whitfield and in my Fig. 7, Pl. vii.

SCHROEDEROCERAS CASINENSIS.

LITUITES EATONI, var. CASINENSIS. Whitf. (*Bullet. Am. Mus.*, New York, i, No. 8, Pl. xxxii). Pl. vi, Figs. 36-38, and Pl. vii, Figs. 4-6.

Loc., Fort Cassin, Lake Champlain.

This is a distinct species, the sutures being straighter in the ephebic stage than in true *Eatoni*, the venter and sides are more decidedly flattened, and the relative proportions of the last whorl at the same age different.\* The ventro-dorsal and transverse diameters are about equal, whereas in *Eatoni* the transverse is considerably longer than the ventro-dorsal in the mesal plane. The amount of involution in *Eatoni* and the depth of the contact furrow in the ephebic stage is also greater.

Whitfield's figure is given on Pl. vi, Fig. 36, with some emendations taken from the original specimen. This shows that the ephebic stage had not a free living chamber, and that shown in my Fig. 4, Pl. vii, represents the gerontic stage. The front view, Fig. 5, shows the deeper contact furrow and the dorsal lobes in the dorsum of the metephebic substage and the slight but imperceptible change which takes place in the broader, shallower zone of the early part of the gerontic living chamber below. The free part of this chamber is at first concave just beyond the broken end of the metephebic whorl, then flattened, and finally convex on the dorsum, as shown in Figs. 5 and 6.

The length of this living chamber was nearly three-fourths of a volution, beginning somewhat beyond the broken part given in

\*Whitfield himself thought this was probably a distinct species, as shown by his remarks on page 332.

Figs. 4 and 5. The siphuncle is very large and propiodorsan in the ephebic and gerontic stage.

*Litoceras.*

This genus was described in *Genera of Fossil Cephalopods*, page 259.

The siphuncle is very large and is dorsad or below the centre in adults, but is ventrad in *Litoceras Whiteavsi* in the neanic and earlier stages, and is very likely ventrad in the young at some stage in all species, as it is in those of *Schroederoceras* that have been studied. The young are slightly costated also and the adults smooth, as in other genera of similar groups. The umbilical perforation is of good size, and in the nepionic stage the shell is cyrtoceran and similar to the shells of *Schroederoceras* of the same group, but with much broader whorls and deeper umbilici. These differences are maintained in the later stages of growth, the whorls being much larger, broader and have in the ephebic stage similar abdomens and convex, divergent sides without umbilical shoulders, resembling the neanic stages of species of *Schroederoceras*.

The increase by growth in the lateral diameters of the whorl is rapid, as in the young of *Schroederoceras* and other allied genera, but it continues longer, and even the adults may have very broad whorls, so that these adults resemble in form the neanic stage of *Schroederoceras*.

The aperture is less compressed than in the full-grown shells of *Schroederoceras*, and resemble those of the anephebic stage of that genus, but are not flaring or trumpet shaped, as in *Trocholites*. In fact, there has been a slight turning in of the edges in all the specimens observed, but this, however, may be due to compression. The hyponomic sinus is smaller and shallower than in the ephebic aperture of *Schroederoceras*.

The contact furrow is broader and deeper than in *Schroederoceras* and the involution more marked on account of the rotundity and breadth of the abdomen, which is covered in.

The end of the whorl, even in full-grown shells, is not free, and in this respect also the species resemble the neanic stage in *Schroederoceras*. The living chambers are, so far as observed, longer than in *Schroederoceras* and shorter than in *Trocholites*.

The sutures have deep dorsal lobes, saddles on the lines of

involution and broad lateral lobes, and the invariable ventral lobe of *Schroederoceras* is replaced by a saddle or nearly straight suture.

The type of this genus, when it was first described, were the specimens in Geological Museum at Ottawa identified as *Nautilus versutus* of Billings, but these appear here as *Litoceras Whiteavsi*, since there is every reason for supposing that they are not the species described by Billings under the name of *versutus*.

LITOCERAS WHITEAVSI.

NAUT. VERSUTUM (?) (*pars*), Bill. (*Geol. Can., Pal. Foss.*, i, p. 258).

Loc., Point Rich and Gargamelle Cove, Newfoundland.

Having examined the so-called originals of this species, so far as they exist in the Geological Survey Museum at Ottawa, I have found that none of them came from Billings' locality, Bonne Bay, and none of them agree with Billings' description. Billings' species had ten septa to the inch; this species has the sutures about one-quarter of an inch apart, a difference showing essential distinction.

The young on the second whorl has the siphuncle ventrocentren and are slightly costated. These costæ disappear before the end of this whorl and the surface is marked only by the lines of growth. The siphuncle also shifts gradually, becoming centrodorsan, but in the adult it does not approximate to the dorsum, remaining nearer the centre than the dorsum. The abdomen is very broad in the later stages, and in the adult the diameter through the abdominal angles is longer than the ventro-dorsal diameter.

The sides are divergent; that is, slope inwardly. They are rounded and have no umbilical shoulders, the dorsum being coextensive with the contact furrow which covers the abdomen completely. The sutures are sinuous, having well-marked ventral saddles, lateral lobes and probably dorsal lobes, although the latter were not seen. The specimens from which this description was taken were collected at Gargamelle Cove, near Billings' locality, and probably belong to this species, as it is identified by the Geological Survey of Canada. The form of the whorl is not so broad laterally, the chamber of habitation is less than one-half of a volution in length and smaller in every way than in *Litoceras insolens*.

A section of the whorl is more like that of *insolens* in the ephe-

bic stage than in the specimens in the museum at Ottawa, but the sides are rounder at the stages of growth observed.

The siphuncle is similarly situated and somewhat smaller than in *insolens*.

The diameter of the largest and most perfect specimen was about 150 mm. The transverse diameter of the fourth whorl at the whole diameter of 75 mm. was 42 mm., and the ventro-dorsal 25 mm. The diameter of the siphuncle at this stage was 4 mm. The diameter of this organ increased slightly to the living chamber, but probably did not exceed 6 or 7 mm. On the last quarter (probably of the fourth whorl), just before the living chamber was reached, the siphuncle was found to be misplaced, as is not uncommon in species from this locality. This organ has very thick walls and often maintains its form and proportions when unsupported by the septa, although thrown out of place by the movements in the matrix, as happened in this case. It is thrown over to the left and arches towards the venter rising above the centre. The specimen being excavated, however, it was found to be in its usual place, a few septa younger than the point at which it appeared. The entrance into the living chamber was not, however, satisfactorily observed, the septum being broken by compression, although the entrance seemed to be in the usual place, between the centre and the dorsum. The septa were about 6 mm. apart as measured on this siphuncle.

The shell was very thick near the aperture, which was similar to that of *insolens*, but appeared to have a narrower hyponomic sinus than in that species. The way in which the lateral crests run forwards to the lines of involution indicate that there was a crest on the dorsum also, but this could not be observed.

LITOCERES INSOLENS (?).

NAUTILUS INSOLENS (?) Bill. (*Pal. Foss.*, i, p. 258). Pl. vi, Figs. 9-11, nat. size.

Loc., Gargamelle Cove, W. Coast Newfoundland.

This species is so similar in dimensions and characteristics to the one described by Billings and was found so near his locality that I have ventured to apply the same name, although he does not distinctly state whether the siphuncle was dorsad or ventrad of the centre.

The types were not to be found in the museum at Ottawa during my visit to that museum several years ago.

The young of this species increases in the transverse diameters with great rapidity. The ananepionic stage, Figs. 9, 10, Pl. vi, has the usual straight, fine striæ and the metanepionic and succeeding substages throughout the first, and a part of the second whorls have the costations which are common at the same age in other shells of this family. The umbilical perforation is of considerable size; the whorls change from the rounded, cyrtoceran form of the ananepionic substage, which apparently has the ventro-dorsal longer than the transverse diameters, very rapidly as the gyroceran stage approaches on the latter part of the first half of the first whorl or the metanepionic substage. In the paranepionic on the last half of the first whorl and before the whorls touch, the whorl is like the metanepionic volution as shown in section in Fig. 11, Pl. vi, trigonal, the venter broader than the dorsum, and the angles are rounded. In the ananeanic substage, after the completion of the first whorl, the whorl becomes digonal, with a contact furrow. Near the end of the first whorl, in the paranepionic substage, the ventro-dorsal diameter was 3 mm., roughly measured; the transverse through the abdominal angles were approximately 6 mm.; half of a volution beyond this, in the ananeanic substage, the transverse had become 10 or 11 mm., and the ventro-dorsal about 6 mm.; less than one-half volution later in the parananeanic the transverse had become 16 mm. and the ventro-dorsal about 7 mm.; somewhat more than one-half volution later, in the anephebic substage, the whorl had become changed to kidney shaped in section, and the septum at the base of the living chamber was exposed. The transverse diameter was 29 mm., the ventro-dorsal 12 mm., both taken without the shell.

Fig. 11, Pl. vi, shows a sectional view of the metanepionic, neanic and ephebic volutions. The diameters through the umbilical zone, parallel with the mesal plane, were equal or about the same, roughly measured, as the ventro-dorsal diameters.

The anephebic sutures of the septum at the base of the living chamber in the specimen figured has a well-marked median saddle, narrower than in a full-grown shell, and on either side of this were faintly marked ventral lobes. These last were continued on the sides, rising steeply to the umbilical zones, where they culminated in broad saddles. These descended abruptly in the contact furrow, forming a broad, deep, dorsal lobe. These sutures are quite

distinct from those of full-grown shells. The siphuncle was propiodorsan, being a shade less than its own diameter removed from that surface, its diameter being 3 mm.

The whorl is still kidney shaped in section in this substage, with rounded lateral zones, elevated rounded abdomen and rounded abdominal angles, but there is an evident tendency to broaden on the sides and to form steep, horizontal umbilical zones. These parts, being developed out of a digonal whorl, have the usual primitive form of the kidney-shaped whorl, but the slightest flattening of the lateral zones would convert the section into a quadragonal outline. There is a deep wide contact furrow at this age, and the involution completely covers the abdomen of the next inner whorl to the abdominal angles, the umbilical zones actually bulging inwards, and encroaching somewhat on the umbilici, comparing closely with the younger stages of *Trocholitoceras Walcottii*, Fig. 12, Pl. vi.

The living chamber of this specimen, Fig. 9, although incomplete, was nearly one-half of a volution in length at the end of the third volution. About one-quarter of a volution from the septal floor it measured in transverse diameter 33 mm. and the ventro-dorsal 15 mm., showing that the rate of growth in the transverse diameter had begun to lessen considerably. The depth of the umbilicus measured from the umbilical shoulders was 15 mm. at about the end of the last half of the third whorl. The shell was very thick on the venter even at this age.

During subsequent growth the sides are apt to become broader and flatter, but the transverse diameters always exceed considerably the ventro-dorsal. The fossils are all apt to be more or less distorted by pressure, so that it is difficult to draw the line between this species and *Litoceras Whiteavesi*, except in the young. In these the whorl is of greater breadth and the siphuncle nearer to the dorsum than the last mentioned.

As the sides become better defined the sutures change. The ventral saddle disappears in a broad lobe or almost straight suture, slight saddles appear at the rounded abdominal angles and the broad lateral lobes ascending to the lines of involution and the blunt saddles, as in the young, on the primitive and rounded umbilical zones are all better defined. The broad deep dorsal lobe also remains as in the young in the contact furrow.

The whorl was not free at the aperture in any specimens observed.

The diameter of the largest specimens was estimated at 177 mm.; the imperfect living chamber in this was somewhat less than one-half of a volution in length. The transverse diameter of the septal floor of this chamber was, estimating by half measurement, more than 74 mm.; the ventro-dorsal about 50 mm. The siphuncle from which the measures were taken may not have been in the centre in this specimen, so the measurements of the transverse diameter may be faulty. The living chamber in this and the next specimen described reached well into the first half of the fifth volution, as estimated by careful comparison with the young specimen above described and figured.

The most perfect fossil of this species was 140 mm. in diameter. The living chamber showing lines of what appeared to be the rugged edge of an aperture was just one-half of a volution in length. The suture of the septal floor was similar to that described above. The transverse diameter at the septal floor was about 60 mm., the diameter through the side about 31 mm. The transverse diameter midway in this chamber became nearly 74 mm., and the diameter through the side 40 mm.

Near the aperture the ventro-dorsal diameters continued to increase and the transverse decreased, or in other words the aperture was not so broad as the middle of the chamber which was slightly expanded. The shell was enormously thick on the venter, showing age, it was near the middle about 2 mm. in thickness, and near this aperture 6.5 mm. in thickness. The lines of growth indicated a very large, broad and deep hyponomic sinus and broad lateral crests, but these were not distinctly seen.

The siphuncle, in the specimen 177 mm. in diameter, reached the large size of 11 mm. at the septal floor, and less than one-half of a volution younger was 6.5 mm. in diameter. The septa were only 6 to 6.5 and 7 mm. apart as measured on the siphuncle at this age near the living chamber. They were nearer together than in adults at this gerontic stage as is usual in outgrown specimens. The last two sutures of the smaller fossil described as 140 mm. in diameter were 7 mm. distant, which is probably the average distance of a full-grown shell, judging also by the remains of an isolated siphuncle in the collection belonging to this species.

LITOCERAS BIANGULATUM, n. s.

Loc., Pt. Rich., Newfoundland.

This shell appears in the collection at Ottawa under the name of

*Nautilus versutus*. The sides, however, until a late stage are angular, forming a truly digonal whorl with broad rotund abdomen.

The ventral saddle is more plainly marked and more prominent, and the whorls more numerous at the same age. There are saddles at the abdominal angles and lateral lobes; the dorsal sutures were not seen. The contact furrow is about the same as in *Litoceras Whiteavesi*. It is simply a species retaining the digonal, neanic whorl until a late stage, probably throughout life.

LITOCERAS? HERCULES.

NAUTILUS HERCULES, Bill. (*Rep. Geol. Surv. Can.*, 1856, p. 306).  
Loc., Charleton Pt., Anticosti.

This smooth shell found in the Lower Silurian of Anticosti has the digonal form of whorl similar to that of *Litoceras biangulatum* and the young of *Litoceras insolens*. It is, however, a very much larger and more rapidly growing shell. The sutures have ventral median saddles, and on either side ventral lobes as in the young of *insolens*. The abdominal angles have saddles and there are well-marked lateral lobes rising to slight saddles at the lines of involution. The diameter of Billings' specimen was  $6\frac{1}{2}$  inches with incomplete living chamber.

*Trocholitoceras*, n. g.

This genus has been framed to include forms which are essentially similar to Trocholites, but have the siphuncle ventrad of the centre in the earlier substages of development.

The forms stand in development and adult characters between *Litoceras* and Trocholites.

Type is *Trocholitoceras Walcottii*.

TROCHOLITOCERAS WALCOTTI. Pl. vi, Figs. 12-20.

Loc., Fort Cassin.

The series of sections drawn in Figs. 14-19, Pl. vi, gives the history of the development of the shell and siphuncle in this interesting species. The first sectional cut (Fig. 14, Pl. vi) shows the round ananepionic volution, the umbilical perforation and below this the paranepionic volution with the siphuncle ventro-centren, and the outline beginning to broaden and approximating to the kidney-shape, above the round ananepionic section is the ananeanic whorl with the siphuncle centrodorsen. It will be observed that this section

cuts at right angles to the long axis of the narrow pear-shaped umbilical perforation and that there is a faint but well-defined dorsal furrow in the dorsum of the paranepionic volution. In Fig. 15 a somewhat older section is shown and the siphuncle of the metanepionic substage is propioventran. The umbilical perforation is narrower in consequence of the approximation to the dorsum of the paranepionic whorl and the dorsal furrow is well-defined at this bend, and broader and deeper than it is beyond this in Fig. 16.

The birth of the dorsal furrow is shown in Fig. 16, since one can see here the distinct outlines of the metanepionic volution broadening out internally, and the dorsal side of this remaining stiff and rounded while the plastic dorsal side of the growing paranepionic volution was bent into a dorsal furrow while being built around this abrupt bend. In Fig. 17 the section has passed inside of the paranepionic whorl, and the aspect begins to be confused by the fact that it cuts across the septa and shell. This and Figs. 18 and 19 are similarly confused, and are of value only for tracing the positions of the siphuncle. This organ obviously begins in a subventran position, becomes propioventran in the metanepionic and paranepionic, centrodorsan in the ananeanic after the completion of the first volution, and finally subdorsan in the meta-neanic substage on the third volution. This position is retained throughout life, as is shown in the section, Fig. 13, Pl. vi.

The innermost volution shown in the side view of the same specimen (Fig. 12) is the last quarter of the third and first quarter of the fourth volutions. The smooth, still kidney-shaped whorl of the last quarter of the third volution in Fig. 13 shows the paranepionic substage. The third sectional outline of a whorl below the central rounded ananeptic tip gives this age, and the third sectional outline of a whorl above the same ananeptic centre gives the section across the first quarter of the fourth whorl, which is the anephebic stage, and has a very distinct outline. Owing to the decrease in the rate of growth of the lateral diameters, the sides and abdomen have become contracted and the kidney shape of the earlier ages has been exchanged for a helmet shape in outline.\*

The living chamber in this specimen occupies at least the greater part of one-half of a volution, but its exact length could not be ascer-

\* This section is unluckily in a position which is the reverse of that of Fig. 12.

tained. The aperture was not very plainly discernible, but was approximately as given in the figure.

The ephebic stage has raised lines or bands of growth straighter on the sides than in the gerontic stage, which has evidently begun on the last whorl. This has moderately heavy ridges which are reflected on the cast of the living chamber.

It is separable from *Schroederoceras Eatoni* by the broad whorls of the young and the near approximation of the siphuncle to the dorsum in the neanic stage.

#### TROCHOLITOCERAS (?) EICHWALDI.

CLYMENIA RAROSPIRA, Eichw. (*Leth. Rossica*, Pl. 1, Fig. 2, a, b, c, and 6, a, b, c; not Fig. 1, a-b, and 3).

The descriptions and figures of Eichwald show conclusively that this is widely different from *Schroederoceras rarospira* and is nearer to true Trocholites. The form of the whorls in the young, the slow rate of increase in the dorso-ventral diameters, the rotundity of the sides and abdomen in the young and even in the full-grown whorls, the small diameter and close approximation of the siphuncle to the dorsum, make this shell very like a species of Trocholites.

On the other hand, the sutures are more sinuous, having deeper ventral and lateral lobes than are common in that genus. The living chambers are less than one-fourth of a volution in length, with the lateral crests of the aperture most prominent about the centre of the lateral aspect.

The question of affinity can of course only be definitely settled after the development of the siphuncle in the apex of the conch has been studied. The appearance of the umbilicus, as shown in Fig 6 of Eichwald, is similar to that of other species of this genus, but this of course may be due to erroneous draughting.

#### *Trocholites.*

This genus has been fully described and correctly defined by Schröder,\* and the following description is largely taken from his work and adapted to the needs of this work. The shell of the neopionic stage, as first shown by Holm,† is so closely coiled that no umbilical perforation is externally visible. Observations of two young specimens of T. described below have, however, shown the

\* "Unters. ub. sil. Ceph.," *Pal. Abt.*, Dames et Kayser, N. F. (current Vol. v), heft 4.

† "Sil. Ceph.," *Pal. Abh.*, Dames et Kayser, iii, Pl. v, Figs. 9, 10 and 11.

existence of lateral depressions or open nepionic umbilici, and the usual umbilical perforation is present, although rendered very small by the closeness of the coiling. -

The first air chamber observed in two specimens is unusually deep and broadens laterally by growth with extreme rapidity. I have not been able to expose a complete apex so as to see the cicatrix, but have seen the outline of the umbilical perforation at the centre. The siphuncle is closed at the end, but not perceptibly swollen into a pouch as in most Nautiloids. It is not close to the dorsum in the first chamber, but the cæcal end is centren as shown in the section of the ananepionic substage (Fig. 24, Pl. iv).

It clings closely to the dorsal side as in the young of *internastriata*, as shown in Fig. 25, which represents a truncated apical chamber and the paranepionic substage of the first whorl. Holm and Schröder's observations have shown that it is ellipochoanoidal or has in other words short funnels and a porous wall between contiguous septa. Schröder's observations apply to the full-grown shell and Holm's to the young.\*

The extremely rapid expansion of the whorls ceases before the first whorl is completed, but it gives to the nepionic shell, when seen from the venter, the aspect so common in Ammonoids during what is usually called the goniatic stage. So far as now known to me, no other Nautiloid possesses this peculiarity to such a remarkable degree in the nepionic stage, Fig. 39, Pl. vi.

The mode of growth of the siphuncle is independent of the close coiling, since it has the same history in *Trocholites internastriata*, with a large umbilical perforation, as in true *Trocholites* of later times, with a more minute perforation.

The septa as in most nautiloids are much wider apart, at first gradually decreasing until the end of the first whorl or thereabouts, as shown in Holm's figures, when they assume the normal distance and are less deeply convex. The sutures exhibit corresponding differences, having large ventral saddles, deep lateral lobes and probably, although these were not clearly seen, dorsal saddles in these earlier stages.

The lines of growth are much straighter in the nepionic stage than subsequently. The hyponomic sinus is so broad and shallow that it is hardly observable on the third quarter of the first whorl

\* Holm's observations and mine are similar and I have reproduced his figure in Pl. iv of this paper.

and the lines are almost straight on the sides. The lines of growth alone are visible. There are no prominent bands marking permanent apertures, nor are the characteristic costæ of *Trocholites* visible, nor any longitudinal ridges in my specimens. Growth lines show that in the nepionic stage not only the form and sutures were distinct but also the aperture. The apertures are trumpet-like in the ephobic stage and have a moderate hyponomic sinus with broad lateral crests, increasing in prominence towards the dorsum. Whether there are sinuses in the contact furrow has not been determined, but one infers their presence because the lines of growth incline apically just before reaching the lines of involution. The form of the whorl continues rounded in all species of this genus, although in some there is a distinct tendency towards angulation of the sides.

The contact furrow appears very early in consequence of the close coiling of the whorl. This zone is not deep, but it is well marked and may extend nearly to the abdominal angles in some species and it remains throughout life. So far as known no specimen has been found with even a part of the last whorl free. The form of the whorl in section is consequently nephritic, except in some species having flatter sides and more pronounced abdominal angles than usual.

In one species only, *T. circularis*, is there any tendency to form a pentagonal whorl and this was not only very obscure but observed only in one specimen, the type form. The whorl is therefore very primitive.

The length of the living chamber is given as usually about three-quarters of a volution by Schröder, but some of his species have it less than one-half of a volution. *T. Remelei* and *T. ammonius* have one invariably somewhat less than one-half of a volution in length. It is obvious that in this genus it varies between these limits.

#### TROCHOLITES INTERNASTRIATA.

LITUITES INTERNASTRIATA Whitf. Fort Cassin Foss. (*Bull. Am. Mus.*, New York, i, No. 8, Pl. xxix, Figs. 5-8). Fort Cassin.

This species, of which I have studied the originals, has young of cytrocera form, with a good-sized umbilical perforation, as in *Schroederoceras* and *Litoceras*. The siphuncle is centren in what is probably the second septum, and it has not the prolongation beyond this septum, as figured by Whitfield. It inclines

rapidly towards the dorsum, attaining a fixed position in the fifth septum, if I am right in estimating the first septum drawn by Whitfield as the second.\*

It is much larger in the nepionic stages, contracting as it nears the sixth, and becoming a narrow tube in the seventh septum. Subsequently it again increases by growth as the shell grows larger, so that it has the usual large diameter common in this group. If the trend of the siphuncle towards the apex from the dorsum to the centre is followed out it can be seen that the cæcum must have been situated somewhat on the ventral side in the apical chamber.

The rapidity with which the siphuncle becomes propiodorsan, attaining this position in the metanepionic substage or as the first whorl bends to assume the gyroceran curve, shows affinity apparently for *Trocholites*, but the position in the second septum and the size of the siphuncle and the sutures of later stages are not in favor of this view. The form of the whorl is very similar to that of *Schroederoceras Eichwaldi*, but from this it is separated by the sutures, which in the ephebic stage on the fourth whorl have slight saddles instead of lobes on the venter and the siphuncle is not so close to the dorsum and is larger. The suture of the earlier stages are straight and are trocholitean in aspect, with well-marked dorsal lobes, as is also the form and ornamentation of the young whorls, which are slightly costated.

There is a well-marked contact furrow, and I did not find the tendency of the last whorl to become free, as described by Whitfield, the contact furrow being well defined at the termination of the whorls in the original of Fig. 5, Pl. xxix, of his work.

The slower growth and distinct form of the apex, which is more cylindrical and not cap shaped, and the development of the siphuncle, separates it from the young of *Schroederoceras Eatoni*, and also that of *Schroederoceras teres* and *Trocholitoceras Walcottii*.

Although the position of the siphuncle at an early stage is not yet known in species of *Litoceras*, this species is obviously distinct because of the narrowness of the whorls, which resemble those of *Eatoni* in outline. Besides the ventral saddles, the sutures of the fourth volution have well-marked lateral lobes and dorsal lobes in the contact furrow. The whorl remains throughout life in transverse section depressed, elliptical, as in *Trocholites*,

\*I am not satisfied with this correction. The aspect of the first chamber is more natural in Whitfield's drawing than in mine.

and the markings resemble those of that genus, as does also the development of the siphuncle. The larger size of the umbilical perforation is interesting, but this alone does not warrant generic separation.

TROCHOLITES CANADENSIS, Pl. iv, Figs. 23 and 24, and Pl. vi, Figs. 39 and 40.

Loc., Falls of Montmorency, near Quebec.

The four specimens representing this species came from the Bronn collection. They are similar to *T. ammonius* in form, but differ in being broader proportionately in the transverse diameters of the whorls and have deeper umbilici. The whorls are rounded, there being no tendency to angularity, either of the sides or abdomen, and in these specimens the size is small. There are fold-like costæ from an early neanic stage and the living chamber may be considerably over one-half of a volution in length. The exterior is marked by longitudinal lines along the venter and often on the sides, but these have none of the regularity and prominence observable in Conrad's figure, and that figure shows no costations which are more prominent and fold-like in this than in *T. ammonius* or any other described species of Trocholites.

The extremely broad aspect in section of the ananepionic volution is given in Fig. 24, as seen from the front. The umbilical perforation between this and the larger paranepionic volution is very narrow. In Fig. 23 looking through the transparent paranepionic volution one sees the umbilical perforation and the metanepionic volution as it is turning or revolving around the core of the perforation. The outlines in both of these views belong to different ages and are, consequently, quite distinct. The upper section of a whorl in Fig. 24 is the ananepionic substage; the upper section in Fig. 23 is a visual section of the metanepionic whorl just before it changes by growth into the paranepionic, which is seen below in same figure, and this last in turn is younger than the lower section in Fig. 24, which is a later age of the same substage. Taking these in regular order, it is seen that the ananepionic has a rounded dorsum and almost digonal whorl on account of its very rapid transverse growth; that this, as it becomes older, acquires a concave dorsum in the metanepionic of Fig. 23. Then, as the whole revolves while growing, at a later age but part of this same substage, after the shell has passed this bend and is freer to grow on

the dorsal side, the centre of the dorsum again begins to round out, but traces of the primitive dorsal furrow remain in the depressions on either side of the central, gibbous dorsal face formed by this outgrowth, as in Fig. 24.

This gibbous face is immediately suppressed when the whorls come into contact, and its transient appearance can only be accounted for as due to the genetic tendency of the paranepionic whorl to resume the gibbous metanepionic form of dorsum as soon as the pressure resulting from the abrupt curve is slightly relieved.\*

#### TROCHOLITES AMMONIUS, Hall.

This species, of which the collection of the Museum of Comparative Zoölogy possesses a very large number, collected by Mr. C. D. Walcott, has a very peculiar, rough, fretted surface, and only very few specimens show longitudinal lines such as are described and figured in *T. planorbiformis* by Conrad. This surface is due to the minute crenulations or waves in the outlines of the projecting edges of the laminæ of growth. When these are wide enough apart one can distinguish crenulated transverse lines; when too close they interfere and the regularity and continuity of the lines are broken into a multitude of more or less discontinuous, short lines. Sometimes a network of lines is formed by the regularity of the intersection of the crests of the crenulations in successive laminæ. This cuticular ornamentation is so easily destroyed that it is often present only on parts of the same specimen.

Longitudinal lines may be seen through it, but, as stated by Hall and observed by the writer, these are rarely present in the New York specimens. They do, however, sometimes exist all over the abdomen and sides, and are well defined in specimens in which the cuticular corrugations are absent.

The lines of growth are extremely crowded, and what are called the costæ occur at wider intervals and more irregularly. They are probably the traces of former apertures. These are more prominent in some specimens than in others, but never seem to have the aspect of true fold-like costations.

The lines of growth form deep, broad sinuses on the venter; rise into lateral crests on the sides, sinking towards the lines of involution, and forming a sinus in the contact furrow. These are

\*This opinion would be more convincing, if it were not for the fact, that in *Cranoceras* similar transformations occur in an adult cyrocæran form of the Devonian.

parallel to the outlines of the apertures, but these last not infrequently have shallow, broad constrictions and slightly projecting or trumpet-like lips in full-grown whorls.

The specimens of *T. ammonius* from the same locality may vary from very broad-whorled forms to those with much narrower almost cylindrical whorls, the former being slightly deeper umbilici and the latter being shallower, as in *T. circularis*. The venter and sides are, however, almost invariably projecting and rounded, unless angulated by compression, whereas in *circularis* there is a distinct tendency towards truncation or flattening of the abdomen and sides.

The sutures in the ephebic stage may be nearly straight, but there are in most specimens broad ventral lobes, saddles at the abdominal angles, lateral lobes and saddles on the umbilical zones and lobes in the contact furrow. These inflections are, however, always slight, and the sutures give the impression of being almost straight in most specimens.

The contact furrow is distinct but not deep in the ephebic stage and continues to be present in the aperture of the whorl, which is never free.

TROCHOLITES INCONGRUUS, Ang. et Lindst.

CLYM. INCONGRUA, Eichw. (*Leth Rossica.*, Pl. 1, Fig. 7).

CLYM. INCONGRUA, Schröder (*Ceph. d. Untersil., Pal. Abh.*, Dames et Kayser, v, heft 4, Pl. ii, Fig. 2-4).

TROCHOLITES INCONGRUUS, Ang. et Lindst. (*Fragm. Sil.*, Pl. ix, Figs. 15-18).

This species is beautifully figured by Angelin and Lindstrom and the living chamber and the lines of growth and sutures fully given. It is obviously a smaller species than *T. ammonius*, with deeper umbilical whorls much broader proportionately, abdomen very broad, but sides rounded as shown by Schröder.

TROCHOLITES HOSPES.

PALEONAUTILUS HOSPES, Remelé (*Zeitsch. deutsch. geol. Gesell.*, xxxiii, 1881, Pl. ii, Fig. 1).

TROCH. HOSPES, Schröder (*Ceph. d. Untersil., Pal. Abh.*, Dames et Kayser, v, heft 4, Pl. i, Figs. 8, 9).

This species, supposed by Remelé to be distinct generically from Trocholites, is merely, as shown by Schröder, a species of Trocho-

litæ, with very broad whorls quite similar to those of his *T. contractus*.

TROCHOLITES DEPRESSUS.

CLYMENIA DEPRESSA, Eichw. (*Leth. Ross.*, Pl. 1, Fig. 5).

TROCH. DEPRESSUS, Schröder (*Ceph. d. Untersil., Pal. Abt.*, Dames et Kayser, v, heft 4, Pl. i, Fig. 4).

TROCHOLITES MACROSTOMA, Schröder (*Ceph. d. Untersil., Pal. Abt.*, Dames et Kayser, v, heft 4, Pl. i, Fig. 1).

TROCH. CONTRACTUS, Schröder (*ibid.*, Pl. i, Fig. 2).

Excessively broad whorls and deep umbilici but no lateral zones. Living chamber about one-half volution in length according to Schröder's drawings. Schröder also describes the following species :

TROCH. ORBIS, Schröder (*ibid.*, Pl. i, Fig. 23).

“ MACROMPHALUS, Schröder (*ibid.*, Pl. i, Fig. 5).

“ SORAVIENSIS, Schröder (*ibid.*, Pl. ii, Fig. 1).

TROCH. REMELEI, Schröder (*ibid.*, p. 18), was described as *T. incongruus* by Ang. et Lindst. (*Frag. Sil.*, Pl. ix, Figs. 15-18), and this has a living chamber not quite one-half a volution in length. His *Troch. damesi* (*ibid.*, Pl. v, Fig. 2) shows sculpturing and form of the young which appears to place it in the genus Schroederoceras rather than in Trocholites and it has been referred to that genus.

*Trocholites circularis*, Mill. et Dyer, of the Cincinnati group of the Hudson river, is probably a distinct species. The type is in the Museum of Comparative Zoölogy. This has an aperture like that of *T. ammonius* and length of living chamber as in that species about one-half of a volution. The whorls are not so stout as in *ammonius*, the sides being slightly compressed, the abdomen narrower than the dorsum.

TROCHOLITES DYERI, n. sp.

This is a form in the Dyer collection from the Cincinnati group, having a form of whorl broader and quite like that of *T. ammonius*, but with a longer living chamber and distinct aperture.

The living chamber is considerably over one-half of a volution in length and the lateral and ventral edges of the aperture are flaring like the mouth of a trumpet. This gives extraordinary prominence to these parts and especially to the hyponomic sinus. The umbilici were not seen, but are probably deeper than in *T. ammo-*

*nus* or *circularis* and the involution of the whorl, although not distinctly seen, is also apparently greater.

*Trocholitus minusculus*, Mill. et Dyer, is a small species having such extraordinary sutures that one suspects some distortion, nevertheless there is no proof of any action that would have brought this to pass. The form, except the size, is like that of *T. ammonius*. The incomplete living chamber is somewhat less than one-half of a volution in length. The sutures have flexures like those of the lines of growth in other forms, *i. e.*, they form a deep, broad sinus on the venter, rise into prominent saddles on the sides which internally sink towards the lines of involution, probably forming a lobe in the contact furrow. These outlines are unique among the species of Trocholites. The shell is shown on part of another specimen, and the hyponomic sinus in the lines of growth on the venter is narrower than the ventral lobe of the sutures.

*T. planorbiformis*, sp. Hall, may be distinct from *T. ammonius*, since the name has been adopted by Hall, who has studied the type, and this may be the same as *T. planorbiformis*, Conrad.

#### TROCHOLITES BLAKEI.

TROCHOLITES PLANORBIFORMIS, Blake (*British Ceph.*, Pl. xxix, Fig. 9).

This species, considered by Blake as identical with *planorbiformis* Conrad, is obviously a distinct form. It has deep ventral lobes in the sutures and costæ which are figured on either side of the abdomen. No longitudinal ridges are described, although the surface was studied and the transverse markings were plainly seen.

Blake states that this is identical with *Lituities hibernicus*, Salter,\* but the latter is a ribbed species with part of the whorls free and does not even belong to the same family. There are probably several species confused under this one name.

It occurs in the Bala beds at Llandovery.

#### TROCHOLITES ANGUIFORMIS.

NAUTILUS (TROCH.) ANGUIFORMIS, Blake (*Brit. Ceph.*, Pl. xxviii, Fig. 2).

This is also a true member of this genus.

\* Murchison's *Siluria*, p. 220, Fig. 3.

## TROCHOLITES SCOTICUS.

NAUTILUS (TROCH.) SCOTICUS, Blake (*Brit. Ceph.*, Pl. xxix, Fig. 6, Pl. xxviii, 14).

Blake's figures show sutures, but he states that none are discernible. The aperture and form of whorl and striæ indicate that this is a species of Trocholites.

*Hercoceratidæ.*

In "Carboniferous Cephalopods," second paper, *Fourth Annual Report Geol. Survey of Texas*, I separated the Tainoceratidæ, including the Temnocheilus, Metacoceras and Tainoceras from the Hercoceratidæ, but further study leads me to think that this is not advisable considering the approximation in form and characters of the two sets of genera and have reunited them here under the old name.

In genera of fossil Cephalopods I regarded *Ptyssoceras* (*Cyrt.*) *alienum*, sp. Barrande, as the arcuate radical type of this family. It has a single row of large, lateral tubercles, sutures nearly straight, whorl in section depressed, elliptical and siphuncle ventral, and it has no dorsal furrow. The genera properly included under this family name are as follows:

Ptyssoceras, Trochoceras, Hercoceras, Anomaloceras, Lower Silurian; Centroceras, Devonian; Temnocheilus, Devonian to Dyas (Permian); Metacoceras, Tainoceras, Carboniferous and Dyas; Foordiceras,\* Dyas.

I have also provisionally placed Coelogasteroceras in this family on account of the general resemblances of the form of the nepionic stage, the smooth shell and the hollow ventral zone in the abdomen.

*Ptenoceras*, † n. g.

Under this name I propose to place all those forms formerly included under the name of Hercoceras in my *Genera of Fossil Cephalopods*, whether turbinate or coiling in the same plane, which have no impressed zone at any stage. The whorls are open, or barely in contact, and are rounded in the early stages and subquadragonal later in life. The apertures are similar to those of Herco-

\*All these genera are mentioned or redescribed below as far as needed for the purposes of this paper except Foordiceras and Tainoceras, which have been described in "Carboniferous Cephalopods," quoted above.

† Πτερόδες, winged.

ceras, but are more widely open and often have spreading lips to the lateral sinuses as in *Ptenoceras* (*Gyr.*) *alatum*, Barrande, Pl. xlv.

These forms are interesting because of their obviously close genetic affinity with *Hercoceras*, and yet the entire absence of an impressed zone at any stage in consequence of the loose mode of the coiling.

*Ptenoceras flexum*, sp. Barrande, Pl. xlv, and *Ptenoceras tardum* should also be included in this genus, and probably Barrande's *Trochoceras nodosum*, Pl. xxv, but his other forms described under this name belong to widely different genera.

### *Hercoceras.*

This genus described by Barrande (*Systeme Silurien*, ii, Text i, p. 152) should be limited to such species as those placed under this name by this author. I formerly included also under this name certain gyroceran and trochoceran forms. These are separated here, but so far as regards their near affinity, I still hold the opinion that they belong to the same family group, and are genetically connected. *Hercoceras* includes only nautilian forms, having a small umbilical perforation, the impressed zone being present only after the whorls come in contact. They have peculiar contracted apertures, figured by Barrande, depressed whorls broader on the venter than on the dorsum, often with large spines or nodes, siphuncle subventran, and are often trochoceran in their mode of growth.

The section of *Hercoceras mirum*, the type of this genus, given in Figs. 13, Pl. viii, shows the small comma-shaped umbilical perforation, deep apical chamber and septa of the nepionic stage. The cæcum is very small and is packed away in the ventral angle of this chamber under the septum. The siphuncle is phenomenally small in this genus in the nepionic substages, but increases subsequently to a respectable size. This and the absence of longitudinal ridges on the exterior of all of this genus and its allies has a genetic significance which is not yet understood.

The young are sometimes in contact only in the neanic stage, and in the same species this may vary so that the whorls remain in contact throughout the ephebic stage, the last whorl with the living chamber being free as in *Hercoceras* (*Gyroc.*) *nudum*, sp. Barrande. *Hercoceras* (*Troch.*) *transiens*, sp. Barrande, Pl. xxx, is a species of this genus, and it seems to me quite possible that Barrande's

*Gyroceras minusculum* (Pl. xxx) may also prove to be related to species of this genus.

The young of these forms are all closely coiled and have contact furrows when the volutions are in contact, and these are also retained more or less in the gerontic stages.

The section is at first rounded, then broadens out to a digonal form, which in some species may remain more or less digonal or become quadragonal.

The young of *Hercoceras* has the subquadrangular form in some species like that of the adults of *Trochoceras*.

*Hercoceras (Adelphoc) secundum*, sp. Barrande, is a giant form of this genus, with the impressed zone retained in the gerontic stage.

#### HERCOCERAS IRREGULARIS.

HERCOCERAS MIRUM, *var.* IRREGULARIS, Barrande (Pl. xliii). Pl. viii, Figs. 14-15.

This is a distinct species having different and less closely coiled young than the typical *Hercoceras mirum*, and is transitional between *Hercoceras* and *Ptenoceras*. The nepionic stage given in Figs. 14-15, Pl. viii, shows that the metanepionic whorl is a depressed ellipse, the paranepionic volution is more rounded, the ventro-dorsal slightly longer than the transverse diameter, and the neanic whorl may be subquadrangular, or pass from this directly to the digonal form of the ephebic stage.

The exterior of the nepionic and neanic volutions have very coarse, transverse ridges without any longitudinal markings.

The cæcum is large in the apex. It is not correctly given in Fig. 15, and is ventrocentren. In another specimen at a somewhat younger age, it was very large compared with the diameter of the ananepionic volution and centren. In this also it remained in the mesal plane in later ages, although shifting to propioextraventrans position.

The umbilical perforation is small and comma-shaped, and although it seems impracticable that the paranepionic whorl should succeed in growing around the apex without enveloping it, this really occurs, and no impressed zone is formed in the ananeanic substage. The volutions come in contact later, and a faint contact furrow appears in the metaneanic substage, which becomes deeper in the ephebic stage as figured by Barrande.

There is obviously a great variation in the coiling of the shells of this transitional species as is shown by Barrande's figures. One shell has no contact furrow at a very late substage of development. It is possible, however, that there are several species included under this name.

A slight impressed zone or flattened dorsum is retained in the gerontic stage. Considering the slight coiling of the shells, this fact is important.

*Anomaloceras.*

This genus was described in *Genera of Fossil Cephalopods*, p. 283, and includes nautilian forms having close-coiled young with a small umbilical perforation. The whorls are depressed oval, kidney-shaped or digonal with a deep impressed zone. The sutures are almost straight, or with slight ventral and lateral lobes.

The siphuncle is subventran, and in the type is always laterad of the mesal plane.

ANOMALOCERAS ANOMALUM.

NAUTILUS ANOMALUS, Barr. (Pl. xxxiv). Pl. vii, Figs. 16-20.

Loc., Bohemia.

This species possesses very closely coiled whorls, and is of great interest in connection with the history of the impressed zone, as is demonstrated by the sections given on Pl. vii. These sections began with Fig. 16, which passed through the larger end of the comma-shaped umbilical perforation. The paranepionic section just below the centre is distorted slightly by the obliquity of the direction of the cut, and has a septum crossing it just below the siphuncle, and this organ is excentric and not so near the venter as in the later stages. The section of a volution above the perforation is also paranepionic, but older, and shows rapid expansion in lateral diameters and a tendency to assume the nephritic outline, and has in correlation with this a very slight dorsal furrow. The lateral asymmetry of this whorl is probably in part due to a slight obliquity of the section. The siphuncle is subventran as in all later stages. The metaneanic substage appears in the second outline of a volution below the perforation, and this has a digonal nephritic form.

This becomes trapezoidal and more rounded in the sections of the outer ephelic volutions above and below those described above, and in the full-grown specimens of some shells may become a much

depressed oval, as shown in Barrande's figures. Fig. 17 gives a cut farther in towards the narrower part of the umbilical perforation and shows the paranepionic substage younger than in Fig. 16, and with more depressed and approximately digonal outline. Above this the paranepionic whorl is older than in Fig. 16, and with a more decided impressed zone and broader transverse diameter approximating to the nephritic shape.

In Fig. 18 the cut has passed beyond the perforation and shows the paranepionic volution above when it first touches the dorsum of the metanepionic or ananepionic substage below. The latter is distorted because the cut goes through the inner or dorsal side of the curve of the metanepionic and ananepionic substages. The oval in the centre is apparently due to a cut through the fundus of the first septum, which must be deeply concave. In Fig. 19 the cut has approached nearer the ventral side of the apical chamber and is apparently wholly within this and shows the increase in depth of the impressed zone as the ananeanic substage begins and also the decidedly nephritic outline which this at once assumes. This also shows that the digonal outline of the volution below the centre belongs to the neanic stage. In Fig. 20 the cut has passed close to the outer side of the ananepionic substage and as in the centre it does not intersect any septum it is probably wholly within the apical chamber. This chamber must be very deep, as it is in *Hercoceras* and some other forms. The broader shaded outline of the ananepionic substage is the shell which is cut obliquely by the section. The sections of the ananeanic whorl above and the metananeanic below intersect a number of septa and show the passage to the farther side of the umbilical perforation from that with which the series began in Fig. 16.

#### *Temnocheilus.*

This genus is very similar in its general aspect to *Hercoceras* and *Anomaloceras*, but it has distinct young and this shows that it has been directly evolved from a cyrtoceran form and not from either of these nautilian genera.

The form known as *Gyroceras proximum*, sp. Barrande, Pl. ciii, has the tuberculations on the lateral angles, a trapezoidal whorl, the siphuncle subventran and sutures and impressed zone as in this genus, but until it is better known it is not practicable to decide whether it belongs to this genus or to *Hercoceras*.

I have also examined another young specimen of a different species of this genus which has a much larger umbilical perforation, but is otherwise quite similar in the characteristics of the nepionic stage. The contact furrow begins in this specimen with a very slight impression late in the neanic stage and the tubercles appear earlier than in *Temnocheilus subtuberculatus*.

TEMNOCHEILUS SUBTUBERCULATUS.

NAUTILUS SUBTUBERCULATUS, Sandb. (*Verst. Nass.*, Pl. xii, Fig. 3).

Pl. x, Figs. 27 and 28.

The umbilical perforation is large and open (Fig. 27, Pl. x). The nepionic stage has the first apical chamber very deep. The first suture has the usual ventral saddle and lateral lobes, but on the dorsal side there is a well-defined dorsal saddle. The apical chamber and the inner parts from the second to the fifth are coated with calc spar, while the centre is filled with iron pyrite.

The second suture has a dorsal lobe in place of a saddle and this persists in later stages. In the paranepionic substage a digonal whorl is developed and the lateral saddles appear dividing the lateral lobes from ventral lobes that replace the ventral saddles of the metanepionic substage. Contact takes place in the metaneanic or paraneanic substage after the digonal whorl has been replaced by a trapezoidal outline.

The form of the whorl soon after contact is shown in Fig. 28 and this has the adult outline with the exception that the contact furrow and the tubercles have not yet made their appearance.

This description was taken from a specimen in coll. Museum of Comparative Zoölogy, from the lower Devonian of Wissenbach.

*Metacoceras.*

This genus, which has been described in my *Genera of Fossil Cephalopods* (p. 268), and subsequently redescribed in "Carboniferous Cephalopods," *Second Annual Report of Texas, 1890*, and *Fourth Annual Report of Texas, 1892*, is of no special value in this connection except as an illustration of a number of genera of the same genetic stock as *Temnocheilus*, which have more or less similar characteristics in the young. They all have large umbilical perforations and a similar history in the development of the impressed zone.

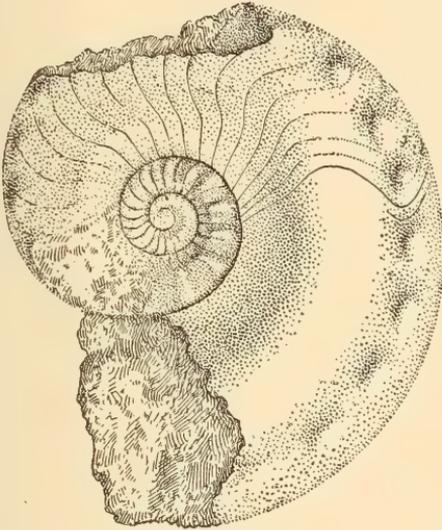


FIG. 16.

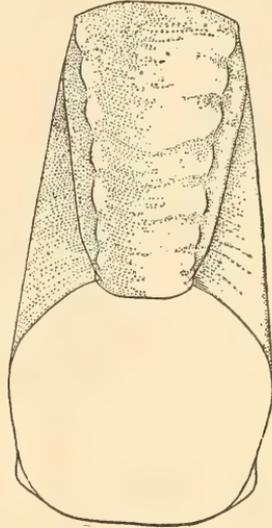


FIG. 17.

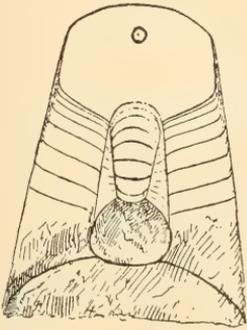


FIG. 18.

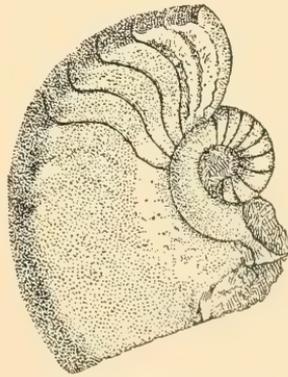
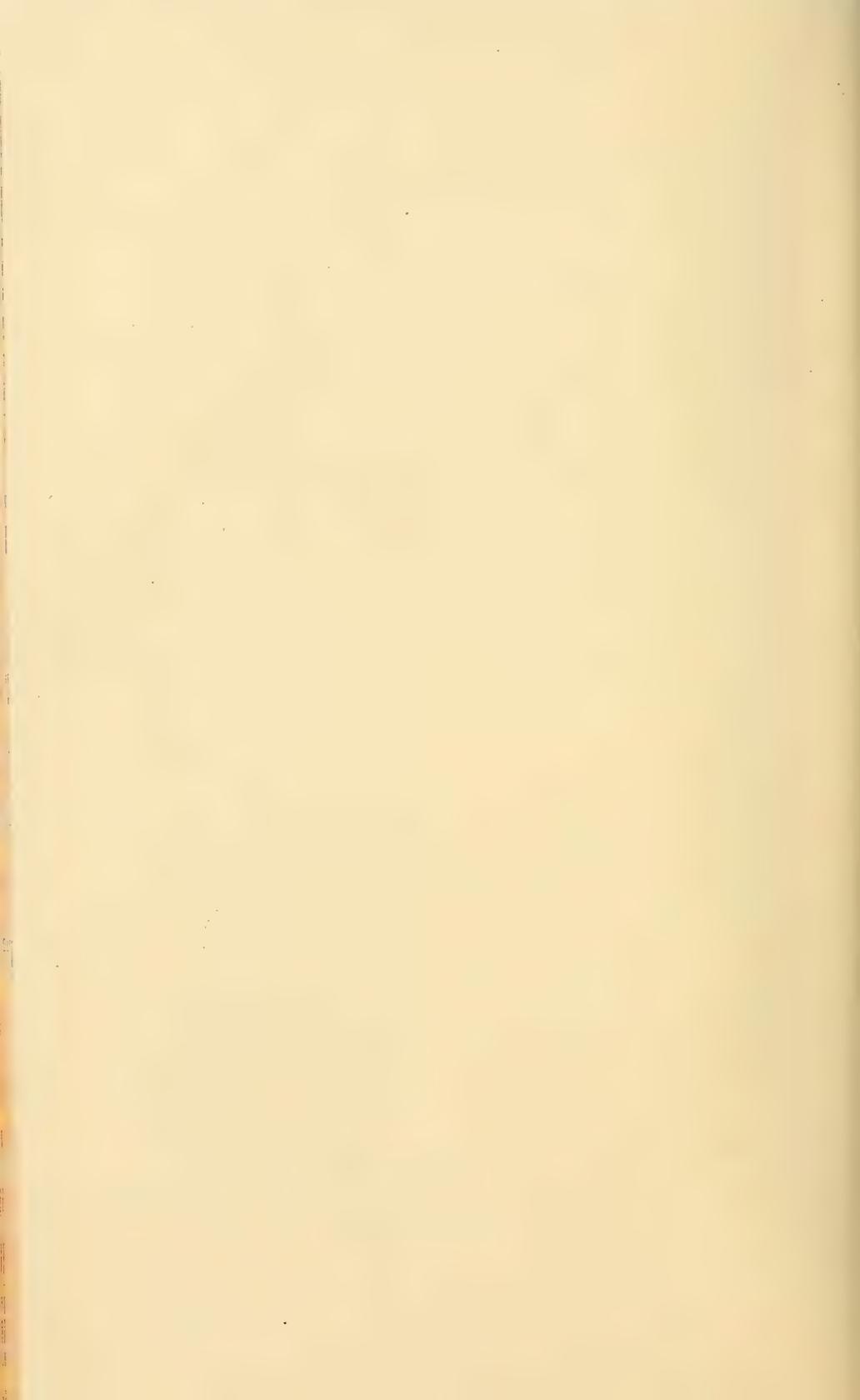


FIG. 19.

METACOCERAS CAVATIFORMIS.

(Hyatt.)



Figs. 16-19 give the adult and general aspect, and Fig. 32, Pl. x, shows the beginning of the contact furrow. This begins only after contact with the apex and in strict correlation with the rounded immature form of the metanepionic and the temnocheilan or tetragonal trapezoidal form assumed by the paranepionic volution. The sutures have ventral and dorsal saddles throughout the metanepionic, but in the paranepionic become straighter on the venter or with a faint lobe, and a similar change takes place in the dorsal sutures. The dorsal lobe is more easily perceptible after contact and becomes deeper with the increase in depth and breadth of the contact furrow and seems to be correlated in development with that modification, although it appears before this furrow is formed.

#### *Tainoceras.*

This genus has similar young to those of *Metacoceras* and probably has a similar history.

#### *Centroceras.*

This genus, described in *Genera of Fossil Cephalopods*, possesses a typically quadrangular whorl in the adult stage of the less involute forms, but has a digonal whorl in the nepionic stage, and this becomes similar to that of *Temnocheilus*, that is trapezoidal in outline and furnished with tubercles in the neanic stage. The contact furrow is faintly marked in some forms like *Centroceras* (*Cyrt.*) *tetragonum*, sp. Vern.,\* but it is a mere narrow band on the dorsum.

It is obvious in this genus that the impressed zone exists only in the later stages and after the whorls come into contact. Hall describes a slight impressed zone in *Centroceras* (*Discites*) *ammonis*, sp. Hall† and shows the living chamber complete and nearly one-half of a volution in length.

It is likely that Hall's *Gyroceras Stebos*‡ may prove to belong to genus *Centroceras* (*Gyroceras*) *Ohioense*, sp. Meek,§ is a very large shell of the Corniferous fauna of Ohio which has the form of whorl and single outer row of tubercles of this genus.

\* *Trans. Geol. Soc. London*, vi, Pl. xxx.

† *Pal. N. Y.*, v, Suppl., Pt. ii, Pl. cxxv.

‡ *Ibid.*, Pl. cxxvi.

§ *Pal. of Ohio*, i, p. 230, Pl. xxii.

*Coelogasteroceras.*

This genus was described in my "Carboniferous Cephalopods," second paper, *Fourth Ann. Rep. Geol. Texas.*

*Coelogasteroceras canaliculatum* of the Carboniferous has an umbilical perforation of considerable size, but the history of the impressed zone is similar to that of *Anomaloceras*. One section was obtained shown in Fig. 33, Pl. x. This cut across the metanepionic as it was changing in form on its passage into the paranepionic substage and shows the dorsum becoming flattened and an outline transitional to the full nephritic outline of the paranepionic, which is drawn below at a plane which passed through this substage just before the apex was reached. In making this section, the apex was seen and passed through by grinding.

The size and shape of the umbilical perforation in this species does not justify the assumption that the dorsal furrow could have resulted from the abrupt bending of the volution at the gyroceran bend. The curvature of the first whorl is gradual; the expansion of the volution laterally and ventro-dorsally is not remarkable. The diameter of the umbilical perforation was four millimetres in one specimen and in the section figured it was somewhat less at the same points. The increase by growth was also approximately the same in both of these fossils.

Unfortunately the absence of a dorsal furrow on the dorsum of the metanepionic substage was not demonstrable with unquestionable certainty in either of these specimens, but it seemed to be entire and gibbous in both as given in the figure.

The shell is apparently smooth in the nepionic stage, although this may have been in part due to the condition of preservation. It is obvious that there are no lateral furrows or ridges as in *Coloceras* at any stage. Faint transverse folds were observed in the neanic stage of one specimen, and the abdomen and lateral zones become flattened at the same time. A hollow, central, ventral zone appears in the anephebic substage and persists throughout the ephebic stage.

The sutures are nearly straight in the nepionic, and then acquire a slight ventral lobe in the neanic stage; this deepens in correlation with the ventral hollow zone in the ephebic stage, and the lateral lobes and saddles on the umbilical shoulders also become more marked in this stage.

The siphuncle is propioventran in the paranepionic and very large ; in subsequent stages it is somewhat nearer the centre and continues to be large.

*Discoceratidæ.*

This family includes some genera formerly associated under the Tainoceratidæ and others not heretofore noticed in my classification.

Although it is a provisional and heterogeneous group in some respects, the genera are alike in being more or less heavily ribbed, and in having open apertures so far as known. This association also brings together forms having a tendency to develop into more or less turbinate coils.

The genera are as follows : Peismoceras, Systrophoceras, Trochoceras, Mitroceras, Lower Silurian ; Plectoceras and Discoceras, Quebec faunas to Upper Silurian.

*Plectoceras.*

This genus was described in *Genera of Fossil Cephalopods*, page 268, by the author to include the costated forms similar to Discoceras, but having the siphuncle ventrad of the centre.

The type was *Plectoceras (Naut.) Jason*, sp. Billings. The mode of coiling may be quite close and regular, with perhaps a slight impressed zone or flattened dorsum, or the coil may be open, and sometimes it is very irregular. In several specimens of *Jason* the first whorls may touch, the ephebic volution may be open and free and yet the extremity of the living chamber again come in contact. The umbilical perforation is large and the impressed zone is absent until the whorls come into contact and it is invariably absent in gerontic whorls.

The species are as follows :

PLECTOCERAS JASON, sp. Billings (*Canadian Nat.*, iv, p. 164).

Type in Museum of Geological Survey at Ottawa. It occurs in the Calciferous of the Mingan Islands and there are similar forms in the same horizon in Newfoundland.

PLECTOCERAS OBSCURUM, n. s.

This species occurs in the Black River fauna in New York and is quite commonly mistaken for the young of *Eurystomites undatus*.

but it has an open gyroceran spiral, the siphuncle is nearer the venter and the costæ are more highly developed and more prominent, and have a distinct character from those of that species.

PLECTOCERAS BICKMOREANUS, sp. Whitfield (*Bull. Am. Mus.*, New York).

This species of the Niagara fauna has an open gyroceran whorl, and in the gerontic stage the last whorl is free and in some specimens completely straightened out and litiuitean in aspect.

*Peismoceras*,\* n. g.

Under this name I propose to separate such costated forms as those described by Barrande as *Trochoceras*, but which differ from true *Trochoceras* and *Discoceras* in the development of the form, outline of the apertures, position of the siphuncle and so on.

*Peismoceras* (*Troch.*) *angulatum*, *optatum*, *placidum*, *disjunctum*, sp. Barrande and others agree in having plain rims to the apertures without deep sinuses, except, of course, the ventral sinus.

The siphuncles are ventrad of the centre, the whorls oval in section, the volutions are barely in contact or open, the apices are very large and the umbilical perforations excessively open and large, and there is no impressed zone at any stage.

*Discoceras*.

The type of this genus was described and figured by Eichwald under the name of *Clymenia antiquissima*, but was subsequently considered as a distinct genus by Barrande.†

The genus has been subsequently recognized by Schröder and Remelé, but it has by both these authors been used for the smooth forms, having a quadrangular section to the whorl and dorsal siphuncle, as well as for the costated shells.

The neanic stage of all the smooth shells of allied species having the siphuncle dorsal and, therefore, formerly included under the same name, has decided costations with the same aspect and contour as in the adult of *Disc. antiquissimum*. Similar species having costations throughout life cannot be included in the same genus with those that have them only in the neanic and earlier

\* Πεῖσμα, a cable.

† *Syst. Sil. de la Boheme*, ii, p. 177.

stages of growth. The large number and great variety of form of these smooth species, while still maintaining this difference of the later stages of growth, shows that this separation indicates a natural distinction, and I have therefore placed all under the generic name of *Schroederoceras*, to commemorate that author's distinguished services in this field of inquiry.

DISCOCERAS ANTIQUISSIMUM.

CLYMENIA ANTIQUISSIMA, Eichw. (*Urwelt Russl.*, ii, Pl. iii, Figs. 16, 17).

This is a peculiar species represented in the collection in the Museum of Comparative Zoölogy by a specimen from Porsgrund, in Norway. It is heavily costated, as in the figure given by Eichwald, and these costations are deeply impressed upon the cast throughout the earlier stages and in the ephebic stage. They degenerate only in the gerontic stage.

The abdomen is broader than the dorsum and the sides convex and evenly rounded. The costæ are very prominent and sharply defined, as in the original figure. The sutures, as far as these could be seen, appeared to be similar. The size was also similar and the last whorl in close contact, as in Eichwald's figure of this species.

The specimen described had reached the anagerontic stage, the costæ having disappeared, or, at any rate, ceased to be reflected on the cast near the end of the last whorl, whereas in all previous stages, except probably the earliest nepionic, they are almost equally prominent on both the cast and the shell.

The siphuncle is subdorsan at all the stages observed from what appeared to be the second to the third and fourth whorls. It is quite large, especially on the second whorl.

The neanic whorl is digonal and heavily costated. The ephebic and gerontic whorls are depressed ovals, the abdomens broader than the dorsi. The section of the gerontic volution had ventro-dorsal diameters 25 mm. and transverse 35 mm., without the shell. The whole diameter of this specimen was about 110 mm.

DISCOCERAS GRAFTONENSE.

LITUITES GRAFTONENSIS, M. et W. (*Proc. Acad. Philadelphia*, 1870).

LITUITES GRAFTONENSIS, M. et W. (*Geol. Ill.*, iii, vi).

LITUITES MULTICOSTATUS, Whitfield (*Geol. Wisconsin*, Pl. xx, Fig. 7).  
 TROCHOLITES MULTICOSTATUS, Whiteaves (*Geol. Canada, Pal. Foss.*,  
 iii, Pt. i, Pl. vi, Fig. 1). Pl. viii, Figs. 21-23.

This interesting species of the Niagara fauna is given here in order to show the young neanic stage which was preserved in relief attached to the centre of a mould of the older whorls, Figs. 22, 23, Pl. viii. The close connection of Discoceras and Trocholites is demonstrated by this drawing. In fact, if separated at this age, the young would have to be placed in that genus. Fig. 21 shows the cast of a perfect mould of another specimen of the same species which has reached the epebic stage.

Whether this had a dorsal furrow in the umbilical perforation could not be determined. The perforation is certainly very small. Whiteaves' figure shows that the siphuncle is subdorsan in the epebic stage as it is in the neanic stage described above.

*Systrophoceras*,\* n. g.

This genus includes the remarkable series of costated trochoceran and gyroceran forms described by Barrande in his *Systeme Silurien*, which have the whorls either very slightly in contact, or not touching at any stage, and are devoid of an impressed zone.

*Systrophoceras* (*Troch.*) *arietinum*, *rapax* and *pingue*, sp. Barrande, have a depressed subtrigonal or subkidney-shaped outline to the whorl with the siphuncle dorsad of the centre, and in many characters are distinct from the others cited below under the name of Peismoceras. These species may have been close-coiled in their younger stages.

*Trochoceras*.

Barrande described this genus in 1848,† and in the same publication later gave a list of the species‡ in which the characteristic form, *Trochoceras Davidsoni*, was mentioned first, and this consequently is his type. Hall described the same genus under the same name, but without knowledge of Barrande's work in the Paleontology of New York,§ but his types are both quite distinct, and do not belong to any genus yet described from Bohemia.

\* Σύστροφος, rolled up.

† Haidinger's *Berichte*, iii, p. 266, 1847.

‡ *Ibid.*, iv, 1848.

§ Vol. ii, 1852, p. 336.

Thus, although both Barrande and Hall have courteously acknowledged each other, and have mutually joined names as authority for this genus calling it *Trochoceras*, Barrande and Hall, the *Trochoceras* of the former is not the same as that of the latter, and the name of one or the other or both must be dropped.

I have therefore retained *Trochoceras* Barrande, and propose for Hall's remarkable forms, *Trochoceras Gebhardi* and *turbinatum*, the new name of *Mitroceras*\* with *Mitroceras (Troch.) Gebhardi*, sp. Hall, Pl. lxxvii and lxxviii as the type.

It must not be supposed that all forms of Nautiloids having the turbinate spiral are devoid of impressed zones. There are some species that do have this characteristic, but it is invariably slight, and occupies necessarily a position on the sides rather than on the dorsum of the whorls.

#### *Lituitidæ.*

Recent investigations have shown that this group, instead of including about all of the unrolled, shell-covered Cephalopoda of the Paleozoic, must be limited to certain well-defined homogeneous series with peculiar characteristics.

My observations lead me to think that *Lituites* is a degenerate form of *Cyclolituites*, a view similar to that of Holm and Schröder, who regard this genus as the radical of the *Lituitidæ* corresponding to the younger stages of true *Lituites*.

The genera included in this family form a degenerating series which may have evolved from *Cyclolituites*, or some form that this most closely represents, becoming specialized by reduction of the spiral and simplification or loss of correlative characters during growth of the whorl, lessening curvature of the annuli and lines of growth and in the outlines of the apertures, until finally, in the extreme forms of *Rhynchorthoceras*, the whole shell is straight or orthoceran, except during the earliest stage, the nepionic, and in that it is not a perfect coil.

This process takes place through the disappearance in the earlier stages of the progressive characters of *Cyclolituites* and the gradual replacement of these by characteristics that first appear in the paragerontic stages of such species as *Ang. præcurrans*. That is to say, *Rhynchorthoceras* has from a comparatively early stage the ven-

\*From *Μίτρα*, a girdle, but also used for "turban," in which sense it is here quoted.

tral and dorsal crests and lateral sinuses in its lines of growth that are first observable in the degenerative stages of the ontogeny of allied and more complicated shells (*Ang. præcurrans*), it includes in other words some species at least that are purely phylopara-gerontic.

No genus of this family, except *Cyclolituites*, has an impressed zone, the transverse section being round or more usually a compressed oval ellipse. The most obvious external characteristic, which fails of being distinctive only in some species of *Angelinoceras*, and in them in the ephebic stage only, is the forward curvature of the lines of growth and costæ on the sides and the prominent paired ventrolateral crests and corresponding lateral sinuses.

The shell varies from that of *Cyclolituites* with whorls touching until a late ephebic stage, only a part of the living chamber being free, through forms like *Lituities* with a portion of the camerated whorl and the whole of the living chamber free and straight, to *Rhynchorthoceran* forms which have uncoiled whorls.

The apertures vary, but possess in *Lituities*, *Ancistroceras* and *Cyclolituites*, prominent ventro-lateral crests and deep ventral sinuses.

The siphuncle is large and subcentral, central or just above the centre and in the young approximates to the dorsum. It is, so far as known, ellipchoanoidal and microchoanitic, *i. e.*, composed of short funnels that are directed towards the apex and having porous walls between the funnels and the next septum.

All of these forms known to me occur in the *Orthoceran* and *Varginatus* limestones of Northern Europe and *Niagara* limestones and *Quebec* faunas in this country. They seem to be absent from more southern faunas of the same stages.

Foord doubts the appearance of true *Lituities* in the rocks of Great Britain, and I think he could have positively denied their appearance there since *Lit. ibex*, sp. Sowerby, certainly has none of the usual characteristics of any of this family.

*Trochoceras speciosum*, Blake\* has most extraordinary costæ turned forwards as in the *Lituitidæ*, but the siphuncle is ventral and the description is inadequate, and at variance with the figure so that one cannot arrive at any definite conclusion.

\* *Brit. Ceph.*, Pl. xiv, Figs. 12-15.

*Cyclolituities.*

This generic name was given by Remelé, who has done more than any other one author to clear up the relations of the different forms of Lituitidæ. The species mentioned by him was *Cyclolituities applanatus*, and to this Holm added a new form, *Cyclolituities lynceus*. His drawings show that *Lituities Lynnensis*, Kjerulf,\* is a species of this genus. The drawing made by Barrande of this last is defective in representing the umbilical perforation as too large. Kjerulf's drawing gives this much smaller. It also gives the lines of growth as bending apically on the first volution and first half of the second volution. They then change to the peculiar forward bend of the Lituitidæ, and without doubt the aperture changes at this time also to the outline of the adult, so that this is the anephebic substage. The hyponomic sinus is narrow and deep, and the crests on the abdominal angles, at first blunt in the anephebic stage, become more prominent in the ephebic stage. The sides have lateral sinuses and probably the dorsum is occupied by a crest. Only the last quarter of the outer volution is free. Schröder doubts whether this is a distinct genus, thinking that it may prove to be the young of true Lituities.

## CYCLOLITUITES AMERICANUS.

Loc., Gargamelle Cove, Newfoundland.

This species has a quadrangular whorl with somewhat flattened lateral zones. The abdomen is also depressed, but with a slightly gibbous central zone and linear ventral channels on either side, the abdominal angles appearing, in consequence, as lateral ventral ridges. The lines of growth show that the usual hyponomic sinus was present in the aperture, with sharp, narrow crests on the abdominal angles and broad lateral sinuses on the sides. The lines of growth on the venter are crossed by a secondary system due to the impression of the dorsal lines of an outer whorl, which has been broken off in this specimen. These show that the aperture has a prominent median dorsal crest and that the coiling was close, as in other species of this genus.

The sutures seen through the thin shell are nearly straight at first, then in the ephebic stage become flexed with very slight lateral lobes and ventral saddles. There are probably slight flex-

\**Vivies i Christiania*, p. 14, 1865.

ures or lobes to correspond with the ventral channels, but these were very indistinct through the shell.

The siphuncle is of medium size and ventro-centren in the middle of the volution actually seen, and at its termination in what seemed to be the septal floor it was centren.

The original specimen is a nearly completed whorl, 36 or 37 mm. in diameter, and if prolonged and restored to a point opposite the dorsal marks described above it must have been, when complete, about 74 or 75 mm. in diameter.

The dark blue color of the last septum of the fragment described indicated that it might have been the floor of the living chamber, and if so, that living chamber must have been over three-quarters of a volution in length. Every observer, however, knows that this inference is open to great doubt because of the frequent invasion of the matrix into septal chambers through accidental breaks in the shells. Pseudo-septa were observed in this specimen. So far as could be seen the involution simply covered the abdomen, and the contact furrow, although not perceptible on the first part of the whorl described, was evidently present later. This is very interesting, because this furrow is not persistent upon the uncoiled whorls in any species or form of *Lituities* yet described and seems to have no hold at all upon the organization.

#### *Lituities.*

This generic name has been applied to the majority of forms that have the last part of the last whorl or the living chamber free. This general application of the name is so erroneous that it hardly needs discussion. It is, as stated above in this paper, a common tendency of the growth of the whorls in degenerative shells of the Nautiloids throughout the Paleozoic and of the similar forms of Ammonoids during each geologic period, and also a common tendency of the extreme senile or paragerontic substage in the ontogeny of all shells of both orders whenever they attain the extreme limits of their existence. Later authors, especially Remelé, Nötling, Dewitz and Holm, have recognized this fact in some way, either directly or by limiting the generic application of the name *Lituities*, or by separating the genera *Ancistroceras*, etc., from *Lituities*. Remelé was the first to demonstrate the divisibility of the *Lituitidæ* into different genera, Boll's previous effort in this direction being unsystematic and subsequently repudiated by himself.

Nötling\* shows conclusively that there are two groups usually included in Lituites that differ in their lines of growth and apertures, etc. The true Lituites have, according to Nötling, four principal sinuses, deep ventral and dorsal and shallow lateral sinuses. Schröder has criticised this statement, making out five sinuses and five crests in the apertures and lines of growth. Nötling's† statement is substantially the same so far as the larger sinuses and crests are concerned, but Schröder pointed out that the dorsal sinus was subdivided by a central crest into two smaller sinuses. The correct way of describing the sinus of the inner side, judging by the growth and development, is to regard it as the dorsal sinus, and the dividing crest and minor sinuses being developed later as minor or subsidiary dorsal crest and sinuses.

Holm‡ has confirmed this view and, with the fine materials at his command, has figured the dorsal sinus spreading at the base and divided by a slight reëntrant crest, which is also reflected in the lines of growth on that side of the living chamber, while the ventral sinus is deeper and narrower and undivided. These facts increase the differences of the aperture between Lituites and Ancistroceras, and at the same time the slight median crest in the aperture and lines of growth on the dorsum of Lituites makes the affinity with Cycloceras and Ancistroceras clearer than it would otherwise be. The crest and sinuses are also very much more pronounced in Lituites, and the enrolled portion of the whorl is continued longer and is more closely coiled, the whorls being in contact for between three and four volutions. Holm's figures of *Lit. lituus* show that on the early part of the straight whorl the lines of growth are entirely different from the later parts of the same whorl. The outlines have a slight, shallow dorsal sinus, the median dorsal crest not having yet been developed. The same peculiarity is observable in Nötling's figure on a part of the shell preserved and show the lines of growth at about the same stage of growth, and also upon Lossen's figure of the same species. There are also decisive costations on the coiled whorls, which are similar in both of these figures. These in the younger substages are bent apically towards the venter and forwards towards the dorsum, and have not the more complex curves of the older stage.

\* "Beitr. z. Kennt. d. Ceph. a. Silurg. d. Prov. Ost-Preussen," *Jahrb. d. k. Preuss. Geol. Landesanst. u. Bergak.*, 1883, p. 126 *et seq.*, and *Zeitsch. Deutsch. Geol. Gesell.*, 1882.

† "Untersuch. u. Sil. Ceph.," *Pal. Abt.*, Dames et Keyser, v, heft iv, p. 44.

‡ *Aftryck. Geol. Fören. Stockholm Förhandl.*, xiii, 1891.

It is plain that the coiled young represents the nepionic and neanic stages and that the aperture must have differed essentially in these stages and perhaps may have been open or else more like that of *Cyclolituites*.

Nötling also demonstrates in his paper in the *Zeitschrift* that the earlier stages had compressed whorls, the abdomen broader than the dorsum, and also that the siphuncle was nearer the dorsum in the youngest stage observed, and gradually departed from this towards the centre, becoming dorsocentren in the ephebic or outstretched whorl. In old age it again changes its position and tends towards the dorsal side. Nötling has also shown that the siphuncle was elliphochoanoidal, consisting of short funnels and the usual porous sheaths, or that which corresponds to this part in the siphuncles of other forms. The structure of the siphuncle in the younger stages was, however, not described or figured. A list of the species according to Nötling is as follows: *L. lituus*, De Montfort; *L. perfectus*, Wahlenberg; to this Holm added, *L. Tornquisti*, Holm, and gave very instructive figures of the two species already known. *L. discors*, Holm, has a broad dorsal crest in the lines of growth and aperture and is here referred to *Ancistroceras*, and *L. appplanatus* Remelé.

*Angelinoceras*, n. g.

There are several species usually referred to *Lituites* which can neither be included in this genus nor in *Ancistroceras* or *Holmiceras*. These have open coils in the young, and the usual lituitean outstretched free whorl in the ephebic and gerontic stages. The only species known to me are those described by Angelin and Lindstrom in their *Fragmenta Silurica*. The lines of growth, and the annuli, during the neanic stage, have curves similar to those of *Cyclolituites* in *A. latus*, viz., with deep ventral sinuses, crests at the abdominal angles, deep lateral sinuses near the dorsum and dorsal crests. These curves change in the ephebic whorl, becoming less sinuous, but, beyond the fact that they differ very much from those of *Ancistroceras* or *Lituites*, they cannot be defined with accuracy from the figures given.

The increase by growth is more rapid than in *Lituites* and less rapid than in *Ancistroceras*, in *A. latus* and in *A. anguinus* it is very slow throughout life. The ephebic whorl is extended with the usual lituitean curve and closely resembles in aspect, but not in the

lines of growth, *Holmiceras præcurrens*, sp. Holm. In *A. anguinum*, however, it remains attenuated. The coiled portion of the shell has about three whorls coiled, and their attenuated proportions and compressed form approximates more closely to those of *Lituities* than to those of *Ancistroceras*. The close coiling in *Ang. sp. indet.* (as figured by Angelin) of the nepionic stage shows also more affinity for *Lituities* than for *Ancistroceras*. The figures of *Lit. lituus* given by the same authors show also essential differences from those of the true *Lit. lituus*, as figured by Lossen and Nötling. The coiled whorls are not in contact, not so compressed, free from the large fold-like costations of that species and have the characteristic lines of growth bending forward and with prominent ventrolateral crests near the apex of the whorl if correctly figured. Taken altogether, the characteristics of the species of this genus show a series of forms standing apparently between *Lituities* and *Ancistroceras*.

*Ancistroceras.*

The name of *Strombolituities* was substituted by Remelé.\* Boll had originally used the name *Ancistroceras* in connection with *A. undulatum*, the species which must be considered the type of the genus, but had subsequently abandoned its use,† and this and his insufficient diagnosis was supposed by Remelé to justify the suppression of his name. Boll's type, however, being a good species and a distinct genus, his name must stand in spite of his own desire to suppress it and his defective description. Nötling has also demonstrated that *undulatum* has a closed spiral for one and one-half whorls (said by him to be about two whorls). This is compressed elliptical in the nepionic, and becomes more or less quadrangular near the end of the spiral, assuming very quickly the circular form after this.

Remelé's paper deals also with *Lituities* and he really divides the group of *Lituities* into three genera, since he endeavors to limit the name of *Ancistroceras* to the forms which he subsequently described as *Rhynchorthoceras*.

The genus *Ancistroceras* differs from *Lituities*, according to Nötling, in having only three sinuses, a ventral and two lateral sinuses in the lines of growth and aperture, the dorsum being occupied by a broad low crest. Schröder, in the paper quoted above,

\* *Zeitsch. geol. Gesells.*, 1881, Pl. clxxxvii, "Strombolituities," etc.

† *Arch. d. Verds. Freunde d. Naturg. Mecklenburg*, xi.

asserts that lines of growth in *Lituities* and *Ancistroceras* are similar and certainly this appears to be in part true. There are distinct inflections indicating the probable presence of five crests and five sinuses as this author states. These are perfectly well shown in *Anc. Torelli*, as figured by Remelé, and in his *Anc. (Stromb.) Bolli*. But in all of these there are other characters not found in *Lituities* or in other genera of this family which separate these fossils as a distinct group in my opinion of generic value.

While the lines of growth are similar, they show that differences must have existed in the form of the crests and sinuses on the dorsal side of the aperture corresponding to the slight development of the median minor crest and paired minor sinuses on the dorsal side. In fact when one describes the curves of the dorsal lines of growth as indicating a dorsal crest in place of a lobe, he is coming nearer to the actual aspect than when he correctly classifies the outlines as a broad sinus subdivided by a minor crest and secondary sinuses. In other words, the great dorsal sinus of *Lituities* has reached the disappearance point in this genus during the ephebic stage but has not entirely vanished except perhaps in some species. It, also, as is well known, is a much larger, broader form, spreading out rapidly in the outstretched or free part of the whorl. It is also plain that the enrolled part or young shell of *Ancistroceras* has fewer and less closely coiled whorls than in *Lituities*. Thus *A. Torelli*, as figured by Remelé, has only one to one-half volutions enrolled and these do not touch although closely approximate. In fact the young of *Ancistroceras* are only coiled during the nepionic stage, and perhaps ananeanic substage, and the figures show much larger, stouter whorls even at the apex than in *Lituities*. The figures of Remelé of *A. Torelli* and of Nötling of *A. undulatum* are very careful studies, and exhibit the changes in development of the lines and annuli. These have in the neanic stage subacute, narrow crests, lateral sinuses rising to prominent ventro-lateral crests and between these on the venter is a deep, broad median sinus, thus resembling those of *Cyclolituities*. The paraneanic substage is present on the early part of the outstretched whorl in *Torelli* and *undulatum*.

The siphuncle is also much larger in this genus than in *Lituities*. The study of the pseudo-septa by Holm led him to observe the siphuncle in *A. undulatum* and *Torelli* and his description is as follows:\* “Der Siphonen scheint mir wenigstens auf der einen oder

\* *Paleontol. Abh.*, Dames u. Kayser, iii, hft. i, “Organiz. Silur. Ceph.,” 1885, Pl. xxi.

der anderen Seite, keine eigene, festere, verkalkte Hülle gehabt zu haben." If the siphuncle were holocoanoidal, it would have as thick and might have thicker walls than the septa themselves.

A list of the species is as follows, as given by Nötling: *A. undulatum*, Boll.; *Torelli*, Rem.; *Barrandei*, DeWitz.; *Bolli*, Rem. To these Nötling has also added *Cryt. Odini*, Eichwald (*Lethea Rossica*, Pl. xxvi, Fig. 14a-b), and he thinks this may be identical with *undulatum*.

*Ancistroceras* (?) *Dyeri*, n. s., is a large fragment quite different from any European species, having the sutures with slight broad ventral lobes, slight saddles at the abdominal angles, lateral lobes, saddles at the umbilical shoulders, and apparently narrow dorsal lobes.

The fragment is that of a rapidly enlarging arcuate whorl, subquadragonal in section, the lateral zones slightly convergent outwards, the dorsum broader than the venter.

The siphuncle is ventrocentren.

The lines of growth seen on the living chamber had the characteristic ventral sinus, slight crests on the abdominal angles, slight lateral sinuses, broad low crests on the umbilical shoulders and internally faint minor dorsal sinuses apparently rising to an equally faint median dorsal saddle.

It has characteristics which appear to be intermediate between *Ancistroceras* and *Rhyncorthoceras*. This fossil is from the Niagara Group near Chicago, Ill., Dyer collection, Mus. of Comp. Zoölogy, and is worth describing in this connection, although until it can be studied in the young and figured it is hardly safe to refer it to this genus. It has been named *Cyrtoceras amplicornis*, Hall, and closely resembles that species, but the section is more decidedly quadragonal, the sides and venter flatter and the transverse diameter broader.

#### *Rhyncorthoceras*.

The designation *Rhyncoceras* has also been used by Remelé and others, but *Rhyncorthoceras* was used first, and should be exclusively employed. *Rhyncoceras* is not an equivalent, and there cannot be two names for one genus.

Remelé's description of this genus is perfectly clear and satisfactory. It is in my opinion another grade in morphic degeneration of the *Lituitidæ*, and is directly in line with and supplementary

to the modifications of *Lituities* and *Ancistroceras*. It is completely uncoiled in the young, and the tip or apex has not even the open coiling of *Ancistroceras*, but is really an open or cyrtoceran curve.

The annuli of the shell are also simpler in curvature and according to Remelé they have low broad dorsal and ventral crests and corresponding low broad lateral lobes. These phylogerontic curves appear to be acquired in the early ephebic stages, and therefore appear earlier in the ontogeny than in *Ancistroceras*.

The siphuncle is large and may be either dorso-centren, or about centren, and in *R. Beyrichea* is said by Remelé to be nearer to the venter than to the dorsum or ventrocentren.

The list of species given by Remelé\* is as follows: *R. Beyrichia*, *Zaddachi*, *Oelandicum*, *damesi*, *tenuistriatum*.

*Rhynchorthoceras* (?) *dubium*. In the Dyer collection, Museum Comparative Zoölogy, there is a fragment that shows this genus probably occurs in the Niagara group of Indiana, but the younger stages are wanting and it cannot be surely placed here until these are known. The first part of the free volution has the usual bands of growth with hyponomic sinus, these lines inclining orad and without inflections or with hardly perceptible lateral sinuses to the dorsum where they unite in low, broad saddles.

There are also three inconspicuous low, broad costæ on this part of the shell. The form is a slightly compressed ellipse, the siphuncle large, ventrocentren, the sutures have ventral and dorsal saddles and lateral lobes. The growth bands lose their inclination in the older part of this volution, becoming straighter on the sides and the hypomic sinus almost disappears. This last characteristic seems to place these fossils in this genus.

#### *Holmiceras*, n. g.

*Lituities præcurrrens* sp., Holm, has open, discoidal whorls, like those of *Angelinoceras latum*, and closely resembles this species in form and proportions, both of the enrolled and outstretched whorls, but the lines of growth and annulations are very distinct. It has the four major sinuses in the lines of growth, as in *Lituities*, but the median dorsal crest is absent. The aspect shows the presence of another genus in this family and the sutures are also different from those of *Lituities*, having distinct ventral and dorsal lobes in the ephebic stage, with low, broad, almost straight, lateral saddles.

\* *Zeitsch. Deutsch. Geol. Gesell.*, xxxiv, 1882.

The figure by Holm, p. 763; shows conclusively that the sutures in the nepionic stage are straight, Trocholites like, and quite distinct from those of the later stages. The narrow annuli cross the whorl during the ephebic stage or first part of the free whorl, with the true Ancistroceran curves, namely, with shallow ventral sinus between two low, narrow ventro-lateral crests, broad, shallow lateral sinuses and a very slight but perceptible dorsal sinus not divided by a crest, as in *Lituites*.

These change in the gerontic stage, the ventral and dorsal sinuses being replaced by low, broad crests, the lateral sinuses alone remaining. This stage repeats exactly the degenerate characters of the curves in the lines of growth of the ephebic stage of *Rhyncorthoceras* and show, together with other facts, that we are dealing with a degenerating series. The siphuncle is dorsad of the centre in the ephebic stage, but it is nearer the centre than in *Lituites*.

This genus does not seem to stand in the line of modifications leading from *Lituites* to *Ancistroceras*, nor in that leading from *Lituites* to *Rhyncorthoceras*.

#### *Ophidioceratidæ.*

The apertures and costated whorls of *Ophidioceras* have been supposed by several authors to show that it belonged in the family of the *Lituitidæ*. The apertures are, however, distinct, having only three large sinuses and a corresponding number of crests and the costations and lines of growth have not the peculiar forward bending lateral curves of the *Lituitidæ*. The ornamentation of the younger stages and the form of the nepionic stage is so widely different that no close comparisons can be made with the young of *Cyclolituites*, the closest coiled form of the *Lituitidæ*.

This genus was formerly supposed by the author to belong in the same group with *Ascoceras* and *Glossoceras*, which had similar apertures, but recent investigations have shown that these genera are widely separated in structure.

#### *Ophidioceras.*

This genus, fully described by Barrande, becomes very interesting in the history of the impressed zone on account of its highly ornamented and costated whorls and the peculiar, excentric character of the free whorl and the aperture with deep, narrow hypono-

mic sinus, lateral crests and dorsal crests bending inwards and contracting the opening. It is also of interest in this connection as showing how narrow and comma-shaped the umbilical perforation may be without affecting the form of the dorsum, and especially with regard to the history of the degeneration of the impressed zone on the dorsum of the free whorl and living chamber.

*Ophidioceras.*

OPHIDIOCERAS RUDENS.

OPHIDIOCERAS BARRANDE (*Syst. Sil.*, Pl. xlv); Pl. viii, Figs. 29-35.

Loc. Bohemia.

This species has a flattened comma-shaped umbilical perforation and, although the increase in size is rapid, it is not excessive in the lateral diameters as compared with the ventro-dorsal from the ananepionic substage to the paranepionic. The result is a volution which curves evenly about the core of the perforation and preserves the rounded dorsum and the general aspect of the section without great modification throughout the nepionic stage. The cicatrix is well-marked, as shown in Fig. 30, and the ananepionic substage has an elongated ventro-dorsal and short transverse diameter.

In the metanepionic substage the whorl becomes broader on the venter than on the dorsum, and in the paranepionic the dorsum spreads, becoming broader, but does not quite equal the venter in breadth. In the ananeanic substage the longitudinal ridges become more prominent and more easily observable and the costations also appear.

The contact furrow begins as soon as contact is complete and is at once deep and definitely defined, as a hollow fitting over the ananepionic tip, and it completely covers in this substage. The contact takes place on the dorsal side of the ananepionic substage and the furrow is deeper at this point in proportion to the whorls than it is at any subsequent age.

There were two specimens showing the nepionic stages of this species under observation, the one drawn and this one. Both exhibit the peculiar globular form of the apex, and the well-defined ana- and metanepionic substages, which can be quite closely compared with those of *Nautilus pompilius*, and they have similar constrictions to the first two constrictions depicted in Henry Brook's drawings on Pl. i of this paper.

The dorsum of the whorl becomes at the same time broader and the whorl alters in shape to an approximately kidney-shaped outline with the ventro-dorsal, shorter than the transverse diameter. After this age the increase of growth proceeds more slowly. In the meta-neanic substage, the costæ and longitudinal ridges become well developed, but the venter remains rounded and the lines of growth show a deep, broad hyponomic sinus and lateral crests, and the aperture at this stage must have been very distinct from that of the next substage.

In the paranecanic substage the central ventral zone appears at first as a broad band, in low relief, arising obviously from the elevated edges of the narrow hyponomic sinus, which begins to appear at this age. In the anephebic stage, at the beginning of the third volution, this acquires its specific prominence and characters. The metephebic stage is introduced by the subsequent moulding of the dorsum over this broad carination which modifies the outline of the contact furrow in section, and gives it the peculiar central dorsal face and narrow lateral dorsal faces as peculiar to this genus as are the ventral modifications which give rise to them.\*

The sutures do not seem to be much modified after the nepionic stage is passed by. The cæcum, if a spot observed on the broken apex of one specimen is correctly translated, is subventran or nearly so in the first or metanepionic septum and the siphuncle is about the same position relatively or propioventran in the paranepionic substage as observed in two specimens and given in one of these, Fig. 30, Pl. viii, and then changes slowly to centroventran in the anephebic substage. The living chamber is very long, being, if the excentric free part were applied to the coil, almost one volution in length. It is, as has been described by Barrande, present in small (young?) shells, but I doubt its existence, as well as that of the peculiar ophidioceran aperture, before the substage in which the ventral zone appears.

The free whorl in this genus is specially interesting, because even in large shells the impressed zone is preserved on the dorsum in a very significant way. It is well known that most of the shells, if not all of this genus, have the lituitan bend, that is to say, the free living chamber, after it becomes free and excentric, bends suddenly ventrally, as in Fig. 27, Pl. viii, making the last part of the living

\*This is usually called a keel or carina, but it is a modification of a different kind and sometimes has keels upon its borders.

chamber straight on the dorsum and producing a slight curvature in reverse of the spiral on the venter. In *Ophidioceras* this is accompanied by the outgrowth of a transverse dorsal spur which divides this region into two distinct parts, as shown in the same figure. The inner part of the living chamber, Figs. 32, 35, has the central dorsal face and lateral dorsal faces derived from the closely coiled whorls. These parts and the whole zone disappear as they approach the dorsal spur, Figs. 32, 34. On the outer side of this spur the impressed zone reappears, but it is the primitive form of this which reappears and is perpetuated, the dorsal faces of the ephebic impressed zone are not reconstructed, Figs. 32, 33. The spur is not a prolonged costation; it occurs indifferently between two costations or as the continuation of a costation, and is obviously independent in its origin and construction.

These facts show that there is some constantly recurring peculiarity in the growth of these shells which causes the outgrowth of the dorsal spur, and this outgrowth temporarily interrupts the construction of the impressed zone. Notwithstanding this interruption, the latter has even in the largest shells made such an impression on the organism or become so fixed in the organization that, as soon as the outgrowth stops, the impressed zone reappears. The spur either directly obliterates the ephebic characters of this zone, the dorsal faces, or else fills the space which transitional characters would have occupied, so that when the zone comes in beyond the spur it is evenly rounded as in the neanic stage. It is, however, shallower and nearer the aperture it, in part or almost entirely, disappears. The spur always occurs as a divide between the excentric spiral and the reversed curve which begins beyond it, and has some obvious connection with this change in the mode of building the shell, as is shown in Fig. 29, Pl. viii.

The sutures occupying the nepionic whorl are six in number and very wide apart from the first to the fourth.\* The fifth and sixth show approximation and the seventh is about the normal distance. The growth of the shell in the nepionic substages and in the aneanic substage, to which the fourth, fifth and sixth sutures belong, must have been very much more rapid than subsequently. They

\*The great size and depth of the apical air chamber is very remarkable. It is not satisfactorily settled in my mind that there is not at least one septum nearer the apex than that which is here counted as the first, but even in well-preserved specimens this has not been observed.

have ventral and dorsal saddles until the contact furrow is formed, and then probably a ventral lobe is always generated.

Barrande's figure of this species, Pl. xlv, Fig. 21, gives similar observations upon a different specimen. When the median ventral zone appears, the broad ventral saddle becomes narrowed to the width of this zone and the lateral lobes are proportionately broadened out.

OPHIDIOCERAS TENER.

OPHIDIOCERAS TENER, Barrande (*Syst. Sil.*, Pl. xlv); Pl. viii, Figs. 24 and 25.

Loc., Bohemia.

The specimen of this species, Figs. 24 and 25, gives the peculiar and very large ananepionic substage of this species, and in the side view the two marked constrictions indicating the same changes of form as are described in *Ophidioceras rudens*, but subsequently there is a marked bulging of the sides, in what has been termed in other forms the metanepionic substage, beyond the second constriction. If the first septum occurs where it is figured, the metanepionic substage must be placed in the Ophidioceran forms later than in other forms like *Nautilus pompilius*, which have the first septum nearer to the apex, and the ananepionic substage must be considered as greatly prolonged. Although the specimen had a perfect surface on the side depicted of the nepionic stage, it is possible that there may have been other septa\* between this and the apex, but of so fragile a nature that they were not preserved. The surface of this cast is iron pyrite. There are also six septa occupying the nepionic stage of this specimen.

There was a minute circular mark on the apex, indicating the position of the cæcum to be propioventran, but this was not absolutely certain. In the second septum the siphuncle was extracentroventran and in the neanic stage it attained a centroventran position. The subsequent stages observed were similar to those of *Ophidioceras rudens* except that the peculiar flattened ventral zone of this species was introduced later than in that species, as described and figured by Barrande.

The primitive rounded outline of the impressed zone was maintained longer in this species than in *Ophidioceras rudens*.

\*See *Ophid. tessellatum*.

## OPHIDIOCERAS TESSALLATUM.

OPHIDIOCERAS TESSALLATUM, Barrande (*Syst. Sil.*, Pl. xlv); Pl. viii,  
Figs. 26-28.

Loc., Bohemia.

The specimen, Fig. 28, Pl. viii, showed the metanepionic substage with the usual two septa and long apical chamber, but internal to the first septum there was on the venter internal dark lines, indicating a subventran siphuncle. This was cut off by another dark line which may possibly have been the fragmentary remains of a septum. Nevertheless there was no positive proof of this and the question must still be left open. The usual circular mark occurs, indicating the cœcal termination on the worn apex in a subventran position. In the second septum the siphuncle is extracentroventran.

The formation of the ventral zone began earlier in this species than in *Ophidioceras rudens*. The flattening of the abdomen began even in the paranepionic substage and in the ananeanic substage the formation of the zone was well advanced. The development of the costæ seemed also to be accelerated in some specimens.

Fig. 27, Pl. viii, shows the contact furrow as it first appears when crossing the apex. Fig. 27 shows that the umbilical perforation is larger in this species than the others described here, since the first whorl does not meet the ananepionic substage on the dorsal side but strikes it on the surface of the apex, ventrad of the centre. The contact furrow is consequently not at first so deep as in other species, unless this characteristic is variable.

*Rutoceratidæ.*

This family consists of a number of genera which are interesting in connection with the history of the impressed zone only in so far as they show that this peculiarity is correlated with close coiling, or, in other words, is due to contact.

Thus, Zitteloceras, Halloceras, Rutoceras, Kophinoceras and Strophiceras as a rule do not have the whorls in contact and do not have an impressed zone. The shell in most of these is a rough imbricated structure with ridges or nodes arising from the greater or less permanency of the frilled projections of the apertures. These genera, found in the Silurian and Devonian, were described in my *Genera of Fossil Cephalopods*, p. 284, and associated

with others of the Silurian *Adelphoceras* and *Triplooceras*, which also had rows of large nodes but were true nautilian shells and had contact furrows.

The genus, *Coelogasteroceras* (*Solenoceras*), described in my "Carboniferous Cephalopods," second paper, p. 447, was there removed from the *Rutoceratidæ* and placed with *Coloceras* under the name of *Coloceratidæ*, an error corrected in this paper.

I also included in this family the Triassic genus *Phloioceras*, having nautilian shells and a deep impressed zone, with *Phloioceras* (*Naut.*) *gemmatum*, sp. Mojsisovics, as the type and also with *Pleuronautilus*, of Mojsisovics.

I am strongly inclined to the opinion that the resemblances of these Triassic shells to *Rutoceras* are superficial, but having no specimens at my command I cannot make comparisons.

#### *Adelphoceras.*

This genus was described by Barrande in his *Système Silurien*, and *Adelphoceras Bohemicum* the type, is a large shell with a highly contracted dumbbell-shaped aperture set in the dorso-ventral diameter or vertically. The outline in section is depressed kidney shaped, with a shallow impressed zone, which is probably not present before the whorls come in contact, or at any rate is very slight at a late stage of growth, according to Barrande's figures.

This species has a large subventral siphuncle and there are three rows of tubercles on either side, and it is obviously closely related to *Triplooceras*, but is remote from *Hercoceras*, as is demonstrated by the aperture form ornaments and lines of growth.\*

#### *Triplooceras.*

This genus, described in *Genera of Fossil Cephalopods*, is obviously closely related to *Adelphoceras*, having three rows of tubercles on either side, but the form is more highly developed, being a depressed oval and the coiling closer with a deeper contact zone and the ornaments disappear much earlier on the shell. It is obviously a grade more progressive than *Adelphoceras*, but in the same genetic group.

Besides *Triplooceras* (*Naut.*) *inspiratum*, sp. Barrande, Pl. "461," there is *Triplooceras* (*Troch.*) *reliquum*, sp. Barrande, Pl.

\* Barrande's *Adelphoceras secundum* is here referred to *Hercoceras*.

"493," which has also the characteristic form and markings of this genus. This last has no contact furrow, according to Barrande's Fig. 7, even in a late neanic substage, although there is a distinct contact furrow in the ephebic stage according to his figure of the full-grown shell.

*Melonoceratida.*

Under this title, in *Genera of Fossil Cephalopods*, I included a number of genera having special interest in this connection. The impressed zone is not present in *Melonoceras*, which is an arcuate form, and in most species of *Oonoceras*.

*Cranoceras*, containing the only apparently arcuate form possessing a dorsal furrow, belongs to this family and appears to be allied to the more closely coiled nautilian forms *Nedyceras*. All of these forms have subtrigonal whorls, with siphuncle ventrad of the centre. The resemblance of *Estonioceras* and *Remeléceras* have led me to place them also under the same family name.

*Estonioceras.*

This genus was described by Nötling,\* and separated from *Lituites*, which it only remotely resembles in having some of the volutions free.

Schröder has more fully described the genus† than any other author, and given all the European species with great care, but has, in my opinion, included in it some forms with quadrangular whorls and siphuncles in different positions which should be separated as *Remelé* has done under the name of *Facilituites*.

*Estonioceras* has a nepionic stage with a large umbilical perforation like that of other species of the same phylum. The apex itself, the ananepionic substage, is remarkably large and grows with extreme rapidity in its transverse diameters, showing the tendency to form a broad, digonal whorl, and is cap-shaped when seen from the side as in *Trocholites* and *Ophidioceras* and very large in all its diameters. The sutures of the meta- and paranepionic substages throughout the greater part of the first whorl, as seen in the specimen Fig. 13, Pl. vii, and in Schröder's figure of apex of *Estonioceras imperfectum*, Pl. iv, Fig. 5, a-b, reproduced here on Pl. vii, Figs. 20

\* *Op. cit.*, *Jahrb. d. könig.-preuss. geol. Landesam. u. Bergak.*, 1882.

† "Ueber Sil. Ceph.," *Pal. Abh.*, Dames et Kayser, v, hft. 4.

and 21, have saddles on the venter with perhaps very slight ventral lobes on either side of this, saddles at the lateral angles and faint dorsal saddles. Schröder also describes the same substages in *Estonioceras perforatum* and the sutures of the first whorl, but his descriptive nomenclature is not clear and the text is consequently not perfectly intelligible. Apparently the first whorl has broad ventral saddles and nearly straight dorsal sutures with sometimes very slight dorsal saddles. He states very distinctly, however, when the whorls touch, at or near the end of the first whorl, that a decided change takes place, the dorsal sutures acquiring well-marked dorsal lobes. He also clearly states that in the uncoiled volutions this dorsal lobe, although it persists, loses in height and breadth.

In his descriptions of *Lituities Muellauræi*, of Dewitz, he makes these statements clearer by saying that the dorsal and ventral saddles possessed by the adult of this species are similar to the sutures of the young species of *Estonioceras perforatum* and *imperfectum*, which have sutures with ventral and dorsal saddles as figured by him only on the venter of *Estonioceras imperfectum*. There is also a shallow lobe developed in the middle of the dorsal saddle in *Estonioceras perforatum*, which persists even in the gerontic stage. After the lateral angles disappear in the ephebic stage, the saddles and lobes are less prominent and become almost straight in the more rounded volutions of the gerontic stage, but the approximate return of the same outlines as are found in the paranepionic substage is plainly visible, Figs. 17 and 18, Pl. vii.

The lines of growth show a broad hyponomic sinus and lateral crests which increase in prominence towards the dorsum, but directly in the centre of that side there is a crest and on either side of this shallow dorsal sinuses. There is, however, a dorsal sinus which persists in the gerontic stage in the lines of growth of a specimen figured by Schröder of *Estonioceras heros*.\*

The aperture is wide in the ephebic stage, but evidently contracts with the whorl in extreme age, as shown in Schröder's figure of *Estonioceras imperfectum*, Pl. iii, Fig. 2, b, and in the figures of *Estonioceras biangulatum* in this paper, Pl. vii, and sometimes the ventro-dorsal diameter may become longer than the transverse in the paragerontic substage. This is, in part, a return to the early proportions, since Schröder describes the apex of his *Estonioceras*

\* *Op. cit.* Pl. v.

*perforatum* as having an apical chamber in which the breadth but little exceeds the ventro-dorsal diameter and doubtless at the apex itself in the ananepionic substage, as in most Nautiloids, the ventro-dorsal diameter exceeds the transverse.

The coiling is so loose that the umbilical perforation is of very large diameter, and the impressed zone, generated only after contact, is very slight even on the second whorl and does not persist after the whorls separate. The dorsum is, however, affected to a limited extent on the free whorl in some species as shown in Schröder's admirable figures. These figures give one great satisfaction, their accuracy, size and detail being full of information.

The whorls touch during the neanic stage only in some species, *Estonioceras ariense*, but in others they may continue in contact probably throughout the ephebic or a large part of that stage, *Eston. perforatum* and *imperfectum*.

The lateral angles become rounded in the ephebic stage, but there is no tendency to form lateral zones or to flatten the abdomen as in *Falcilituites*. The whorls simply become rounded, depressed ovals and in the paragerontic stage the length of the transverse diameters decrease.

The siphuncle is fully described by Schröder in *Estonioceras imperfectum*, and it is plainly ellipsochanooidal in the ephebic stage. What it may be in the young has not been determined. The funnels are very short and the connecting walls thin and long. The position is subventran in the young, tending more towards the centre and becoming extracentroventran in some species with the advance of age. In the paranepionic substage it may again return to a position nearer the venter.

The species described by Schröder are as follows :

*Estonioceras perforatum*, Schröder; *Estonioceras* (*Lit.*) *lamellosum*, sp. His. *Discoceras lamellosum* as figured by Angelin et Lindstrom seems quite distinct with closer coiled whorls and deeper impressed zone, too deep in fact for a species of this genus, whereas Hisinger's figure in the *Lethea suecica* is a true *Estonioceras*. Nevertheless Schröder asserts that both figures were made from the same "individual." *Estonioceras* (*Lit.*) *heros*, sp. Remelé; *ariense*, sp. Schmidt; (*Lit.*) *imperfectum*, sp. Quenstedt.

*Estonioceras muellaueri* and Schröder's *Estonioceras decheni* have been referred to the genus *Falcilituites* of Remelé in this paper.

ESTONIOCERAS PERFORATUM, Schröder (*op. cit.*, Pl. xxvi); Pl. vii,  
Figs. 9-12.

Loc., Reval.

The specimen, Fig. 10, Pl. vii, shows the dorsum of the paranepionic volution with the shell of the dorsum preserved. The dorsal crest and dorsal sinuses of the lines of growth and in part the sutures are visible. After this was drawn a part of the shell was removed, exposing the dorsal sutures which are given in Fig. 12, Pl. vii. These show the presence of a dorsal lobe as described above with faint saddles, the remains of the younger dorsal saddle, on either side of this. The ventral sutures have saddles at this stage as may be seen by the outline of the whorl, but these were not seen, although the ventral lobes on either side are plainly visible in the side view of the paranepionic volution in Fig. 11. In the metanepionic substage the dorsal lobe broadens and deepens in correlation with the widening and deepening of the contact furrow, and the lateral lobes appear then almost like saddles on the sides as in Fig. 11 above in the outline of the only septum visible at this age in this specimen. They are, however, still really slight aborad inflections or lobes. There is no true annular lobe at any stage.

Fig. 9, Pl. vii, reproduced from Schröder's figures of *Estonioceras perforatum*, shows that in this species in at least some varieties the neanic stage probably does not acquire a contact furrow until it strikes the metanepionic substage.

The specimen figured is in collection of Mus. Comp. Zoölogy.

ESTONIOCERAS BIANGULATUM, n. sp. Pl. vii, Figs. 13-19.

Loc., Breslau.

The figures of this species show the large umbilical perforation and digonal whorl of the paranepionic substage and neanic stages seen from the side in the centre of Fig. 13, Pl. vii, and then from the front with part of the outer whorl between the broken lines and also the terminal part of the free whorl removed in Fig. 15. The portion removed belongs to the ephebic stage, which in this species has a digonal section. The lateral angles do not show rounding and the lateral diameters continue to increase steadily and rapidly until the anagerontic substage begins as the whorl becomes free. Then a decisive decrease is noticeable in both of these characteristics. In this specimen the transverse diameter through the middle of the free volution without the shell, Fig. 17 and 18, was 42 mm., the

ventro-dorsal .30 mm. at the termination of the same, the fragment of the living chamber also devoid of shell was transversely about 40 mm., while the dorso-ventral had increased to 32 mm. This and the point of view of Fig. 18 gives the aspect of a more considerable diminution in the lateral diameters than actually took place. The sectional view of this end shows true proportions in Fig. 19, Pl. vii.

The section, Fig. 15, gives the neanic whorl at the inner break in the side view, Fig. 13, and this shows how very small and slight the zone of involution is in this species. It broadens slightly with age, but immediately disappears in the free part of the whorl, as it does also in most species of this genus.

The lines of growth are given on the dorsum of the metagerontic substage in Fig. 17, and these do not differ materially from those of the nepionic stage in *Estonioceras perforatum*. The lines of growth could not be observed on the dorsum of the earlier stages of growth, but it is probable that in the stages in which the whorls are in contact that the dorsal crest is narrow and occupies the area of the impressed zone.

The sutures in the paranepionic substage have ventral saddles with very slight ventral lobes on either side, saddles at the lateral angles and apparently lateral lobes. Three sutures of this substage were followed on the dorsum to the centre and no central inflections could be seen. This was somewhere about the sixth or eighth septum, as nearly as could be ascertained, and the suture formed a very shallow lobe across the dorsum, but this would ordinarily be described as straight. These, in other words, are closely similar and of about the same age as the complete dorsal sutures of *Estonioceras imperfectum* given in Fig. 21, Pl. vii, and probably about the same age as the dorsal sutures of *Estonioceras perforatum* given in Fig. 12, Pl. vii. In the ephebic stage broad lobes appear on the venter, reaching to the saddles at the lateral angles. The septum, Fig. 15a, Pl. vii, given to show the contact furrow, also shows that a faint narrow dorsal lobe coextensive with this furrow is produced by contact. In the paragerontic substage, as shown on the last three sutures of Fig. 18, the broad ventral lobe is replaced by faint saddles with very faintly marked lobes on either side and the saddles of the lateral angles in consequence of the rounding of these angles have become lateral saddles. The lateral lobes appear only very faintly or are absent on the

under side or dorsum. The dorsal lobe is not, however, affected to the same extent by senile degeneration, and persists, although narrower in proportion in the centre of the suture, as may be seen in Fig. 17, Pl. vii.

The siphuncle is propioventran in all the stages observed from the ephebic to the anagerontic.

*Remeléceras*,\* n. g.

This genus, known at present only by one species, is closely allied as regards aspect and the late appearance of a contact furrow to *Estonioceras*. It differs in having a much deeper furrow, a nephritic instead of a digonal or depressed elliptical form of whorl and in the dorsal sutures and, apparently also in the extraordinary form of annular muscle.

REMELÉCERAS IMPRESSUM. Pl. viii, Figs. 1-8.

Loc. (?)

This extraordinary form is described and figured in this memoir on account of its interesting connection with the history of the impressed zone, notwithstanding the absence of any information with regard to the locality. The side view, Fig. 1, Pl. viii, shows the sutures, which are similar to those of *Estonioceras*, and the impression of what appears to be the annular muscle at the base of the living chamber is very distinct. This may be seen on the dorsal side, Fig. 3, where the lower line has a deeper and broader depression in the cast reaching across the contact furrow. These two lines of depression depart from each other widely on the ventral side, Fig. 2, the outer one forming a broad saddle. They of course correspond to raised ridges on the inner surface of the shell of the living chamber and may have been due to abnormal action in the secretions along the upper and lower borders of the annular muscle.

The depth of the contact furrow in the full-grown shell near the end of the incomplete living chamber was somewhat greater than is given in Fig. 4, but only a shade deeper, and is also slightly deeper than this beyond the base of this living chamber on the septate part of the volution. In younger stages, shown successively in Figs. 5-7, with their accompanying sections, Figs. 6-8, this furrow diminishes in depth and breadth and almost disappears

\*Dedicated to Remelé, well known for his original observations on fossil Cephalopods.

on the third fragment. This shows that it did not begin to exist in this shell until late in the neanic stage and the younger nepionic stage must have been similar to that of *Estonioceras*.

It is also interesting and suggestive to note that the depth and development of the dorsal lobe correlates exactly with the depth and breadth of the contact furrow. The lateral asymmetry in the dorsal lobes of the sutures is another fact to be noted in this specimen.

The central whorls existed in this specimen, but were completely concealed by the matrix. A section was made of these, but they exhibited no structures.

The siphuncle was not visible.

This cast reminds the observer more closely of *Estonioceras* (?) *lamellosum*, as figured by Angelin and Lindstrom, than any other form, but according to Schröder this last is a true estonioceran form with only a slight contact furrow.

#### *Nædyceras*.

This genus was described by the author in *Genera of Fossil Cephalopods*, p. 281. It includes a large number of species with subtrigonal whorls, the dorsum much broader than the venter, which is elevated and usually subangular. The siphuncle is subventran and quite large.

The sutures have ventral saddles, lateral lobes and the dorsum may have a slight lobe or be nearly straight. The genus is of interest in this connection because, although completely coiled and the whorls in contact in several forms and although the whorl approximates to the nephritic outline, it never has an impressed zone. This is easily accounted for when one examines the figure of *Nædyceras vestustum*, Barrande, Pl. "35." This shell shows that, although close-coiled, the rate of growth is slow and the umbilical perforation very large, so that there is no pressure of one whorl upon another.

The genus has a number of forms in the Devonian, which also show similar peculiarities whether they are similar or more open in their coiling than *vestustum*, or have the turbinate mode of growth, which last is not unusual.

The shells are all smooth.

*Cranoceras.*

This genus was described in *Genera of Fossil Cephalopods*, p. 281, for a series of cyrtoceran forms having in the Silurian representatives like *Cranoceras* (*Cyrt.*) *hospitale*, sp. Barrande, Pl. "151;" *nigrum*, Pl. "127," and *Turnus*, Pl. "483" and "484."

The whorls are subtrigonal with the dorsum, much wider than the venter, which is apt to be elevated and subangulated. The young, until they are quite large, are compressed elliptical in section, with the ventro-dorsal diameter longer than the transverse, then expanding more rapidly they become more depressed and take on the subtrigonal outline, the dorsum broader than the venter, which in some species changes subsequently into the nephritic with a slight impressed zone, Fig. 43, Pl. viii.

The sutures have ventral saddles, slight lateral lobes and slight broad dorsal lobes, but in some species may be approximately straight and in the young stages are of this character in most forms. Considering the size of the shells the septa are remarkably close and numerous, and only slightly concave.

The siphuncle is propioventran and apt to be filled with radiating deposits. The Silurian forms do not have the nephritic outline and also have no impressed zone at any stage, judging from the large shell of *Cranoceras turnus*, which, although it has a nautilian-like form in the large fragment described by Barrande, probably did not coil very closely.

The Devonian forms are, however, more interesting in connection with the history of the impressed zone. These can be included under the names of *Cranoceras* (*Cyrt.*) *depressum* and *Cranoceras* (*Cyrt.*) *lineatum*.

In the Museum of Comparative Zoölogy, in the Schulze collection from Pelm near Gerolstein, in the Eifel, there is a specimen of *Cranoceras lineatum* 159 mm. in length along the median lateral line, transverse diameter of smaller end 45 mm., abdominodorsal 41 mm., and diameters of larger end 109 mm. and 85 mm. This is evidently a quick-growing and very large specimen, but showing no signs of having been coiled. It has, however, near the larger end on the incurved dorsal side a very faint impressed zone given in the outline, Fig. 43, Pl. viii, traced from the specimen. Some specimens do not exhibit this depression, but most of this species do have similar depressions and some of these are so nearly straight

and the angle of growth so convergent that it becomes difficult, perhaps impossible, to attribute the existence of this zone to contact and pressure of a coiled whorl, unless it was acquired by inheritance through some unknown closely coiled forms.

None of these specimens have the double impressed zone figured in *Cranoceras* (*Cyrtoceras*) *depressum*, by D'Archiac et De Verneuil,\* but I have studied some fragments of this species showing the same peculiarity. The two latero-dorsal impressions or faces and the central gibbous dorsal face give an outline similar to that of the young of the *Trocholites canadense*, given in Fig. 24, Pl. iv, of this paper. The history of the appearance of this modification in this large adult whorl, arising as it does from the direct modification of the younger rounded dorsum† without being preceded by the formation of an impressed zone is, however, entirely distinct from that which occurs in the paranepionic substage of *Trocholites*. In several genera of Carboniferous nautiloids (ex. *Asymptoceras*, *Apheloceras*) similar faces appear on the dorsum, but the central, gibbous dorsal face is fitted into the hollow flute or ventral zone of the next inner whorl and is obviously a result of close-coiling and adaptation of the plastic dorsum of the growing external volutions to the ventral modifications of the inner volution.

In *Solenocheilus* of the Carboniferous, however, the whorl has a rounded venter and yet notwithstanding this a gibbous dorsal face and dorso-lateral concave faces or furrows are formed independently. In *Cranoceras depressum* the origin of the gibbous dorsal face and latero-dorsal faces or furrows appears also, so far as the facts go, to have been entirely independent of any correlation with the ventral surface, which is rounded and gibbous. These characteristics do not seem to have had a mechanical origin in any of the shells, so far examined, which have the dorsal side free or comparatively free from contact.

A very large and remarkable specimen in the Schulze collection, Mus. of Comp. Zoölogy, shows a very short living chamber, which has an aperture very broad transversely and with a nephritic outline and apparently very broad and well-marked impressed zone. This species is not a variety of *lineatum*, but a distinct species precisely similar to D'Archiac and De Verneuil's figures of *Phragmoce-ras subventricosum*, but the siphuncle is ventral.

\* *Geol. Trans. London*, 2d ser., vi, Pl. xxix.

† This is also figured by Roemer, *Harzgeb. Paleontogr.*, iii, Pl. vi, in a young specimen.

It is questionable, however, even in this form, whether there was anything more than a flattened dorsal side on the septate part of the whorl, since this is the aspect of the perfect side, the left side of this specimen, the right dorsal side and part of centre being crushed in by pressure. A second specimen of smaller size shows the peculiar dorsal aspect of *Cranoceras depressum*, but so faintly that the gibbous face and flutings are hardly perceptible.

I have been, of course, struck by the resemblance of these shells to the young of the nautilian forms of the Mesozoic, but there is still closer resemblance in the general aspect of species of *Uranoceras* and the closely set septa of the species of *Cranoceras*, and their contracted apertures show that it is not safe to consider them as radical forms.

They resemble the young of some species of the *Nephritidæ*, but this family has a peculiar ornamentation in young shells and is a closed generic series having apparently its own slender radical forms in the Devonian and possibly even its own arcuate radicals in this period.

#### *Nephritidæ.*

This family name is given to cover a series of genera having heavily ridged shells in the young, and for the most part in adults, with whorls having considerable resemblance in general outline and sutures to the true *Nautilidæ*, with which I formerly associated them.

*Sphyradoceras*, described in my *Genera of Fossil Cephalopods*, page 298, contains the remote radicals of the group and this genus has arcuate and trochoceran forms. They are of value in this connection only in so far as they show that the impressed zone, as a rule, is not present when shells are not in close contact.

*Uranoceras* has a number of large stout shells with solid, nautilian-looking whorls which are, however, never, so far as I have seen, in sufficiently close contact to produce a contact furrow. These forms are interesting, however, because the dorsum is always slightly flattened and has the aspect common to the nepionic stage of nautilian shells, so that one continually expects to find a specimen with a dorsal furrow. I have, however, not yet found an example of this kind, although the whorls are often so close as to touch each other. The type is *Uranoceras (Cyrt.?) uranum*, sp. Barrande, in the Silurian, but most of the species occur in the Devonian.

My references, in *Genera of Fossil Cephalopods*, to some Carboniferous nautiloids as probably members of this genus were erroneous. Barrandeoceras has been referred to above as belonging to the Tarphyceratidæ.

Pselioceras, mentioned also in my *Genera of Fossil Cephalopods*, as another member of this family, may possibly be a genus of Rineceratidæ, but it does not belong here.

The family of the true Nautilidæ have been properly limited farther on to Mesozoic genera.

*Rhadinoceras*,\* n. g.

The species here noticed under this name were formerly included in the genus *Nephriticeras*. They have compressed elliptical or almost rounded whorls, growing more slowly than in *Nephriticeras*, have the impressed zone only in the later stages of growth and are transitional between gyroceran forms and *Nephriticeras*.

RHADINOCERAS CORNULUM.

NAUTILUS CORNULUS; Hall (*Pal. N. Y.*, v. Pt. ii, Pl. lx).

Hall's figure shows the nepionic and neanic stages of this shell, and there is a slight contact furrow.

The form of the whorl in section is almost circular, not changing much throughout the nepionic stage.

The sutures are similar to those of *Nephriticeras*, with slight ventral and dorsal lobes and rather narrow lateral lobes.

The siphuncle, according to Hall, is dorsal of the centre.

The shell has only fine striæ and fine longitudinal ridges.

Having studied the original of this species in Prof. Hall's collections, I can confirm his observation and state that this is obviously a close-coiled nautilian form with a slight contact furrow produced after the whorls come into contact in the ananeanic substage, but not existing previously.

The umbilical perforation was very large, and young shells show that *Rhadinoceras* contains transitional forms between *Nephriticeras* and some cyrtoceran ancestor. In other words, these two genera were not derived from any coiled nautilian form of the Devonian or Silurian, but are progressive modifications of some closely allied arcuate form. This conclusion is sustained also by the existence of a peculiar cyrtoceran form associated with these

\* *Pādīvós*, slender.

which may be a survivor of the ancestral genus of this group. I allude to the peculiar arcuate species described by Hall from the Goniatites limestone of Manlius, N. Y., under the name of *Cyrtoceras liratum*. Hall recognized the affinity of this shell, in the ornamentation and form to species here described as included in *Rhadinoceras*, and it can be easily observed that the young of *Rhadinoceras cornulum* directly repeats the characters of his *Cyrtoceras liratum*.

#### RHADINOCERAS HYATTI.

NAUTILUS HYATTI, Hall (*Pal. N. Y.*, v, Pt. ii, Pl. cxxvi).

This species, so far as figured by Hall and so far as known to me from the observation of Prof. Hall's collection, is even less closely coiled than *Rhadinoceras cornulum*.

The early stages figured by Hall show no dorsal furrow and the form is similar to that of *cornulum*, but it is a depressed ellipse in the nepionic stage, increasing more rapidly by growth in its transverse diameters than in *cornulum*. The affinity of this species with the nepionic stage of *Nephriticeras* is indicated not only by the form of the whorl, which is identical, but by the presence of coarser longitudinal ridges, and by the sutures.

Whether the whorls of this species were ever in close contact is doubtful, on account of the absence of more complete specimens and the want of a contact furrow on the fragments, so far as known to me.

But the single fragment figured by Hall, and examined by me, was not old enough to settle this question, and I am inclined to the opinion that it will be found to be a true nautilian shell.

#### *Nephriticeras.*

This genus, described by the author in *Genera of Cossil Cephalopods*, p. 300, formerly included the transitional species separated above under the name of *Rhadinoceras*.

These shells are all unquestionably nautilian:

The early part of the nepionic, probably metanepionic substage, is similar in transverse section and ornaments to the full-grown shells of *Rhadinoceras*, but the paranepionic volution becomes speedily depressed and subtrigonal, the dorsum broad and much flattened, the abdomen elevated and narrower than the dorsum.

The siphuncle is dorsad of the centre.

The sutures have ventral and dorsal lobes and lateral lobes in the ephelic stage, but in the earlier stage there are ventral saddles.

NEPHRITICERAS LIRATUM.

NAUTILUS LIRATUS, sp. Hall (*Pal. N. Y.*, v. Pt. ii, Pl. lvii and Pl. lx).

This species in the metanepionic substage is distinctly annulated and also has broad longitudinal ridges, as shown in Hall's figures on Pl. lx. These ridges disappear together with the annulations on the abdomen of the paranepionic volution, but persist longer on the dorsum, and in some specimens they are very large flutes on the sides even in the neanic, as is shown in Hall's Fig. 3, Pl. lvii.

In the neanic stage the form of the volution changes from sub-trigonal to a broad depressed oval.

No impressed zone has been observed, but this may be due to the age of the shells so far observed, none of which as figured, nor so far as I have seen, exceeded one volution.

NEPHRITICERAS JUVENIS.

NAUTILUS LIRATUS, var. JUVENIS, Hall (*Pal. N. Y.*, v. Pt. ii, Pl. lvi, Figs. 5, 6).

This shell, described as a variety of *liratus* by Hall, is obviously distinct. The form changes more rapidly than in *liratus* and, in the fragment of the nepionic volution figured by Hall, it may also be seen that the longitudinal ridges are much smaller than in *liratus*, more like those of the young of *Nephriticeras bucinum*. It differs from the last in having no impressed zone at the same age.

It is highly probable that an impressed zone appeared in a later stage than has yet been described.

NEPHRITICERAS SUBLIRATUM.

NAUTILUS SUBLIRATUM, sp. Hall (*Pal. N. Y.*, v. Pt. ii, Pl. lvii).

This species has similar changes of form to those of *liratum*, but it is altogether a broader whorled species and acquires the nephritic outline at an earlier stage of growth, and probably has in perfect specimens a smaller umbilical perforation.

There are no longitudinal ridges on the ventral side in the original specimen, which was in the neanic stage of development, but these are large and persistent on the dorsum as in *Nephriticeras liratum*. In Hall's figures the sutures have been confused with the

lines of growth and the dorsal sutures are not correctly given. The dorsal lobes exactly coincide with the impressed zone in Fig. 6 of his plate. This figure shows the last part of the paranepionic volution in section below and the ananeanic with the impressed zone above this. The smoothness of the impressed zone in Hall's Fig. 6 of this species shows that the longitudinal ridges were obliterated as they are in other forms by the pressure of the growing whorl, and that this zone is probably due to contact and did not occur on the free side of the volution in the umbilical perforation. I use the general term "impressed zone," because, although my notes and Hall's observations and the figures all seem to warrant the statement that this zone in this species is a contact furrow, I have not been able to revise and confirm these observations.

#### NEPHRITICERAS BUCINUM.

NAUTILUS BUCINUS, Hall (*Pal. N. Y.*, v, Pt. ii, Pl. lx).

The paranepionic volution is shown in Hall's Fig. 1, Pl. lx, with a convex dorsum, and in Pl. cvii, Figs. 2 and 3, it is again shown with the siphuncle dorsad of the centre and the outline distinctly subtrigonal. These figures indicate great variability in the time at which the impressed zone appears, since the section in Pl. cvii is very much larger than that of about the same age of Fig. 2, Pl. lx. One is disposed to think that these are perhaps different species. Fig. 2 of Pl. lx gives in front view a section of the paranepionic volution with a distinct but narrow impressed zone marked on the dorsum. This whorl has a nephritic outline and is very different from the subtrigonal outline of a whorl with convex dorsum referred to above, which belongs to an obviously later stage of growth in a larger species.

Having examined these specimens in Prof. Hall's collection some years since, I find in my notes the statement that "no depression (meaning the dorsal furrow) occurs in the centre of any of these shells until the whorls touch, which they do at a late stage of growth." The form changes from a depressed oval in the metanepionic to nephritic more rapidly than in *Nephriticeras sublivatum* and the transverse diameters increase faster. The longitudinal ridges are smaller and less prominent than in *Nephriticeras livatum*.

The sutures in the young have ventral and dorsal saddles and only in later stages these are replaced on the dorsum and venter by

broad, shallow lobes, but in some specimens the sutures are nearly straight or may retain slight saddles on the venter.

The siphuncle is extracentrodorsan.

NEPHRITICERAS CAVUM.

NAUTILUS CAVUS (*Pal. N. Y.*, v, Pt. ii, Pl. cvi).

The fragment of the neanic stage, figured by Hall, has the nephritic whorl and similar sutures to the full grown of *Nephriticeras bucinum*, but the dorsal lobes are deeper perhaps and more V-shaped. The septa are different in being much more widely separated, but are otherwise similar to those of the later stages in *Nephriticeras bucinum*. I find in my notes that the impressed zone occurs after the dorsal lobes are formed and at an earlier stage than in *bucinum*.

Siphuncle is unknown.

NEPHRITICERAS ACRÆUM.

NAUTILUS ACRÆUS, Hall (*Pal. N. Y.*, v, Suppl., Pl. cix).

The fragment of the neanic stage, figured by Hall, shows the nephritic outline impressed zone and ridges similar to those of the older stages of *Nephriticeras bucinum* occurring at an earlier stage than they do in *Nephriticeras cavum*.\*

NEPHRITICERAS MAGISTER.

NAUTILUS MAGISTER, Hall (*Pal. N. Y.*, v, Pls. lxii, cvii, cviii).

The large fossils of this species which I have examined have not afforded me any information with regard to the young, but the nephritic form of the whorl, the impressed zone and large beaded siphuncle dorsad of the centre show that the species belongs in the same genus with *Nephriticeras bucinum*.

This species may have either slight ventral lobes or saddles on the venter.

NEPHRITICERAS MAXIMUM.

NAUTILUS MAXIMUS, Hall (*Pal. N. Y.*, v, Pt. ii, Pls. lxxiii, lxxiv).

This is like *Nephriticeras magister*, known only through large fossils, but the young of the specimen figured by Hall on Pl. lxxiii

\*I regret very much that in finishing this paper I have had no opportunity to revisit Prof. Hall's collection and study again his old and new materials. It is not improbable that his fine series of Nephriticeran species may show that the impressed zone was present as a dorsal furrow in the paranepionic substage of some of the more involute and tachygenic shells.

has, according to my notes, and when seen from the side, a general resemblance to *Nephriticeras oriens*.

The sutures and position of the siphuncle and form of whorl places it in this genus.

NEPHRITICERAS ORIENS.

NAUTILUS ORIENS, Hall (*Pal. N. Y.*, v, Pt. ii, Pl. lxi, and Suppl., Pl. cvi).

This species is obviously closely allied to *Nephriticeras magister* and *maximum*. The shell shows coarse longitudinal ridges and striations of growth as in other species of this genus, and the sutures and position and structure of siphuncle also justify its associations with these species in the same genus.

NEPHRITICERAS INELEGANS.

GYROCERAS (NAUT.) INELEGANS, Meek (*Pal. Ohio*, i, Pl. xxi).

This form is closely allied to *magister* and is probably a species of this genus.

#### *Eudoceratidæ.*

This family was described in my *Genera of Fossil Cephalopods*, and again in "Carboniferous Cephalopods," *Fourth Annual Rep. Geol. Surv. Texas*, p. 465.

The genera are of interest in this paper because of the absence of the impressed zone in the more generalized open-whorled *Edaphoceras*, its appearance as a contact furrow in *Endolobus* and its appearance as a dorsal furrow in *Potoceras dubium*. I have placed this last form in this family with much reservation. The young have characteristics similar to those of *Endolobus Avonensis*, but the development is more advanced and decidedly tachygenic.

The absence of a dorsal furrow in the nepionic whorl of so highly specialized and so involute a shell as *Ephippioceras* is upon the whole rather remarkable and requires confirmation with a better preparation than the one at my command. The highly digonal form of the young has induced me to transfer this genus from the *Apsidoceratidæ*, under which it appeared in my *Genera of Fossil Cephalopods*, to this family.

#### *Edaphoceras.*

This genus was first described by the author in *Genera of Fossil Cephalopods*,\* the type being a large Carboniferous species

\* *Proc. Bost. Soc. Nat. Hist.*, xxii, 1883, p. 288.

eight inches in diameter described by Meek and Worthen\* and fully figured by them. These figures reproduced on Pl. vii, Fig. 22-24, show the generic differences of this species and the forms on the same plate, which are good examples of the genus *Estonioceras*. *Edaphoceras* differs in having non-involute whorls without an impressed zone and a more completely digonal outline in transverse section of the full-grown volution.

The sutures have ventral lobes, saddles at the lateral angles and dorsal lobes with slight median saddles if the figure is correct.

The siphuncle is centren in the adult.

Notwithstanding the close resemblance of the type species to *Estonioceras ariense* as figured by Schröder, I doubt whether this Carboniferous type has direct genetic connection with *Estonioceras* of the Silurian. Until the young are known it will be impracticable to settle this question, but at present the close-coiled shells of *Edaphoceras niotense*, as described by Meek and Worthen, and of *Edaphoceras (Naut.) hesperis*, Eichwald,† both with siphuncles nearly or exactly centren and neither having an impressed zone and the peculiar form described by Foord‡ as *Solenocœtilus caledonicus* which is similar but has a slight impressed zone, all point to a separate phylum from that of *Estonioceras*.

I do not, however, wish to imply that they did not arise from the same common origin, possibly some form of *Eudoceras*, but simply that *Edaphoceras* does not appear to be a direct descendant of *Estonioceras*.

#### *Endolobus.*

This genus was first described in *Genera of Fossil Cephalopods*, and subsequently in the *Second* and *Fourth Ann. Rept. Geol. Surv. of Texas*.

Unluckily I have never been able to study the young of the type *Endolobus spectabilis* of Meek and it may be that none of the species referred to this genus really belong to it.

#### ENDOLOBUS AVONENSIS.

NAUTILUS AVONENSIS, Dawson (*Geol. of Acadia*, p. 311). Pl. viii, Figs. 36-39.

Loc., Joggins, Nova Scotia.

The ananepionic stage of this species, Fig. 38, Pl. viii, has a trigonal shape and the cicatrix, although necessarily exaggerated in

\* *Geol. of Ill.*, v, Pl. xix.

† *Leth. Rossica*, Pl. xlv, Fig. 7.

‡ *Cat. Foss. Ceph.*, ii, p. 172, Fig. 30.

the figure, is approximately given. This form is like that of the arcuate forms of genus *Tripteroceras* in their ephebic stage. The shell was smooth. A paranepionic septum is shown below and in the specimen (Figs. 36-37) a still younger septum was developed after this drawing was made. These have ventral saddles, very faint lateral lobes, and minute shallow dorsal lobes, resembling in shape those of the older stages.

As shown in these drawings, the dorsum of the nepionic stage, which ends with the section just below the apex, is rounded and the impressed zone is a contact furrow beginning in the ananeanic substage only after the whorls touch. This zone deepens rapidly, but is never very broad or deep.

The side view shows the cyrtoceran form of the metanepionic substage and the large size of the umbilical perforation, which is given by a dotted line.

The siphuncle is nearly subventran in the paranepionic substage, but it does not increase proportionately in size and becomes centroventran in the neanic septum as shown above the apex, and ventrocentren in the ephebic stage.

The lateral angles are more acute and the form more perfectly digonal in the neanic and early ephebic stage than in the paranepionic or gerontic stages.

The specimen figured is in Museum of Comparative Zoölogy.

A young specimen of this species from Windsor, N. S., in the Museum at Ottawa, shows the living chamber of the early ephebic stage or paranepionic substage at the end of the second whorl. This is not quite one-half of a volution in length and has a deep, rather narrow hyponomic sinus with large median lateral crests and deep sinuses near the lines of involution.

#### *Lophoceras.*

This genus, described in *Fourth Annual Report Geological Survey of Texas*, has a very slight impressed zone in some species and it is clearly dependent upon the contact of the whorls.

#### *Potoceras.\**

POTOCERAS DUBIUM, n. sp. Pl. x, Figs. 15-22.

Loc. (?).

The nepionic stage is shown enlarged in Figs. 16-18, Pl. x, and

\* *Πότος*, drinking.

this is in a general way very similar to that of *Endolobus avonense* during the ana- and metanepionic substage, but in the paranepionic a dorsal furrow appears which is not present in *Endolobus* at the same early age. The longitudinal ridges appear also in this substage, the previous substages being smooth. The umbilical perforation, Fig. 15, shows the very abrupt bend which takes place at the end of the metanepionic substage just before the dorsal furrow appears. This furrow is broad and well defined and cannot be said to be correlative with a nephritic outline. The section of the whorl at this age, Fig. 17, still retains in some measure the trigonal outline of the ana- and metanepionic substages. It has become temnocheilan or trapezoidal through the great broadening of the abdomen, but if no furrow were present it would have to be described as a modified subtrigonal (see Fig. 17 which gives the form correctly). It is in no sense nephritic, although obviously transitional and standing between the preceding digonal and succeeding nephritic outline shown in the ananeanic substage. This substage occupies the last quarter of the first whorl. The broadening out of the furrow, which also increases in depth, although the curvature remains constant, can be observed in this same substage while the volution is still free, also the advent of a purely nephritic outline and a minute annular lobe in the middle of the dorsal lobe. The siphuncle shifts somewhat nearer the centre.

Contact takes place on the ventral side of the ananepionic volution, but the apical end is not free. The dorsal sutures in consequence of the annular lobe have a much spread-out or flattened V shape like those of *Endolobus avonensis* at a later stage and in the contact furrow (see Fig. 37, Pl. viii).

The form of the adult also resembles that species. The sutures have ventral saddles, lateral lobes and dorsal lobes in the ephebic stage and the outline is nephritic. The annular lobe does not increase much in size with advancing age and seems to disappear in this stage. Although the locality of this specimen is unknown, the probable age is Devonian.

Fearing to trust my own conclusions in this instance, and having one valve of a Brachiopod which was detached from the specimen described above, I sent the latter to Mr. Charles Schuchert in the National Museum, Washington, for determination. This gentleman very kindly gave me the benefit of his great special knowledge of this group and returned it to me with some other specimens of a

species of *Martinia* from the Iberger Kalk, Upper Devonian of Grund, Germany, with which he considered the species to be closely related.

*Ephippioceras.*

EPHIPPIOCERAS FERRATUM, Hyatt.

NAUTILUS FERRATUM, Owen (*Geol. Kentucky*, iii, Pl. x, Fig. 2).

Figs. 23-26, Pl. x, enlarged 5 diameters.

The nepionic stage is given in Fig. 23, from the side showing the lateral longitudinal ridges of the paranepionic and part of the metanepionic substage. These ridges are more acute on the venter and wider apart and blunter on the sides. The form in section of the metanepionic is digonal, and that of the paranepionic substage has a more elevated venter and flatter dorsum. There was no dorsal furrow in the paranepionic substage, so far as could be ascertained, but the condition of the specimen left this fact open to doubt.

It is interesting to note that the form and characters of the young of this very aberrant form seem to indicate affinity with the Eudoceratidæ.

The peculiar ridge-like mesal division of the septa, which correlate with the prominent ventral and dorsal saddles of this genus, are not present in the nepionic stage. The imperfect condition of this fossil did not enable me to make detailed observations upon the young farther than in the stage figured.

*Trigonoceratidæ.*

This family includes the close-coiled nautilian forms *Coelonautilus*, *Stroboceras*, *Apheleceras*, *Subclymenia* and *Diorugoceras*. The young of all of these genera, except possibly *Diorugoceras*, which I have not seen and which is also very involute, have a similar history. They are rounded in the nepionic stage and have an impressed zone only late in life, if they have it at all. Usually the form is similar to that given in Figs. 29 and 30, Pl. x, of *Apheleceras mutabile* (sp. D'Orb.), Hyatt.

This species shows in the young that the genus has been but recently derived from an arcuate type. The apex in the ananepionic and part of the metanepionic substage is free and the whorls barely touch at first. The corrugated shell of the nepionic and neanic stages show also the same primitive characters and the resemblances of these younger stages to the loosely coiled gyroceran form

of *Trigonoceras* are closely parallel. If the adults were not known they would be referred necessarily to that genus.

The group is of importance in the history of the impressed zone since it shows in its most specialized and highly involute members that a contact furrow may appear even in a form of whorl that has naturally a gibbous dorsum and concave abdomen.

Fig. 2, Pl. xii, of *Diorugoceras* (*Naut.*) *planidorsatum* (sp. Portlock), Hyatt shows the peculiar character of the contact furrow in these forms when it occurs.

It is probable that the early neanic stage has a gibbous dorsum fitting into the hollow abdomen and that the involution is acquired rapidly in the later substages of the neanic stage, but not having seen specimens of the young I cannot state this as a fact.

#### *Triboloceratidae.*

The figures of *Thoracoceras puzosianum* of Pl. ix show a shell which in form is a slightly depressed oval and both in this respect and in the fluted ornamentation approximates to the nepionic stage of *Thoracoceras canaliculatum* and other subspinous forms of the same genus. This last species has also a similar form, and by comparing this with the young of the loosely coiled, gyroceran forms on the same plate, Figs. 14 and 15 of *Triboloceras*, it will be seen how closely they resemble them. *Triboloceras* in turn grades into the nautilian form of the same family, *Vestinautilus Konincki*, Figs. 5-13. The figures show the development of this form through a nepionic stage which is at first similar to *T. puzosianum*, then becomes similar in ornamentation to *T. canaliculatum* and then passing into the neanic stage these primitive characters are replaced by the peculiar ornamentation and whorls having the hollow, central, ventral and lateral ventral zones of this family and smooth, gibbous, umbilical zones with broad, fluted, lateral faces. The subspinous ornamentation persists in this form on the ridges throughout the ephebic stage. In the gerontic stage these progressive characters disappear and with them the fluted faces and zones also tend to extinction and in the paragerontic stage do actually give way to a rounded form without salient angles. This last is not figured, but the tendencies towards extinction of the ornaments, etc., may be seen in the anagerontic substage delineated in Figs. 5 and 6.

*Vestinautilus Konincki* leads into such forms as *Vestinautilus pinguis*, Figs. 16-19, which has the ridged characters, etc., confined to the nepionic stage, which is somewhat abbreviated. The sub-spinous characteristics are also crowded back and replaced earlier by gerontic modifications similar to those which occur only in the senile stage of *V. Konincki*. Thus these degenerative changes are shown to occur in what is properly the parephebic substage of *V. pinguis*. The history of the impressed zone accords with that of the other characters and may be seen in the figures to have been introduced as an acquired character dependent upon close coiling. It is not present in *Triboloceras* nor in the nepionic or aneanic substages of the nautilian forms. It appears only after contact, and in other words is a contact furrow and its characteristics are determined wholly by the moulding of the dorsum on the peculiar ventral surfaces which are encountered during growth.

COLOCERAS GLOBATUM.

NAUTILUS GLOBATUS, De Koninck (*Calc. Carbon.*, Pl. xxxi).

Pl. x, Figs. 1-14.

The development of this species was partially described in my "Carboniferous Cephalopods," second paper, *Fourth Ann. Rept. Geol. Surv. Texas*, p. 447-451, but no figures were given and the genus *Coloceras* was then erroneously referred to the same genetic series as *Coelogasteroceras*. More extended study of both of these forms has shown me that the latter belongs to a distinct series. *Coloceras globatum* has the peculiar lateral flutes and characteristics of the *Triboloceratidæ* in the nepionic and neanic stages, and the hollow ventral zone of the paranepionic substage, which led me to suppose that it belonged to the same genetic series as *Coelogasteroceras*, may be accounted for equally well when *C. globatum* is referred to the *Triboloceratidæ*. Figs. 5 and 6, Pl. ix, of *Vestinautilus Konincki* show that the broad, hollow, ventral zone of the epebic stage becomes narrow and the abdomen is gibbous on either side of it in the anagerontic substage of this form.

The similarity of the ventral hollow zone of the young of *C. globatum* may be accounted for, if it is supposed to be an accelerated phylogerontic character. The only difficulty in the way of this assumption is the preëxistence of the lateral flutes in the neanic stage. I have, however, frequently seen similar examples of the unequal acceleration of characters and this is probably another of

this class. At any rate the ornamentation, form and lateral flutes all plainly point to the same genetic stock as Koninickioceras, whereas in *Coelogasteroceras*\* there are no lateral flutes or faces and a very distinct and more primitive shell, especially in the nepionic stage, as may be seen in the section, Fig. 33 of Pl. x.

The figures of *Coloceras globatum* on Pl. x give the history of the dorsal furrow. They show also that considerable variation exists in the form of the ananepionic substage and it may be that Figs. 10-12 belong to a different species from those that show a flatter and more trigonal outline in the early stages. The umbilical perforation, however, remains about the same in all the specimens. This is of good size and there is no abrupt curve at the beginning of the paranepionic substage which would account for the genesis of the nepionic furrow in the dorsum of the specimen in Figs. 10-12, which is perfect in its proportions and markings. In the specimens given, 1 and 2 and 7, there is a more abrupt curve at this point and more sudden appearance of this zone, but the passage of the form into the nephritic outline is gradual even in these specimens. The first suture in Fig. 10 obviously belongs to the first living chamber of the metanepionic substage, while the second and third are paranepionic, although the second is still within the limits of the metanepionic volution, *i. e.*, built in that part before the dorsal furrow appeared. The third suture is indented by the furrow. The ananepionic substage is at first smooth except for horizontal and inconspicuous growth striæ, then becomes longitudinally ridged, Fig. 7.

The changes of form in this substage, which can be divided into three parts, are well marked in these drawings. There is first the age of the cicatrix with a form which is a very elongated trigonal and quite distinct in every way from the next; then the age in which the broad trigonal form appears, but the surface of the shell is still smooth, and lastly the digonal, longitudinally ridged age passing into the metanepionic and often bounded by a slight constriction. The metanepionic, Fig. 6, has an elliptical form with longitudinal ridges intersected by the edges of the growth bands. In this the digonal outline tends to disappear, although sometimes it is maintained more or less by the early appearance of the prominent, broad lateral ridge. This ridge, however, usually appears later, as shown in section, Fig. 3, and is characteristic of the species.

\*I have provisionally referred *Coelogasteroceras* to the family of the *Hercoceratidæ*.

The dorsum becomes flattened in the latter part of the metanepionic substage and other transitions to the nephritic outline are obvious in the gradual spreading out of the transverse diameters.

The dorsal furrow appears as described above sometimes when the bend is abrupt and sometimes when it is gradual; in other words, it is obviously not correlated with the size or shape of the umbilical perforation nor dependent upon the curvature of the volution. It appears always in the same place at or about the third suture and when the nephritic outline is assumed at the beginning of the paranepionic substage. But it will be observed in section Fig. 4, that the outline, which has been very carefully drawn, is not remarkable for being very broad in proportion, nor does the study of this specimen give any grounds for supposing that the dorsal furrow could be considered a necessary condition of the mode of growth. The curvature is about the same during the remainder of the first volution, but the zone broadens with growth and development of the nephritic outline, as may be seen in Figs. 2, 11, 13, 14 and Sec. 3. This zone has longitudinal ridges, but these are much finer than those of the sides and abdomen.

The neanic stage begins when the longitudinal ridges and central zone disappear on the venter. The ridges persist on the dorsal side, but disappear in what is probably the paranepionic substage, leaving the heavy lateral ridge and its accompanying flutes. The neanic stage is therefore phyloanagerontic.

The ephebic stage is perfectly smooth and phyloparagerontic in aspect.

The action of tachygenesis upon degenerative characters is thus clearly apparent throughout the neanic and ephebic stages in this interesting species. This fact is entirely in accord with the principles of Bioplastology as explained above with regard to the action of this law upon retrogressive characters.\*

#### *Rinoceratidæ.*

The figures of Pl. ix show that this family has characteristics closely resembling the arcuate forms of Thoracoceras which are repeated in the ananepionic substage. Rinocerases, however, never has a hollow ventral central zone but remains gibbous on the abdomen throughout life.

This characteristic also serves to distinguish the nautilian mem-

\*See pp. 373, 415, 417.

bers of the same family when compared with the closely allied forms of the Triboloceratidæ, all of which have a hollow central ventral zone at some stage.

*Lispoceras sulciferum*, Fig. 24, shows the nepionic stage and ananeanic substage with form and characteristics approximately repeating those of Rineceras, and these resemblances are considerably closer than the figures would lead one to suppose. I did not notice until too late to replace them that these figures were not so complete as I had thought them to be.

The greatest development of the impressed zone in this family occurs in the compressed lenticular form of Phacoceras, Figs. 26, 27, and although Fig. 27 is not entirely satisfactory in the young, as given by DeKoninck, it seems to demonstrate together with his description that the nepionic stage had a section which would place it either in this family or in some other with fluted whorls and a gibbous abdomen. None of these genera have any species so far known which have a dorsal furrow, the impressed zone being strictly a contact furrow as in the Triboloceratidæ.

The genus *Pselioceras* of the Dyas is perhaps a member of this family, but I have strong doubts whether it does not belong to an independent family phylum in spite of the general similarity to other genera of Rineceratidæ. It is of some interest here because the umbilical perforation is very large, and it adds one more illustration to the many already noticed of shells having primitive forms and primitive modes of coiling in the young, which have the impress  $\zeta$  zone only in the shape of a contact furrow. There is a slight contact furrow generated after the whorls touch in *Pselioceras ophioneum*, sp. Waagen.

#### *Thrinoceras.*

I mention this genus of the Rineceratidæ especially because I wish to correct here a curious mistake that has inadvertently occurred in my drawing of *Thrinoceras kentuckiense*, p. 432, *Fourth Annual Report of the Geological Survey of Texas*. The section Fig. 13 shows a furrow on the free dorsum of the nepionic volution. A careful reëxamination shows that this does not exist. There is a mark due to erosion which occurs at the point previously examined, but this is not present on other parts of the same volution.

The history of the impressed zone in this species does not differ from that of the same character in other genera of the same family

of which the best known form is *Discitoceras* (*Naut.*) *discors*, sp. McCoy. All species have large umbilical perforations, the nepionic stage has no dorsal furrow and there is only a contact furrow generated in later stages.

*Koninckioceratida.*

The genera *Koninckioceras* and *Domatoceras* have been examined and these have no impressed zone until after contact.

*Solenocheilida.*

In *Aipoceras*, the arcuate form of this family, there is no impressed zone, and in *Oncodoceras*, some of which last are gyroceran, no impressed zone has been observed. In *Asymptoceras*, although the forms are all close coiled, this zone is only faintly indicated in some species, and when it is better defined it occurs late in the ontogeny, and then only as a contact furrow. The same remarks apply also to species of *Solenocheilus*. In the description of *Cranoceras* this genus was referred to as comparable with *Cranoceras depressum* in the peculiar configuration of the dorsum.

There are however, differences which show that this resemblance is not very close or significant. In *Solenocheilus Springeri*, for example, the gibbous dorsum and latero-dorsal flutes and heavy ridges on the umbilical shoulders appear before the contact furrow, but this comes into existence as soon as the whorls touch and modifies the dorsum in proportion to the amount of involution. The latero-dorsal flutes also are dependant upon the extent and size of the ridges or keels on umbilical shoulders and are not as in *Cranoceras* primitive inflections of the dorsal surface.

*Incerta Sedes.*

The new genera *Peripetoceras* of the (Permian) *Dyas* and *Syringoceras* of the *Trias* together with Mojsisovics genus *Pleuromantulus* of the *Trias* have been given together here as a matter of convenience, although it is by no means certain that they belong to the same family.

*Peripetoceras*,\* n. g.

This genus has been instituted for a single species described below, which cannot be placed with any other species.

*Περιπετής*, clasped around.

PERIPETOCERAS FRIESLEBENI, Geinitz (Leonh. et Bronn, *Jahrb.*, 1841, Pl. xi, Fig. 1). Figs. 1-3, Pl. xi.

Loc., Tunstall Hill, England, Dyas.

This shell has a metanepionic substage with a subangular abdomen and siphuncle propiodorsan. The umbilical perforation is small and a dorsal furrow appears in the paranepionic substage. The apex, as shown in Fig. 1, Pl. xi, is narrow and compressed; the metanepionic, Figs. 2 and 3, broadens on the dorsum but remains rounded; the dorsal furrow at its first appearance, just beyond the gyroceran bend in the paranepionic, is deeper, as shown in Fig. 3, than it is subsequently when opposite the largest diameter of the umbilical perforation, Fig. 2, and the whorl changes at the same time from digonal to trapezoidal or temnocheilan-like. The siphuncle, however, remains propiodorsan.

The neanic substage has a nephritic outline and in the ephebic stage the volution becomes subquadrate with a flattened abdomen.

The living chamber is somewhat over one-fourth of a volution in length, with broad, shallow, hyponomic sinus, broad, low, lateral crests and sinuses on the umbilical zones.

The siphuncle continues to be propiodorsan in position.

The sutures have broad, ventral and dorsal lobes and lateral lobes. There are annular lobes in older stages according to Geinitz. I could find none in the early ephebic stage of the single specimen from Tunstall Hill, which showed a perfect septum, but they may be present in later substages.

*Syringoceras*,\* n. g.

This genus has been framed for Triassic species like the type, *Syringoceras granulosostriatus*, which have a tubular, nepionic volution with the siphuncle subventran. The early nepionic shell is also ornamented with very closely set transverse ridges, but it has no longitudinal ridges until a comparatively late stage. This nepionic ornamentation is like that of the genus *Hercoceras* at the same age. The impressed zone is present only after contact and is not deep.

The genus includes the group of *Nautilus Barrandei* of Mojsisovics, the equivalent of *Nautilus linearis*, Laube, and *S. (Naut.) evolutum*, sp. Mojsisovics.

*Syringoceras (Naut.) granulosostriatus* and *linearis*, stated by

\* Σφύτζ, a tube.

Mojsisovics to be the same as *Acis Munst*, have been figured on Pl. xi, Figs. 4-8, to show that the impressed zone is present only after contact in these Triassic species, which have good-sized umbilical perforations and a cylindrical first whorl.

*Pleuromutilus*.

This genus was described by Mojsisovics to include a number of costated nautilian shells of the Trias, having in one section of this genus shells with the nepionic stage marked by transverse bands and in the species copied from Mojsisovics, Pl. xii, Fig. 3, the umbilical perforation is very large.

In correlation with this the apex is free and the generic characters appear late in the neanic stage.

This shell appears at first to be an extraordinary exception to the rule that generalized forms, with large umbilical perforations, slow growth of the dorso-ventral diameters and more or less cylindrical first volutions, always have a gibbous dorsum in the nepionic stage. Mojsisovics' figure, copied here, Pl. xii, Figs. 4 and 5, and in his description, has a dorsal furrow in the paranepionic substage. In order to confirm or refute such an important observation I wrote a letter of inquiry to Dr. Edmund Mojsisovics von Mojsvar and have received in return the following courteous reply, which shows clearly that the species cannot be quoted as exceptional in the opinion of this eminent authority. I quote below both my translation and the original letter :

“Die Impression auf der intern Seite des (auf Taf. iv, Fig. 3, meiner Hallstätter Cephalopoden) zu *Pleuromutilus superbus* gestellten Fragmenten kann nicht durch eine Verdrückung erklärt werden, sondern nun als eine thatsächlich der Schale sukommende Eigenschaft betrachtet werden. Ich halte es aber jetzt für wahrscheinlich, dass dieses Fragment trotz seiner grossen Uebereinstimmung mit dem ersten Umgänge von *Pleuromutilus superbus* nicht zu dieser Art, sondern zu einer andern neuen Art gestellt und nicht als erster Umgang betrachtet werden darf. Ich neige vielmehr jetzt der Ansicht zu, dass die Impression auf der concaven Seite von weggebrochenen innern Umgängen herrühren dürfte.”

“The impression upon the inner side of the fragment (Pl. iv, Fig. 3 (?) of my *Hallstätter Cephalopods*), referred to *Pleuromutilus superbus*, cannot be explained as due to compression, but must be

regarded as an actual characteristic belonging to the shell. I now, however, consider it probable that this fragment, in spite of its great similarity to the first volution of *Pleuromutilus superbus*, should not be placed with this species, nor regarded as a first whorl, but as another new species. I incline much more at present to the view that the impression (the author's dorsal furrow) upon the concave side might have originated from a whorl now broken away."

*Nautilidæ.*

Without attempting at present to limit the chronologic distribution of this family, it is necessary in this connection to make some remarks with reference to my observations on the general affinities of the genera described in this paper, which are all Mesozoic.

Digoniceras is obviously the most primitive type yet found in the Mesozoic, and the most primitive or most generalized species is *Digoniceras excavatum*, as figured by D'Orbigny. The broad first whorl of this species is persistent in adults and so also is the slight amount of the involution and the discoidal character of the coil. The digonal and approximately nephritic outline of the young in the paranepionic is succeeded by a subtrigonal outline in the adult.

This is substantially paralleled by the development of the species of *Cenoceras*, *Cymatoceras*, *Eutrephoceras* and *Nautilus*.

All of these are apt in their nepionic substages to bring out the nephritic, and in the paranepionic the subtrigonal form of whorl with a broad dorsum, converging lateral zones and more or less subacute or elevated venter. This occurs even when the nephritic outline or some other is assumed in the later stages.

There is, therefore, in all of these genera some direct reference to the form of the ephebic stage of *Digoniceras*.

This fact is of great importance in connection with the assumption made in this memoir, that after the Trias the survivors of the Nautiloids are all nautilian shells and bear the marks of their descent from close-coiled ancestors and are not directly connectible with straight or arcuate types as the nautilian shells of the Paleozoic often are.

*Digoniceras*, n. g.

*Digoniceras excavatum*, was described in my *Genera of Fossil Cephalopods*, as a member of the genus *Endolobus* surviving in the

Jura, but the observations on the young given in this paper show that these forms are not so closely related as I then supposed.

The species differ from any species of *Endolobus* in the form of the young and in having the annular lobe and dorsal furrow developed earlier and in not having any large nodular tubercles. The form of the whorl in section is, however, similar in adults of *Digonioceras* and also the aperture. The umbilical perforation is larger than usual in other allied genera of the same period and the involution is apt to be less in the older substages, leaving the umbilici open.

D'Orbigny's figure copied on Pl. xi, Figs. 13, 14, shows that a dorsal furrow was present in the paranepionic substage\* and there is a similar furrow at the same age in *Digonioceras rotundum*, the type of this genus.

#### DIGONIOCERAS, sp. (?)

The species from Balingen, Middle Lias, Figs. 19-21, Pl. xi, shows a form similar to *Digonioceras excavatum*. The metanepionic outline in this has no dorsal furrow, as shown in the corrected section, Fig. 21, but the suture has an annular lobe. The dorsal furrow begins on the dorsum at the second septum of this fragment, which was probably the fourth or fifth of the complete shell.

#### DIGONIOCERAS ROTUNDUM, n. s.

This has affinities with *excavatus*, but the large fine young specimen, Figs. 6-11, Pl. xii, show that the shell was specifically distinct. It is obviously from the Oolite, but the locality is not known. Figs. 6 and 7 show the neanic stage and Fig. 8 the nepionic. The involution is not greater than it is in *D. excavatum* and the form is very similar in the paranepionic. The whorl, however, is really nephritic in the aneanic substage, and has already assumed an outline in section quite distinct from that of *Digonioceras excavatum*. This last-named species retains throughout life, if correctly figured by D'Orbigny, the same form as the paranepionic involution of *D. rotundum* shown in Fig. 8. The outer whorl in Fig. 7 should be a little broader in proportion and more completely nephritic. There is a slight trace or linear depression near the median line on the abdomen, but this may be an individual character, and not important to the diagnosis of the species.

\*This species, at first referred to the Lias, was subsequently in this author's Prodrôme placed in the Inferior Oolite.

*Cenoceras.*

This genus was described in my *Genera of Fossil Cephalopods* to include a number of the Nautili of the Trias and Jura which should be separated. I propose now to limit the genus to those forms which, like *Cenoceras intermedium*, as figured by D'Orbigny, have trigonal ananepionic substages with subquadrangular metanepionic volutions and a dorsal furrow in the nepionic stage. The ephebic stage is also more or less quadrangular, with the dorso-ventral longer than the transverse diameters and the lateral zones convergent. The umbilical shoulders are prominent and the umbilical zones broad and at right angles to the plane of the coil. The sutures have ventral and dorsal saddles only in the first and second septa. The annular lobe and dorsal lobe are apt to develop very early, in some species certainly in the third septum. The siphuncle is near the centre in the first septum and subsequently varies from dorsad to ventrad of centre, but is never near either the venter or the dorsum. The ornamentation has both longitudinal ridges and transverse bands, but the former may or may not be present in adults.

## CENOCERAS INTERMEDIUM.

NAUTILUS INTERMEDIUS, Sow. (?) (*Min. Conch.*, Pl. 125).

NAUTILUS INTERMEDIUS, D'Orb. (*Terr. Jurass.*, Pl. 27).

Loc., Balingen, Middle Lias.

Pl. xi, Figs. 15-18.

I feel considerable doubt whether Figs. 17 and 18 are really the young of *C. intermedium* and the name is taken solely on D'Orbigny's authority. It has, however, a peculiar compressed form and obviously a large umbilical perforation in the ananepionic and a subquadrate outline in the metanepionic, with siphuncle ventrocentren as in most specimens of this species. The ana- and metanepionic substages have no dorsal furrow.

Figs. 15 and 16 show the paranepionic and ananeanic substage of a specimen with the siphuncle dorsocentren, evidently an unusual position, since several other specimens of nearly the same age have it ventrocentren and in adults it is still nearer the venter. The whorl is tetragonal in the paranepionic, with well-marked ventral, lateral and dorsal lobes in the sutures and annular lobes. The dorsal furrow is also well developed and the umbilical perforation, restored with a dotted line in Fig. 15, must have been quite large.

There seems to have been no close bending of this whorl sufficient to cause the formation of a dorsal furrow in this shell.

The ananeanic volution given in section, Fig. 16, is too rounded, the lateral zones in this specimen are quite flat and convergent as in adults, and the abdomen is also flattened. The zone of contact is marked by a shaded space in Fig. 16 and is deep and well marked off from the dorsal furrow above in the same figure.

CENOCERAS LINEATUM.

NAUTILUS LINEATUS, Sow. (*Min. Conch.*, Pl. 141).

NAUTILUS LINEATUS, D'Orb. (*Terr. Jurass.*, Pl. xxxi).

Loc., Bayeux, Inf. Oolite.

Pl. xi, Figs. 22-27 and 28-31.

The ananepionic and metanepionic substages and part of the paranepionic are shown in Figs. 24-27, and also the cicatrix and general form and shell ornaments, which last are continued in the adults of several species of this genus.

The umbilical perforation is small and comma-like, contact taking place on the dorsum of the ananepionic volution. A well-developed dorsal furrow is present in the paranepionic but not in the metanepionic, as shown in Figs. 26, 22 and 23. There are annular lobes in the nepionic stage, but these disappear in the paranepionic substage.

Figs. 28-31 are so similar to the early stage of this species that I have referred them to it, although this was identified by Quenstedt as *Nautilus aratus*, Schlot.

CENOCERAS ARATUM.

NAUTILUS ARATUS, Schlot.

Loc., Suabia, Middle Lias.

Pl. xi, Figs. 32-35.

The specimen shown in Figs. 32-35 was figured first in my *Embryology of Fossil Cephalopods*, is one of Saemann's originals and although quite perfect in some respects has no shell.

It is a cast in iron of the interior and shows the characteristics figured very distinctly. The early beginning of the annular lobe in the third suture and that of the dorsal furrow in the metanepionic between the third and fourth sutures is very interesting in view of the fact that this shell had a comparatively large umbilical per-

foration and the curvature of the first whorl is so uniform that its early origin cannot reasonably be attributed to that as a cause. The furrow deepens immediately and affects the outline of the fourth suture. A slight dorsal lobe appears in the suture of the third septum at the same time with the annular lobe, and is better given in Fig. 33 than in Fig. 34. The flattening of the dorsum is apparent in the second suture, and, so far as I could see after repeated observations, my former figure in *Embryology of Cephalopods* was erroneous in placing an annular lobe in this suture. This species shows highly accelerated development in all of its characteristics and this acceleration is obviously genetic and independent of the size of the umbilical perforation, which is very large considering the fact that it is a Jurassic species.

I have also examined another less perfect specimen of this species having a considerable part of the shell preserved, but the first and second apical chambers were lost. The external shell of the umbilical zones had longitudinal ridges as well as external parts of the lateral zones and the venter in the paranepionic substage. The form of the whorl in section near the ends of the paranepionic substage remains about the same, except that the venter becomes slightly broader and flatter. The umbilical perforation is not quite so large and the gyroceran bend is more abrupt in this specimen, but otherwise it is exactly similar to the first described specimen. It is in Museum of Boston Society of Natural History.

#### CENOCERAS CLAUSUM.

NAUTILUS CLAUSUS, D'Orb. (*Terr. Jurass.*, Pl. xxxiii).

Loc., St. Vigor, near Bayeux, Inf. Oolite.

Pl. xii, Figs. 12-15.

This species has a small umbilical perforation. The form and general aspect are very similar to those of other compressed shells of this genus, but the shell in the paranepionic substage has peculiarly well-marked and broad growth bands with interrupted longitudinal ridges. The ana- and metanepionic volutions are shown in Figs. 13-15 and have a rounded dorsum, the dorsal furrow appears in the paranepionic at the gyroceran bend and deepens rapidly as the shell grows around the perforation. The amount of involution is probably about the same as in *Cenoceras granulosus*, which it also resembles in general aspect as well as in ornamentation.

## CENOCERAS GRANULOSUM.

NAUTILUS GRANULOSUS, D'Orb. (*Terr. Jurass.*, Pl. xxxv).

Loc., Chatillon, France, Oxfordian.

Pl. xi, Figs. 36-39, and Fig. 31, Pl. xii.

In this species, which is well characterized by its compressed form and tubercular ornamentation, the compressed form is present even in the nepionic stage. Figs. 37 and 38 show that the umbilical perforation is of medium size. Contact takes place on or near the dorsal edge of the cicatrix on the apex, as shown in Fig. 31, Pl. xii. The cicatrix is plainly visible in several specimens of this species and it is also obvious that in none of them does the dorsal furrow appear until after the gyroceran bend begins. The dorsum of the metanepionic substage remains rounded and gibbous until the bending begins and then it becomes flattened and immediately hollow, showing the commencement of the dorsal furrow as in Figs. 36 and 37, and this continues to deepen and broaden throughout the paranepionic, as is shown in Figs. 38 and 39.

*Cymatoceras.*

This genus, described in *Genera of Fossil Cephalopods*, had for its type *Cymatoceras (Naut.) pseudoelegans*, sp. D'Orb., which is found in the Necomian together with *Cymatoceras neocomiense*. Both of these have costæ which pass entirely across the venter. In the type species these appear very late in the ontogeny in the ephebic stage, whereas in *neocomiense* and other species the costations appear earlier in the ananeanic substage. The sutures have slight ventral lobes or saddles with deep lateral and dorsal lobes. There are annular lobes at a very early age in some species.

## CYMATOCERAS ELEGANS (?).

NAUTILUS ELEGANS (?) Sow. (*Min. Conch.*, Pl. cxvi).NAUTILUS ELEGANS (?) D'Orb. (*Terr. Jurass.*, Pl. xix).

Loc., Texas, Cretaceous.

Pl. xii, Figs. 16-21.

This species is represented by a number of specimens of the young, but these do not break apart well and have to be cut and viewed, as a rule, in sections.

The large size of the apical chamber is noticeable, and the great distance apart of the first sutures indicates the rapid growth of the

young shell. This fact is very interesting since here we also find a high degree of acceleration in other characters. Thus the dorsal furrow appears in the ananepionic substage at a considerable distance from the gyroceran bend and continues after this, as shown in Fig. 20, along the dorsum and is continuous with that of the paranepionic.

The costations appear in the neanic stage.

CYMATOCERAS DESLONCHAMPSIANUM.

NAUTILUS DESLONCHAMPSIANUS, D'Orb. (*Terr. Jurass.*, Pl. xx).

Loc., Rouen, France, Cretaceous.

Pl. xii, Figs. 22-27.

This species, which is represented by several good specimens of the young, has very nearly the same ontogeny as *Cymatoceras elegans*, except, of course, in the specific characteristics and the position of the siphuncle. This last is propiodorsan in the metanepionic instead of being propioventran as in *C. elegans* (?). The sutures of the early epembryonic stages differ from those figured by Branco for the same species, but this may be owing to the fact that we have really observed different species. The dorsal furrow appears as in *Cymatoceras elegans* in the metanepionic at the second septum, as in Fig. 24, and is continued in the paranepionic substage.

CYMATOCERAS SIMPLEX (?).

NAUTILUS SIMPLEX, Sow. (*Min. Conch.*, Pl. 122).

Loc., England, Cretaceous.

Pl. xii, Fig. 28.

This single specimen differs somewhat from the specimens of *Cymatoceras deslonchampsianus* and may be more distinct in the adult, but I do not feel sure of the fact that it is a different species.

It has been figured in this connection because it shows that the dorsal furrow is present in this shell both in the metanepionic and paranepionic substages.

CYMATOCERAS RADIATUM.

NAUTILUS RADIATUS, Sow. (*Min. Conch.*, Pl. 356).

NAUTILUS RADIATUS, D'Orb. (*Terr. Jurass.*, Pl. xiv).

Loc., Rouen, Cretaceous.

Pl. xii, Figs. 29 and 30, and Pl. xiii, Figs. 1 and 2.

The ananeanic substage is shown in outline in centre of Fig. 30,

Pl. xii, and in Fig. 1, Pl. xiii, which is the reverse of that of Fig. 30, but enlarged two diameters. The presence of an annular lobe is noted as it appeared in the specimen, but this part was covered by remnants of the nacreous layer and it was not positively defined. The dorsal furrow began between the first and second septum and is faintly shaded in Fig. 1, Pl. xiii. The dorsal sutures were covered except as far as represented. The side view, Pl. xiii, Fig. 2, shows these sutures, so far as seen, the last two in this figure being the first two of Fig. 29, Pl. xii.

The broad costæ of the genus made their appearance in the ananepionic substage at the same time that the septa approximate and the zone of contact is formed.

It will be observed that the costæ are broader at first than they are in later age even in this figure, showing that growth was more rapid at first as in the development of the septa.

*Eutrephoceras*,\* n. g.

This genus includes these forms like the type *Eutrephoceras Dekayi*, which have globose ananepionic substages, increasing subsequently with great rapidity in all their diameters. The ana- and metanepionic substages are highly tachygenic and these shells have very small, and often hardly perceptible and much flattened, umbilical perforations. The siphuncles are subdorsan from the apex through the nepionic stage in some species, in others this position is not maintained, but the siphuncle is generally in later stages near the dorsum and in the ephebic stages it is dorsad of the centre.

The nepionic stage has longitudinal ridges and transverse bands, the former disappearing in adults which are smooth.

The form of the whorl in section is nephritic from an early age and changes but little throughout life.

The sutures are almost straight, having but slight ventral lobes, broad ventro-lateral saddles, lobes on the umbilical zones and deep lobes in the zone of impression. There are no annular lobes at any stage of development.

\* *Ευτροφεής*, clasping around.

EUTREPHOCERAS, Dekayi.

NAUTILUS, Dekaui. Morton (Synop. Org. Rem., Pl. viii, Fig. 4).

Loc., Dakotah, Cretaceous.

Pl. xiii, Figs. 4-8; Pl. xiv, Fig. 1.

The ananepionic substage in this species is very obtuse and almost saucer shaped, the whorl increases so rapidly in all its diameters. The cicatrix is present on one specimen and is a double depression with a dividing ridge on the cast of the apical chamber. There is a peculiar plate of nacreous matter which may be the equivalent of a similar plate which fills in the apex of the shell in *Nautilus pompilius* or it may be simply a remnant of the apical deposit which has this peculiar form. However this may be, the cæcum is seen through it in one specimen, and in another it can be seen in the same position, although the plate is not visible, the apex being more completely covered by the external shell.

It seems clear that the dark spots observed in these two specimens were due to the presence of the cæcum filled by a dark, sparry deposit and showing through the nacreous layer.\* If so this organ is close against the venter of the apical chamber. I was not able to see the youngest septa, but there are evidently very few of them and the one shown in Fig. 4 is probably either the third or fourth septum.

The metanepionic substage is not so smooth as the ananepionic, and although it is difficult to observe without making a section, I am quite sure that there is a faint dorsal furrow present before the gyroceran bend begins. The longitudinal ridges and the transverse bands with the usual crenulated edges begin to be observable in this substage.

The bend which begins the paranepionic substage is very abrupt and almost at right angles to the dorsum of the metanepionic substage and has a deep dorsal furrow. The umbilical perforation is consequently so small and arcuate that it is very difficult to observe. In Fig. 6 the lateral angle of the shell and of the first septum that is built upon the dorsum of the apex has been cut off and shows the opening of the umbilical perforation in part, but has a misleading outline since it is just the reverse in shape of the true internal perforation. It, however, shows that there is a perforation as does also Fig. 4. This shell must grow in these younger substages with

\*It can be observed in the apex of *Nautilus pompilius* through the thin shell of the ananepionic substage.

great rapidity upon the venter in order to swing that part around the very sharp curve made by the gyroceran bend.

The paranepionic substage has well-marked longitudinal ridges and transverse bands of growth given in Fig. 6. The latter part of the paranepionic in this species, if this be properly limited by means of the ornamentation, is close coiled. That is to say, it touches dorsum of the ananepionic and envelops it, the involution being almost complete from the very beginning.

The umbilical perforation is, however, not completely closed nor is it subsequently closed by extra growths of shell as in *Nautilus pompilius*. The area of the umbilical zones is marked off at an early age by the smoothness of the shell, the longitudinal ridges being absent on these parts. In some specimens the shell markings are much stronger than in others, but in all they seem to grow more decided until near the end of the metaneanic substage.

The meta- and paranepionic substages have an elevated subangular abdomen not shown in any of the figures, the outline of the section of the whorl is in reality in these early substages depressed subtrigonal similar to the young whorl of *Cymatoceras*, but less acute, and to that of *Nautilus pompilius*, but more pronounced than in that species on account of the subangularity of the venter; the venter of *Nautilus pompilius* being more rounded in the paranepionic substage.

The ananeanic and metaneanic are blended and probably not separable, but the paranepionic can be distinguished. The former has the siphuncle tending more towards the centre, although in some specimens this alteration is not so great as in others. The transverse bands become broader and their edges have tubercular-like short ridges on a secondary band, which are sometimes well marked off on their apical borders from the sunken younger parts of the same bands of growth. These ridges are always continuous from band to band and over the sunken parts of each band. In the paranepionic substage, as shown in Figs. 7 and 8, these ornaments begin to diminish and finally die out. In Fig. 8 this substage is limited by the retention on one side of a partial constriction or permanent aperture, which, however, is not present in all shells.

In the anephebic stage, also shown in Figs. 7 and 8, orad of the constriction, the shell is very nearly as smooth as it is in the full grown. The form of the whorl remains about the same. The siphuncle has become dorso-centren in position in this shell, in

others it may still remain nearer the dorsum, but in most shells it shifts its position somewhat.

In the metephebic stage the shell appears to have been smooth and the whorl is apparently somewhat more depressed or more absolutely nephritic in outline. This distinction is due to the larger size and greater proportionate increase in lateral growth. The dorsal sutures in this substage and probably throughout the ephebic and possibly earlier have not only the broad dorsal lobes in the contact furrow, but narrow and very shallow lobes, which cannot be described as annular lobes, although they resemble these as they appear in the neanic stage of *Endolobus avonensis*, Fig. 38, Pl. viii. They are, however, much shallower. In the centre of these, in the only specimen perfect enough to show this, there were minute linguiform saddles as given in Fig. 1, Pl. xiv. The sutures have to be in perfect condition to observe such markings and this may account for the absence of similar markings upon other nauti-roids. The siphuncle may be either ventrocentren, centren or dorsocentren, but it is more commonly dorsocentren.

EUTREPHOCERAS, sp. (?)

Pl. xiii, Fig. 3.

Loc., France, Cretaceous.

This shell is referred to here because it shows clearly the presence of a faint dorsal furrow in the metanepionic substage opposite a corresponding furrow in the paranepionic. The cast of the perforation was preserved in this specimen and it was extremely flat and comma shaped. The whorls are coiling towards the observer so that there can be no doubt that the section of the central volution is metanepionic.

EUTREPHOCERAS FAXOENSE, n. s.

Loc., Faxoe, Denmark, Cretaceous.

Pl. xiii, Figs. 9-12.

This species differs from *Eutrephoceras Dekayi* in the extreme subdorsan position and smaller size of the siphuncle in the nepionic stage, has larger umbilical openings and is also apparently a smaller form. Otherwise it is very close in sutures and form to this species. The umbilical cast is preserved on one side in Fig. 9, and shows the involution to have been considerably less than in *E. Dekayi*. The development is, however, so similar otherwise that no

special description is necessary. It must be noted, however, that the shell was absent, so that no comparison of the ornamentation could be made.

EUTREPHOCERAS IMPERIALIS.

NAUTILUS IMPERIALIS, Sow. (*Min. Conch.*, Pl. xiii, Figs. 13-16).

Loc., Isle of Sheppy and Isle of Wight, Tertiary.

Pl. xiii, Figs. 14-16.

In this interesting Tertiary species the siphuncle is subdorsan even in the apical chamber, as is shown in Fig. 14, and it clings to this position throughout the nepionic stage. The form does not seem to differ materially from that of *Eutrephoceras Dekayi*. The umbilical perforation is of about the same form and size, that is to say, it is as small as is practicable to afford room for the shell to turn and has a depressed comma shape. The external umbilici are more open than in *E. Dekayi* and smaller than in *E. Faxoense*. The ornamentation is quite distinct. In the nepionic stage there are longitudinal ridges and transverse bands, but these are never so prominent as in *Dekayi*. In what I suppose is the neanic stage these still persist, but are so fine that their intersecting lines, with minute depression in the checker-board-like spaces between them, give a punctate aspect to the surface when viewed with a cross light.

The specimens from the Isle of Sheppy, supposed to be identical with this species, shows the presence of a dorsal furrow in the opposed dorsi of the meta- and paranepionic volutions, Fig. 16, and the very small size of the perforation.

This species has an annular lobe which has no connection with the subdorsan siphuncle. I could not find any traces of these in the older sutures. The sutures resembled those of *Eutrephoceras Dekayi* except that I could not find any signs of the linguæ-form dorsal saddles in the centre of the dorsal lobes.

*Nautilus.*

Before beginning the brief notice of this genus, which I propose to give, I desire to return thanks to Henry Brooks, whose observations and drawings have contributed so largely to the interest of this paper. These are also noticed in connection with the figures themselves. I am also deeply indebted to Dr. Charles E. Beecher, of New Haven, who has loaned me a series of beautiful prepara-

tions, making a complete series of all of the substages of development in *Nautilus pompilius* and more or less of other species, and also to Dr. R. T. Jackson, for similar material. I hope to use this material more extensively and effectually in the future. In this paper full justice cannot be done to the work of Dr. Beecher or Mr. Brooks.

This generic name, heretofore supposed to include nearly all of the coiled or nautilian forms of Nautiloidea and still used by some conservative paleontologists in this way, is really not applicable to any forms except the living species of nautiloids and possibly some shells in the Tertiary. Even these last cannot be satisfactorily referred to the genus *Nautilus* until their nepionic substages have been worked out.

The genus *Eutrephoceras* is a near ally but still distinct in most of its characteristics. The broad outline of all of the epinepionic stages of growth, the general position of the siphuncle, dorsad of the centre, and the distinct sutures of *Eutrephoceras* separate the species. The minute umbilical perforations and closer coiling of the younger substages of the conch in *Eutrephoceras* show also that it is the terminal group of some other genetic series than that to which *Nautilus* probably belongs.

The genus *Cymatoceras* of the Cretaceous differs in the broad costations as well as in the outline of the nepionic whorl. The sutures of this genus are more like those of *Nautilus* than the sutures of *Eutrephoceras*.

The genus *Nautilus* is obviously still more remote from *Cenoceeras* of the Jura in the sutures of all stages and form of the ananepionic and succeeding nepionic substages, although in the outline of the ephebic whorl and position of the siphuncle there is close approximation. If one excepts the comparison of the ananepionic substage, which is obviously similar to that of *Eutrephoceras Dekayi*, being only more compressed, the nepionic stage and the ananeanic substage are very close in aspect to those of *Digonioceras*, although the succeeding substages become quite distinct.

I cannot in this memoir give full descriptions of the substages of development which I hope to treat fully in the future. It will suffice to refer to the accurate drawings of Mr. Brooks, given on Pl. i, and to notice the fact that young shells and preparations now in my possession of *Nautilus umbilicatus*, *pompilius* and *macromphalus* show no variations in their characteristics worth noticing here. It

is essential, however, to call attention to the statement made elsewhere, that the dorsal furrow begins in *Nautilus umbilicatus*, *pompilius* and *macromphalus* in the metanepionic or at any rate before the gyroceran bend begins.

The ornamentation is similar to that of the young of most other genera of the Mesozoic during the nepionic stage, but the young of *Nautilus* do not repeat the broad costæ of the epinepionic stages of *Cymatoceras*. The shell of *Nautilus pompilius* becomes smooth in the ananeanic substage which begins when contact occurs.

The color of the ana- and metanepionic substages are pearly, the outer layer of shell being thin and colorless in these substages. A uniform brown spreads over the exterior in the paranepionic substage. This tends to break up into transverse bands in the ananeanic at the same time that the ornaments begin to disappear.

This breaking up into bands is due to a decided fading out of the coloration which may sometimes seriously affect the stripes themselves. In the metaneanic, sometimes after the coloration has for a brief space been reduced, the bright, broad, brown stripes of the adult appear upon a white ground.

The form of the outline of the whorl changes in the ananeanic, the sides and venter becoming flattened and being less involute, the whorl repeats approximately the ephebic whorl of *Nautilus umbilicatus*. To speak more accurately, it would at this time be identical with any species that might have an ephebic form exactly intermediate between *Nautilus umbilicatus* and *pompilius*, since the involution of the latter is at all stages somewhat greater than that of the former species at the same age. In the paranepionic the animal begins to deposit calcareous matter along the lines of involution in the umbilical zones and thus spreads more towards the centre and increases the involution. This process really begins with the metaneanic and is often marked by a permanent constriction beyond which the transverse lines of growth become coarser than they are in the ananeanic substage.

In the anephebic substage, the closing of the umbilici by the spreading inwards of the calcareous deposits of the umbilical zones begins and is carried out fully in the metephebic substage, the umbilici being completely covered up and obliterated. In the parephebic substage the brown coloration disappears, leaving the surface white. No degenerative modifications other than this loss

of color and occasional approximation of two last septa have been observed in any shells that have come under my observation, and, therefore, I have thought this change probably belonged to the later ephebic and not to the true gerontic stage.

These facts show clearly that in this genus the least involute of existing species, *Nautilus umbilicatus*, is the most primitive and has characteristics repeated more or less in the young of the more involute *Nautilus pompilius*. This observation is of great importance in this paper, since it confirms the opinion that genetic groups of Nautiloids and Ammonoids are series of parallel morphic modifications, in the evolution of which the shells progressed from less closely coiled and less involute to more closely coiled and more involute shells.

Dr. Beecher has called my attention in his preparation of *Nautilus macromphalus* to a very important fact in connection with the bioplastology of the Nautiloids, viz., that there are indications in the ontogeny of this species of degenerative changes which have also taken a parallel course to those observed in other genera and families; in other words, that it is more closely coiled and more involute in the nepionic stage than later in life.

The nepionic stage of this species differs in form from that of *Nautilus pompilius*, but the most marked distinction lies in the abrupt bending of the shell in building the gyroceran curve. This consists partly in the formation of thick extensions of the shell along the lines of involution. These are similar to the testaceous umbilical extensions occurring in the same situation in *Nautilus umbilicatus*, but begin later in the ontogeny of that species, and also similar to those occurring in the young of *N. pompilius* earlier than in *umbilicatus*, but later than in the ontogeny of *macromphalus*. All of these facts and also the form of the young of *macromphalus* can only be accounted for by assuming that it is probably a descendant of *Nautilus pompilius*, which exhibits an accelerated development of earlier nepionic substages and then in the ephebic stage becomes less involute.

I shall try to put these propositions in future papers into convincing form with illustrations, but it is easy to verify them with any good specimen of *N. macromphalus* since the internal whorls are visible in every case.

These observations confirm in the most unexpected manner the generalization deduced from fossil shells, that in progressive series,

evolution is towards closer coiling of the shell and in retrogressive series the direction of evolution is towards uncoiling.

*Aturidæ.*

In my second paper on "Carboniferous Cephalopods," *Geological Survey of Texas, Fourth Annual Report*, p. 389, I pointed out the fact that the genera *Enclimatoceras* of the Mesozoic, *Hercoglossa* of the Cretaceous and *Aturia* of the Tertiary formed a distinct group by themselves.

These genera have ventral saddles, deep lateral lobes and lateral saddles of so highly specialized outlines that the sutures resemble those of some of the *Clymeninæ*. The forms are compressed and as a rule deeply involute. Unfortunately I have been unable to get the ananepionic substages of *Enclimatoceras* or *Hercoglossa*.

It is, however, fortunate that the involute character of the young in these genera and close coiling of adults in the entire group makes it highly probable that the young when investigated will not be likely to contradict the conclusions obtained from the study of *Aturia*.

Through the kindness of the Directors of the National Museum and Geological Survey and Dr. W. H. Dall and Mr. T. W. Stanton, I received a number of sections of *Enclimatoceras Ulrichi*, from Prairie Creek, Wilcox county, Alabama, and Zell county, Texas, Tertiary, but not one of these had a centre perfect enough to be of any use.

*Aturia.*

This genus, first described by Bronn, has long been admitted and is easily recognized by the aid of the peculiar sutures and siphuncle.

ATURIA MORRISSI, Michellotii.

Loc., Baldasseres, Tertiary.

Pl. xiii, Figs. 17-19.

The ananepionic substage in this species is very globose and the growth of the apex is certainly very rapid in all its diameters. This rapid increase is, however, not sustained in the transverse diameters of the metanepionic and succeeding stages. The gyroceran bend is so abrupt and the coiling is so close at the end of the metanepionic, that I have not yet succeeded in seeing and studying the dorsum of this substage. The opening of the umbilical perforation

can be seen in Fig. 19, which is enlarged six diameters, as a black spot at the junction of the sutures and is visible only under a magnifier in the original. The other figures are also enlarged six diameters.

Fig. 19 also shows the first three sutures and the highly accelerated development of the first suture which takes on immediately the peculiar lobes and saddles of the generic group to which this species belongs, and also the great depth of the apical chamber.

*ATURIA ZIZAC*, Bronn.

Loc., Dax, France, Tertiary.

Pl. xiii, Figs. 20-22.

Figs. 20 and 21 give front and side views of the nepionic and half of the neanic stages enlarged about ten times with the first four sutures.

This species has a globose apex similar to that of *Morrissi* and the umbilical perforation is also minute. This and the closeness of the coiling is shown and the subdorsan siphuncle are shown in Fig. 22. I have restored the dorsal shell of the anepionic substage in this specimen. The extraordinary depth of the apical chamber, the lobate character of the suture of the first septum, and the highly tachygenic (accelerated) development of all of the characters of the apex are noticeable in this species as in *Aturia Morrissi*.

*Scaphites*.

The phylogerontic forms known by this name are of interest in this paper because of the invariably excentric retroversal character of the living chamber and their obviously intermediate station between the more uncoiled phylogerontic genera and such phylogerontic genera as *Sphaeroceras* and the like which are closer approximations to normal shells and are consequently persistently involute at all stages of development.

The figures of this genus, in consequence of the retroversal bend of the living chamber, do not usually give any data, and although the literature is so abundant I was forced to make what observations I could in finishing up this paper upon the materials immediately in hand. In one fine large specimen of *Scaphites* from Mingusville, Mont., Coll. Bost. Soc. Nat. History, I was able to excavate the dorsum and found the impressed zone retained even

upon the edge of the aperture or rather in the base of the dorsal crest. The aperture had the usual shelf-like constriction figured by Meek and on the dorsal side were two narrow sinuses and a median dorsal crest, the length of which could not be determined.

Mr. Stanton, in his "Colorado Formation,"\* shows a similar retention of the impressed zone in *Scaphites ventricosus*.

The gerontic whorl is quite free for some distance, and although the impressed zone sensibly diminishes in depth and breadth towards the aperture it is not obliterated. These two species have comparatively short living chambers, which are free only for a part of their length, and one would naturally expect that the very deep contact furrow of the epehelic and anagerontic substage would persist. The conditions are quite different from those that occur in shells with more extended gerontic stages, like *Scaphites larvæformis*, Meek and Hayden, and in these the paragerontic substage may perhaps have no impressed zone.

I have, however, examined a considerable number of scaphitoid shells from European localities and some of these gave positive information of the persistence of the impressed zone in the lower, inner border of the aperture, although, as in *Scaphites nodosus*, it was sometimes hardly perceptible in the outline of this part.

#### *Helicancylidæ.*

This family name serves the purpose of temporarily uniting all phylogerontic species of the Cretaceous in America which have three rows of tubercles on either side. The characteristics are given below under the generic title "Helicancylus."

#### *Helicancylus*, Gabb.†

It is probable that genetic connection as shown by the ornamentation existed between cretacic shells of normal involute form like *Acanthoceras Rémondi* of the nodose variety figured by Gabb as having three rows of tubercles and his *Crioceras latus*.‡ This last also has three rows of spines and single costæ, but has an open coil without an impressed zone. There are similar marks of affinity in the species described by the same author as *Helicancylus æquicostatus*, which has also three rows of nodes. The last, however, has the

\* Bull. U. S. Geol. Survey, Pls. xlv and xlv.

† Pal. Cal., i, Pl. xiii, and ii, Pl. xxv.

‡ Ibid., i, Pl. xv, Fig. 2.

composite mode of development described below in *Nostoceras* and *Emperoceras* with a gerontic stage which is a close approximation to *Hamulina* and *Ptychoceras*,\* and affords evidence that this genus is a phylogerontic form in which the gerontic retroversal last volution replaces the helicoceran. These and other forms appear at any rate to give an approximate solution of the difficult problem of the derivation of such form as *Hamites*, *Hamulina*, *Ptychoceras* and *Baculites*, and also *Turrillites* and *Helicoceras*.

The helicoid spiral appears sandwiched between a phylogerontic nepionic stage in *Nostoceras* and *Emperoceras* and a true ontogenetic, gerontic living chamber with a retroversal curvature. This ontogeny shows this spiral to be a special, probably pathologic adaptive mode of development peculiar to the ephebic stage of some of the phylogerontic series, but not necessarily having any corresponding feature in the gerontic stages of any large number of normal formed *Ammonitinæ*.

This explanation is in accord with the fact that all normal *Ammonoids* and *Nautiloids* revolve in the same plane even in the gerontic stage, and enables one to explain the most puzzling of the degenerative forms. Thus there may be, as in *Macroscaphites Ivanii*, shells with retroversal gerontic stages derived directly from normal *Ammonitinæ*. Some helicoceran forms are also derived directly from similar normal forms, the most wonderful example being the series discovered and accurately described many years since by Quenstedt, who traced helicoceran and crioceran, and even baculites-like shells all back to their proper origin in *Cosmoceras* (*Amm.*) *bifurcatum* of the Jura. Neumayr is constantly alluded to as the person who discovered this important biological fact, whereas the credit is due to Quenstedt, who showed that all such forms in the Jura were probably pathologic derivatives of normal forms. I have examined a considerable number of the species of *Turrillites* and *Helicoceras* from European localities, and although the apices of some of these were small enough to have shown at least the beginning of an excentric nepionic or neanic stage, if any had existed I did not succeed in finding any indications of the presence of such forms in the young. It is, however, very strange that the youngest stages are invariably absent even in large series of specimens of the same species, and this suggests that the youngest stage was especially liable to destruction, and might not have been like a normal formed

\*See remarks on *Ptychoceras*.

involute Ammonoid, *i. e.*, it might have been excentric or helicoid. So far as known, however, all European series approximate to normal forms in the young. Here and there also there are diseased individuals, as in the so-called *Turrilites Boblayei* (*Arietidae*) and *Turrilites Valdani* and *Coyarti* figured by D'Orbigny, and other isolated examples of unsymmetrical shells having helicoid tendencies in the ephebic and even younger stages. It is also fully demonstrated by specimens and drawings that many *Turrilites* and helicoceran forms do not have a retroversal living chamber in the gerontic stages as in the scaphitoid and ancyloceran-like series traceable to various genera. This may be due to the incompleteness of the specimens heretofore collected and the perishability of the excentric gerontic volution when present. This hardly accounts for those species having contracted living chambers and apertures, the presence of which are almost conclusive in favor of the opinion that they could not have had retroversal gerontic living chambers.

These facts and the tendency of the terminal gerontic volution to return to the mode of revolution in the same plane and to resume the lost bilateral symmetry of the whorl in *Emperoceras* and *Nos-toceras* show plainly that the helicoid spiral is acquired, adaptive pathologic tendency that may come in anywhere as an intermediate stage in the ontogeny or phylogeny of any degenerative species or series, and is not strictly speaking a normal phylogerontic characteristic.

Another interesting result of the discovery of *Helicancylus* by Gabb is that *Hamulina*, *Hamites*, and probably also the allied *Ptychoceras* can be definitely characterized as phylogerontic forms of phylogerontic series. The author has previously claimed, with Quenstedt, that this was the only way to account for the *Hamites*, *Ptychoceran* and *Baculites*-like modifications of European forms. American forms with helicoid tendencies, like *Helicancylus*, having gerontic stages which differ from true *Ptychoceras* only in the closeness with which the gerontic retroversal bend is made, afford positive evidence in the same direction.

It should be noted in this connection that these remarks do not necessarily imply that *Ptychoceras* has not a distinct mode of development, an ontogeny of its own and also its own peculiar genetic series as may be seen in the remarks on that genus.

I have had an opportunity to study the gerontic stage of a species of *Helicancylus* in the Whitney Coll., Mus. of Comp. Zoölogy,

which may be new. The gerontic stage is the same as that of *H. æquicostatum*, and is closely bent and like *Ptychoceras*, although there is no gerontic contact furrow. The costæ are large, single and tuberculated, not alternately entire and tuberculated as in Gabb's species.

*Nostoceratidæ.*

This is probably a more or less artificial group, but it serves the present purpose of showing the common characteristics of several groups of phylogerontic species. I have united under this name all such distorted forms of the Cretaceous in this country with unsymmetrical spirals in the epebic stages, more or less prominent costæ and two rows of tubercles on the abdomen. The earliest stages are too little known for any general description to be given, the gerontic stages often have a retroversal living chamber and are tuberculated.

The genera are *Nostoceras*, *Didymoceras*, *Emperoceras*, *Exiteloceras*.

Quenstedt was the first to call attention to the persistency of styles of ornamentation in series of degenerative shells and to point out that these were indications of affinity that could not be lightly laid aside. A considerable proportion of the phylogerontic species of the Cretaceous in this country have only two rows of tubercles with costations bifurcated at the bases of these tubercles, but I have not been able to find any corresponding ornamented normal form which might be considered their phylogerontic radical.

*Helicoceras Stevensoni* (Whitfield) is represented among the specimens sent me from Yale Museum by a fine specimen and the youngest part of this specimen indicates a change in the spiral, but the young was not sufficiently defined to enable me to place the species in its proper genus.

I have before me a fragment of a whorl very similar to *Stevensoni* in costæ and tubercles, but of larger size than is usual in that species, and yet this has an irregular contact furrow on the upper side. The irregularity of this furrow may be due to age and the species may have been a true turrilites-like form when younger, or it may indicate that the separation of shells with the helicoceran mode of growth into different genera from true turrilites-like shells with a contact furrow is artificial and not advisable. This fragment

reported as found at Colorado City Mineral Springs, and is in Museum of Comparative Zoölogy.

*Helicoceras umbilicatum*, Meek, *Invertebrate Paleontology*, Pl. xxii, Fig. 5, is probably a close ally of *Stevensoni*, but my information is not satisfactory.

*Heteroceras Conradi*, as figured by Whiteaves in *Mesozoic Fossils*, i, Pt. ii, Pl. xii, and supposed to be identical with *Ammonoceratites Conradi* of Morton is also a form that is not sufficiently well-known to be referred to its proper genus. The costæ have no tubercles and resemble those of the young of *Nostoceras Stantoni* and *helicinum*. There is also obviously a retroversal gerontic volution shown by Whiteaves in his Fig. 3, and there is apparently no contact furrow, the mode of growth being helicoceran and not turrilitean.

It may be useful in connection with these descriptions of phylogerontic forms to note the fact that there are some series of true ancyloceran forms in this country having shells revolving in symmetrical spirals in the same plane, and not having helicoidal ephebic stages. They are similar to most of the European series, and it is not advisable to name them till proper comparisons can be made.

*Ancyloceras percostatum* and *Rémondi*, Gabb, described in *Paleontology of California*, are good examples of species having this kind of spiral.

#### *Lindigia.*

This genus Karstens,\* with *Lindigia heliceroïdes* as the type, has (in this small species) linear, untuberculated costæ, a helicoceran spiral in the ephebic stage, and comparatively a very large and long retroversal gerontic volution.

*Heteroceras Conradi* of Whiteaves may be a species of this genus occurring in North America, but *Lindigia* has peculiar ventral crests in the costæ of the anagerontic substage that are quite distinct from those figured by Whiteaves in his species.

*Helicoceras simplicostatum* of Whitfield resembles this species, but it may nevertheless be the parephebic substage of some other tuberculated species which has lost its ephebic tubercles.

#### *Nostoceras*, † n. g.

The species of this genus have a close-coiled unsymmetrical shell during the ephebic stage and are true turrilites. There are two

\* *Geol. de la Colombie, Venezuela, etc.*, Pl. i, 1856.

† *Νόστος*, a return.

rows of ventral tubercles, which become more or less deflected during development towards the lower side (whether this be the left or right side) of the whorls. There is a contact furrow which is maintained as long as the whorls are sufficiently close coiled and then disappears on the free gerontic volution. This volution is excentric and then recurved as in all retroversal living chambers. The nepionic stage is not yet known, but it is obviously quite different from that of the more loosely coiled helicoceran spirals of the genus *Emperoceras*.

This genus has the two rows of ventral tubercles and general aspect of the shells of *Ptychoceras* and *Emperoceras*, described in this paper and these characters contrast decidedly with those of the *Helicancyclus* phylum.

The nepionic and perhaps earlier neanic substages are not known, but there are indications in some specimens of *Nostoceras helicinum* that in the early neanic substages the whorl is not a normal ammonoidal spiral, but an open, whorled, irregular shell of some kind. The specimens I have in hand also show that in both species, *Nostoceras Stantonii* and *Nostoceras helicinum*, the last neanic or earliest ephebic substage has no contact furrow and has single costæ without tubercles. The ephebic stage has tubercles as a rule, and more or less bifurcated costæ, but both may be absent in some shells. The gerontic volution is apt to have tubercles even when they are absent in the ephebic stage.

This genus is of interest in connection with the history of the impressed zone because here, as in other allied forms, this characteristic enters upon a new phase of its history. The nepionic stage being unknown, one cannot state positively that it has a close-coiled shell and a contact furrow, but since this has now been found in so many uncoiled forms, it is legitimate to infer that it was present. In such shells the contact furrow which arises after the degeneration and loss of the nepionic contact furrow is obviously distinct, occupying the side and not the dorsum of the whorl.

The type is *Nostoceras Stantonii*, U. S. National Museum; Loc., Chatfield, Novarro county, Texas.

#### NOSTOCERAS STANTONII.

Loc., Chatfield, Novarro county, Texas.

This species has several varieties.

#### *Var. retrorsus.*

This variety has from five to six complete turrilites-like whorls

before the retroversal gerontic stage begins. The apex does not exhibit any indications that the species had an excentric young stage even at the small diameter of 5 mm. in one specimen. There appear to be no tubercles on the earliest whorls examined, probably the neanic stage. Two irregular rows of tubercles are introduced in the ephelic stage with alternating untuberculated costæ. The tuberculated costæ are sometimes bifurcated, and sometimes single. The costæ are closely set, subacute ridges, with concave flutes between them both, arching apically, the flutings broader than the costal ridges, but the surface is otherwise smooth.

The height of the coil is over 40 mm. in the largest specimen, through the ephelic whorls, although the apex is imperfect. In two other specimens this length is much less, although the number of the whorls is about the same. The diameter of this specimen through the paraphebic whorl is 34 mm. The height (transverse diameter) of the paraphebic substage is 19 mm., the ventro-dorsal diameter about 13 mm. The diameter of the umbilical opening must have been less than 12 mm.

The costæ are wider apart in the last of the ephelic stage, or paraphebic substage, and I expected to find that they died out altogether for a certain space, but there was no evidence of this. They, however, appear to be slightly more prominent on the gerontic volution than on the paraphebic substage.

The contact furrow begins early, being present on the smallest whorl examined. There is therefore no positive indications that this species had uncoiled or excentric young as in *Emperoceras*.

In the anagerontic substage the whorl bends downwards or orally in two dextral specimens, and in the metagerontic acquires larger tubercles and coarser costæ, sometimes bifurcated, and bends upwards towards the base of the ephelic volution, forming the retroversal living chamber. The last part of this, or the paragerontic substage, is nearly or quite straight, the bifurcations disappear, leaving the costæ straight, and the tubercles also gradually disappear. The latest senile substage is also nearly if not quite bilaterally symmetrical and strongly contrasts in this respect with all the stages preceding the metagerontic substage. The return to the symmetrical form of whorl really begins in the metagerontic substage. The living chamber has an aperture in one specimen. This is straight across the venter, has slight crests on the sides, and is straight or with very slight crest on the dorsum.

Mr. Stanton has kindly examined the numerous specimens in the National Museum, and estimates that the retroversal chamber in this variety is generally the sixth or seventh volution and also remarks that one specimen is nearly double the size of the largest one mentioned above, and that there are but few that are smaller. The three specimens I have of this variety are dextral, but there are others in the National Museum which are sinistral.

*Var. prematurum.*

This variety has more closely set costæ and smaller tubercles and the gerontic stage begins earlier, there being, if my estimate is correct, only three or four closely coiled whorls. The last volution is well preserved in the only specimen of this variety that I have and this shows clearly an open aperture, almost straight across the venter, with slight crests on the sides and equally obscure crest on the dorsum. It is, in other words, precisely similar to the aperture of variety *retrosum*. The specimen here described is sinistral, and is the only one obviously belonging to this variety in the collection of the National Museum.

*Var. aberrans.*

This variety may have three, four or five closely coiled whorls and considerable variation in the tuberculations, etc., but when the gerontic stage begins, the aspect is distinct. The anagerontic substage does not bend so abruptly as in *retrosum* or *prematuum* it is more oblique to the axis of the spire and the retroversal meta-gerontic substage, if it be superadded in this variety, would be more oblique than in var. *prematuum*. One specimen is dextral and the other is sinistral.

*Remarks.*

This species was discovered by Mr. Stanton in the Ripley beds, where it is associated, as stated by the same gentleman, with a number of other phylogerontic species, such as two species of Ptychoceras, *Turrilites splendens*, Shum., *Nostoceras (Turr.) helicinum*, Shum., *Helicoceras navarroensis*, Shum., and a variety of other typical Ripley species. Mr. Stanton also informs me that out of 26 specimens in the National Museum, 16 are dextral and 10 are sinistral.

NOSTOCERAS HELICINUM.

HETEROCERAS HELICINUM, Shumard.\*

Loc., Chatfield, Novarro county, Texas.

At the diameter of 8 mm. in one of the two specimens before me, there are indications that the young was more loosely coiled, and perhaps more or less excentric in comparison with the later closer-coiled stages. The contact furrow was also obviously absent in these earlier substages. In the other specimen, at diameter of about 9mm., there are similar indications. Nevertheless, I was by no means sure of what these changes indicated, whether a helicoceran, scaphetoid or hamites-like shell. All that can be said is that they show irregularities in the growth of the young not present in the turrillitean volutions of the ephebic stage.

The young, probably in the anephebic substage, has single costæ, each tuberculated on either side of the venter. These become more or less irregularly bifurcated, and with intermediate entire costæ without tubercles, usually one, sometimes two, in each interspace in the metephebic substage. The whole is a flat turbinated coil of not more than four or five whorls with prominent tubercles and costations.

In the anagerontic substage the volution abandons the spiral, the contact furrow disappearing immediately, and the shell grows downwards and outwards, as in the anagerontic substage of *Nostoceras Stantoni*, var. *aberrans*.

The single tuberculated costæ of the young are similar to those of the later stages of *Ancyloceras Jennyi*, Whitf., *Pal. Black Hills*, and some of the helicoceran forms found elsewhere; but the young shells were obviously quite different, being more closely coiled and stouter shells. Specimen in Coll. U. S. Nat. Mus., No. 21103.

*Didymoceras*, † n. g.

There are a series of forms having loose helicoid spirals, two rows of more or less irregular ventral tubercles and irregularly bifurcated costæ, which also have, or appear to have, a gerontic stage with a retroversal volution, as in *Nostoceras*. These are all larger shells and are separable by the helicoceran mode of growth in the ephebic stage.

\* Received through the kindness of Mr. T. W. Stanton, who identified the species.

† Δίδυμος, double.

Beside the type form, *Didymcoeras nebrascense*, in the Yale University Museum, there are several closely allied species, as follows: *Didymoceras* (*Het.*) *cochleatum* and *tortum*, Meek, *Invertebrate Paleontology*, Pl. xxi.

Some of the species described by Whitfield and others from the Black Hills have similar ornamentation and helicoceran whorls, and probably belong to the same series, if not this genus. I refer to *Heteroceras Newtoni*, *Exploration of the Black Hills*, Pl. xv, and its possible gerontic stage, *Ancyloceras tricostatus*, Fig. 7 of same plate. With regard to this form I have, however, doubts arising from its close resemblance to *Nostoceras helicinum*, and these make it necessary to study the young before it can be definitively referred to the same genus with *Nebrascense*.

DIDYMO CERAS NEBRASCENSE.

HETERO CERAS NEBRASCENSE, Meek (*Invert. Foss.*, Pl. xxii, Fig. 1).

HETERO CERAS, Whitf. (*Pal. Black Hills*, Pl. xv, Fig. 6).

Loc., Near Buffalo Gap, S. Dakota.

Pl. xiv, Figs.

The young of this species is unknown, but the younger stages of the closely allied *cochleatum* show that it did not have a contact furrow—at least in the early ephebic substage. The metephebic substage has more or less irregular, obscure tubercles and rather fine, closely set costæ, occasionally bifurcated at the tuberculations. These disappear in the parephebic substage. The gerontic volution is retroversal as in *Nostoceras*. The costæ increase in size and prominence in the anagerontic substage, and also become tuberculated and bifurcated. During the metagerontic substage these characters are more developed, and the volution makes a retroversal bend. All of the ornaments are lost, however, in the paragerontic substage, the costæ depressed and finally disappear except on the venter, and the whorl becomes again bilaterally symmetrical. The costæ and lines of growth bend slightly forwards across the venter, then backwards into sinuses on the inner parts of either side and form symmetrical crests across the dorsum. The aperture is preserved in this specimen and shows the same outline.

Mr. T. W. Stanton\* in discussing a collection of fossils from Fort Pierre shales, near Boulder, Colo., described substantially the same remarkable characteristics in this species and in *tortum*, and

\**Proc. Colorado Scien. Soc.*, ii, Pt. iii, 1887.

was the first to state that most of our Western forms of *Heteroceras* probably had similar irregularities in the development of the last volution.

*Emperoceras*,\* n. g.

The young are hamites-like, so far as known in the neanic stage and become helicoceran in the ephebic stage. It is not positively known that they have an extended gerontic stage.

EMPEROCERAS BEECHERI.

Loc., Near Buffalo Gap, S. Dakota.

This species has, in the earliest substage, observed probably the metaneanic straight volution with straight costæ, having each two minute tubercles on the venter, and no intermediate untuberculated and single costæ. The section is compressed oval, the dorsum broader than the venter. The siphuncle is certainly in the mesal plane between the rows of ventral tubercles in this substage. The sutures are simple and appear to be symmetrical, or more nearly so than in the succeeding substages.

The paraneanic is introduced when the hamites-like first bend of this specimen is made, and is terminated by a permanent constriction in the elbow of the second bend in both specimens of this species. Bifurcated costæ appear and intermediate untuberculated costæ in this substage.

The next arm, probably the anephebic substage, is bent more or less downwards, but the curvature is distinct from that of the metephebic stage, and the form of volution in section is still a depressed oval, although much more gibbous on the upper than on the lower side. The section is that of a compressed ellipse, the ventrodorsal diameters increasing faster than the transverse.

The intermediate single costæ running uninterruptedly across the venter are more numerous in this substage, occurring from one to three between each bifurcated and tuberculated costation. The bifurcations are not always well marked, but they are more distinct than those given in the drawings, and here and there a costation may be single and have tubercles. This volution begins to twist in the metephebic substage, and the asymmetrical helicoceran form is fully developed in the flattening of the lower side and the increasing gibbosity of the upper side, whether this be right or left, and the tubercles are correspondingly deflected. The siphuncle has

\* *Ἐμπερηρος*, deformed.

shifted less, and consequently the upper row of tubercles is brought over the trace made by this organ in the cast of the interior. Great irregularity appears in this substage, the costæ may be bifurcated at the tubercles and between them, or they may run across the venter and be bifurcated at the base of the tubercle of the opposite side. This ornamentation is similar to the fragment figured by Gabb in *Paleontology of California* as *Ammonites Cooperi*, Vol. i, Pl. xiv.

The dorsal crests formed by costæ occupy the somewhat flattened dorsum of the early part of the paraneanic substage, but when the twisting begins these dorsal crests begin to be unsymmetrical also. In other words, the lines of growth and costæ assume the usual direction and aspect of turbinate shells, whether Gasteropoda or Cephalopoda.

The spiral is quite irregular in the anephebic substage, but is more regular in the metephebic and parephebic substages. In the parephebic substage the tubercles disappear in this specimen.

There is a decided contraction of the transverse diameter of the spiral in this substage.

The absence of the tubercles on this substage is similar to the change that takes place in *Nostoceras nebrascense* at the same age and enables one to classify all the substages satisfactorily.

*Exiteloceras*,\* n. g.

After a careful survey of the forms referred to this genus, it has become evident that there is a series having the following characteristics and quite separable from the full-grown stages of any other genus referred to the Nostoceratidæ. They are, however, not so easily separated from the young of *Nostoceras* if my observations are correct, since the single costæ with two lines of tubercles are found in the young of that genus and of *Emperoceras*. This, however, is entirely in accord with the system advocated in this and other publications and is in my opinion another argument in favor of distinguishing the group by another name.

The series of forms figured by Meek in his *Invertebrate Paleontology*, Pl. xxi, have a single costæ with two rows of tubercles, each costation being tuberculated. The epehebic stage is helicoceran and the gerontic stage probably has the retroversal living chamber.

\*'Εξίτηλος, becoming extinct.

The species are as follows: *Exiteloceras* (*Heteroceras*) *Cheyennense* and *angulatum*. *Exiteloceras* (*Ancyloceras*) *uncum*, Meek, *Invertebrate Paleontology*, Pl. xxi, is probably a fragment of the gerontic stage of one of these.

*Exiteloceras* (*Ancyloceras*) *Jennyi*, Whitfield, *Paleontology of the Black Hills*, Pl. xvi, has also similar ornamentation, but the costæ differ somewhat. This form, if the drawing is correct, has a tendency to asymmetry and when older was probably helicoidal.

*Ancyloceras lineatus*, Gabb, *Paleontology of California*, has also similar costæ, form and tubercles, but this may be a fragment of *Ptychoceras*.

I have also before me two fragments, one 20 mm. in transverse diameter by 19 mm. ventro-dorsally, the other 17 mm. transversely by 20 mm. ventro-dorsally, which have precisely the costæ and tubercles of *Exiteloceras angulatum*, as figured by Meek, namely, very prominent, subacute single costæ reaching completely round the whorl, each one having two tubercles on the venter with a slight depression on the prominent costation between them. They are fragments of helicoceran whorls and the aspect is altogether distinct from that of any form in other genera. Loc., Elm Fork, Dallas county, Texas. *Hamites Fremonti*, Marcou, *Geology of North America*, p. 36, Pl. i, Fig. 3, is probably a gerontic stage of some species of this group. The anagerontic substage in his figure has single costæ without tubercles, but the metagerontic substage has the retroversal bend and every third costation has two ventral tubercles. All costæ are single and prominent.

*Exiteloceras* (*Helicoceras*) *pariense*, White, *U. S. Geol. Survey W. 100 Merid.*, Wheeler, Pt. i, *Pal.*, Pl. xix, Fig. 2, is another species of this series which shows by the twist in the costations that it is probably in older stages helicoidal.

#### *Ptychoceratidæ.*

I use this family name here provisionally and only in order to make clearer the essential distinctions that seem to exist between the series represented by the genera, *Sciponoceras*, *Ptychoceras* and *Diptychoceras* and other series of genera described in this paper.

The young, so far as known, have slight, smooth shells in the neanic stage, the ephebic stage has the lines of growth and costæ inclined forwards in passing over the sides and venter and probably

corresponding apertures like those of *Baculites*, but with less prominent rostra or ventral crests. As the gerontic stage begins the aperture changes in outline and the shell bends with a sharp curve and forms a gerontic perforation, which is long and narrow. A gerontic dorsal furrow appears in this bend and beyond it a gerontic contact furrow also appears. In *Sciponoceras* the gerontic stage has not been fully observed and in *Diptychoceras* these gerontic characters begin to appear in the ephebic stage.

The family characters are therefore simply the straight mode of growth and the changes in the aperture and also probably the tendency observed in all species of *Ptychoceras* to lose the rostrum in old age. This can be seen in the backward or aborad inclination of the costæ on the gerontic arm as compared with the forward curves of the same in the ephebic stage on the opposite parts of the first arm.

*Sciponoceras*.\*

This form apparently completes the series of which *Ptychoceras* and *Diptychoceras* are obviously members. In comparing these two last and in studying their development and comparing them also with the young of *Emperoceras* I was struck by the peculiar form of rostrum or low, broad, ventral crest indicated by the lines of growth in the ephebic stage and the irregularities of the constrictions indicating apertures especially at the gerontic bends. The apertures of the ephebic stage may have had considerable resemblances to the apertures of species of *Baculites* in the ephebic stage, but when old age approaches the modifications attending the tendency to bend in *Ptychoceras* are entirely distinct and the apertures altogether different.

These facts are nicely shown in D'Orbigny's figures of the type of this genus, *Sciponoceras* (*Baculites*) *baculoides*, *Terrains Crétacés*, Pl. cxxxviii. This shell at first appears to represent the ephebic and younger stages of a species of *Ptychoceras*, but on more closely examining the drawing, if this be correct, it can be seen that it is an outgrown or aged specimen having a gerontic stage of its own. This is indicated by the partial disappearance of the costæ near the terminal aperture, which is also just beginning to make the first gerontic bend and has an entirely different outline from the constrictions figured below on the cast of the same specimens.

\* *Σκίπων*, a staff.

The extremely attenuated and much elongated cone of this species is also altogether different from that of *Ptychoceras*.

Another very interesting line of investigation is suggested also by these studies. The resemblances of this shell and the full-grown and senile stages of *Baculites* are indications either of affinity or very close morphic parallelism. I am personally inclined towards the latter opinion since *Baculites* itself seems to me to be a composite of the extreme phylogerontic forms of several different genetic series.

### *Ptychoceras*.

This genus is interesting here on account of its relations to the gerontic stage of *Helicancylus* and also because of the presence of a secondary development of the impressed zone, which appears during the gerontic stage of the ontogeny of most of the species now referred to this genus. This last character and the close angular bending of the straight limbs of the whorl, separate the species wherever they occur. It is very likely that eventually this and *Baculites* will be split into distinct series and shown to belong to a number of different genera, but just now, with the exception of *Sciponoceras*, this is not desirable.

The American fossils I have seen all have the two rows of ventral tubercles and are not similar to the *Helicancylus* phylum in their ornamentation. They are much more like the young of *Emperoceras Beecheri* in the singleness and tuberculation of each one of the costæ.

PTYCHOCERAS CRASSUM, Whitfield.

Loc., Near Boulder, Colo., Cretaceous.

Pl. xiv, Figs. 18-21.

Fragments of this species kindly loaned me by Mr. T. W. Stanton and identified by him show the following significant facts in the history of the impressed zone. The ephebic stage, which is I think the latter part of the straight arm with closely set tuberculated costæ inclined orally, is of the usual rounded form in section. The venter between the two rows of ventral tubercles is narrower than the dorsum, which is somewhat flattened but still entirely gibbous, the ventro-dorsal and transverse diameters are nearly equal near the bend. As the bend is made a decided enlargement of the ventro-dorsal diameters occurs and the costæ after this become more

widely separated and are inclined apically and the sides flatter. This difference in the inclination of the ribs shows that the slight crest in the lines of growth and probably apertures of the ephebic stage have been lost in the gerontic stage.

The dorsum as the bend is made becomes flattened and when this is completed it is a distinct furrow which cannot be called a dorsal furrow or a contact furrow. The true dorsal furrow, if it occurred at all in this form, must have been between the protoconch and the apex, the true contact furrow probably did occur in the nepionic stage which has not yet been seen.

This furrow then which occurs in the bend before the contact of the gerontic volution or arm takes place is probably a gerontic dorsal furrow. The lines of growth in this furrow are bent forwards into a slight but well-defined crest in two of the specimens examined and the costations were wholly absent. The umbilical perforation which occurs here is not very small and it occurs between two straight volutions and is the reverse morphically of the nepionic perforations; thus it also is a gerontic perforation and not an umbilical perforation, a degenerative and not a progressive character. The length of this perforation was 4 mm. more or less in three specimens; the vertical diameter was very much less but was not measurable.

Just before contact takes place one costation crosses the dorsum with a forward bend or crest in two specimens. Close to it, but at the contact, in another specimen, there occurs a costation which is the reverse of this, having a sinus which marks the beginning of the gerontic contact furrow. This furrow in the only fragment showing the dorsum in older parts of the gerontic stage obliterates the costæ. The lines of growth were nowhere visible in this contact furrow, so that, whether this side had crests or sinuses in the apertures, could not be observed.

PTYCHOCERAS TEXANUM, Shum.\*

Loc., Chatfield, Texas.

Three fragments of this species, sent like others through the kindness of Mr. T. W. Stanton, show peculiarities with reference to the gerontic contact furrow and gerontic dorsal furrow, resembling essentially those described for *Ptychoceras crassum*, but in this

\*Identified by Mr. T. W. Stanton. See Shum., *Proc. Bost. Soc. Nat. Hist.*, viii, p. 190.

small fossil the gerontic umbilical perforation is much larger and wider in proportion.

One in fact begins to find the same difficulties in the application of the purely mechanical theory of the origin of the gerontic dorsal furrow here that was mentioned in accounting for the origin of the dorsal furrow in the nepionic stages of the close-coiled Nautiloids. My opportunities and materials do not permit me to discuss the subject intelligently but merely to note the facts.

One fragment of a volution or an arm, apparently of this species and identical in every way with the other two of the same lot in ornamentation and form, has, however, a gibbous dorsum.

It is either not a *Ptychoceras* or it is the paragerontic substage of this species after it has passed the age in which the gerontic contact furrow is present, or else, as I have suspected from the examination of other species, any species of *Ptychoceras* may have modifications that would place it in the genus *Hamulina*, *i. e.*, some specimens may not be closely appressed in the gerontic stage and may not have the gerontic contact furrow.

*Diptychoceras*.\*

The single species described by Gabb as *Diptychoceras laevis* is of interest in this connection as a further modification of *Ptychoceras*.

It has in its ephebic stage a straight arm occupying the same position with relation to the younger or first straight arm as that of the gerontic arm of *Ptychoceras*. That this is the ephebic stage is shown not only by the presence beyond it of the third straight arm, but also by the presence on the second arm of costæ that incline orally in passing on to the venter.

The gerontic characteristics of *Ptychoceras* are therefore only in part, not as a whole, carried back into the ephebic stage of *Diptychoceras*. The gerontic stage or third arm in the ontogeny of the shells of this species is similar to that of *Ptychoceras* and this has its own gerontic characters. The tendency to the peculiar mode of growth first found in the gerontic stage of *Ptychoceras*, the closely appressed retroversal straight limb is, however, inherited in the ephebic stage of *Diptychoceras*.

It would be interesting to follow out the history of the impressed zone in the gerontic stages of shells of this species, but I have no

\*Gabb, *Pal. Cal.*, ii, p. 143.

materials. Gabb states that both the second and third arms envelop more or less the preceding, and they must therefore have contact furrows in both stages.

## VI. SUMMARY.

The importance of the impressed zone can be made apparent better by discussing the correlative facts of the morphology than by any other means.

When one considers the mode of growth of the young of any one of the straight or primitive arcuate forms of Nautiloids, the prominent fact is the bilateral symmetry of the cone and the asymmetry of the ventral and dorsal sides as in *Spyroceras* (?) *cro-talum*, Figs. 10-12, p. 361, and the young of other forms, p. 360. It is obvious from these drawings and other observations that this asymmetry is due to the more rapid growth of the ventral as contrasted with the dorsal side. This is shown by the greater breadth of the bands of growth and the intervals between the sutures that are greater on that side. Subsequently in the ontogeny of the straight forms, in *Endoceras*, *Orthoceras*, the growth becomes more nearly equal and in many forms is practically equal and the shell is built out in nearly straight lines. The angles of the curves made by the dorsal and ventral sides near the apex are on this account entirely distinct from each other, the venter departing from the end of the cicatrix at a much wider angle than the dorsum, which is much less inclined and soon tends to assume an almost straight line.

The two sides, venter and dorsum, tend therefore to become less divergent after the nepionic stage is passed, but they nevertheless continue as long as the cone increases in the ventro-dorsal diameters to grow in more or less divergent directions during the neanic and ephebic stages except in the living chambers of certain species. In these the diameters become shortened towards the aperture and the sides converge more or less either in the lateral or ventro-dorsal diameters or in all diameters. This occurs in some species only in the gerontic stage, but in others it may occur at any stage after the nepionic.

In all shell-covered cephalopods, so far as known, the nepionic shells have open apertures and all four sides are continually divergent in these younger substages of development. The asymmetry of

the apex of the conch in all arcuate and coiled forms is also very strongly marked and there is an obvious correlation between the close coiling of the young, the size of the umbilical perforation and the rate of increase of the outer or ventral side. Thus in shells with large umbilical perforations, the first whorl increased slowly and was more nearly equal on the ventral and dorsal sides than in those with small perforations in which the outer sides or ventral increased much faster than the inner. This is shown by the lines of growth whenever they are observable and by the distance apart of the sutures, both of these being much more widely separated on the venter than on the dorsum, and also by the extremely long and gibbous outline of the venter as compared with that of the dorsum.

One can readily illustrate this by drawing a circle with lines radiating from the centre and then roughly projecting upon this background the figure of any of the species given, allowing the centre of the radii to coincide with the centre of the umbilical perforation. It can then be easily seen, that as the whorl grows, if the umbilical perforation be small, the outer side has necessarily in keeping pace with the inner to describe a much larger arc in proportion than it does when the umbilical perforation is larger. This necessarily follows because the two sides, starting from a given place in the plot of the radii, are more nearly parallel in proportion as the perforation is larger. Thus in shells with small perforations the increase of the ventro-dorsal diameters of the body is often much in excess of all other diameters and this preponderance in highly involute shells may be continued until near the end of the gerontic stage. The proportional increase in breadth of the growth bands of the venter as compared with those of the dorsum is a corollary of this proposition, or in other words the bands on the outer convex side necessarily have quicker growth than those of the dorsum, being built out farther in the same periods of time.

The ananepionic substage, as a rule, has the lines of growth straight or with ventral crests broader in the median line than at any other part, but in the metanepionic or early paranepionic at latest the hyponomic sinus is introduced. While the bands of growth still remain broader on the venter in spite of this depression on that side, there is after this stage a constant lagging behind of the central ventral surface due to the presence of the hyponome.

Among Ammonoidea this is not the case except in the more gen-

eralized Goniatitinæ.\* The higher Goniatitinæ and almost all shells of the remaining suborders of this order have a rostrum on the venter. Shells having this peculiar structure, due to the absence of a hyponome, continue to increase or broaden out the bands of growth after the rostrum is introduced into the ontogeny, producing often long-pointed or palmate growths. This is certainly independent of the spiral mode of growth and has no effect upon it, since the rostrum is very well developed in forms like *Baculites*, having phylogerontic straight whorl, and it may be entirely absent in the gerontic stage of *Ptychoceras* and in forms with lateral lappets to the apertures as in some *Scaphites* and other genera which are more closely coiled.

Taking into consideration all of such facts there still remains a certain obvious and necessary relation between the ratios of growth of the bands on the outer and inner sides of a coiled shell which has been described above, and which is a mechanical necessity of growth in a spiral.

It is also true, as a rule, that the lateral diameters increase faster in shells with small umbilical perforations than in those with large open centres. But this seems to be merely a function of the quicker growth and general accompaniment of the early age of such types and to have direct exceptions that do not enable us to bring it under any uniform law. Thus *Estonioceras* is a type with large umbilical perforations and slow-growing ventral bands of deposition, but the lateral diameters increase fast as in the young of some forms like *Estonioceras imperfectum*, Figs. 20 and 21, Pl. vii.

In nearly all shells there is a noticeable tendency to decrease the lateral diameters in the later nepionic and neanic stages, and is obviously due to Minot's law of growth, which is noticed in the Introduction, p. 381.

Among Nautiloids it is observed in *Trocholites* as a generic character occurring in the neanic stage and is in these species and in the nepionic stage of *Ammonoidea* an absolute decrease so well marked that in the former the apex and in the latter the protoconch are not covered and can be seen beyond the outer volution, this being the usual aspect in a ventral view of a Goniatite or the young of *Ammonitinæ*.

A similar decrease occurs in other forms of Nautiloids than

\* See Introduction, p. 355.

Trocholites,\* but is usually less and occurs later and more slowly and it is not an absolute decrease. That is to say the outer whorl never falls off so much in the ratio growth as to become actually smaller than the inner volution in any of its diameters until the gerontic stage. In this stage the falling off in the rate of increase by growth may and sometimes does accomplish this result on the last part of the outer whorl.

A description of the parallelism of different genetic series and the constant and often repeated tendency that these exhibit to evolve a series of similar forms has been given in the Introduction. This tendency produces straight, arcuate, loosely coiled and close coiled, and finally involute shells in each group, however distinct they may be in structure.

The tendency to bend towards the side opposite the hyponome is almost universal in all shell-covered Cephalopods. There are a few arcuate species that bend towards the hyponome like Barrande's *Cyrtoceras nitidum*, but many even of his group of the so-called "endogastrica" have, like his *Cyrt. Murchisonia* and *Cyrt. neutrum*, the hyponome and therefore the true venter on the outer or convex side. There is only one genetic series or genus, as a whole, that appears to contradict this statement. All of the species of the true Phragmoceras except one, *P. perversum*, Barrande, bend towards the ventral side and about all have the siphuncle and also, of course, the azygos sinus of the hyponome in the aperture and the corresponding sinuses in lines of growth on the same side. The shells of this genus are much compressed and the apertures are very much elongated and present a unique aspect. They are contracted along the central parts and the hyponome or motor organ is removed as far as possible from that part of the aperture which must have given opportunity for the external extension of the arms. This fact, however, is counterbalanced by the aperture of *P. perversum*, this being an extreme case of differentiation and removal as widely as possible of the hyponomic and brachial sinuses of the apertures and yet the shell is bent towards the dorsum and the siphuncle is ventral. Many species of Gomphoceras (*Acleistoceras*) are bent ventrally, whereas others with similar apertures and characteristics are bent dorsally. So far, therefore, as the characters of the apertures go, it is not possible to state that the bending is inva-

\*This peculiarity has led some authors to suppose that Trocholites had a protoconch like that of the Ammonoidea.

riably towards the dorsum, but that this is the general tendency of arcuate forms is obvious.

When it comes to the evolution of coiled forms the problem is different. Among these last, including also the loosely coiled or gyroceran, there is so far as known no exception to the rule that all such shells are bent dorsally from the earliest substages of the conch.

I have assumed in other papers that coiling among Gasteropoda could be accounted for by the unequal growth caused by the weight of the shell when carried above the foot and the facts appear to justify this conclusion in so far as that class is concerned. The presence of the hyponome on the ventral side in Cephalopoda would of itself account for the tipping of the shell towards the opposite or dorsal side both when the animal was crawling and swimming. This would leave the ventral edge of the mantle free to deposit calcareous matter undisturbed by pressure, whereas the dorsal edge would be more subject to disturbance and to shocks from compression which might interfere with the work of excretion. It is reasonable to suggest such a mechanical explanation both for the general tendency to bending and coiling and also for the dorsal direction.

If it were possible to account for the exceptions observed, as in the tendency of Phragmoceras towards the venter, by means of exceptional habits or structures, this suggestion would have more force, but unfortunately this cannot be done, at least at present. It is obvious, however, that there is some directive cause which acts upon every genetic series in greater or less proportion, giving to each evolving series the same tendency to produce in succession the straight, arcuate,\* and then the coiled forms in different degrees of intensity and that most of these have coiled in a dorsal direction away from the hyponome or organ of locomotion.

The position of the siphuncle with reference to the mode of coiling need not be discussed, since it obviously has no general relations, except that it is always, except in turbinate forms, Trochoceras, Turritites, etc., and in abnormal forms, like some species

\*Even in large and some small species and specimens of *Baculites* there is an arcuate tendency. D'Orbigny figures this in *B. incurvatus*, *Terr. Crétac.*, Pl. cxxxix, and Mr. Stanton has put together a very large specimen of *Baculites* in Nat. Mus. having a curve like *Cyrtoceras*. This is some five feet long, straight or nearly so in the younger part and arcuate in the older stage.

This specimen is from the Ripley Formation, Texas.

of Psiloceras and one of Anomaloceras and in pathologic individuals, always in or approximate to the mesal plane. There is, however, a fact to be noted. In the Endoceratidæ and Actinoceratidæ it is always in direct connection with the cicatrix. In other forms not having an endosiphuncle\* this connection is not strictly maintained, and while it is often situated over the area of the cicatrix, it may be, as in *Eutrophoceras Dekayi*, near the shell but not over the cicatrix, or as in *Hercoceras*, Fig. 13, Pl. viii, at some distance from the apex. There is upon the whole, however, a distinct tendency towards location in the mesal plane and centre or ventrad of the centre, those having a subdorsan siphuncle like some species of *Eutrophoceras* and *Aturia* being exceptional. In most forms, even those having siphuncle subdorsan in the second septum, it is nearer the venter in the first septum; marked examples of this are the *Eutrophoceras Dekayi* of the Cretacic, Fig. 4, Pl. xiii, and several species of *Schroederoceras*, or else it tends towards the centre, as in *Trocholites canadensis*, Figs. 39 and 40, Pl. v. It is also to be observed that in the adults of most forms of Nautiloids the siphuncle is centre or ventrad of the centre, that is on the same side with the hyponome. This tendency is more general among arcuate and coiled Nautiloidea than among straight forms, which as a rule have the siphuncle centre,† and finally in the Ammonoidea the subventran position is universal.

Whatever may be the cause of the general tendency of each genetic series to evolve along parallel lines of modification so far as the tendency towards coiling is concerned, it is obvious that it is not dependent upon time, climate or any special differences of structure. The bending takes place in every series even in the *Piloceras* with a huge siphuncle filled with calcareous matter and there is no positive proof that they may not have had coiled forms which belong to the same genetic series although none have been found. Arcuate and coiled shells are also found in every period, and under every condition of climate so far as geographic distribution is concerned.

It has been assumed in the Introduction that differences of habit could be used to account for these general tendencies producing

\* See Introduction, p. 412.

† The exceptions to this rule are very interesting. They include the radical type *Diphragmoceras*, the Endoceratidæ and the remarkable genus *Bathmoceras*. All of these have the siphuncle in most examples ventrad of the centre and in many of them it is subventran.

parallelisms in the evolution of different and diverging genetic series. Thus the Belemnoids and Sepoids, both preëminently swimming types\* and with organizations obviously derived from an Orthoceran radical, have straight internal shells.

There is an obvious correlation between coiling of the shell and the habit of crawling. Thus all univalve crawling mollusca have this general tendency. Among Gasteropoda, this is well known and those shells which degenerate and tend to lose the spiral mode of growth and become irregularly straightened out in these older stages of growth, are forms which become attached or lead sedentary lives, *i. e.*, *Vermetus* attached late in life and *Magilus* buried in coral. The most significant case, however, is that of *Fissurella*, which has a coiled shell in the nepionic stage and becomes similar to *Patella*, a depressed, straight cone in the neanic and ephebic stages, the habitat being like that of *Patella* and the approximate forms of *Haliotis* and others, comparatively sedentary upon littoral rock ledges.

A habit of crawling could be considered as sufficiently general in application and sufficiently persistent in an organization like that of the Nautiloids and Ammonoids, which are covered by shell and possess only the hyponome as a motor organ to affect entire orders and continue constant through time and geologic changes in the majority of forms.

With such a habit the tendency to become more exclusively crawling and to depend upon that mode of life, might, as has been explained in the introduction, produce in each series the same tendency, but it seems impracticable, so far as my experience goes, to find any other cause sufficiently general and likely to be undisturbed by geologic and climatic changes.

It is certainly not inherent in the organism to coil up. If the converse be assumed one must account for the continuance and persistence of the absolutely straight *Orthoceras* from the earliest times to the Trias and why these were unaltered and did not become arcuate or coiled as a whole. Inherent tendencies must, if the term has any meaning at all, work out their own evolution to some degree. They must sensibly affect the organization in all series having a common embryo unless held back or kept in abeyance by interfering causes. It is difficult to imagine any interfering cause acting so constantly through long geologic periods that it could

\* See Introduction, p. 356.

hold in abeyance the inherent tendency to become coiled in the genus *Orthoceras*. This is more obvious when one considers that this trunk form is perpetually giving rise to branches that show the tendency to coil up. In assuming that habit is the cause as determined by the law explained in the Introduction, p. 367, the greatest difficulty seems to disappear. As long as the shells could maintain themselves in the station they have been forced into, or had chosen, just so long would they maintain the form suitable for their habits or surroundings and they would change only in proportion as they changed their stations. Thus the main line might continue as long as it existed to hold the same form while its branches seeking new habitats and novel modes of life would change in directions determined by those. Whatever the causes may be, the fact is obvious, that the tendency towards becoming arcuate and coiled is general in the descendants of straight shells and not confined to any special series or time.

That it is an acquired character seems also to be a reasonable conclusion. An acquired character is one that is introduced into the life of the individual and is not present in the embryo before the tissues become differentiated into germ plasm and somato plasm. It is impossible to disprove or prove that a characteristic is acquired or genetic unless it can be followed back to its origin. Until this is done one cannot assert positively that it was not potentially existent in the embryo and became apparent at the proper time in the ontogeny in accordance with genetic law.

The law of acceleration can be true only upon condition that there are such things as acquired characteristics introduced in epembryonic stages. The examples given above in support of this law are all instances of acquired characters introduced late in the ontogeny and gradually forced back to younger and younger stages in successive generations, or species, or genera. This law is based upon the assumption that such characteristics exist and it is also supposed to show the mode in which they are inherited.

It is not necessary for me here to deal with any of these facts, except the tendency towards coiling among shell-covered Cephalopods. This tendency is manifested in the conch alone of the Nautiloidea, that is, in the epembryonic stages, and we can follow it as described above, both in the phylogeny and ontogeny, progressing with equal steps. That is to say, the more generalized of each genetic series show in their ontogeny that they were derived from

the more loosely coiled, and the more specialized show that they were derived from forms which were tightly coiled. In other words, the tendency to closer and closer coiling gains in the organization of the different genetic series, and is manifested more intensely in the young of more specialized forms and makes them coil more quickly and closer. In general, it is also easily seen that after the trunk forms die out in the Trias, as explained in the Introduction, page 370, and it is not possible for any new genetic series to be given off from these, this tendency has greater force. In the Jura and Cretaceous the shells are exclusively nautilian, and even the nautilian shells with very large perforations, common even in the Triassic, have entirely disappeared.

In the shells shown on Pl. xi-xiii there is not one that has a really large umbilical perforation and a free cyrtoceran apex, such as is seen in so many of the Silurian, Devonian, Carboniferous, and even in some Triassic shells. All of these transitional forms disappear with the trunk forms, and the same fact is true of the Ammonoidea. The transitional forms disappear in the Devonian at the same time with *Bactrites*, the radical straight form of this order. With regard to special series, it becomes more difficult to show agreement between chronology and bioplastology on account of the deficiencies in the records of collected forms and the general tendency of radical species to persist and be found either on exactly the same level with their descendants or even to outlive them and be present in later faunas.

In studying the coiling of nautilian shells one is struck by the fact that the ana- and the metanepionic substages are comparatively straight. They are not really straight, as has been explained above, but their comparatively straight aspect, in contrast with the succeeding stages of development, is noticeable.

At the end of the metanepionic substage the curvature is apt to be suddenly altered, bending more rapidly inward. This is what I have called the gyroceran bend, because it is the first indication that the shell is a true nautilian form. If one compares the length of the ana- and metanepionic substages in the different plates beginning with Pl. iv and ending with Pl. xiii, it will be seen that there is a notable decrease in the comparative length of these two substages when the umbilical perforations become very small, and the same is true of the species of the Calciferous and Silurian, which have small umbilical perforations, as shown on Pl. iv-vi.

In many shells with very large perforations the curvature is often uniform, and there is no sudden alteration in the direction of coiling of the first whorl, as in several Carboniferous forms and the remarkable shell *Pleunautilus superbus*, Pl. xii. The same is true of the coiling of all gyroceran forms in their epehebic and earlier stages. The coiling is more uniform than that of more specialized and more closely coiled shells. This, and the presence of smaller umbilical perforations in the same genetic series, is easily accounted for if we admit that the tendency to become closer coiled is genetic, and that in accordance with the law of tachygenesis it affects the growth of the young earlier in the more specialized and later-occurring forms, thus shortening up the ana- and metanepionic substages.

The elliptical outline in section, the universal rotundity of the dorsum in the ana- and metanepionic substages and the sutures, serve to reinforce the assumption that these substages derive their characteristics, so far as form is concerned, from arcuate or straight ancestors. This is in general the adult characters of most species of groups having orthoceran or cyrtoceran forms, and in none, except *Cranoceras* of the Devonian, has any signs of a dorsal furrow been found. The ornamentation of these substages, and usually the paranepionic, in part or as a whole, also points distinctly to some straight or arcuate ancestor. The ananepionic substage is universally smooth or with only a few longitudinal ridges, but the metanepionic varies more. The form and markings in *Vestinautilus*, Pl. ix, point distinctly to a similarly ornamented arcuate ancestor, and the gradual shortening up of the younger substages is also shown by the figures on this plate and the explanations.

The outline of the first volution changes abruptly at or immediately after the beginning of the gyroceran bend, that is, at the beginning of the paranepionic substage in most nautilian shells. The dorsum is apt to become flatter in species having large umbilical perforations, and in those with small perforations, this tendency is intensified and the dorsum is apt to become concave, the dorsal furrow making its appearance. The sutures of the ana- and metanepionic substages are apt to have ventral and dorsal saddles, whereas a dorsal lobe very often appears in the paranepionic, ex., *Barrandeoceras*. This dorsal lobe is still more plainly marked when the dorsal furrow is present in the paranepionic volution.

The flattening or broadening out of the dorsum, which occurs in

a great many forms in the paranepionic, is paralleled by the similar tendencies occurring in shells that have the whorls contiguous. This is the first effect of contact, and the formation of a lobe in the sutures also very commonly accompanies slight contacts. Nevertheless, dorsal lobes in the sutures and the flattening of the dorsal side may occur in cyrtoceran and gyroceran coils of species that appear to be transitional, from more primitive uncoiled to the close coiled nautilian forms, as in *Barrandeoceras Sternbergi*, Pl. xiv, and other examples, such as *Aphetoceras boreale*, Pl. v.

These characteristics obviously exist under different conditions on the free whorls of primitive shells and the similar whorls of the young of nautilian shells than they do on whorls which are in contact. In order to make these distinctions clear, I have named the dorsal hollow zone that appears before or independently of contact, *the dorsal furrow*, and that which occurs after that, *the contact furrow*, both being considered part of the same feature, the compressed zone.

Before proceeding further it is necessary to study the origin and history of the impressed zone, and to define it more clearly than has been done in the preceding pages.

In the first place, as already stated, it does not exist in any of the trunk or radical forms, except *Cranoceras*. Its first appearance, so far as the morphology is concerned, is in nautilian forms after contact, and this occurs constantly in different genetic series. In fact the definition of a nautilian shell is based upon the possession of a contact furrow.

If we regard any genetic series by itself we can often see that the impressed zone is purely a contact furrow. Thus, in the *Estonioceras*, it is absent in the umbilical perforation on the dorsum of the nepionic stage and it is slight and present only in the contact stages, being soon lost upon the free part, or gerontic stage of the coil. In other species of some other groups the same thing occurs either completely or partially: *Eurystomites*, Pl. v; *Tarphyceras*, Pl. vi; *Schroederoceras*, Pl. vii, and so on.

In transitional species with large umbilical perforations, the dorsal furrow is not present in any specimen, although many have been examined and recorded. In the major number of nautilian forms, in the Silurian, Devonian and Carboniferous and quite a number of Triassic species, the umbilical perforations are large and there are no dorsal furrows. In many of these species the

looseness of the coiling is shown by the free apex and the slight development and late incoming of the contact furrow.

It is, of course; as has been stated above, practically impossible in many series to get sufficient evidence to establish the agreement of chronology with bioplastology. But there are here and there series that show such an agreement, and give approximately complete and positive evidence in favor of the descent of nautilian from arcuate forms. But even if this agreement occurred in a smaller number of series than it actually does, the evidence from the morphology alone would be sufficient. It is not possible to explain why the apex of the transitional forms with large umbilical perforations is so often free, or the existence of the larger umbilical perforations themselves, or, in fact, any of the peculiarities of the nepionic stage, which resemble those of radical forms, except on the assumption that they have been derived from these same straight or arcuate radicals through direct genetic connection. Thus, although the chronological record may coincide with the bioplastology only in a few series, these few become positive evidence of the highest value, that confirms the inferences drawn from the testimony of the bioplastology and outweighs any amount of negative evidence derived from the incompleteness of the record.

With these remarks, we can now pass on to the consideration of the history of the impressed zone, and its mode of origin and apparent history in different series.

There are a number of orthoceran and arcuate forms that may be cited as the radicals of the Tarphyceratidæ.

These, like the history of the transitions into *Aphetoceras*, are almost complete, since in this last genus the curvature in the young, until a late stage, is so slight that one is not absolutely certain whether to consider that such a fragment as is figured on Pl. v, Figs. 15-17, is really a part of a gyroceran shell or a fragment of a cyrtoceran form that never coils. The position of the siphuncle, section of the whorl and sutures make the young of these forms genetically identical with the adults of such forms as *Aphetoceras Americanum*, and on the other hand the full-grown characters and large gyroceran coils, are closer in some species than in others and the genus passes by insensible gradations into the more closely coiled nautilian genus, *Pycnoceras*.

This last has the large umbilical perforation and almost cylindrical

first whorl, slight contact furrow of an ordinary transitional form, but otherwise the nepionic stage resembles the adults of *Aphetoceras* in its section and position of siphuncle and sutures.

The gap between *Pycnoceras* and the next member of this series, *Tarphyceras*, is wide and one or more genera are needed to fill up the interval.

In all of the genera mentioned above, except *Tarphyceras*, there is no dorsal furrow, the zone of impression is produced by contact, and the umbilical perforations are large.

In *Tarphyceras*, however, although in form, sutures and position of siphuncle the genus is closely allied to *Aphetoceras*, the young are altogether distinct.

As depicted on Pl. iv, the young have very small umbilical perforations, the whorls broaden out by growth rapidly, and after a short, straight or only slightly curved apical part is built in the ana- and metanepionic substages, the broadening volution makes a sudden and very abrupt gyroceran bend towards the apex. This is very sudden and the umbilical perforation is flat or comma-shaped.

It might of course be shown, if other intermediate shells were found, that the mechanical effects of this sudden bending did not produce the dorsal furrow, but that this is an adequate mechanical cause can reasonably be claimed by those who oppose the view that it is due to heredity.

It has already been shown that the outer side or venter tends to grow faster than the inner, and if this reaches a point in its ratio of growth that far exceeds that of the inner side, it is obvious that it must act upon that side as a force that bends or tends to make it more arcuate in proportion to this excess of growth or rapidity of increase. The outer side being free would be apt to retain its genetic form, and the inner side or dorsum would be greatly influenced or moulded by the pressure to which it was subjected. Thus it can be assumed that in case of a sudden bending, as in *Tarphyceras*, the venter would maintain its rounded outline and forcing the dorsum inward as it grew would tend to make it assume the arcuate form or bend inwards in a crease or dorsal furrow in the paranepionic volution conforming more or less with the shape of the dorsum of the metanepionic volution.

There are some reasons why this explanation is not wholly satisfactory. In the first place, if this be the case, why did not the whorl of the paranepionic completely close the umbilical perfora-

tion and plaster the dorsal shell layers against the dorsum of the metanepionic substage? This is partly answered by the fact that the tendency to shell building on that side would prevent this until a small umbilical perforation was formed and also by the fact that in many shells the whorl of the paranepionic actually does plaster itself on to the dorsum of the metanepionic and the umbilical perforation is reduced to a very small aperture. It is, however, absolutely essential to call in the aid of heredity, otherwise the tendency to shell building in the dorsum of the nepionic stage cannot be considered sufficient to prevent the entire obliteration of the umbilical perforation. The shell on the dorsum of the older stages is in great measure absent in most nautilian shells, but there is no such difference in gyroceran or cyrtoceran forms or in loose coiled gyroceran form with the whorls touching, nor yet in nautilian form with very faint contact furrows. The tendency to build thick shell on the dorsum of the nepionic whorl, while still free, is therefore one that can only have been derived from shells having free dorsal sides and this tendency is obviously strong enough to stiffen that side and prevent the entire closing of the umbilical perforation.

In the second place there are a number of Cretaceous, Tertiary and recent Nautiloids having accelerated development of the dorsal furrow, and in these the furrow appears on both sides of the comma-shaped umbilical perforations. It is perfectly plain in these that no bending of the whorl could account for the result and that it is in no sense due to a moulding of one whorl upon another. The outlines of the dorsum of the paranepionic substage in these species does not coincide with those opposed to it; they are the reverse of each other.

Nevertheless it is practicable, as has been said above, to appeal to the curvature of the paranepionic volution at the gyroceran bend as a possible mechanical cause for the incoming of the dorsal furrow on the distal part of the curve so long as the curve is sufficiently abrupt to produce it, or so long as the absence of ancestral forms does not enable us to trace the origin of this character back to a contact furrow and account for its presence in the earlier stages of species like those of the genus *Tarphyceras* by the action of the law of acceleration.

I have consequently thought it safer for the sake of argument to concede that the dorsal furrow of *Tarphyceras* was perhaps present

in the paranepionic because of mechanical and not through genetic causes.

In the Trocholitidæ the straight and arcuate forms are not yet known nor are the nautilian forms quite satisfactory.

The dorsal side of *Litoceras insolens*, which has a comparatively large umbilical perforation, has not yet been studied in the paranepionic substage, and although it seems very likely that it is gibbous and without a dorsal furrow, this cannot be stated positively. In Trocholiticeras and Trocholites, the umbilical perforations are very small and have dorsal furrows on the paranepionic after the gyroceran bend has been passed by.

The same argument can be framed for their appearance that was used for the Tarphyceratidæ, viz., that the weight of evidence is in favor of the mechanical generation of the dorsal furrow in the paranepionic. There is also one fact possibly of some importance in this connection. In the specimen of *Trocholites canadensis*, in section Figs. 39 and 40, Pl. vi, it can be seen that the inner part of the dorsal furrow, where it first appears, is a single, broad furrow. As it becomes more distant from the gyroceran bend, however, it becomes divided into two smaller furrows by the rising of a central gibbous face.

It might be assumed that the development of this central gibbous face was due to heredity, this being the expression of a tendency to return to the rounded dorsum of radical types as soon as the pressure due to the abrupt bending was removed.

Precisely similar furrows and a median gibbous face occur, however, on the dorsum of Cranoceras. The curvature of this form and all of its characteristics indicate that the bending of the cone could not have been the mechanical agent which caused a single dorsal furrow and the appearance of the two dorsal furrows and the central gibbous face complicates the problem and seems to make it insoluble on a purely mechanical basis. I have called this a gibbous face, but in reality it is not a "face" at all in the sense in which that term is here used. It is a modification of the primitive rounded dorsum and is really a "zone" or secondary modification. In Trocholites it arises as a modification of the dorsal furrow, and is therefore a true "face." It is possible that with advance of knowledge this distinction may be more important than it seems now, and may enable us to explain the exceptional characteristics of Cranoceras.

Before it could be safely assumed that mechanical causes gener-

ated the single or double dorsal furrows of *Trocholites canadensis*, or that heredity influenced the appearance of both, it would be necessary to find more forms of the same genetic series and study their history.

In some species of the genus *Schroederoceras*, the dorsal furrow appears as in *Trocholites*. The umbilical perforation is larger but still small in all of these, so that it can hardly be assumed that the bend is too gradual to have caused the dorsal furrow to arise in the paranepionic.

The gerontic stage of the species of this family, in fossils well enough preserved to be observed, has an impressed zone which is very short-lived in some species when the last whorl is free. The entire obliteration of this zone takes place in *Schroederoceras Eatonii* in one specimen, Pl. vi, Figs. 28-35, and in another it is present for a longer time after the volution becomes free, although evidently much reduced, Figs. 7 and 8, Pl. vii. In *Schroederoceras casinense*, Pls. vi and vii, similar obliteration can be observed.

The zone, however, persists long enough in these forms and others to demonstrate the important fact that it has a deep hold upon the organism. If this were not the case it could not exist in substages of senile degeneration. Its persistency is somewhat less in the species cited than many others, ex. *Eurystomites Kelloggi*, Pl. v, but it is sufficient to show that its continued existence in the ontogeny is not wholly limited by the continuance of close coiling and contact. That it is more or less dependent upon coiling with involution is obvious because it entirely disappears in some species in the older substages of the gerontic stage when these are free.

The Tarphyceratidæ and Trocholitidæ having so closely involute shells in the young are confined, with the exception of *Trocholites*, to the earliest or Calciferous faunas.

The next forms that one meets, having the impressed zone, occur in the Devonian. There are so far as known no shells having an impressed zone in the form of a dorsal furrow between the Hudson River group and the Devonian group, although there are many having the contact furrow.

The Devonian genus *Cranoceras*, referred to several times above, consists of two species with very large shells, and, so far as can be seen, purely arcuate forms, is the only case of a cyrtoceran form with a dorsal furrow that I have been able to find. The zone in this shape appears on the free inner or dorsal side and is obviously a

dorsal furrow similar to that which appears on the dorsum of the nepionic stage. The section of this whorl is nephritic. The appearance of the dorsal furrow is very often in the young and in later stages of growth correlated with the appearance of a nephritic outline in the whorl. This happens so often that I at first supposed it was a general law of association the two appearing together. It is true, that in a number of forms, the nephritic form appears in association with the dorsal furrow, but in quite a number of others the outline is not nephritic, and yet a dorsal furrow arises as will be noted farther on.

The large size and gradual curvature of the cone in this genus makes it unlikely that the existence of the dorsal furrow is due to contact or to any mechanical effect of coiling. The dorsal furrow in these is either due to inheritance from other species, or is acquired in their later or ephebic stage.

The genus may be degenerate and may have arisen from coiled forms and the dorsal furrow and nephritic outline may have been derived from this source. Against this is the fact that the shells are of large size and the septa are closely approximate. Both of these characters are common in primitive Paleozoic shells and uncommon in degenerate phylogerontic series. The study of the fossils themselves does not seem to support this view of their affinities since it is difficult to point to any preëxisting coiled form from which they could have been derived. If it is assumed that they are primitive arcuate forms descended from other arcuate forms or straighter cones, it is easy to trace them back into the Silurian and point out their probable ancestors, in closely allied species which do not have a dorsal furrow.

The problem here assumes a very interesting character due to the fact that the Silurian forms of *Cranoceras*, *C. turnus*, and others have trigonal whorls and sutures which are in every way identical with the young of several nautilian shells of the same period and are evidently their ancestral radicals. These arcuate species, however, do not have dorsal furrows, and it seems, therefore, highly probable that here is a case of acquired characteristic coming in very late in the ontogeny of the ephebic stage, accompanied by a nephritic outline.

Contact furrows arise from close coiling in fossils like *Nedyceras vetustum* having similar subtrigonal whorls, but no examples are

known in these groups of the appearance of a dorsal furrow in the young.

*Anomaloceras anomalum* is a remarkable Silurian fossil, on account of the habitual excentric position of the siphuncle, but this is always near the venter and in this species the form of the shell and character of the sutures show that the genus belongs in the same genetic group with *Hercoceras*.

In *Hercoceras* the evidence is very complete that the impressed zone originated as a contact furrow. In all the gyroceran forms of the allied genus, *Ptenoceras*, there is nothing of the sort. In the loosely coiled forms like *Hercoceras irregularis*, Pl. viii, Figs. 14 and 15, there is no dorsal furrow in the nepionic stage. Even in the closely allied *Hercoceras mirum*, although the last has a small umbilical perforation, there was no dorsal furrow in the single specimen examined and figured (Pl. viii, Figs. 11 and 12). So far it is obvious that close coiling does not of itself even with a favorable form of whorl necessarily bring about the genesis of a dorsal furrow.

If the sudden bending of a broad whorl was necessarily followed by the formation of a dorsal furrow it would certainly have been produced in *Hercoceras mirum*. A single exception in such cases becomes a very significant positive fact against this assumption, and that exception appears to occur in this species. The terminal member morphically of this series is *Anomaloceras*, and in the single species of this genus known, there is a dorsal furrow as shown in Figs. 16-20, Pl. viii. The umbilical perforation was small in this shell, and of course it can be claimed that the furrow in the paranepionic was produced by mechanical pressure, and not inherited from forms like *Hercoceras*, in which it first arose as a contact furrow.

*Potoceras dubium*, which has been figured on Pl. x, Figs. 15-22, has unfortunately no recorded locality, but as noted in the description there were indications that it was a Devonian fossil. At any rate, whatever its age, the characteristics were plain and the presence of a dorsal furrow in the paranepionic easily established.

The length of the ana- and metanepionic substages were decidedly Paleozoic, and so also was the large umbilical perforation. It is more difficult here to account for the genesis of the dorsal furrow upon the mechanical hypothesis than in *Anomaloceras* on account of the large umbilical perforation and the slow growth of the apex. Nevertheless it can be reasonably claimed that the abruptness of

the gyroceran bend in this shell is sufficient to account for the dorsal furrow in the nephritic outline of the paranepionic substage.

In the preceding remarks I have dealt solely with those genetic series and forms in which the dorsal furrow appears, but there are many in which there is no sign of any furrow.

As has been said above, all of the straight and arcuate forms and the gyroceran shells, in none of which has either a dorsal or a contact furrow been found, except in *Cranoceras*. Passing these by, one comes to the nautilian shells which are transitional between the gyroceran and nautilian having the whorls in closer connection than in the gyroceran and a slight contact furrow. These, so far as known, have other correlative characters. The umbilical perforations are large and open, the apex of the conch is often free, the contact taking place on the venter of the ana- or metanepionic substage or later, and the whorls are subsequently never involute, or in other words, they are discoidal shells.

In these shells I have in Paleozoic time found no exception to the rule, that the dorsum of the nepionic stage is convex, and there is no dorsal furrow, a furrow being formed only after contact, and in later stages of development. One of the best examples of these series is that of *Barrandeoceras*. *Barrandeoceras Sternbergi* contains, as has been stated in the descriptions, two distinct forms, one *Barrandeoceras Sternbergi*, Pl. xiv, Fig. 3, has the whorls approximate, and in the other they are not in contact. The purely gyroceran character of these shells is apparent in the loosely uncoiled young as well as in the later stages. They are also valuable in showing that the flattening of the dorsum and a dorsal lobe may arise as in Pl. xiv, Fig. 5, independently of contact, and this and the form of the ephebic stage is precisely similar to that of the paranepionic evolution of *Barrandeoceras tyrannum*. In this last and in *Barrandeoceras Sacheri* and *Bohemicum*, there is no dorsal furrow, but these ephebic characters of *Sternbergi* are repeated and a contact furrow is produced after the whorls touch.

*Estonioceras* is another series in which nearly all degrees of coiling can be studied, and here also the absence of a dorsal furrow in the nepionic stage is a marked characteristic. The contact furrow is maintained as long as the whorls are held together, showing progressive growth, but this rapidly disappears in the gerontic stage, as shown by the figures given on Pl. v and vii.

*Remeléceras impressum* is also a good example of the generation of

a contact zone in the later stages of development given on Pl. viii, Figs. 1-8.

Another belonging to the same category is Eurystomites, of which the species are described and figured on Pl. v. This genus has also its corresponding gyroceran forms in *Barrandeoceras convolvans* described in the text and the resemblance of these to the young of true species of Eurystomites is very close.

The series of the Tainoceratidæ are interesting in this connection, because in the earliest species of *Temnocheilus* itself, which occur in the Devonian, there is no dorsal furrow, and only a contact furrow as is shown in Figs. 27 and 28, Pl. x. The umbilical perforation is not large, and in succeeding species in the Carboniferous, although there are several genera, there are none having the dorsal furrow.

*Metacoceras cavatiformis*, Fig. 16-19, p. 496, and Pl. x, Fig. 32, are good examples of this group.

Among the most remarkable of the Silurian series in which no dorsal furrow was present is that of the highly ornamented and modified genus *Ophidioceras*. The elaborate ornamentation of the shell and the costæ, combined with a peculiar hollow ventral zone bordered by ridges, the free living chamber and aperture with lateral and dorsal crests show this type to be very peculiar and highly specialized. The small size and shape of the umbilical perforation shows also very close coiling. One would suppose this amply sufficient in a quick-growing whorl like that of *Ophidioceras* to force the premature development of a dorsal furrow, but there is not the least sign of one in either of the three species examined and figured on Pl. viii. In this group a very interesting fact is noticeable in the gerontic stage. The impressed zone is persistent on the free dorsum until it meets a projecting spur which coincides with the more or less abrupt lituitean bend on the venter. On the other side of this spur, it has, however, such a hold upon the organization that it is not obliterated by the building of the spur, but is resumed again on the oral side, and continues to the edge of the aperture. In this last stage, however, the impressions made by the sharp ridges on the borders of the median ventral zone are obliterated, and when near the aperture the zone becomes narrower and shallower and finally disappears.

*Endolobus* (Pl. viii, Figs. 36-39) is another example of the absence of a dorsal furrow in a good-sized umbilical perforation and the presence of a contact furrow in the older stages.

The mechanical moulding of the dorsum upon the venter of the next inner whorl is shown of course in all of these examples, but it can be still better illustrated by such forms as *Ophidioceras*, just described, and *Apheloceras mutabile* (Pl. x, Figs. 29-31) and *Diorugoceras planidorsatum* (Pl. xii, Figs. 1, 2). These and many other examples besides those figured serve to demonstrate that in every shell, so far as known, the configuration of the dorsum is absolutely dependent upon the shape of the venter, the former being invariably a reverse or mould of the latter. The same is also true in the earlier stages of the contact furrow in those species that strike and envelop the apex of the conch.

The number of series which have close-coiled shells, but in which the impressed zone is purely a contact furrow, is in the Carboniferous even larger than in the Devonian, but it will suffice to refer to two extreme examples. *Ephippioceras*, which is a highly specialized species with peculiar sutures and septa and very involute, appears to belong in this category, and also *Phacoceras*. These forms are in part figured on Pl. ix.

Similar transitional shells with good-sized or large umbilical perforations are also present in the Trias, and are illustrated in *Syringoceras granulostriatum* and *linearis*, Pl. xi. There are several other species in the Trias that belong in the same category, but it is not always easy to get preparations that will establish the fact that the dorsal furrow is absent.

The disappearance of the straight and arcuate types in this period together with the transitional nautilian shells has been remarked above, and in the course of the following pages this fact will be noticeable. In dealing with those types in the Carboniferous that possess a dorsal furrow, one is struck by their small number and their decisive testimony in favor of the assumption that the dorsal furrow is inherited.

The phylogerontic character of *Coloceras globatum* is evident from the figure of the aneanic stage on Pl. x, and the comparison that may be made with the senile whorls of *Vestinautilus konincki*. It then becomes obvious that *Coloceras* belongs to the same genetic series as *Vestinautilus*, but that it inherits degenerative characters at an early stage. It is in other words a degenerate form with a highly accelerated development of the gerontic or degenerate characters of other species of the same series. Of course this acceleration affects both the ornamentation or ridges as well as the

form. It is to be anticipated of course in species of this kind that other characters will also show acceleration. Accordingly one finds as shown in several figures that in *Col. globatum* a dorsal furrow is to be found in the paranepionic substage.

The umbilical perforation is of good size in this species, the curvature is often gradual and uniform, the ana- and metanepionic volution increases slowly in size, and there is apparently no mechanical agency in any of these characteristics that would have caused or led up to the appearance of the dorsal furrow in the paranepionic substage. Another point is obvious in this species. It is a descendant of a special series which probably arose from *Thoraceras Puzonianum* and *canaliculatum*, or some species of more ancient origin combining the characters of these two. This series then obviously passed through the distinct phases of gyroceran and nautilian evolution and acquired a contact zone, which in the highly specialized phylogerontic Coloceras became by the law of tachygenesis a dorsal furrow inherited in the paranepionic.

The facts in my opinion cannot be accounted for on any other hypothesis.

It is hardly doubtful when other involute and highly specialized shells have been fully investigated that many more examples of the accelerated inheritance of the impressed zone will be found.

*Nannoceras Frieslebeni* (Pl. xi) is the only species in the Dyas that I have been able to investigate, and this has a dorsal furrow and a small umbilical perforation. Its congeneric forms are also unknown, and its evidence is consequently not of much value, except in so far as it shows the occurrence of this class of forms in this period.

I was not able to obtain shells having small umbilical perforations and suitable for examination in the Trias, and have to leave that period a blank record except in so far as noted above.

The close-coiled shells of the Jura are, however, sufficiently abundant and the evidence very interesting.

In the first place, as noticed elsewhere, there are no arcuate radicals in existence. They have all disappeared in the Trias, and with them went also the transitional forms of all kinds, the gyroceran and even the primitive nautilian with very large umbilical perforations. Under these circumstances one should expect to find a decided change in the behavior of characteristics.

If the impressed zone was maintained and perpetuated by mechani-

cal means, by the abrupt curvature of the whorl at the gyroceran bend, and had not through time or constant repetition become fixed in the organism and genetic, one ought to find in some species of the Jura having larger umbilical perforations than others, that a dorsal furrow was absent, or else variable and often very slightly developed.

Suppose, on the other hand, without paying any attention to the manner of the origin of the impressed zone, except in so far as the facts show that it appeared late in the life of primitive species and is an acquired character, one asserts that time and fixation in nautilian shells has made it hereditary.

It is then of no consequence whether a given shell of the Jura has a large or small umbilical perforation. Being a highly specialized nautilian shell and apparently without other than strictly nautilian progenitors, it follows from the law of tachygenesis, that the impressed zone ought to be represented by a dorsal furrow in the paraneponic substage, or earlier in every species. The mechanically generated contact furrow of transitional nautilian shells occurs in the ana- and metanepionic substages, rarely later, consequently if the dorsal furrow arose out of this through the law of tachygenesis it should appear in the preceding stages of the ontogeny before the whorls touch in every shell of the Jura.

It is of course possible that exceptions to this rigorous logical deduction might have occurred in diseased young individuals, or in species directly traceable to arcuate forms in the Trias, but so far no such shells have been found.

In looking at the apices of the species of *Digonioceras* and of *Cenoceras*, considerable difference is noticeable in the sizes of the umbilical perforation. For example those of *Digonioceras excavatum*, Pl. xi, and *Digonioceras*, sp. (?), Pl. xii, Figs. 6-11, are comparatively quite large. But in these the dorsal furrow appears at the same age as in *Cenoceras intermedium* and others having very much smaller perforations and more rapid increase of the metanepionic substage. In other words, the rapid increase of the ventro-dorsal diameters and other diameters and the sudden bending of the shell and the abrupt gyroceran curve of *Cenoceras intermedium* and *lineatum* and *clausum* have no effect whatever upon the genesis of the dorsal furrow. As if to make this conclusion still more secure, *Cenoceras aratus*, the single species in the Jura, which does present a slight acceleration in the development of the dorsal furrow, has

an umbilical perforation which is of medium size and has also slower growth of the metanepionic and paranepionic substage than most of the shells of this period. This species, figured on Pl. xi, Figs. 32 and 33, has so large a perforation and so gradual an increase in bulk of the nepionic, that it affords no basis for a belief in mechanical causes. If it had been found that the dorsal furrow occurred a little later or not at all in this specimen then there might have been some grounds for the supposition that genism had had no influence upon the perpetuation of the impressed zone. But when one finds in place of retardation a slight acceleration in the development of the dorsal furrow the facts certainly appear to be very strong in favor of the ordinary theory of diplogenesis and tachygenesis.

The same argument applies with greater force to the Nautiloidea found in the Cretacic. These being more remote than Jurassic species from any primitive nautilian forms, they ought to exhibit the action of tachygenesis in the earlier appearance of the dorsal furrow at least in a considerable number of the species.

From the remarks already made above and from the figures given, especially on Pls. xii and xiii of this work, it may be seen that so far no specimen has been found in this period which did not show the presence of a dorsal furrow on the metanepionic volution, a substage earlier than most of the species of the Jura. This fact has already been used in other connections, especially in the discussion upon the relations of the dorsum to the venter in nautilian shells. It is very positive evidence against the supposition, that the configuration of the dorsum of the metanepionic substage has any effect upon the outline of the dorsum of the paranepionic even in cases where they are brought close together on the opposite sides of even the narrowest of umbilical perforations. Provided it did not touch it is obvious that the dorsal side of the paranepionic substage in Cretacic shells was free to assume any shape.\*

In following the same theoretical line into the Tertiaries, the evidence is less satisfactory; only one species was found, *Eutrephoceras imperialis*, which gave any evidence. This had the dorsal furrow in the metanepionic substage. The Aturidæ, however,

\*It will be easily seen that this argument could also be applied to the case of *Trocholites canadensis*, but in the absence of positive evidence in the genetic series of the Tarphyceratidæ I have thought it best not to assume that such use could be made of the parallel facts observed in Mesozoic shells.

showed the highest degree of tachygenetic development in all the structural characters of progressive evolution among Nautiloids. That is to say, the size of the apical chamber, the immediate assumption of a highly matured outline in the first suture which has the aturian generic lobes and ventral saddles, the subdorsan siphuncle, the minute umbilical perforation and the rapid increase of all the diameters of the apex in the nepionic stage and the almost complete involution of the apex and first whorl in neanic stage, all indicated a high degree of acceleration. It is therefore probable that in this family a correspondingly early inheritance of the dorsal furrow will also occur, unless there is some interference arising from the highly tachygenetic development of the characteristics cited above in the metanepionic substage that may have replaced it or rendered it very obscure. Sections ought to have been made to establish this fact, but I could not obtain materials for this purpose in the limited time at my disposal.

The existence of the dorsal furrow has been observed in the metanepionic substages of the three existing species of *Nautilus* that are the most important, viz.: the least involute *Nautilus umbilicatus*, the most involute *Nautilus pompilius* and the degenerate shell of *Nautilus macromphalus*. It might of course be expected that some of the less involute shells of the Cretaceous, Tertiary or Present, if any such be found, would resemble the Jurassic shells in having a dorsal furrow in the paranepionic. I expected this might occur in *Nautilus umbilicatus*, but so far as I could see the dorsal furrow appeared in this shell quite as early as in *Nautilus pompilius* or *macromphalus*.

I here take the opportunity to refer to the structure of the shell of the dorsal side among Nautiloidea.

The shell of course in all forms with free whorls is as complete on the dorsal as it is on the ventral side. It is also complete on the dorsum in the nepionic stage of all nautilian species. An additional layer called by various names, but known in the modern *Nautilus* as the black or dark-colored layer, makes its appearance after contact and lies between the exteriors of the shells of the venter and dorsum in each whorl.

I have never been able to detect the homologue of this layer among fossils probably because it is necessary to look for it in sections under the microscope.

As regards the behavior of the shell in the impressed zone after

contact it is obvious in all fossils, as it is in the *Nautilus*, that the outer porcellanous layer is apt to disappear in the contact furrow and that this disappearance is due to contact seems almost beyond question, especially in *Schroederoceras* and other shells that have free whorls in the gerontic stages.

In Paleozoic shells, like *Eurystomites Kelloggi*, *Schroederoceras*, *Estonioceras* and many others the loss of the excretory function is only temporary, since the free volution is protected on the dorsum by a thick shell as soon as it begins to depart from the spiral. In all of these that I have observed, the contact area has not been large, but in *Anomaloceras anomalum*, *Trocholitoceras Walcottii*, *Endolobus avonensis*, *Tarphyceras* and others in which the contact is closer and the furrow broader, the outer porcellanous layer does not pass on to the dorsum.

Pompeckj\* states that the mantle border of *Nautilus pompilius* on the venter and sides has triple folds and two furrows, which indicate that these parts of the rim of the border secreted the outer porcellanous layer which protects the body of the animal on the outer exposed sides. On the dorsum the continuation of this border is entire and not furnished with folds or furrows for secretion of the porcellanous layer which is also absent on that side.

The aperture is not built out on the dorsal side in any involute Nautiloid that I have been able to examine.

I have not yet been able to find in any of the involute shells observed to have this peculiarity and in which the suppression of the dorsal layer was more complete, that the last volution became free and that the deposition of dorsal shell layers was resumed in the gerontic stage. The evidence at present from this accords with that to be obtained from coiling, namely, that shells having a certain degree of closeness of contact or involution do not as a rule have a free volution in the gerontic stage. That the aperture might have become free and still be protected by adequate shell layers on the dorsum in the gerontic stage remains to be determined. That this must have been very rare, if it ever occurred, is shown by the fact that no shell has been observed in the Paleozoic and none have been seen in the Mesozoic, Tertiaries or recent Nautiloids, having such a gerontic stage at the apertural end of an involute whorl.

In recent *Nautilus* it is especially noticeable, as stated above,

\* *Amm. mit "Anormal. Wohnkammer,"* p. 259.

that gerontic degeneration is slight and does not affect the amount of involution nor the size of the whorl. This may be due to the rarity of shells that have reached an advanced age or to the brittleness of the senile volution, but against this there is sufficient evidence.

Thus, in many Mesozoic fossils and in recent Nautili, shells are often found with the last two or three septa approximating and this is plainly a mark of the failure of the powers of growth and shows in most examples of large size that the animal has probably reached the extreme limits of its existence.

One fact is of great interest in this connection. Extreme cases of degenerative series are rare among Nautiloidea. The Lituitidæ stand alone as the only complete series that can be compared with several that are found among Ammonoidea. The Discoceratidæ have also some turbinate genera that can be closely compared with the helicoidal spirals of a number of Ammonitinæ. All such forms and others that may be supposed from their characteristics to exhibit similar characteristics, disappear with the Paleozoic and all, so far as I know, before the Carboniferous period. There are phylogerontic species like *Coloceras globatum* in the Carboniferous, but no uncoiled phylogerontic forms.

In Mesozoic, Tertiary and Cenozoic times, the uniformity of the type is conspicuous, and while it is plainly degenerating from the Carboniferous to the present, this process is not accompanied by the evolution of uncoiled series. The degeneration takes place as stated above in ornamentation of the shell and in the number and variety of the series and forms evolved, but not in the coiling, which is really progressive, nor yet in the sutures, since *Aturia* is certainly one of the most if not the most highly accelerated and specialized of the whole order.

These facts all bear directly upon the history of the impressed zone, since in all uncoiled whorls the primitive contact furrow tends to disappear and the outer dorsal porcellanous layer is restored to its full development on that side.

In Paleozoic time as well as in later times no involute shell has yet been observed with a free gerontic volution, that is to say, when the area of involution reached beyond the limits of the venter and the area covered extended inwardly on to the sides of the next inner whorls, the gerontic stage also remained involute, or, if decreasing in its ventro-dorsal diameters, this decrease never seemed

to reach the extreme point of degeneracy, so as to allow the aperture to become again free and complete on all sides.

This is, of course, negative evidence and it may be, as in Ammonoids, that the dorsal edge of the mantle never loses in any series when restored to freedom the power to resume the shell-secreting structures and function on the dorsal side. It can be readily seen that as the whorl became gradually loosened from the inner whorl the mantle border would extend the secreting furrows inwards from both sides, or, more correctly speaking, perhaps, the non-secreting edge of the dorsal border would be contracted and finally disappear. There is no antecedent improbability that this might not take place in any involute nautilian shell at a sufficiently degenerative substage of its ontogeny. The remarkable fact, however, remains that it does not take place so far as I know, although I have constantly been on the watch for some such examples.

#### *Ammonoidea.*

It is not necessary to give any extended notices of observations on special groups in this order. I have already described the absence of the impressed zone in the ordinal radicals *Bactrites* and in most of the *Nautilinidæ* on pp. 361, 362, 411, 413 and the figures and explanations of Pl. ii, and Figs. 40-42, Pl. viii, of *Mimoceras lituum*. The more specialized genera of the *Goniatinæ* have the impressed zone, but it is strictly a contact furrow and appears as shown in figures of *Agoniatites fecundus*, one of the *Nautilinidæ*, sometimes very late in the ontogeny. In other still more highly specialized species the loose coiling of the young, figured by Sandberger in several species of *Gephuroceras*, *Manticoceras latidorsale* of the Devonian and by the author in *Glyphioceras crenistria* and *atratus* of the Carboniferous\* indicates, that this zone is either absent on the ananepionic dorsum, or, if present, must occur as a slight dorsal furrow due to tachygenesis. The larger number of the *Goniatinæ*, as shown by Branco and the author, have, however, such closely coiled nepionic stages that, as in all *Ceratitinæ*, *Lytoceratinæ* and *Ammonitinæ*, so far as known, the umbilical perforation is closed along the mesal line as shown in Fig. 3, Pl. iii, and is represented only by funnel-like lateral prolongations, which do not appear to have an open connection with each other.

\* *Embryology of Fossil Cephalopods*, Pl. iii.

The impressed zone is among most of the Ammonoidea therefore essentially a contact furrow, and the tendency to close coiling has been accelerated to so great an extent that contact takes place between the permanent protoconch and the ananepionic substage and a contact furrow is thus produced earlier than in any known Nautiloid. The position of the first septum in the aperture of the protoconch shows that contact must have taken place before it was deposited as the floor of the ananepionic living chamber, *i. e.*, at the very beginning of the building of the apex of the conch.

It is also obvious that this high degree of acceleration in development was attained in the Devonian, as a permanent hereditary character of the whole order since the Nautilinidæ are the only representatives of the Goniatitinæ in the Silurian and disappear in the Devonian. There are also but very few species with open umbilical perforations in the Devonian, outside of the Nautilinidæ, and so few in the Carboniferous, that Branco denies the correctness of my figures of the two species above mentioned. That open umbilical perforations should occur sporadically in the young of some Carboniferous species of Goniatitinæ is of course to be expected, and that Branco should not have found any simply demonstrates the rarity of their occurrence.

The history of the impressed zone among Ammonoidea is parallel with that of the Nautiloidea in regard to the shell layers on the dorsum. These are complete in Bactrites and all of the Nautilinidæ which do not have a contact furrow and incomplete in all Ammonoids that do have this furrow, the outer layer reaching only to the lines of involution. This is shown in Fig. 3, Pl. iii, and it is observable in this that the shell of the apex of the conch appears to end at the outer edges of the umbilical perforations, but this observation needs revision or confirmation. There is a third layer between the dorsal and ventral walls of the shell corresponding to the organic black layer of Nautilus and it is often calcareous and well preserved in some fossils.\*

The extraordinary variety of degenerative series among Ammonoidea and their connection with the history of the impressed zone is of great importance in this paper.

The duration of the habit of close coiling and involution in the majority of shells from the Devonian to the Cretaceous is the most

\*There is the same tendency to calcification here as in the case of the protoconch as compared with the membranous protoconch of Nautiloids.

noticeable and one of the most persistent characteristics of the general morphology of the order.

Nevertheless, in every example of uncoiled phylogerontic shells the impressed zone tends to become less and to disappear, obeying the same law as among the Nautiloids. There is, however, a difference in its behavior, which is at first rather confusing. Involute shells may have free gerontic volutions and in these the zone does not appear to have, as a rule, so deep a hold upon the organization of the Ammonoids that it does upon many of the Nautiloids. For example, in deeply involute Scaphitoid shells there may be free living chambers in the gerontic stage and the zone diminishes greatly, almost disappearing on the edge of the aperture. In crioceran and baculites-like forms, however, it does not appear to persist to any marked extent upon the dorsum beyond the cessation of contact in the young whorl.

There are no examples in the history of its retrogression which can be compared with the persistency exhibited in a number of Nautiloids. For example, in *Eurystomites Kelloggi*, *Ophidioceras* and others the impressed zone, although it may not be present in the nepionic stage before contact, and very shallow after contact, nevertheless persists in the gerontic stage. Although showing a tendency to disappear and finally vanishing at the aperture, the process is slow, and it has obviously made a strong impression upon the organism.

What has previously been said of the degenerative characteristics and degenerative series of the Nautiloidea may be of some assistance in clearing up this apparent anomaly. The phylogerontic transformations of the Lituitidæ, as stated above, are the only ones among Nautiloids that can be compared with any of the completely uncoiled retrogressive series of Ammonoids. Although in the Lituitidæ the impressed zone is a mere contact furrow of slight extent and obviously transient development, nevertheless they serve as a comparative standard to show how much more complete the degenerative changes are among the Ammonoids than among Nautiloids. If the observer studies any species of Ammonoid in the gerontic stage the same morphic law becomes apparent. As I have tried to show in *Genesis of the Arietidæ*,\* the greater specialization and more complex ephebic development of the ontogeny in Am-

\* Pp. 28-37.

monitinæ is attended by a correspondingly intensified series of degenerative changes in the gerontic stage.

Considering the nature and extent of these retrogressive changes in both ontogeny and phylogeny, one ceases to be astonished that the impressed zone disappears quickly in any individual and begins to wonder at the conservative power of genism which preserves the close coil of the nepionic stage as a definite record of the derivation of such straightened out shells as *Baculites*. I have tried to account for this by supposing that the young of even these degenerate forms had similar habits as those of their ancestors, or were specially protected. The former supposition may be the true one, since it is entirely in accord with the facts that the tendency to degeneration should not necessarily take effect upon the development of the earlier stages, but the latter can hardly be true.

The retrogressive forms have usually slenderer shells than the normal forms, and there is no evidence that they possessed any special pouches or contrivances for the protection of the young.

It is interesting in this connection to notice the results of an extended research made by Dr. F. J. Pompeckj upon these extraordinary *Ammonitinæ*. His observations include about all of the more remarkable distorted fossils of this kind from the Carboniferous to the Cretaceous, especially those which have contracted apertures and exhibit connections with normal forms. Dr. Pompeckj arrives at the conclusion that the living chambers having such peculiarities are one and all to be classed as senile characteristics.

His conclusions are as follows :

“ 1. Die Bildung ‘anormaler’ Wohnkammern ist nicht mit Resorptionserscheinungen verbunden; Resorptionserscheinungen sind an den Ammonitenschalen überhaupt nicht nachzuweisen.

“ 2. Ein Ammonit mit ‘anormaler’ Wohnkammer ist fast ausnahmslos als vollkommen ausgewachsen zu betrachten.

“ 3. Der ‘anormalen’ Wohnkammer gehen weniger veränderte Wohnkammern voraus und schliesslich in den Jugendstadien solche, die in vollkommen regelmässiger Spirale gewachsen sind; man darf daher bei der Beschreibung von Ammoniten nicht eigentlich von einer anormalen Wohnkammer sprechen, sondern von einer anormalen letzten Wohnkammer des ausgewachsenen Individuums.

“ 4. Die ‘anormalen’ Wohnkammern der Ammoniten sind nicht auf sexuelle Unterschiede zurückzuführen.

“ 5. Die ‘anormalen’ Wohnkammern und die mit denselben

zusammenhängenden Formveränderungen des Ammonitentieres sind als senile Charaktere aufzufassen."

I am not prepared to adopt without more extended study the first of Dr. Pompeckj's results. Although he has presented very strong evidence, it is difficult to believe that in all cases when the aperture is contracted and the whorl or living chamber is excentric that this is never resorbed, because these so often occur in very small shells. These small shells are apparently of the same species with larger ones having similar chambers, and I have certainly considered them as individuals which had inherited the degenerative tendency to excentricity in their early stages. Dwarfs certainly occur having prematurely degenerative characters of this kind, and it may be that Dr. Pompeckj is right in his generalization, and that all such occurrences can be regarded in the same way.

Dr. Pompeckj does not deny that, when change of habit might be such as to favor the inheritance of gerontic characters, that they become genetic and that degenerative series might have been thus built up. If this occur at all the appearance of gerontic characters must take place according to the law of tachygenesis and in consequence of this appear earlier in the ontogeny of descendants of the same series. The shells in every degenerate series, therefore, ought to show this earlier inheritance in proportion to their degeneracy and to their place in the evolution of the series. In other words some at least of the more degenerate species would necessarily exhibit phylogerontic characters in their neanic stage and should be classified not as dwarfs but as young shells.

Through the kindness of Dr. C. E. Beecher my attention has been drawn to a species which is of importance in this connection and this has been loaned me by Prof. O. C. Marsh, Director of Yale University Museum. This extraordinary helicoidal shell, *Emperoceras Beecheri*, is exceptional in so far as it exhibits, in a magnified and unmistakable way, the action of tachygenesis upon gerontic characteristics.

The neanic stage has a single, straight, baculites-like cone which turns in the same plane, building out the peculiar form known as Hamites. This, after making the hamitean bend, deviates from the plane of growth of the neanic stage and becomes a loose but regular spiral which has generally heretofore been described as Helicoceras.

In *Nostoceras* similar phenomena are observable but, in this turrilites-like, closer coiled spiral, the young shells are quite different and it is not certain that they are irregular and similar to *Hamites*. The species of this genus and of *Emperoceras* and *Didymoceras* show that the spiral coiled stage is an ephebic stage, not a true gerontic stage of the ontogeny, because passing beyond this the gerontic stage appears taking on the usual retroversal form. The ephebic whorl departs from the spiral in this stage, again becoming excentric, and then builds back towards itself and towards the spiral, forming the peculiar crook found more or less in the paragerontic substage of the so-called *Hamites*, *Ancyloceras*, *Scaphites*.

Thus one gets in these two genera a demonstration that the turrilites and helicoceran modes of building the shell are acquired characteristics of the ephebic stage of the ontogeny interpolated between gerontic and neanic stages which have the usual characters of these stages in the ontogeny of degenerate forms.

These forms are also interesting in connection with the history of the impressed zone, because if they have close-coiled young, like those of the crioceran and baculites-like shell already studied, which is highly probable, they must have had a contact furrow in the nepionic stage and then lost it in the neanic stage. The genesis of another contact furrow in the still later stages of *Nostoceras* and similar turrilites-like spirals, is therefore secondary and phylogerontic, and is not strictly speaking a progressive characteristic. This furrow is also situated on the lateral aspect and not on the dorsum as in symmetrical shells.

The phylogerontic renewal of the impressed zone is also in *Ptychoceras*, a generic character, as pointed out to me by Mr. T. W. Stanton, to whose courtesy and the kind permission of Mr. C. D. Walcott, Director of the Geological Survey, and Mr. Goode, Director of the National Museum, I owe the fine materials described above.

The return of close coiling in gerontic stages of this species is a remarkable phenomenon. There is a gerontic umbilical perforation formed by the sudden bending of the gerontic living chamber which is elongated and not usually very small, but the gerontic bend is often very abrupt. The inner side at the bend is occupied by a gerontic dorsal furrow which reminds the observer of the dorsal furrow in the paranepionic substage of the coiled young of *Nautiloids*. As in the young of *Trocholites* and *Tarphyceras* the

dorsum of the gerontic volution is brought into contact with the dorsum of the next younger volution and a contact furrow results, which so far as I know occurs in all the species properly referred to this genus, although very slight in some of them.

The significance of the facts brought out by the study of degenerative series has been fully discussed elsewhere, and need not be noticed again.

The facts and arguments brought forward seem to justify the following conclusions :

1. The impressed zone is primitively a contact furrow, an acquired characteristic of the dorsum of the whorls of nautilian shells having large umbilical perforations, which appeared either in the ananeanic or metaneanic substages, and rarely later in their ontogeny. There is abundant positive evidence that in these primitive forms this furrow is a purely mechanical result of the nautilian mode of growth, not appearing in the ontogeny before contact and either partially or entirely disappearing on the free gerontic volution.

2. The impressed zone does occur independently of contact on the free dorsum of the paranepionic substage as a dorsal furrow in some close-coiled, highly tachygenic, nautilian shells in the Quebec group and in the Devonian.

3. While there is no positive proof that the dorsal furrow originated through heredity in the paranepionic substages of these nautiloids of precarboniferous age, there is also no satisfactory evidence that it originated in the young of such species as have this character through purely mechanical agencies.

4. There is positive evidence that the similar dorsal furrow which also appears at the same age in the young shells of *Coloceras globatum* and perhaps *Coelogasteroceras canaliculatum* among Carboniferous nautiloids can be explained only when it is considered as a transmitted, tachygenetic characteristic.

5. This fourth conclusion is supported by the presence of a similar dorsal furrow in the paranepionic substage of the young shells of all of the nautiloids of the Jura, so far as observed.

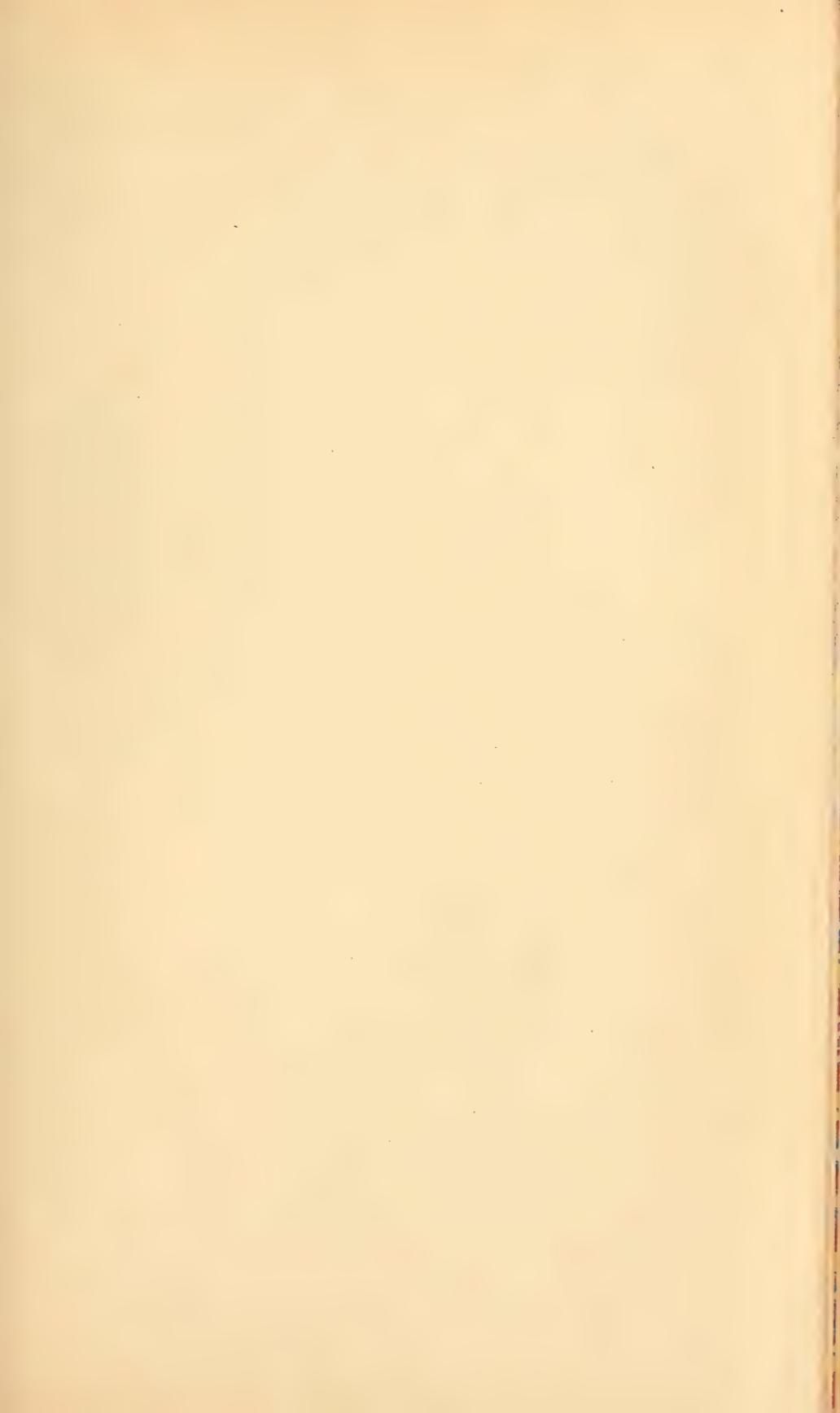
6. The fourth and fifth conclusions are rendered still more probable by the presence of the dorsal furrow at an earlier age, the metanepionic substage, in all of the nautiloids so far as observed, from the beginning of the Cretaceous, through the Tertiaries to and including the living species of the genus *Nautilus*. Its presence on this cyrtoceran volution in Cretacic shells can be explained only

when it is considered as a transmitted, tachygenetic characteristic derived from ancestral, nautilian shells of the Jura, which have the same characteristic at a later age, *i. e.*, in the paranepionic substage.

7. The first conclusion is also sustained by the parallel phylogeny of the impressed zone in the ancestral forms of the Ammonoidea, the Nautilinidæ and especially in *Mimoceras*, the radical genus of this family.

8. The fourth, fifth and sixth conclusions are also supported by the presence of a contact furrow on the dorsum of the earliest age of the conch in the specialized and highly tachygenic forms of the *Goniatitinae* of the Devonian and of all of the remaining Ammonoids to the end of the Cretaceous.

9. These cumulative results favor the theory of tachygenesis and diplogenesis, and are opposed to the Weissmannian hypothesis of the subdivision of the body into two essentially distinct kinds of plasm, the germplasm, which receives and transmits acquired characteristics, and the somatoplasm, which, while it is capable of acquiring modifications, either does not or cannot transmit them to descendants.



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## EXPLANATION OF PLATES.

## PLATE I.

Illustrations of nepionic stage and ananeanic substage in *Nautilus pompilius* from preparations made by Henry Brooks and drawn under his direction. They are all enlarged to show the details of the surface ornamentation and changes of form.

Fig. 1. The paranepionic aperture and earlier nepionic substages seen from the front, this preparation having been obtained by breaking down the full-grown shell. The septum which appears here necessarily belongs to a later time and shows the position of the siphuncle and its large size in the floor of a living chamber older than is represented in this figure, but in the same substage. The actual living chamber of this age was therefore deeper than is represented here at the beginning of the paranepionic substage. The subtriangular outline of the section of the shell is supposed to represent and probably does approximately represent the aperture. It is noticeable also that the dorsal furrow is well developed, although the shell has not yet completed the gyroceran curve.

Fig. 2. Side view of the same showing the apex. The ananepionic substage is not distinctly visible, but the constrictions showing apertures of the metanepionic substages are delineated.\* This figure is especially intended to exhibit the changes that take place in the ornamentation of the shell.

Fig. 3. The ananepionic and metanepionic substages in another preparation seen from the front. The ananepionic is the elongated disk of the apex and scar in the centre of this. The metanepionic includes the shell outside of this to the outer constriction.

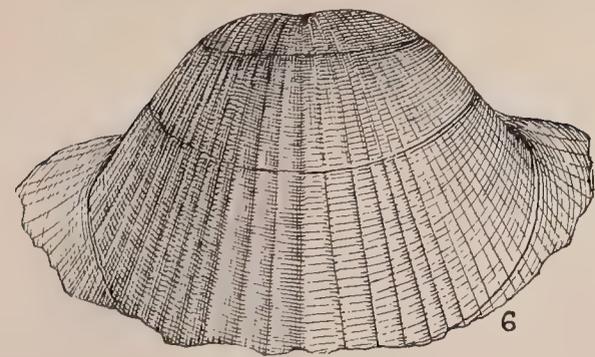
The details in this have not been completely drawn, but the transverse lines of growth are shown upon the shaded side of the drawing.

Fig. 4. Same from the ventral side, showing especially the latter part of the metanepionic substage and the deep constriction that in some specimens marks the termination of this substage. The lines of growth show no trace of a hypomic sinus in this or any other preparation at this age.

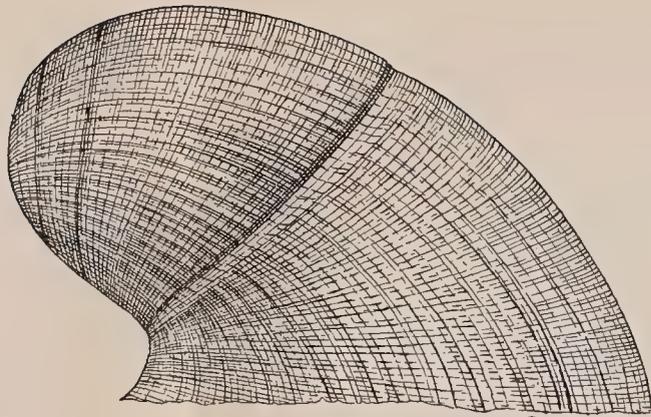
Fig. 5. The same substages of the nepionic stage seen from the front in another preparation. The details of the transverse striation are not fully given in this drawing and this makes the ananepionic substage appear more gibbous than it really is. This impression is corrected by Fig. 6.

Fig. 6. View of the same from the venter, very carefully finished in all its details. The limits of the ananepionic substage and the aperture of the first part of the metanepionic substage are more plainly marked in this specimen than is usual.

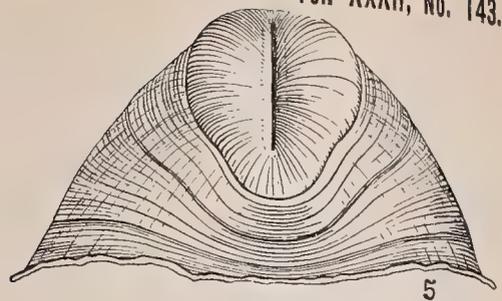
\*These drawings and others in this paper will appear to most observers to be upside down. They are really right side up and the conventional mode of representing these shells followed hitherto in all works is unnatural. It is full time that these forms should be pictured, as are all others in scientific and popular works, as they stand in nature. The greatest objection to this is the inconvenience of comparison with illustrations hitherto published, but this cannot be avoided, and must be endured for the sake of progress.



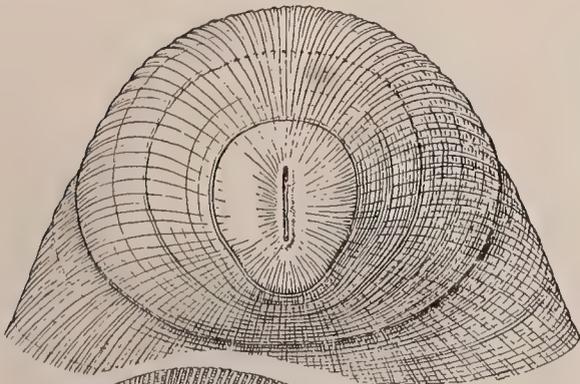
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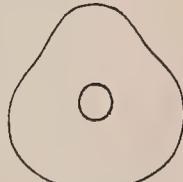
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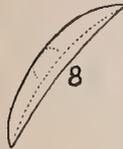
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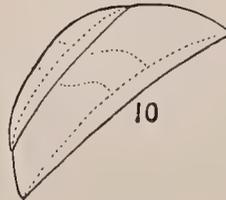
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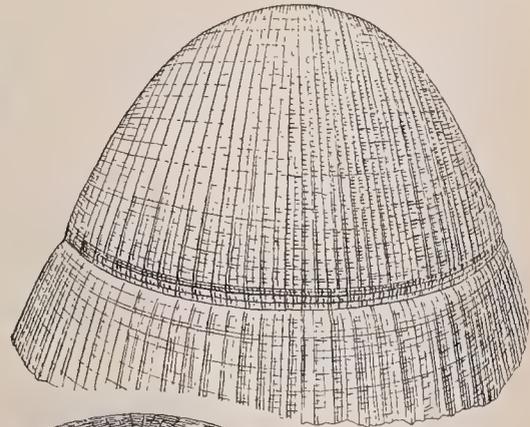
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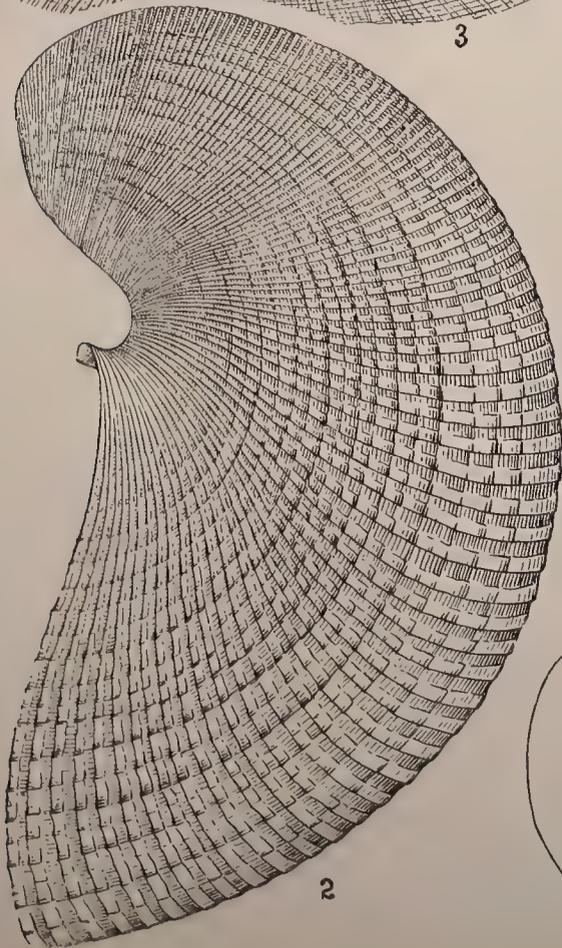
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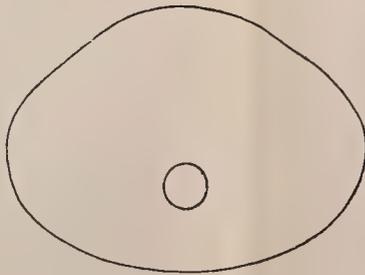
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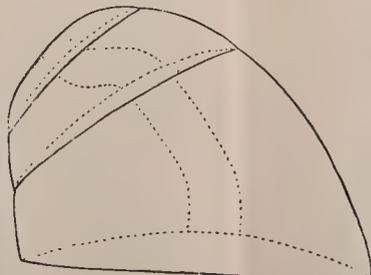
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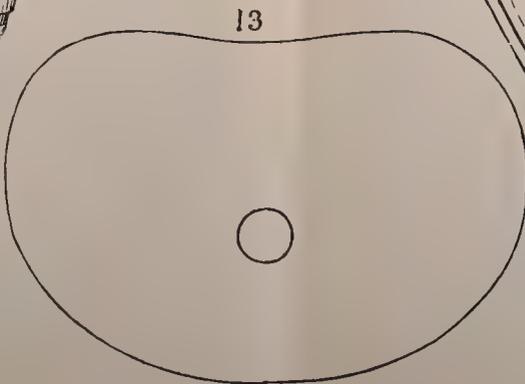
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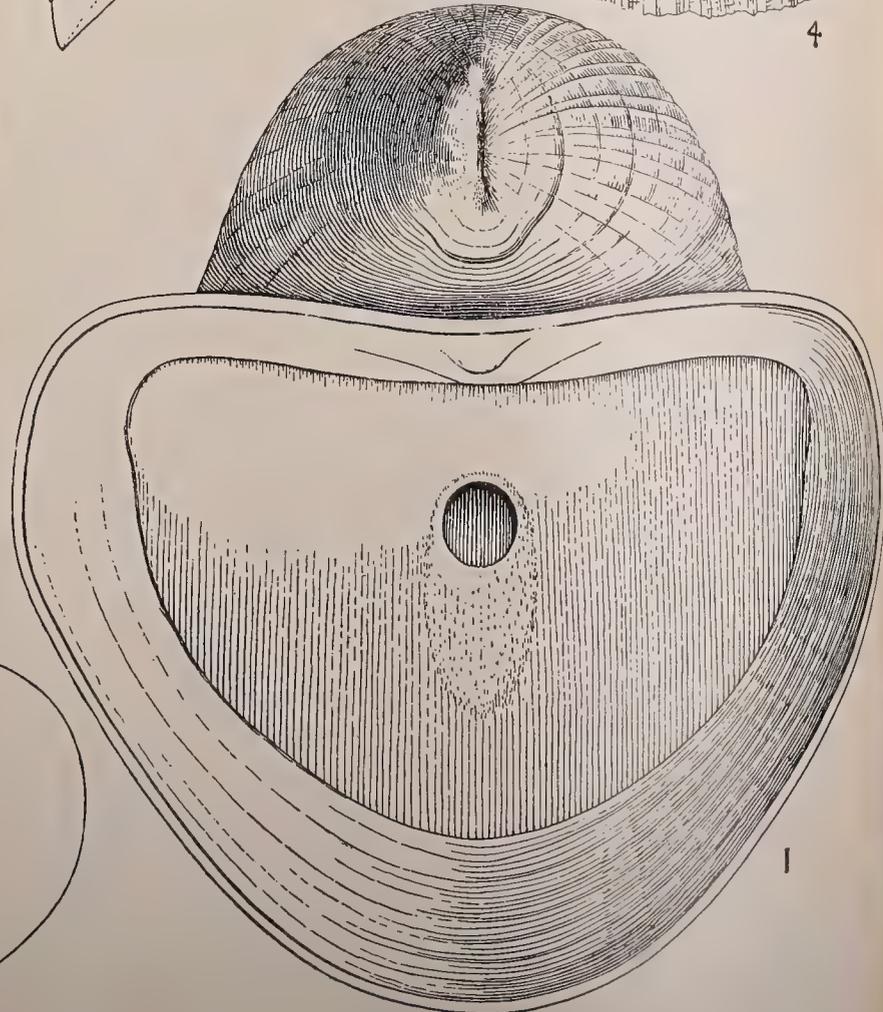
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Fig. 7. Side view of the apex of the conch in another preparation showing the same substages and a part of the paranepionic substage.

Fig. 8. Diagram of the exterior of the ananepionic substage. This also shows the position of cæcum and septum of the first living chamber of the metanepionic in the interior, and supposed outlines of aperture of ananepionic substage. In the ananepionic substage the apex of the conch is empty and this diagram therefore gives the erroneous impression that the cæcum and first septum belongs to this substage, whereas it is obviously a part of the metanepionic substage.

Fig. 9. Front view of the same showing outline of aperture of ananepionic substage and also the position and size of the primitive siphuncle or cæcum first septum of the metanepionic substage.\*

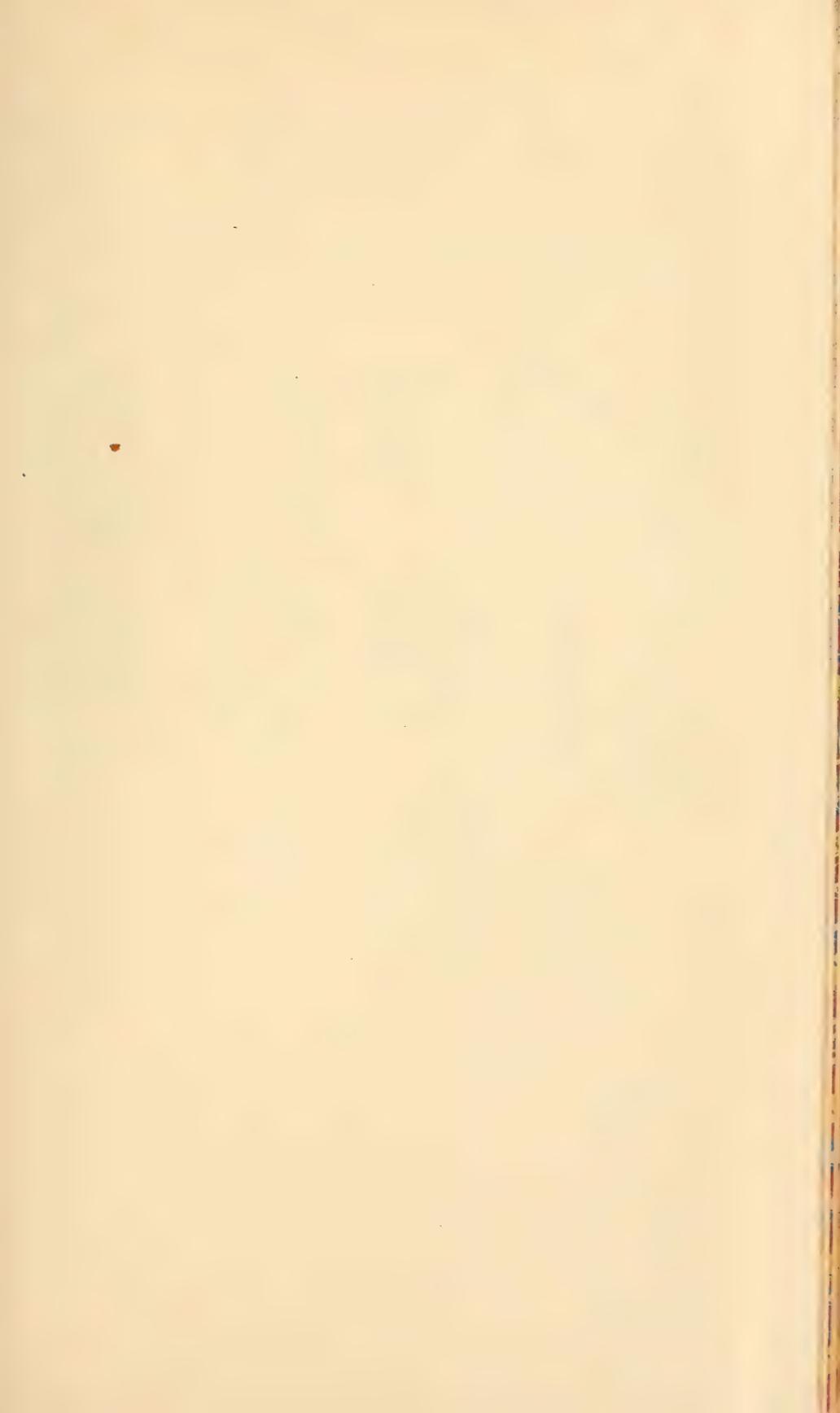
Fig. 10. Diagram of same and exterior of first living chamber of the metanepionic substage showing change of position towards the venter of the siphuncle in the septum of the second living chamber of same substage.

Fig. 11. Front view of the same with siphuncle of the same.

Fig. 12. Side view of the exterior of two first substages and supposed aperture, with the siphuncle and first septum of the paranepionic substage. The siphuncle, it will be observed, changes again towards the centre between these two septa.

Fig. 13. Front view of the same showing approximate outline of aperture taken from actual outline of shell in section at the constriction terminating the metanepionic substage. This shows the nephritic character in the volution and exhibits also the dorsal furrow beginning to form at this early age before the gyroceran curve begins. This drawing is placed so that the observer can compare the outlines of the shell at this substage with that of the later age of the paranepionic substage in Fig. 1. In the latter the siphuncle has assumed the permanent position of the ephebic stage below the centre.

\* Figs. 9-11 should have been reversed to accord with the side views and with the other figures.



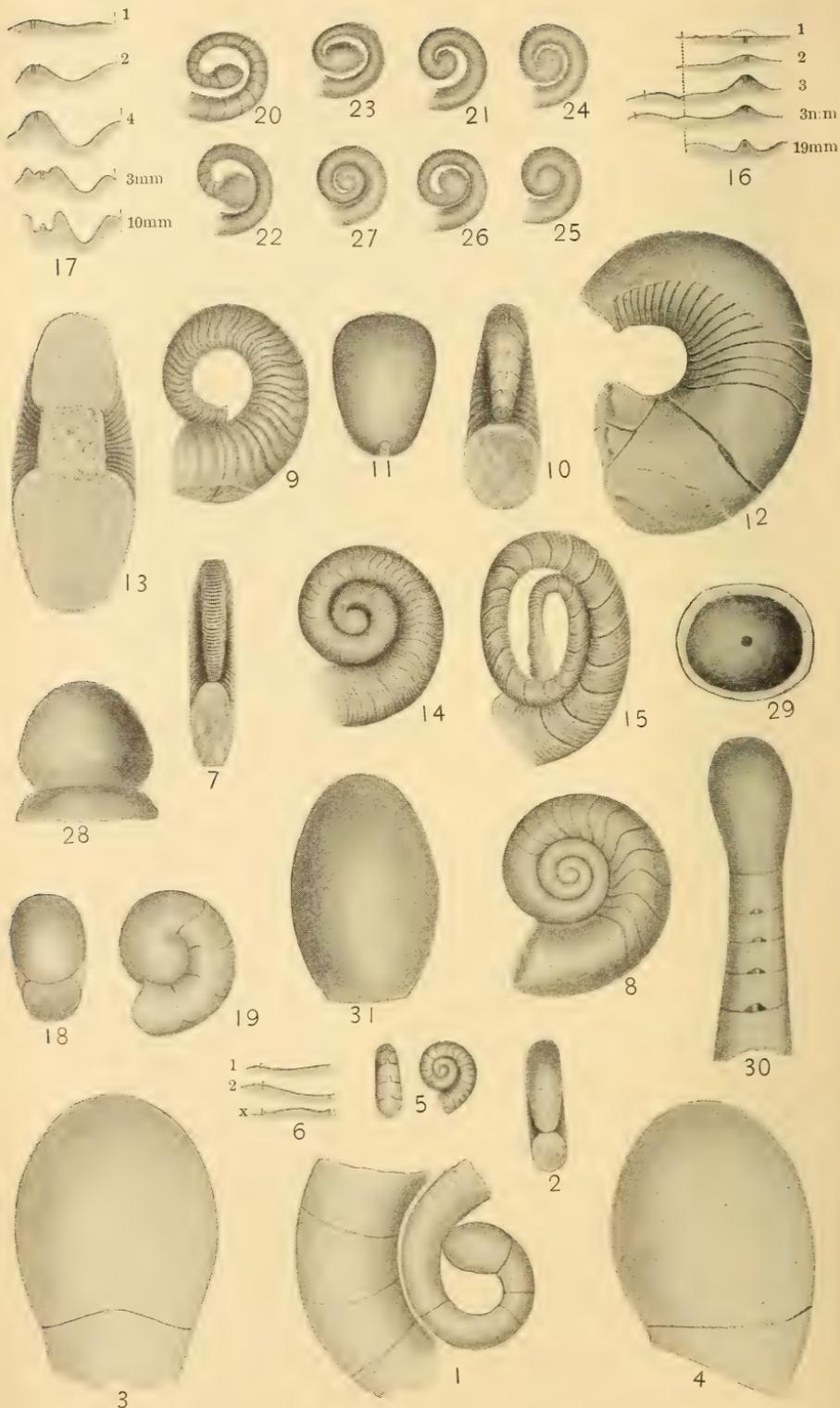


Plate II (Hyatt).

## PLATE II.

Figs. 1-6. *Mimoceras (Goniatites) compressum*, after Branco, *Paleontographica*, xxvii, Pl. viii, much enlarged, to show the loose mode of coiling, absence of impressed zone, primitive nautiloid sutures of the young until a late stage, and protoconch joining the conch without any constriction on the sides or abdomen, but with a slight constriction on the dorsum, showing tendency to coil, these being typical ammonitoid characteristics. Fig. 6, 1 and 2 and *x* represent the first, second, and older septum, the septa of the later stages are shown with ventral siphonal lobe in Fig. 5. Fig. 20 is the same species after Sandberger.

Figs. 7 and 8. *Mimoceras (Goniatites) ambigena*, after Barrande, *Systeme Silurien*, Pl. iii, Fig. 22, and Pl. xii, Fig. 7, showing the absence of an impressed zone at a late stage, probably the ephebic stage of development.

Figs. 9-11. *Agoniatites (Goniatites) fecundus*, after Barrande (*ibid.*), Pl. x, Figs. 13-15, showing the absence of the impressed zone until a late stage; Fig. 11 is nearly natural size, and this shows, when compared with others of Barrande's figures of this species, which have the impressed zone in adults (Barrande, Pl. vii, Figs. 10 and 11), that this characteristic comes at a much earlier stage in some specimens, and is originated by close coiling, as it is in *Agoniatites Vanuxemi*, but at an earlier stage than in *A. fecundus*.

Figs. 12 and 13. *Agoniatites (?) (Goniatites) crebriseptus*, after Barrande (*ibid.*), Pl. vii, Figs. 1 and 2, reduced one-third, showing how similar to some nautiloids the adults of this genus may be, both in form and sutures,\* with the exception of the ventral siphonal lobe, which alone enables one to place them among Ammonoids.

Figs. 14 and 15. *Agoniatites fecundus*, after Barrande (*ibid.*), Pl. xi, Figs. 2 and 4, enlarged to show the variation of the coiling of two varieties in the protoconchial and nepionic stages. These are both included under one name by Barrande.

Fig. 16. *Anarcestes (Goniatites) lateseptatus*, after Branco, *op. cit.*, xxvii, Pl. vi, enlarged, showing the immature ventral sutures of this with the primitive undivided siphonal lobe beginning in the second septum of the metanepionic substage. This continues substantially the same in aspect throughout life in the genera *Mimoceras*, *Anarcestes*, *Agoniatites* and *Pinnacites*, all Silurian forms of *Goniatitinae*.

Figs. 17-19. *Gephuroceras (Goniatites) serratum*, after Branco, *op. cit.*, xxvii, Pl. vi, enlarged, showing sutures of Devonian *Goniatitinae* with accelerated development. The mimoceran undivided siphonal lobe is here shown in the metanepionic substage, 2-4 septa, but in the paranepionic, where the coil is 3 mm. in diameter, the siphonal saddle arises in the centre of this lobe as a new character acquired in the later stages of growth.

Figs. 20-25. These give the protoconch and young of various species of *Goniatitinae* of the Devonian after Sandberger, *Fahrbuch d. Nass. Verein*, 1851,

\* *Mimoceras (Goniatites) lituus* is a still larger form, also figured by Barrande, which has no impressed zone and is very similar to many nautiloids which have similar compressed elliptical whorl and subventral siphuncles. His figure is reproduced here in reduced outline, Figs. 40, 41, Pl. viii.

Pl. iii. They are somewhat enlarged and show the loose coiling of several genera in the nepionic stages of development during this period of their evolution. Subsequently the coiling becomes closer, as has been demonstrated by Branco. Fig. 20, *Mimoceras compressum*; Fig. 21, *Anarcestes subnautilus*; Fig. 22, *Agoniatites bicanaliculatus*, var. *gracilis*; Fig. 23, *Gephuroceras planorbe*; Fig. 24, *calculiforme*, and Fig. 25, *sublamellosum*; Fig. 26, *Manticoceras latidorsale*, and Fig. 27, *Glyphioceras diadema*.

Figs. 28 and 29. Protoconch of *Orthoceras*, after Clarke, *Am. Geol.*, xii, August, 1893.

Figs. 30 and 31. Protoconch of *Bactrites*, after Branco.



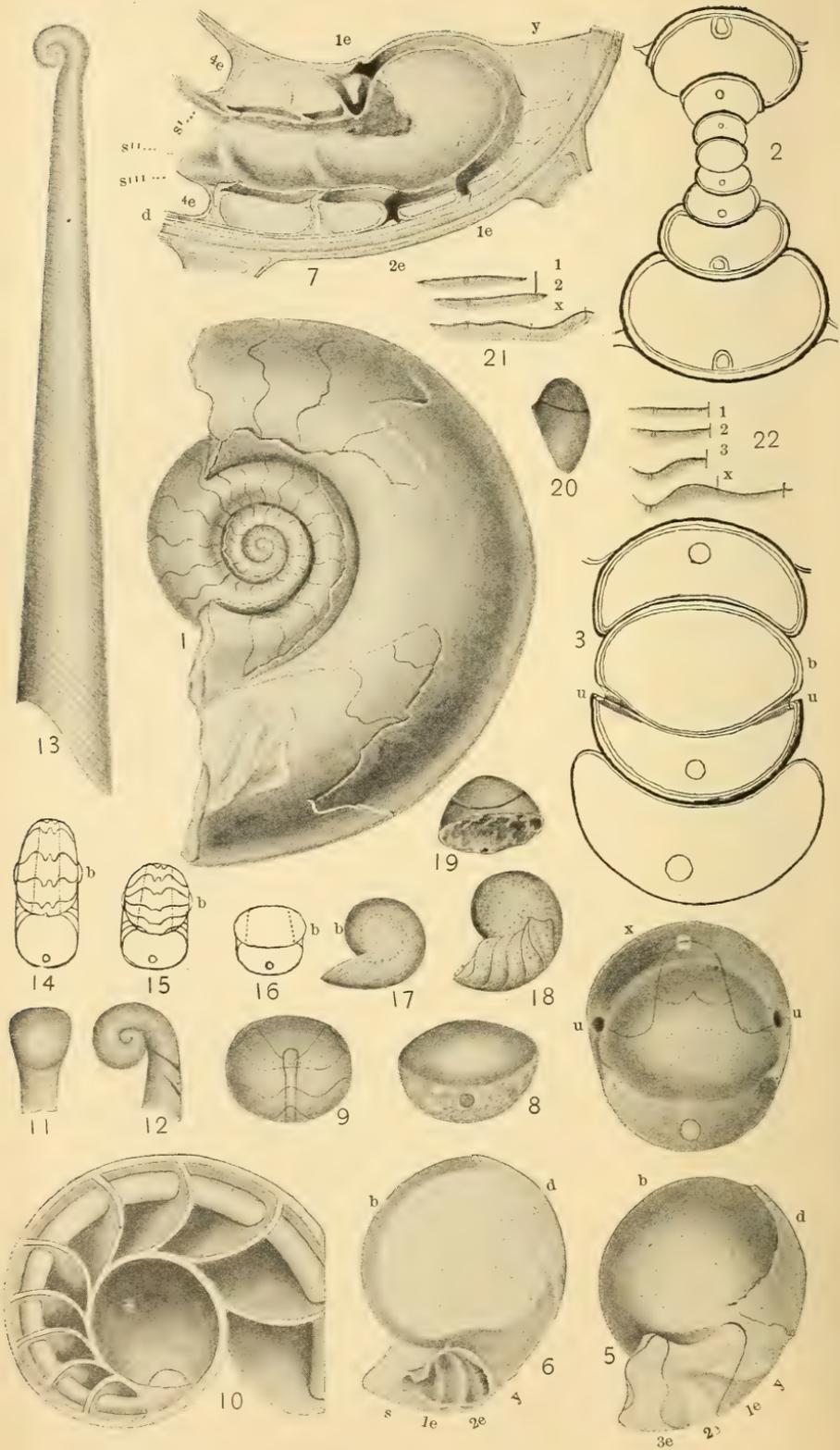


Plate III (Hyatt).

## PLATE III.

Figs. 1-7. *Deroceras* (*Amm.*) *planicosta*, Hyatt, *Embryology Ceph. Bull. Mus. Comp. Zoölogy*, iii, No. 5, Pls. i and ii.

Fig. 1, side view of nepionic and neanic stages,  $\times 80$  diameters. Fig. 2, section of another specimen,  $\times 21.5$  diameters; B, protoconch. Fig. 3, centre of same, enlarged to show the umbilical perforation (U) as it occurs in Ammonitinæ and most of the Goniatitinæ. Fig. 4, protoconch and first volution with ananepionic first septum; x, probably sutures of the first septum on the dorsum seen through the whorl;  $\times 80$ .\* Fig. 5, side view of protoconch, ananepionic first septum 1 e, and metanepionic septa, 2 e, 3 e; D, shell; B, naked cast of interior of protoconch; y, conical appendage of cæcum seen through the whorl. Fig. 6, section of same specimen exposing interior of the protoconch (y), the conical cæcal prolongation, and the fundus of the cæcum and the first two septa, S, being the neck of the small siphuncle at the third septum, which is broken off. Fig. 7, thin section of cæcum and part of conch with four septa, showing formation of cæcum by the first septum 1 e, the composition of the cæcal prolongation y, the neck of the cæcum formed by the second septum 2 e, the siphon begun by the third septum and continued by the fourth, both of which have funnels directed apically as in Nautiloids; S', organic deposit in the interior; S'', inner layer; S''', wall of siphuncle;  $\times 317$  diameters.

Fig. 8. *Deroceras* (*Ægoc.*) *planicosta*, Branco, *Paleontographica*, xxvii, Pl. x, showing protoconch from a different point of view and less magnified. Fig. 9, same, with first to fourth sutures showing.

Fig. 10. *Pleuroceras* (*Amaltheus*) *spinatum*, Branco (*ibid.*), Pl. xiii, enlarged, showing the interior of the protoconch; the septa of first whorl are cut exposing the cæcum. The septa are all convex and strictly ammonitoidal except the first, which is concave, as in Nautiloids and the adults of *Mimoceras*, *Anarcestes* and *Agoniatites* among Ammonoids of the Silurian period.

Figs. 11 and 12. *Crioceras Studeri*, Branco (*ibid.*), Pl. xiii, enlarged, showing the coiled young of this uncoiled degenerate form.†

Figs. 13-18. *Baculites compressus*, Brown, *Proc. Acad. Sci. Phila.*, 1891, p. 159; 1892, p. 136, Pl. ix. Fig. 13, enlarged young shell in the neanic stage, showing the lines of growth, aperture and rostrum on the ventral side. Fig. 14, front view of shell in the paranepionic substage; the siphuncle is not subventran. Fig. 15, front view with the two metanepionic and four paranepionic sutures, those with a siphonal lobe divided by a siphonal saddle being paranepionic in age. Figs. 16 and 17, front and side views, with restoration of the ananepionic substage. Fig. 18, side view of Fig. 15.

Figs. 19-21. Apex from the front and side and sutures of *Nautilus Clemen-tinus*, after Branco, *op. cit.*, xxvii, Pl. ix.

Fig. 22. Sutures of *Nautilus deslongchampsianus*, after Branco, (*ibid.*), Pl. ix.

\* This figure has no number.

† See also for similar forms Pl. xi, Figs. 40, 41.

## PLATE IV.

Fig. 1 *Baculites compressus*, enlarged sutures after Brown, see Pl. iii.\*

Fig. 2 *Deroceras (Aegoceras) planicosta*, enlarged sutures after Branco, *Paleontographica*, xxvi, Pl. x. These show the ananeponic suture 1, the metaneponic or goniatitic sutures 2-4, and the paranepionic with divided siphonal lobe at the diameter of 1 mm. and 2 mm., and the next septum, the 7, here given, is transitional to the first neanic septum, the 8 of this series, which shows the beginning of ammonitic digitations in saddles and lobes and a divided dorsal lobe. By comparing this with the sutures of Pl. ii, Fig. 16, *Anarcestes lateseptatus*, and *Gephuroceras serratum*, Pl. ii, Fig. 17, it will be seen that the ephebic ventral lobes and smooth sutures of the Goniatitinae, represented in *Gephuroceras*, are limited to the paranepionic in *Deroceras*. The goniatitic ventral lobe in other words is replaced in the ananeanic of *Deroceras*, representing the Ammonitinae, by the digitate lobes and saddles of that suborder.

Fig. 3 *Vermiceras (Arietites) spiratissimum*, enlarged sutures, after Branco, (*ibid.*), Pl. ix, showing also acceleration of development through the replacement of the ephebic characters of the Goniatitinae by those of the Ammonitinae in the ananeanic substage.

Figs. 4-11. *Tarphyceras Champlainense*, (sp. Whitfield), Hyatt; Loc., Fort Cassin; U. S. N. Mus., Walcott Coll. Fig. 4, side view slightly enlarged, showing involution and small umbilical perforation; the crack indicates the direction of the section given in Fig. 5. Fig. 6 gives general section and the centre is of about the same age as Fig. 6. Fig. 7 is younger and shows beginning of the dorsal furrow narrower and deeper than in Fig. 6. Fig. 5 shows that it is probably due to the mechanical effects of the sudden bending shown in Fig. 7. Fig. 8, ideal section showing location of sections Figs. 6 and 7. Fig. 9, section of another specimen, natural size, showing a younger stage at the centre. Fig. 10, side view of same specimen. Fig. 11, enlarged section of metaneponic centre of Fig. 9, showing outline like that of *Nautilus pompilius* at the same age.

Figs. 12-16. *Tarphyceras prematurum*, Hyatt, Quebec Group; Loc., Port au Port, Newfoundland. Fig. 12, side view of fragmentary specimen, natural size, giving part of living chamber. Fig. 13, front view of same. Figs. 14 and 15, front and side view of nepionic and part of neanic stage slightly enlarged; Fig. 16, front view of nepionic whorl of same ( $\times 2$ ) showing a dorsal furrow and the abrupt bending of the whorl. The narrowness of the umbilical shoulders is not natural, being probably in part due to the obliquity of the septum and partly to erosion of the outline at this point.

Figs. 17-22. *Tarphyceras Aucoini*, Hyatt, Quebec Group; Loc., Port au Port, Newfoundland. Fig. 17, side view, natural size, of ephebic stage; Fig. 18, part of neanic whorl to show sutures. Fig. 19, section of ephebic whorls, natural size, of another specimen. Fig. 20, section, natural size, of another specimen, the upper whorls a little depressed by pressure; Fig. 21, the nepionic stage enlarged (four diameters) to show more accurate outline and the dorsal furrow and sudden bending of whorl and narrow umbilical perforation. Fig. 22, side view of same. The apex in all of these specimens was too much eroded to show the cicatrix.

\*This figure is not numbered.

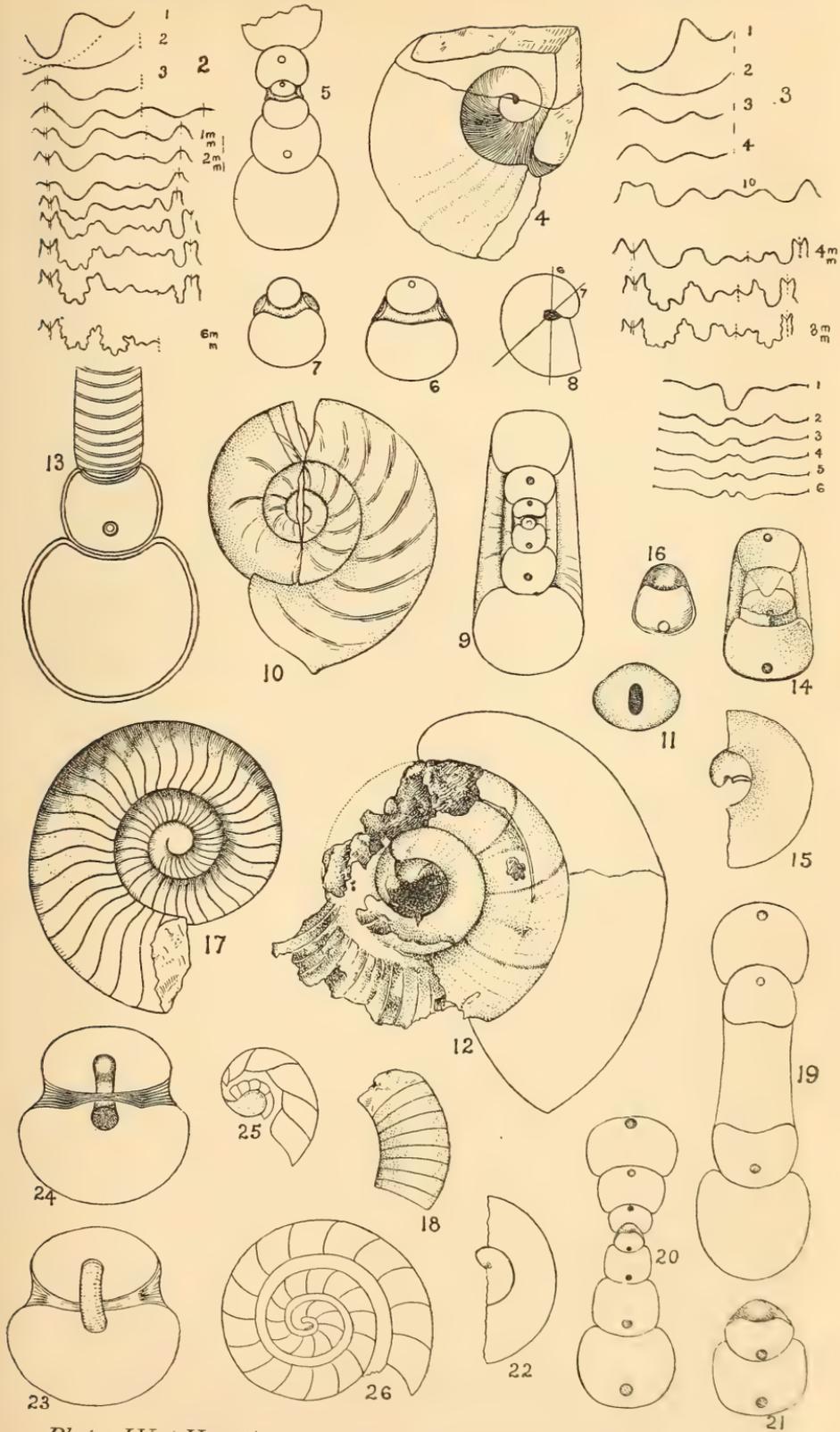
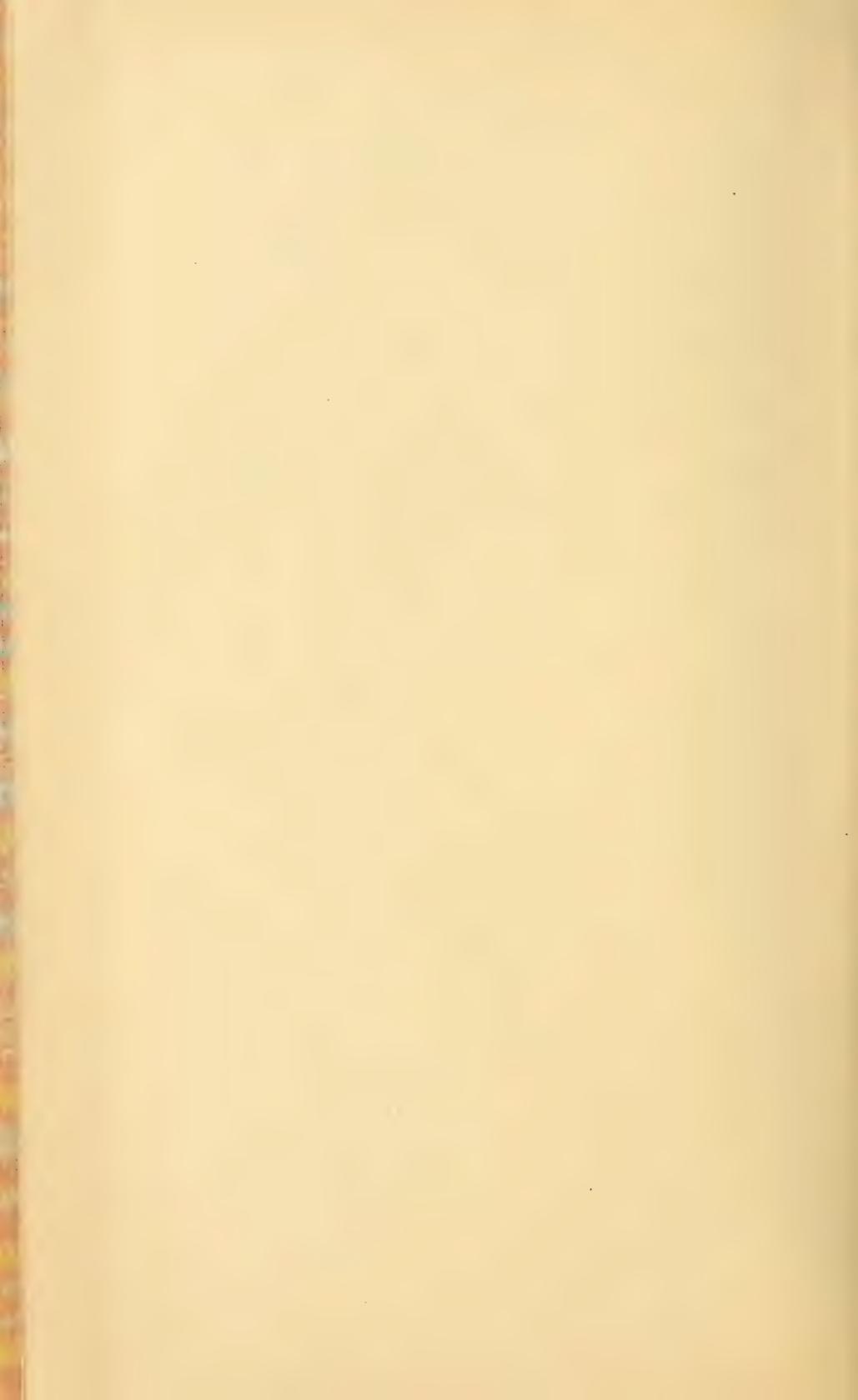


Plate IV (Hyatt).



Figs. 23 and 24. *Trocholites canadensis*, Hyatt; Loc., Falls of Montmorency (?); Coll. Mus. Comp. Zoölogy, Bronn Coll.

Fig. 23. Much enlarged. The siphuncle shows through the transparent venter of the nepionic volution and it passes from subdorsan in the paranepionic below to centren in the metanepionic above. The umbilical perforation appears beyond the siphuncle and has a well-developed dorsal furrow, can also be seen; Fig. 24 shows the gibbeous outgrowth of the dorsum in the umbilical perforation at some distance from the gyroceran bend.

Fig. 25. *Trocholites (Lituities) internastriata* (sp. Whitfield), Hyatt. This was drawn from the centre of his original specimen, *Bull. Am. Mus. Nat. Hist. N. Y.*, Pl. xxix, Fig. 6, enlarged to show the centren position of the siphuncle in the first septum and its gradual approach to the dorsum in the paranepionic whorl as in *T. canadensis*. This also shows a much larger umbilical perforation than is found in *Canadensis* or *ammonius* or the species figured by Holm.

Fig. 26. *Trocholites* sp.? after Holm, *Pal. Abh. Dames et Kayser*, iii, Pl. v, Fig. 11, to show the probable beginning of the siphuncle to be nearer the centre than is described by him. His Fig. 9 of *Trocholites incongruus* shows also a small umbilical perforation and the siphuncle subdorsan, but its tip or cæcum is directed towards the centre of the apical chamber.

## PLATE V.

Figs. 1 and 2. *Eurystomites undatus* (sp. Hall), Hyatt; Black River, Poland, Herkimer Co., N. Y.; Mus. Comp. Zoölogy, Walcott Coll. Natural size, showing large umbilical perforation and absence of dorsal furrow. A contact furrow is formed when the whorls come in contact in neanic stage. Siphuncle is too small and too near the venter in both inner whorls. (Fig. 3 is blank on this plate.)

Figs. 21-25. *Eurystomites rotundus*, Hyatt, Quebec Group; Fort Cassin, U. S. N. Mus., Walcott Coll. Enlarged slightly. Fig. 3, partly diagrammatic side view showing direction of section. Fig. 4, section. Fig. 5, section of nepionic somewhat nearer to that indicated in Fig. 3. Fig. 6 is about on that line and Fig. 7 is on the further side of it in the umbilical perforation. This series shows the large umbilical perforation and absence of impressed zone, until the whorls come into contact in the neanic stage.

Figs. 4 and 5. *Eurystomites (Naut.) Kelloggi* (sp. Whitfield), Schröder; Loc., Fort Cassin, Quebec Group; Walcott Coll. U. S. Nat. Mus. Fig. 4, reduced one-third, showing the cast with the partly exfoliated rough shell in the gerontic stage and the restored gerontic free whorl which is in outline. The matrix was preserved so as to give the dorsal outline of this restored volution but not the sides or the venter. Fig. 5, section of the termination of the gerontic whorl. This is ideal so far as the sides and venter are concerned and may be too long ventrodorsally, but the dorsum is correct and shows the much narrowed but still persistent impressed zone.

Figs. 6-10. *Barrandoceras (Naut.) tyrannum* (sp. Barrande), Hyatt; Loc., Lochkov, Bohemia; Scharly Coll. Mus. Comp. Zoölogy.

Fig. 6, front view of part of the nepionic volution showing the cicatrix ana-, meta- and part of paranepionic substages, the constriction next to the cicatrix and the one just beyond this belongs to the ananepionic substage; the second is also seen in Fig. 7 a, the next constrictions seen in both of these figures belong to the metanepionic substage. There is apparently no hyponomic sinus in these two substages and its absence indicates the limits of the metanepionic substage. It is not plainly visible on this specimen until near the cracked line, which is really the septum of the living chamber. Fig. 7, side view, shell was not on the living chamber, but has been restored from other specimens. Suture is about as indicated with ventral and dorsal saddles and broad shallow lateral lobes. Figs. 6 and 7 are  $\times 4$  diameters. Fig. 7 a, an enlarged side view of apex of Fig. 7 to show true aspect of this part. Figs. 8, 9 and 10, similar views of another specimen showing identity of cicatrix and youngest substages in both shells. The markings are so delicate that they are easily obliterated and are necessarily much coarser in these drawings than in nature. Fig. 10 is enlarged about four diameters.

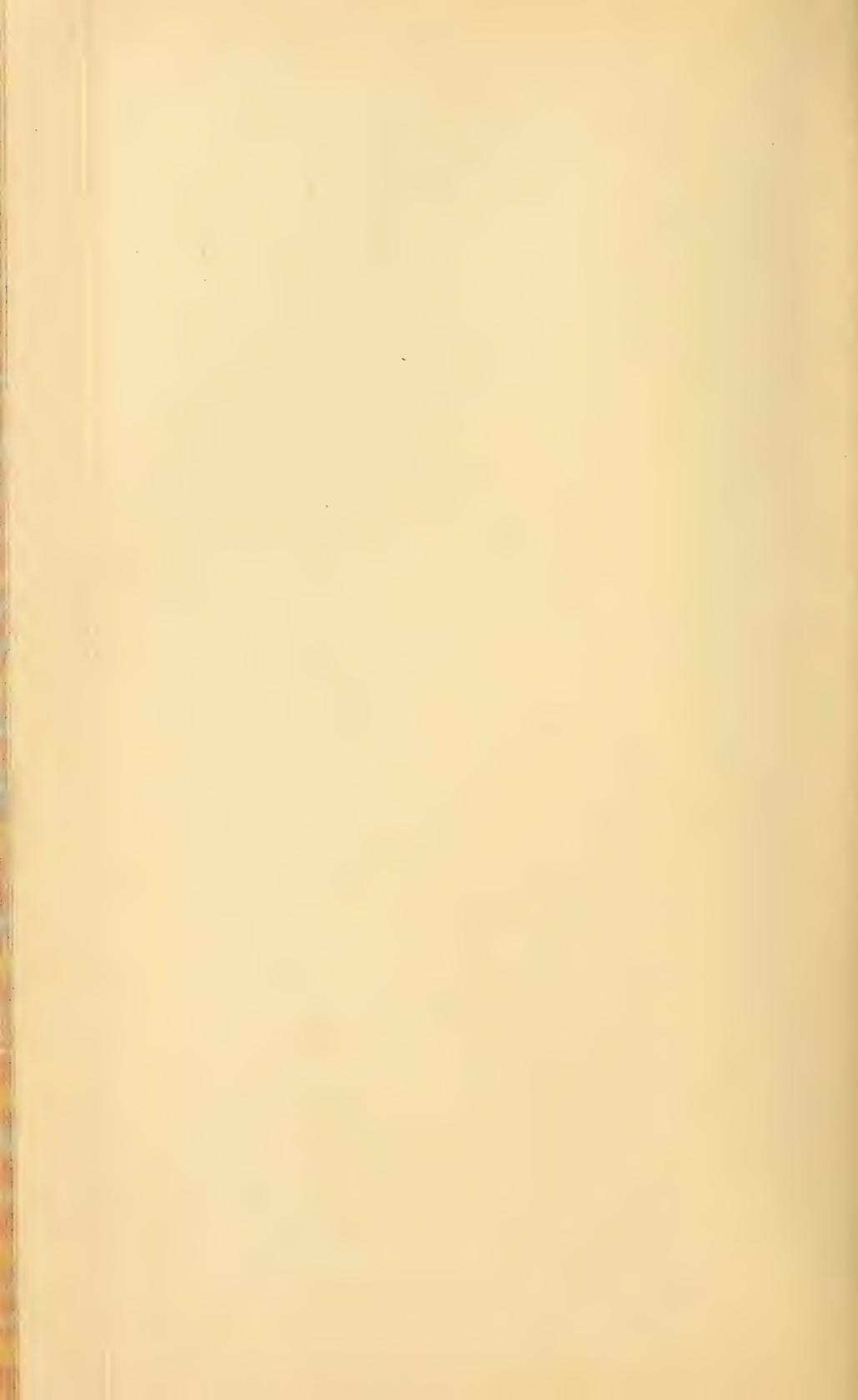
Figs. 11-14. *Barrandoceras Sacheri* (sp. Barrande) Hyatt; Loc., V. ch. Pridoli, Bohemia; Scharly Coll., Mus. Comp. Zoölogy. Fig. 11 shows the large umbilical perforation, the sudden bending of the whorl at the end of the metanepionic substage; this occurs also in Fig. 7 and Fig. 9. Fig. 12, front of same. Fig.







Plate V (Hyatt).



13 shows the dorsal side of Fig. 11 on the paranepionic whorl inside of umbilical perforation and just before the apex is reached. This has sutures with dorsal lobes and is flattened as is shown in section of the same, Fig. 14; this flattening also occurs in the paranepionic whorl of Fig 6.

Figs. 15-17. *Aphetoceras boreale*, Hyatt, Quebec Group; Loc., Schooner's Island, Newfoundland. Fig. 15, side view, and Figs. 16 and 17, sections all one-third reduced, showing form and absence of impressed zone. For other species of this genus see Pl. vi.

Figs. 18-20. *Pycnoceras apertum*, Hyatt, Quebec Group; Loc., Port au Port, Newfoundland. Fig. 18, side view, reduced one third, with apex restored. Fig. 19, view of venter of same encrusted with dorsal shell of older volution, the remainder of this volution having been destroyed by erosion. This shell shows the contact furrow and the dorsal lobes in the sutures of older stages. Fig. 20, view of the part of the nepionic whorl of Fig. 18, enlarged 2 diameters, showing the absence of dorsal furrow and the form of the metanepionic and paranepionic substages of this species. The remnants of the dorsal shell described above are omitted in this figure and in Fig. 18.

## PLATE VI.

Figs. 1-4. *Tarphyceras extensum*, Quebec Group; Loc., Port au Choix, Newfoundland. Reduced one-third. Fig. 1, lateral view, showing position of siphuncle, septa in section and free volution. Fig. 2, section of living chamber at the termination restored by observation of the more perfect parts of the same volution. Dorsum appeared to have no impressed zone in this obviously the gerontic stage. Fig. 4, section of two ephetic whorls in part restored, showing impressed zone and general form. Fig. 3, section of younger whorl, restoration in part. Dimensions are incorrect in these sections, but the form is correct.

Figs. 5-8. *Aphetoceras Americanum*, Quebec Group; Loc., Port au Choix, Newfoundland. Reduced one-third. Fig. 5, side view showing gyroceran mode of growth, suture with ventral lobe and younger sutures with ventral and dorsal saddles. Fig. 7, section of the outer whorl. Figs. 7, 8, sections taken at the two contiguous breaks in the outer and next inner whorls. Dimensions of these sections are not correct, but form is properly represented.

Figs. 9-11. *Litoceras insolens* (?) (sp. Bill.), Hyatt, Quebec Group; Loc., Gargamelle Cove, Newfoundland. Fig. 9, side view of young specimens, very nearly natural size. Fig. 10, interior whorls enlarged to show large umbilical perforation, costations of metanepionic, paranepionic and ananeanic substages, and the loose coiling of the ananeanic substage. Fig. 11, section of nepionic, ananeanic and anephebic volutions showing the absence of impressed zones in the nepionic and changes of form in older whorls. Compare this with the young of *Trocholitoceras Walcottii*.

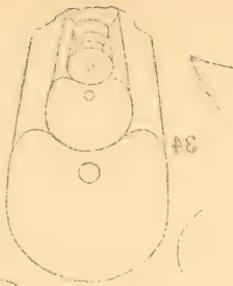
Figs. 12-20. *Trocholitoceras Walcottii*, Quebec Group; Fort Cassin; U. S. Nat. Museum, Walcott Coll. Fig. 12, side view of type specimen natural size. Fig. 13, section of same. Fig. 14, section of centre of same enlarged to show the largest diameter of the umbilical perforation and the ananeptic substage and paranepionic with impressed zone. Fig. 20 gives location of this section and all the rest are taken between the two bisecting lines of this figure. Figs. 15-19, successive sections gradually passing out of the umbilical perforation and showing the position of the siphuncle and increasing depth of the impressed zone after contact. These sections also show that the impressed zone occurs after the gyroceran bend in the beginning of the paranepionic substage, and is apparently a result of the great increase in transverse diameters, nephritic form of whorl and abrupt bending. Fig. 20, location of sections, ideal. The shape of the ananeptic volution in Fig. 13 is more accurate than in Fig. 14 or 15.

Figs. 21-27. *Schroederoceras teres* (sp. Eichw.), after Holm, *Pal. Abh. Dames et Kayser*, iii, Pl. v. Figs. 21 and 22 show the subventral cæcum in apical chamber and shifting of position to dorsad of centre in the ananeptic substage. Compare with *Schroederoceras Eatonii*, Fig. 35. Figs. 23-27, ananeptic, metanepionic substages, the septa belong wholly to the metanepionic. There is no dorsal furrow in this shell until the third septum is reached and by comparing this with sections, Figs. 21 and 22, it is seen that this indicates either the beginning, Fig. 21, or the completion of the gyroceran bend, Fig. 22, although Holm's Fig. 25 would lead to the supposition that the bending had not yet begun.

Figs. 28-35. *Schroederoceras Eatonii*, sp. Whitf., Hyatt, Quebec Group; Loc.,



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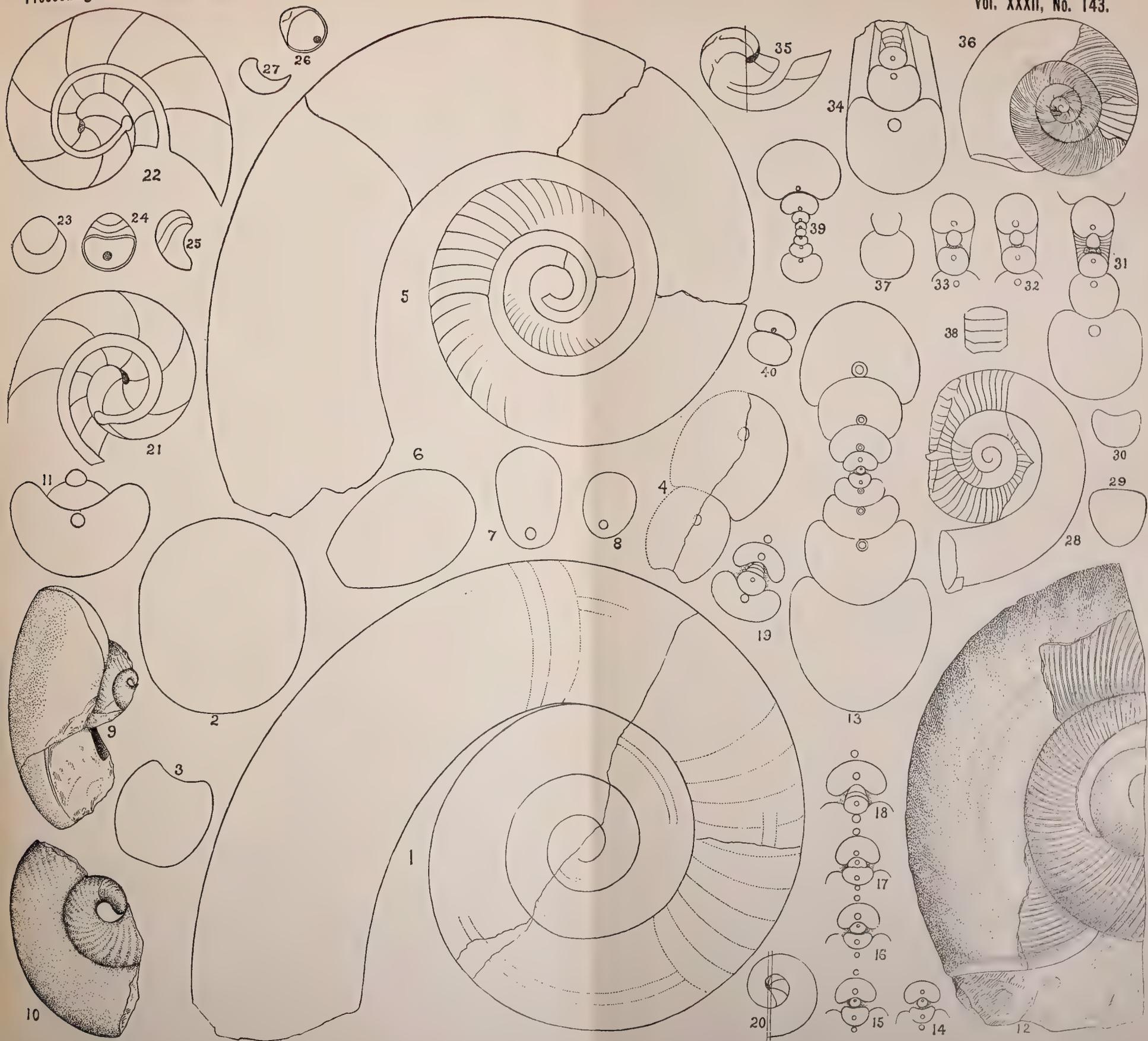


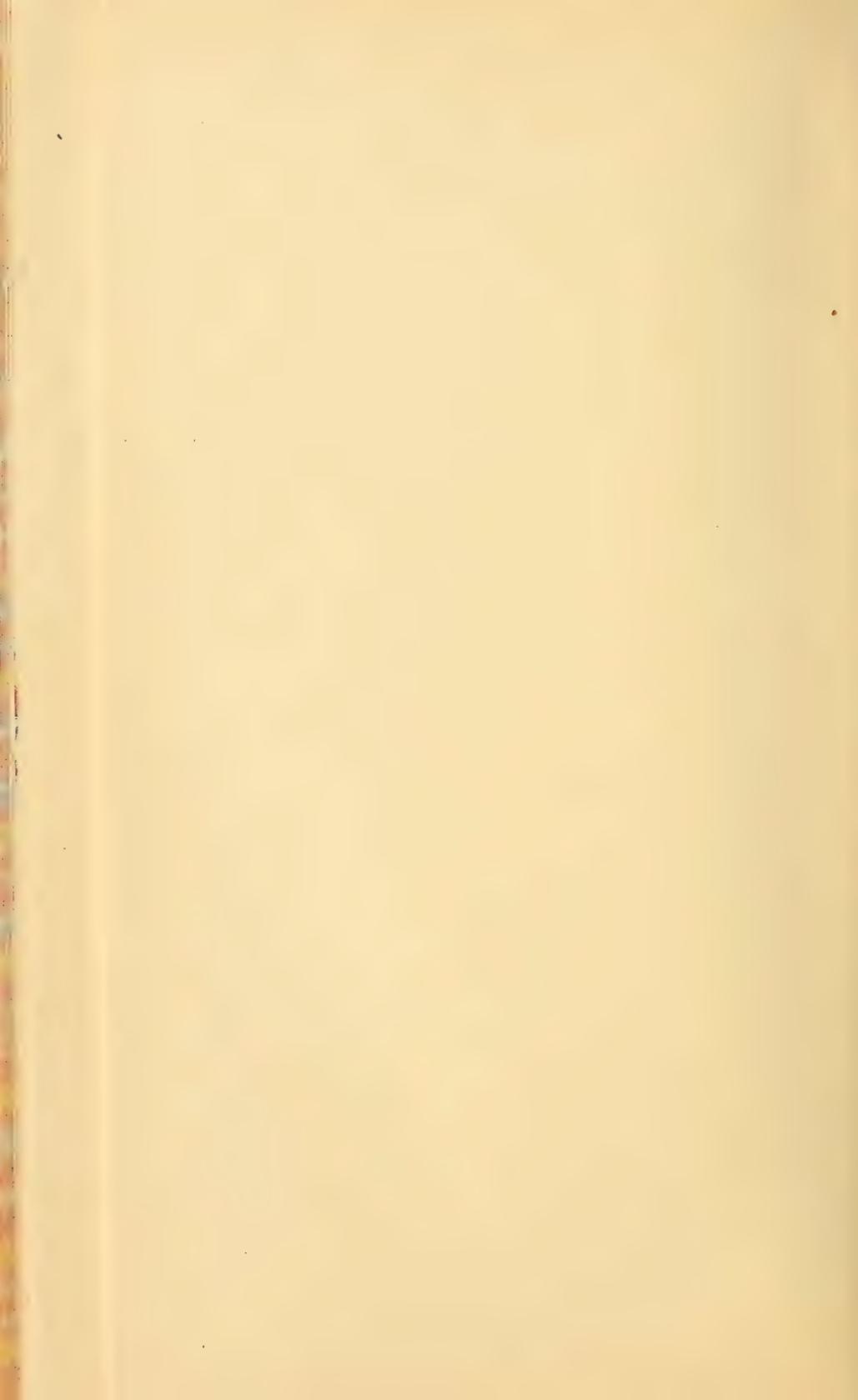
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Fort Cassin; Coll. U. S. N. Mus. and Am. Mus., N. Y. Fig. 28, side view of original (slightly changed), from Whitfield, *Bull. Am. Mus.*, Pl. xxxii, Fig. 1. Fig. 29, section of gerontic living chamber at the end. Fig. 30, section of ephebic whorl just above free end of living chamber. These two show the presence of a well-developed contact zone in the ephebic stage and its complete disappearance on the free gerontic volution. Fig. 31, shows a section of a specimen which exhibits the umbilical perforation with a core of the matrix; this cut passed inside of the line drawn through Fig. 35 and represents the metanepionic above the core and below it the paranepionic volution, the neanic being the next section of a volution above the metanepionic. Figs. 32 and 33, younger ages of the nepionic and older ages of the paranepionic volutions. Fig. 34, section along the line indicated in Fig. 35. Fig. 35, drawing enlarged from Whitfield's original Pl. xxxviii, Fig. 7. Umbilical perforation may be somewhat larger proportionally than in nature.

Figs. 36-38. *Schroederoceras casinense*, Quebec Group; Loc., Fort Cassin; Coll. Am. Mus. N. Y. Fig. 36, side view (somewhat changed), from Whitfield, *op. cit.*, Pl. xxxii, Fig. 2. Fig. 37, section of outer whorl of same near the line of broken shell on the living chamber of Fig. 36. Fig. 38, shows sutures on the venter of same specimen.

Figs. 39 and 40. *Trocholites canadense*; Loc., Falls of Montmorency, Bronn; Coll. Mus. Comp. Zoology. Fig. 39 gives section. Compare with that of *Trocholiticeras Walcottii*. Fig. 40 shows the centre of this; the lower volution is the nepionic and this shows how much wider this is than the older neanic volution above.

## PLATE VII.

Figs. 1-3. *Schroederoceras tubulatum*, Hyatt, pars *Lit. angulatus*, Saem.; Coll. Mus. Comp. Zoöl., Loc., Brevig, Norway. Reduced one-third. Fig. 1, side view of the fragment; the free whorl is restored as shown in this figure. The suture and form of the restoration was taken from the well-preserved dorsum and cast of the interior of the right side of the free whorl. The umbilical perforation is probably incorrect. The aperture follows the lines of growth, but is very likely incorrect and the ventro-dorsal diameter may be too long. Fig. 2, section, the outer volution being restored as regards the venter and right side; the dorsum and left side are accurate. Fig. 3, restored outline of living chamber at termination showing the obliteration of the impressed zone. See also Figs. 6-12, Pl. xiv.

Figs. 4-6. *Schroederoceras casinense*, Quebec Group; Loc., Fort Cassin; U. S. Nat. Museum, Coll. Walcott. Natural size. Fig. 4, side view showing living chamber aperture. Fig. 5, dorsum of living chamber with aperture and ephebic volution. This shows contact zone in the ephebic stage and its disappearance upon the free volution; the whorl was broken away and removed at xx. Fig. 6 showing dorsal crest of the aperture and replacement of impressed zone by a gibbous surface just beyond the shaded area in Fig. 5. See also Pl. vi.

Figs. 7 and 8. *Schroederoceras Eatoni* (sp. Whitf.), Hyatt, Quebec Group; Loc., Fort Cassin; U. S. N. Mus., Coll. Walcott. Natural size. Fig. 7, side view showing lines of growth, sutures, and aperture. Fig. 8, front of same with ventral sutures and rim of aperture removed showing the remnants of impressed zone. See also Pl. vi.

Figs. 9-12. *Estonioceras perforatum*, Schröder, Silurian. Fig. 9, side view after Schröder, *Pal. Abh. Dames et Kayser*, v, Pl. xxvi, Fig. 1 a, reduced one-third, showing free nepionic and free gerontic volutions with lines of growth. Figs. 10 and 11, Loc., Reval, Mus. Comp. Zoöl., Bronn Coll., showing paranepionic whorl with lines of growth on the dorsum and absence of dorsal furrow and lateral sutures, reduced one-third. Fig. 12, three sutures of upper part of dorsum of the paranepionic substage of Figs. 10 and 11, the shell removed and the whorl enlarged.

Figs. 13-19. *Estonioceras biangulatum*, Silurian; Loc., Breslau; Mus. Comp. Zool., Kranz Coll. Figs. 13 and 14, reduced one-third the abdomen of Fig. 13, is distorted by pressure.\* Fig. 15, venter of paranepionic and section of neanic below with beginning of impressed zone (this is more accurately given in Fig. 15 a); above is ephebic whorl, but this and sutures are distorted by perspective. This view is taken from the interior of Fig. 13 with parts between fractures removed. Fig. 16, venter of ephebic stage, showing sutures with ventral lobes not saddles as on outer volution of Fig. 15. Fig. 17, dorsum of free gerontic volution showing lines of growth with dorsal crests, sutures with dorsal lobes; depression in cast perhaps annular muscle, which disappears on the sides; there are faint marks on the venter as if the upper edge of this may have risen into a saddle on that side as in Fig. 1, Pl. viii, of *Remeléceras*. The impressed zone disappears early on this volution. Fig. 18, venter of the same, showing change in sutures and return of

\*The apex of this was not clearly seen and it may be free.





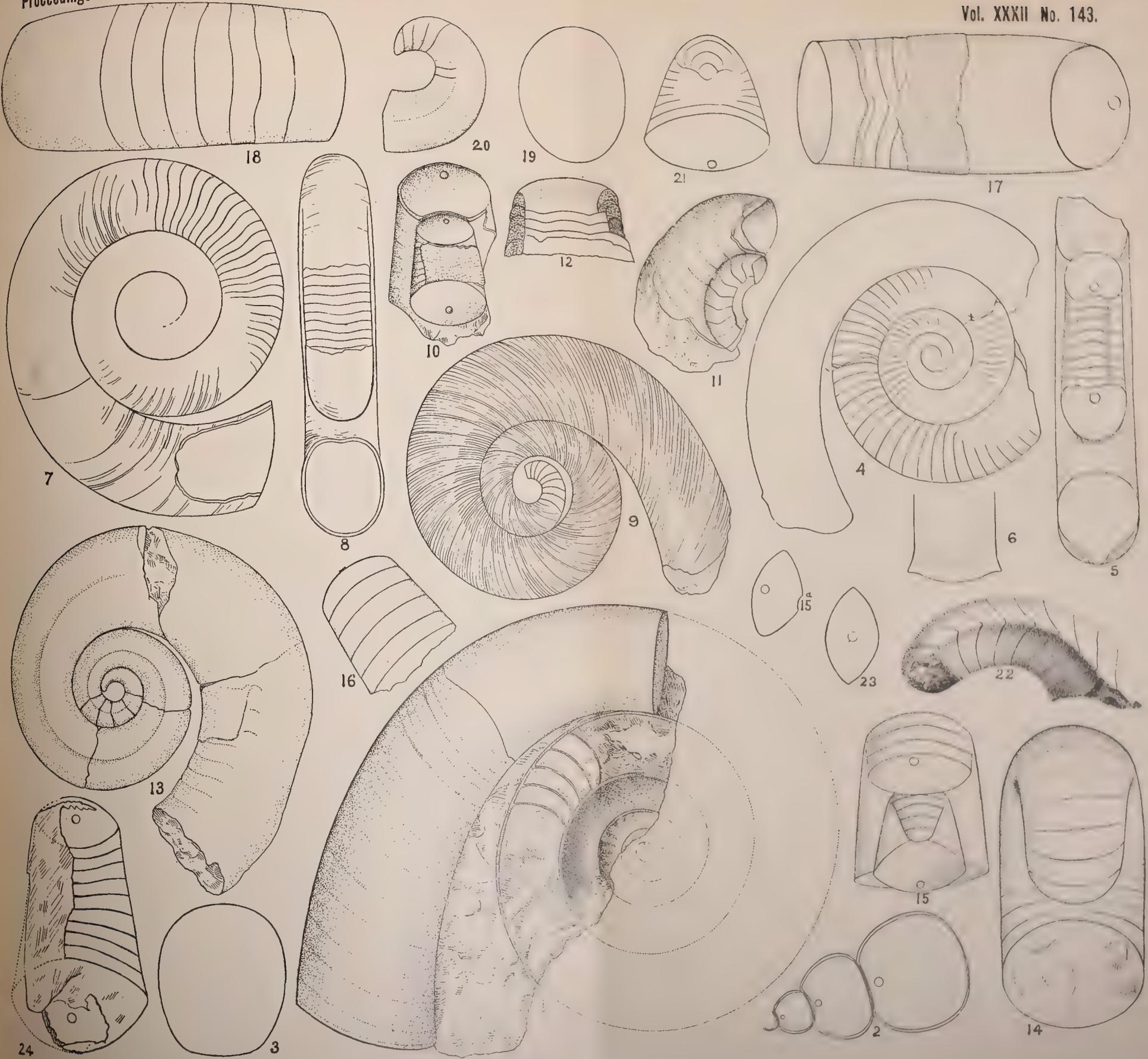
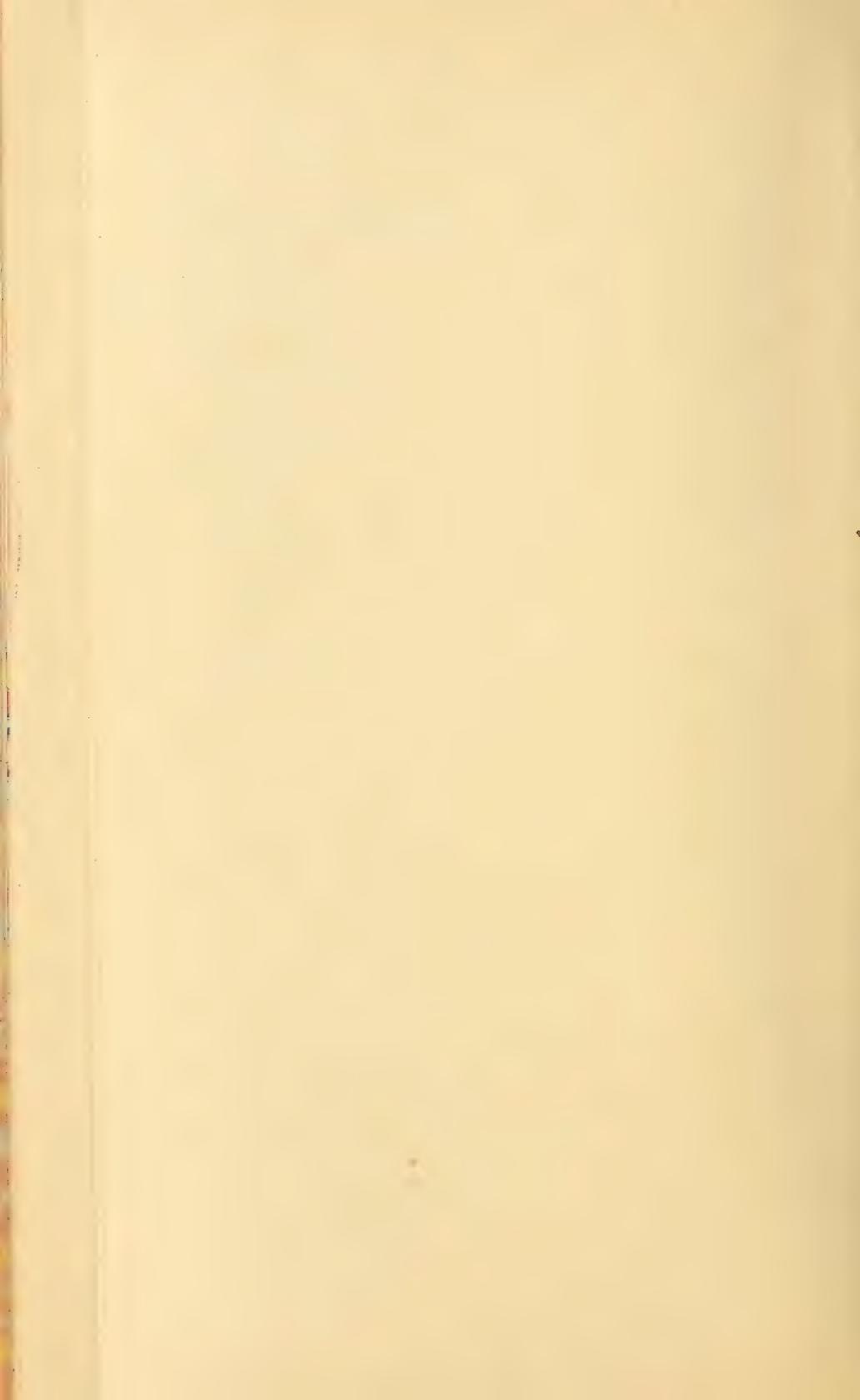


Plate VII (Hyatt).



saddles in the last three sutures of the paragerontic substage. Fig. 19, sectional view of terminal end of Figs. 17 and 18, showing dorsum slightly broader and flatter than venter.

Figs. 20 and 21. *Estonioceras imperfectum*, after Schröder, *op. cit.*, Pl. xxvii, Fig. 5 a, b, showing young enlarged with subventran siphuncle, etc., and no impressed zone.

Figs. 22-24. *Edaphoceras (Tennoch) notense*, *Met. W. Geol. Ill.*, v, Pl. xix, Fig. 3, much reduced in size. Fig. 23, the dorsum is more convex than the venter.

## PLATE VIII.

Figs. 1-8.\* *Remeloceras impressum*; no locality; Coll. Mus. Comp. Zoölogy. Natural size. Fig. 1, side view showing sutures and annular muscle in base of living chamber. Fig. 2, ventral side of fragment of same specimen. Fig. 3, dorsal side of same fragment with impressions of annular muscles on cast. Fig. 4, section of end of living chamber showing the decrease of the impressed zone in the anagerontic substage. Fig. 5, dorsal view of the second and younger fragment of same. Fig. 6, section of older end of same showing depth of impressed zone in the ephebic stage. Fig. 7, still younger fragment of same, showing the dorsal sutures of a late neanic or anephebic substage. Fig. 8, section.

Figs. 9-13. *Hercoceras mirum*, Barrande. Figs. 9-12, slightly enlarged, Koneprusy. Fig. 13, natural size, Hlubocerpy, Mus. of Comp. Zoölogy, Scharly Coll. Figs. 9 and 10, side view and front of the ananeanic substage showing first beginning of contact furrow and the trochoceran form of the young which is more marked than in the adult. Figs. 11 and 12, side view and front of paranepionic substage of the same specimen showing the absence of the dorsal furrow just before the apex is reached.

Figs. 14 and 15. *Hercoceras irregularis* (sp. Barrande), Hyatt; Loc., Bohemia; Mus. Comp. Zoöl. Fig. 14, side view of meta- and paranepionic volution, showing the peculiar costæ without longitudinal ridges of this genus. Fig. 15 shows the form in section of the meta- and paranepionic whorl and the absence of the contact furrow in correlation with the rounded form of whorl. The cæcum is not correct; this organ is large and ventrocran in this specimen.

Figs. 16-20. *Anomaloceras anomalum* (sp. Barrande), Hyatt; Mus. Comp. Zoölogy, Scharly Coll. Slightly enlarged. Fig. 16, section passing through umbilical perforation which is filled with a peculiar dense shell-like deposit, not found so far in other forms, and also cutting the meta- and paranepionic substages. The neanic stage with a deep impressed zone and the two sections of the outer whorl which are in the ephebic stage. The siphuncle appears to be nearer the centre in the metanepionic substage in this and in Fig. 17 than in the later stages. There is a dorsal furrow at the usual place beginning beyond the gyroceran curve in the paranepionic substage in correlation with the nephritic outline of this substage. Fig. 17, view of a section of the metanepionic and paranepionic substages of same cutting deeper into the umbilical perforation which is becoming narrower. Fig. 18, a still deeper cut which has passed through the apex of the conch and shows the first contact of the whorls. Fig. 19 shows the beginning of the contact zone, the paranepionic section having passed into the ananeanic and below the rounded anepionic has replaced the metanepionic volution. Fig. 20, a still deeper cut, showing the shell of the anepionic substage becoming broader through the approach of the section to the exterior of the anepionic apex. A shade farther and the ananeanic and metaneanic sections would blend into one long figure and the anepionic would disappear.

Figs. 21-23. *Discoceras Graftonense* (sp. Meek and Worthen), Hyatt; Loc., Waukesha, Wis., Niagara Group; Mus. Comp. Zoölogy, Day Coll. Natural size.

\*Fig. 1 has no number on the plate.





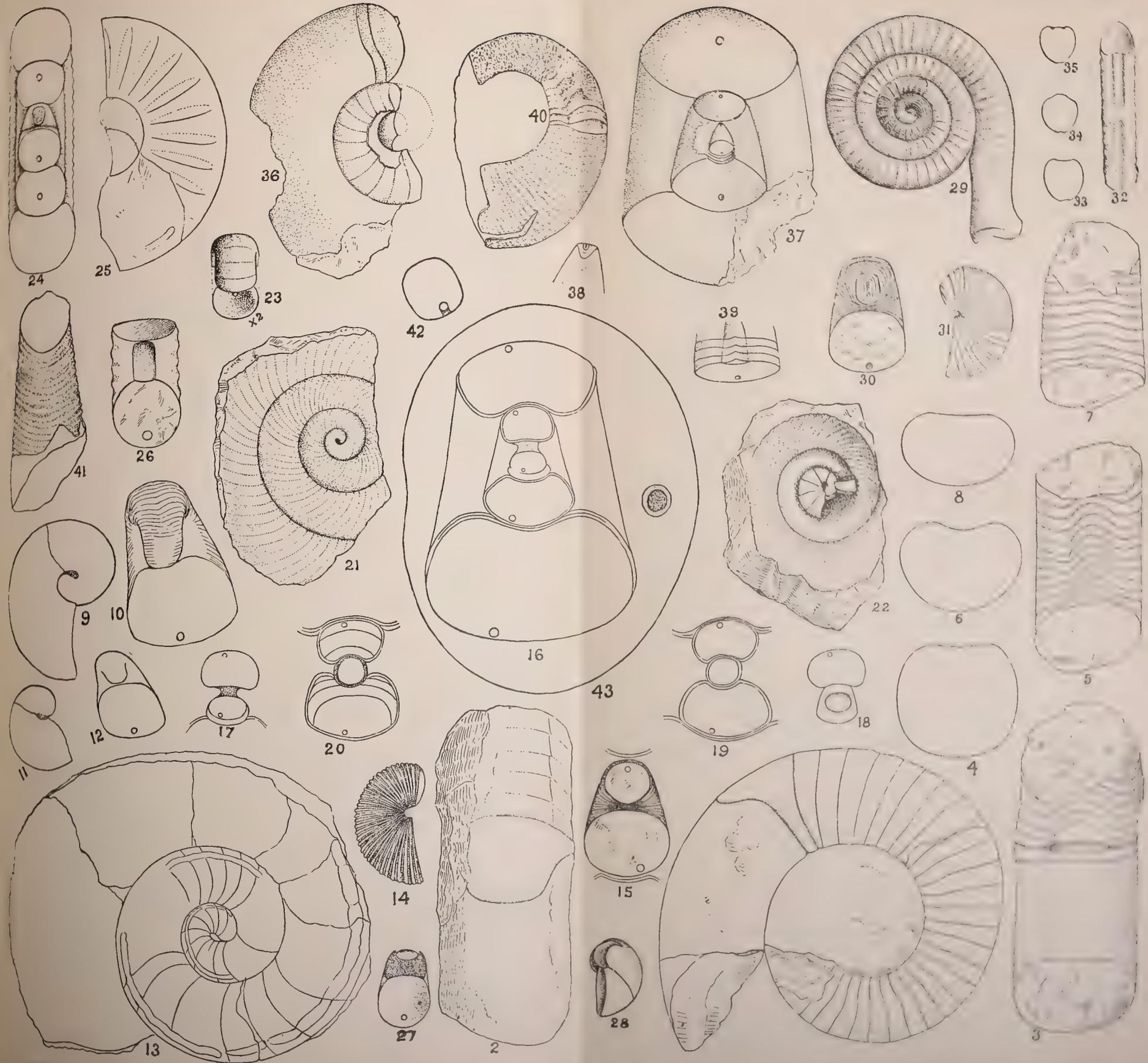


Plate VIII (Hyatt).

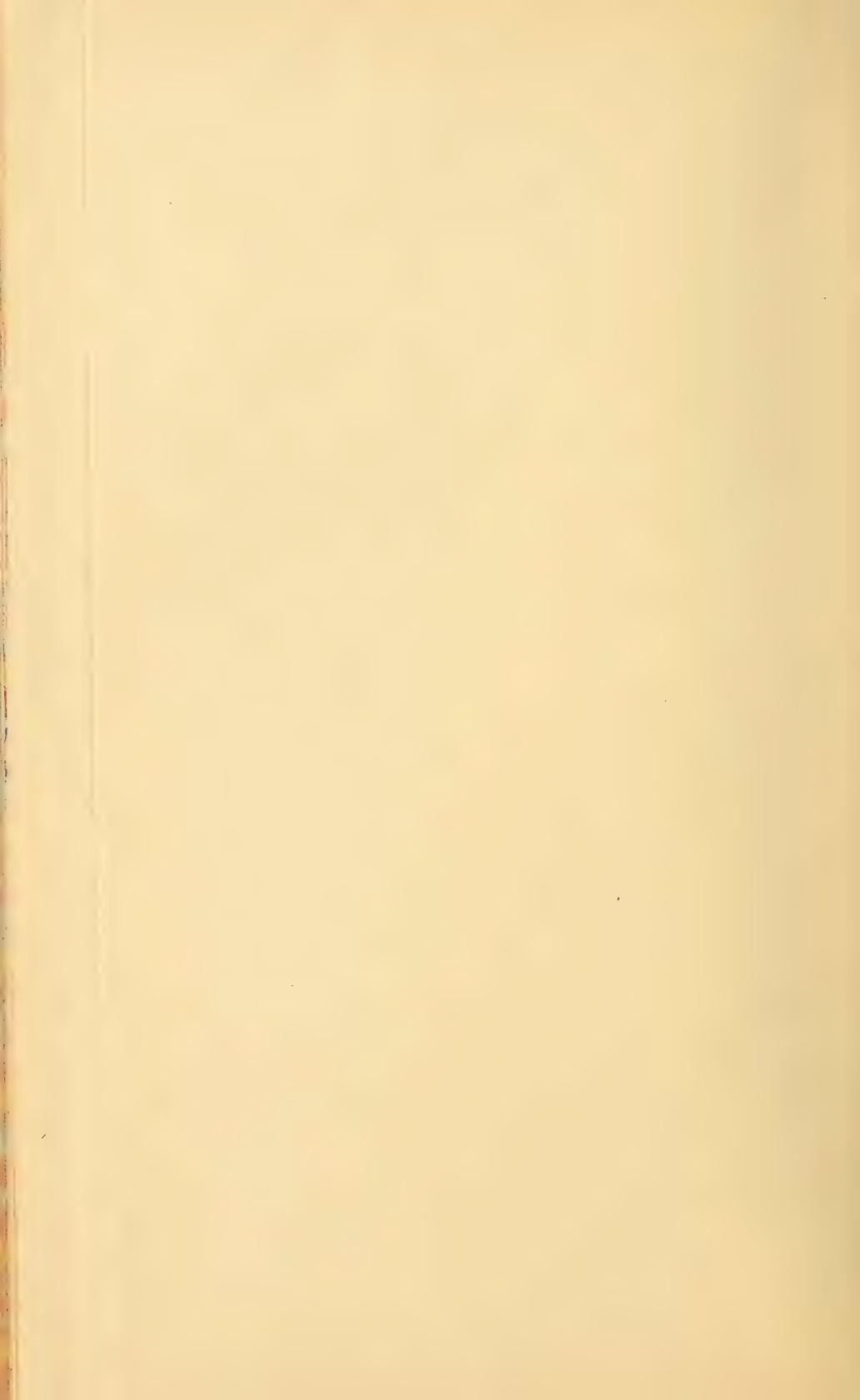


Fig. 21, side view of a cast of a mould of this species. Fig. 22, a similar specimen, but with nepionic stage and the beginning of the ananeanic substage in relief preserved in the centre, showing small umbilical perforation, subdorsan siphuncle (see also Fig. 23 for front view of same) and sutures. The sutures have slight ventral lobes in the ananeanic, but are almost if not quite straight on the venter of the paranepionic substage (shown in Fig. 23). The first suture was not visible in this specimen.

Figs. 24 and 25. *Ophidioceras tener*, Barrande; Mus. Comp. Zoölogy, Schary Coll.; Loc., Bohemia.  $\times 3$  diameters. Fig. 24, front view of section of neanic and ephebic volutions, the nepionic in relief in the centre. The outline of the ananeptic substage is given, but the cicatrix was unluckily destroyed by the incautious use of acid in cleaning it. The position of the siphuncle is nearer the venter than in older stages. Fig. 25, side view somewhat larger to show the constrictions on the nepionic whorl and the great comparative size of the apical chamber and the first suture and constriction.

Figs. 26-28. *Ophidioceras tessellatum*, Barrande; Mus. Comp. Zoölogy, Schary Coll. Fig. 26,  $\times 3$ , to show dorsal outline of paranepionic volution without a dorsal furrow and ananeanic dorsum just below this with the beginning of contact furrow made by envelopment of the apex. Figs. 27 and 28,  $\times 4$  diameters, to show similar characters to those of *O. tener*, and, the matrix filling the umbilical perforation having been retained, this specimen shows also just how the paranepionic volution strikes the apex. The absence of an impressed zone is also noted in the paranepionic and position of siphuncle.

Figs. 29-35. *Ophidioceras rudens*, Barrande; Loc., Bohemia; Mus. Comp. Zoölogy, Schary Coll. Fig. 29, natural size; Figs. 30 and 31,  $\times 4$  diameters; Figs. 32-35, natural size; Fig. 29, side view showing general form of this species and of the genus; Figs. 32-35 show the history of the contact furrow on free whorl with gibbous median dorsal face and lateral dorsal furrows or faces as in section 35, and also as on all of the close-coiled whorls. In the centre is the area of the spur, shown in section Fig. 34, and in the lower part is the modified contact furrow growing slightly narrower and shallower towards the aperture. Section of this part is given in Fig. 33; Figs. 30 and 31, side and front views of nepionic stage of another specimen showing cicatrix, form of ananeptic substage, which is a compressed almost quadrangular ellipse, metanepionic with venter broader than dorsum and paranepionic with dorsum broadening out more but still narrower than venter.

Figs. 36-39. *Endolobus avonensis* (sp. Dawson), Hyatt; Carboniferous; Loc., Joggins, Nova Scotia; Coll. L. Agassiz. Natural size. Fig. 36, side and front views showing the ana- and metanepionic substages in the centre (see also Fig. 38, enlarged view, showing form more accurately and cicatrix). The ananeptic substage coming in when the apex is reached and the absence of the impressed zone until after this contact is shown above the apex in Fig. 37. Below this is seen the dorsal sutures and deep impressed zone produced by contact (shown also in Fig. 39, more enlarged).

Figs. 40-42. *Mimoceras (Goniatites) lituum*, after Barrande, *op. cit.*, Pl. x, showing the young and probably the adult of this form without any impressed zone and its similarity to some species of Nautiloidea, reduced one-third.

Fig. 43. *Cranoceras* (*Cyrt.*) *lineatum* (sp. De Verneuil), Hyatt; Devonian, Palm near Gerolstein; Mus. Comp. Zoölogy, Schultze Coll. Fig. 43, outline to show the impressed zone which seems to appear in this cyrtoceran form in correlation with the nephritic outline independently of contact.

## PLATE IX.

Figs. 1 and 2. *Thoracoceras* (*Cyrt.*) *puzosianum* after De Koninck, *Calc. Carbon.* Pl. xxxiii, Figs. 10 and 11, to show in an adult of arcuate form the same ornamentation and form that are also present in the young of the more highly ornamented species like *Thoracoceras canaliculatum* and the young of many nautilian forms. See Figs. 11-13 of *Vestinautilus Konincki*.

Figs. 3 and 4. *Thoracoceras* (*Cyrt.*) *canaliculatum*, after De Koninck, *ibid.*, Pl. xxxiii, Fig. 9, to show the spinous character of the ornamentation produced by prominent lines of growth in crossing over the longitudinal ridges; also for comparison with the young of *Triboloceras*, *Vestinautilus*, *Rineceras*, etc.

Figs. 5-13. *Vestinautilus* (*Naut.*) *Konincki* (sp. De Koninck), Hyatt; Figs. 5-8, after De Koninck, *ibid.*, Pl. xxx, Fig. 1; Figs. 11-13, Hyatt, *Emb. Ceph.*, Pl. 4; Figs. 9 and 10 original. This series shows ontogeny of this species. Figs. 9 and 10, nepionic stage and ananeanic substage. Figs. 11-13, ananeanic and metanepionic with rounded whorl and cyrtoceran form and ornaments like *T. puzosianum*; the roughened spinous ornaments come in later in the paranepionic substage. The limit of the paranepionic is shown in Fig. 9, the ananeanic begins in last half of the first volution when the inner longitudinal ridges cease on the sides. Compare abdomen with ephebic stage of *Triboloceras*, Fig. 15. The ephebic stage begins near the end of the first half of the second volution when the gibbous face and the lateral dorsal flutes or faces begin to appear in the zone of involution as in Fig. 7. The anagerontic substage is shown in the loss of the ornaments in Figs. 5 and 6, and also in the diminution of the hollow central ventral zone and tendency of the abdomen to become rounded.

Figs. 14 and 15. *Triboloceras* (*Gyroc.*) *intermedium*, after De Koninck, *ibid.*, Pl. xxxiii, Fig. 4.

Figs. 16-19. *Vestinautilus* (*Naut.*) *pinguis*, after De Koninck, *ibid.*, Pl. xxx, Fig. 6 a-c, and Fig. 7 a, b. Figs. 18 and 19 show the anephebic substage with spinous ornaments, the loss of these in the succeeding part of the ephebic stage and the replacement of the ventral hollow zone, which is present in the nepionic stage of this species, by a gibbous face like that of the gerontic stage of *Konincki*. Figs. 16 and 17 show the paraphebic substage and anagerontic substage, the latter occurring through loss of the lateral fluted faces as in Fig. 5, of *Konincki*. In the succeeding gerontic substages the whorl loses its angularity.

Figs. 20 and 21. *Rineceras* (*Gyroc.*) *tessellatum*, after De Koninck, *ibid.*, Pl. xxxiii, Fig. 5, 5 a.

Figs. 24 and 25. *Lispeceras* (*Naut.*) *sulciferum*, after De Koninck, *ibid.*, Pl. xxxi, Fig. 7 a, b.

Figs. 26 and 27. *Phacoceras* (*Naut.*) *oxystomum*, after De Koninck, *ibid.*, Pl. xvii, Fig. 3.





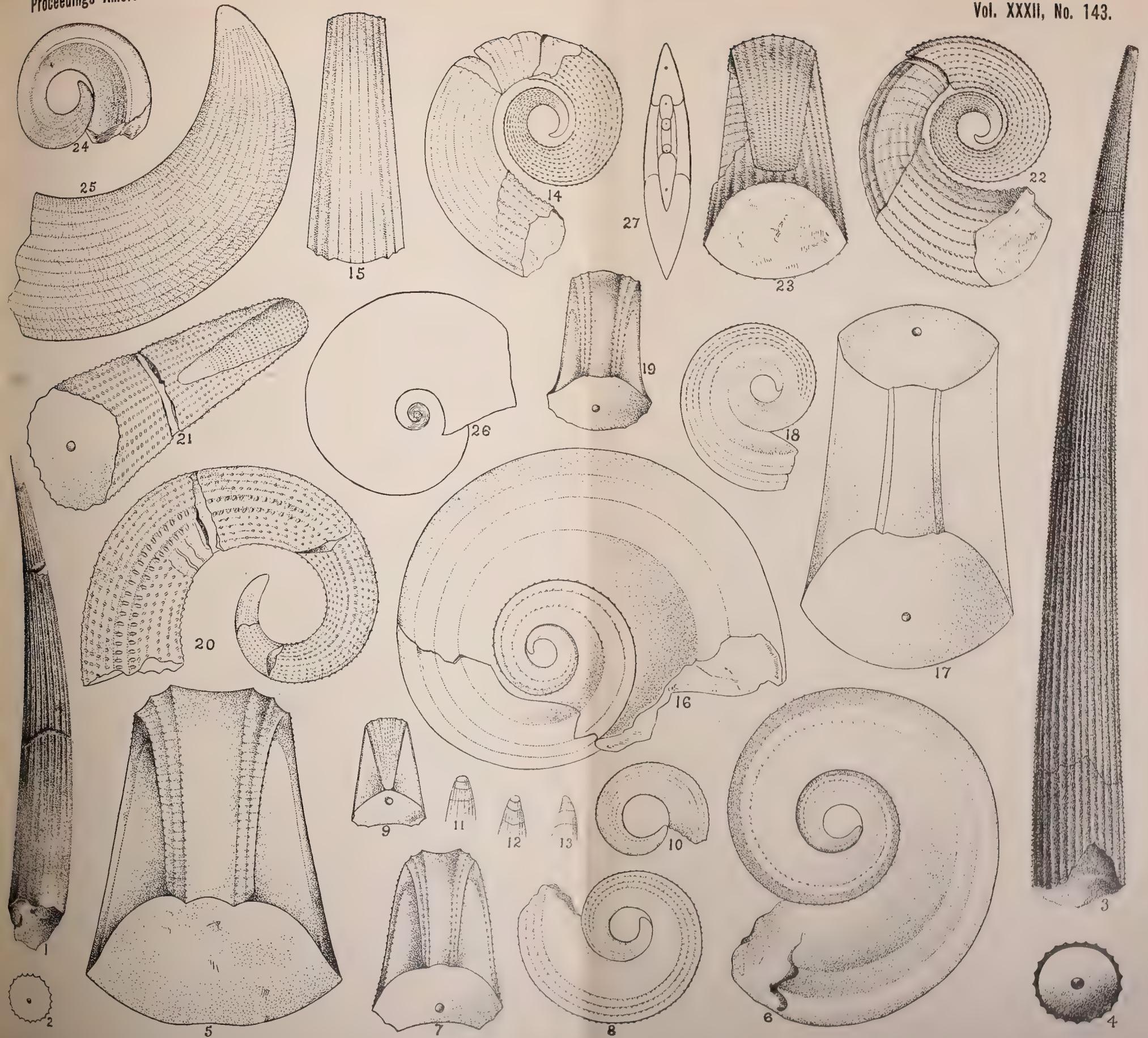
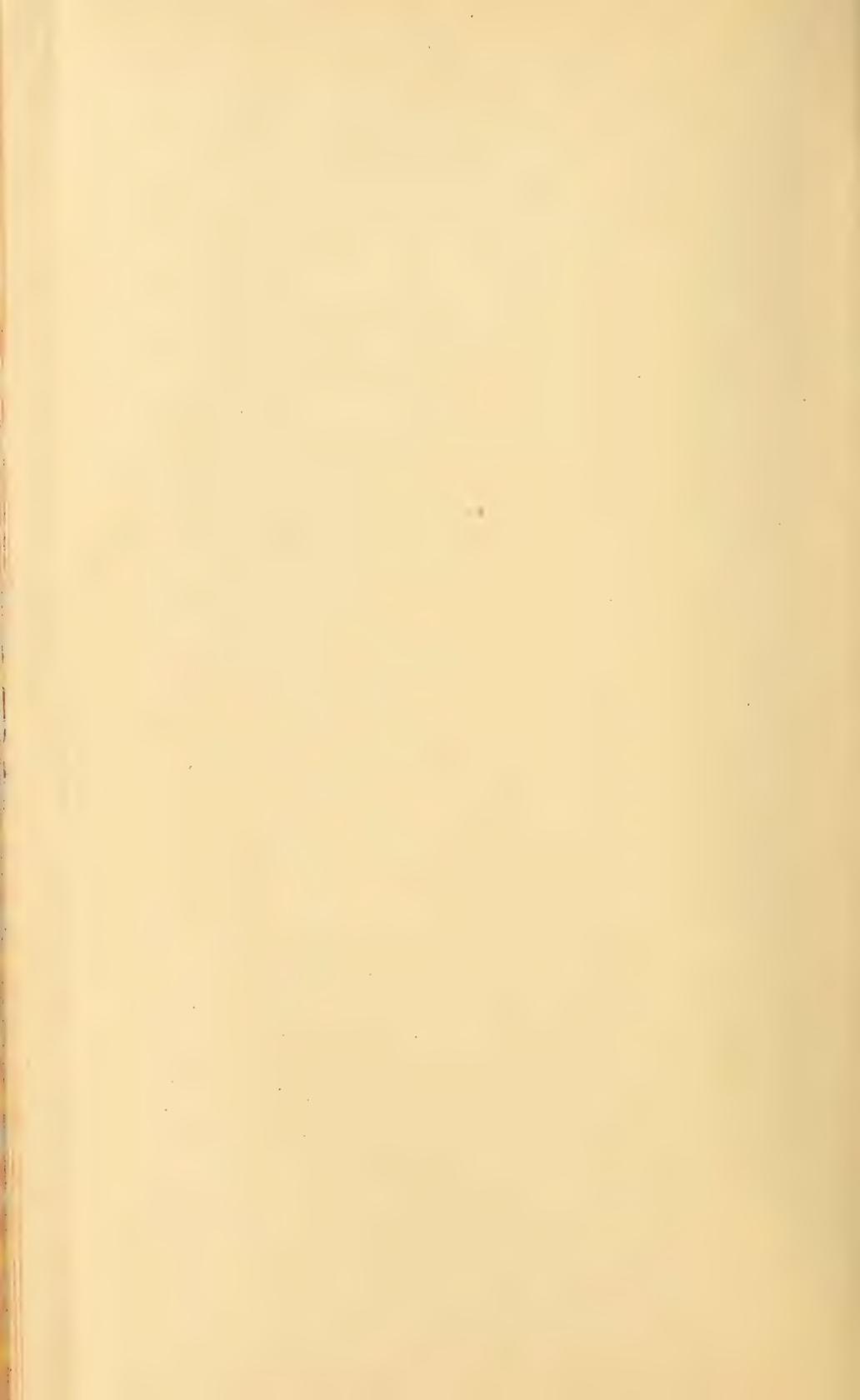


Plate IX (Hyatt).





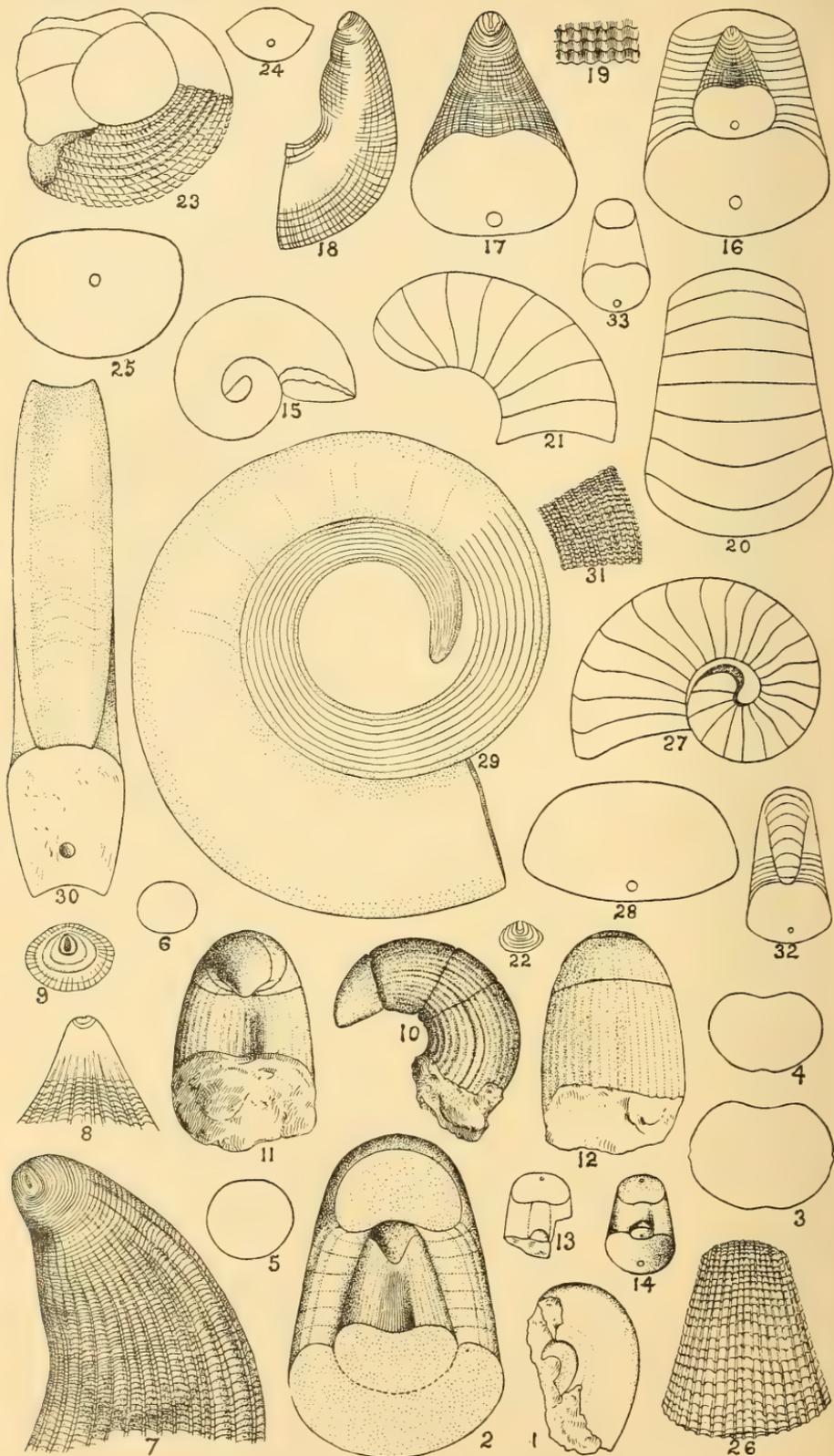


Plate X (Hyatt).

## PLATE X.

Figs. 1-14. *Coloceras (Naut.) globatum* (sp. De Koninck), Hyatt; Loc., Visé, Belgium, Carboniferous; Coll. De Koninck, Mus. Comp. Zoölogy.

Fig. 1. Side view of nepionic and neanic volution, natural size. Fig. 2, same enlarged in front view and ends of volutions restored; compare neanic volution with the gerontic volution of *Vestinautilus pinguis*, Pl. ix, Fig. 17; it will be seen that this genus resembles the latter in the lateral fluted faces, but has rounded sides, such as have been described as appearing in the paragerontic substage of that species; Fig. 2 also shows the impressed zone well-developed in the paranepionic substage. Figs 3-6, sections of meta- and paranepionic substage of Fig. 10, showing development of outline and correlation of impressed zone with nephritic form. The ananeanic substage begins immediately after this on the latter half of the still uncoiled first volution and then the longitudinal ridges disappear on the abdomen and also the crease or hollow central ventral zone, the section becomes in the metaneanic similar to that of the upper volution in Fig. 2. Fig. 7, enlarged oblique view of apex of same, showing the ana- and metanepionic substages and the beginning of the impressed zone in a shaded crescent near the base of the figure. Fig. 8, view of venter of another specimen ananepionic and a part of metanepionic showing the beginning of the hyponomic sinus in the bands of growth. Fig. 9, end view of same with cicatrix. Figs. 10-12, views of another specimen showing the first three sutures, impressed zone and ventral hollow zone of the paranepionic substage. Fig. 13, shows the impressed zone of the ananeanic substage and the beginning of the true impressed zone after contact in the shaded crescent-like depression from which the apex has been removed. Fig. 14, another specimen of same age with the pseudo-impressed zone and the apex (ananepionic substage) in place. In all sections the venter is the lower side.

Figs. 15-22. *Potoceras dubium*. Fig. 15, side view slightly enlarged showing shape of umbilical perforation and abrupt bending of the paranepionic substage when the zone begins. Fig. 16, front view of ana-, meta- and paranepionic substages and neanic volution in part. Figs. 17 and 18, enlarged views of same without the neanic volution. Fig. 19, enlarged view of details of bands of growth and longitudinal ridges taken from same. Figs. 20 and 21, views of ephelic volution, natural size. The history of the impressed zone is parallel with that of *Coloceras* except that it comes in only after the abrupt bending of the first whorl, and the form and character of the ana- and metanepionic substages differ. Fig. 22, view of the ananepionic substage showing the flattened aspect of apex. Figs. 22 and 9 (the latter described above) are, however, more distinct than the specimens.

Figs. 23-26. *Ephippioceras (Naut.) ferratum* (sp. Owen), Hyatt; Loc., Edmondson Co., Ky., Carboniferous; Mus. Comp Zoölogy. Enlarged four diameters. Fig. 23, side of fragment of paranepionic substage, showing also umbilical perforation, apex restored and fragment of cast of ananeanic substage with parts of two sutures. Fig. 26, venter of same. The longitudinal ridges are wider apart and broader at their crests on the sides than on the central parts of the venter as shown in Fig. 23. Figs. 24 and 25 show sections of both ends of the fragment covered by shell in Fig. 23.

Figs. 27 and 28. *Temnocheilus (Naut.) subtuberculatum* (sp. Sandberger), Hyatt; Loc., Wissenbach; Coll. Mus. Comp. Zoölogy; Devonian.

Fig. 27, side view of ana-, meta- and paranepionic and perhaps beginning of ananeanic substages before the whorls touch. It will be observed that the apex is not enveloped even in this closely coiled form and that the dorsal furrow is not present at the end of the volution, Fig. 27, which is given in the section Fig. 28.

Figs. 29-31. *Apheloceras (Naut.) mutabile* (sp. D'Orb.), Hyatt; Loc., Carboniferous; after D'Orbigny, *Pal. Universelle*, Pl. lxxxviii, Figs. 1, 2 and 4. Show the free apex and moulding of the dorsum to fit the hollow venter of this species. Fig. 31 shows the surface of the shell of earlier substages.

Fig. 32. *Metacoceras cavatiformis* (same specimen as Figs. 16-19, p. 496 of this paper) showing the beginning of the impressed zone at contact with the apex.

Fig. 33. *Calogasteroceras canaliculatum*, Hyatt; Loc., Edmondson Co., Ky.; Mus. Comp. Zoöl.; Carboniferous. A section across the meta- and paranepionic volution showing the large umbilical perforation, comparatively slow increase in size of the first whorl and presence of a dorsal furrow in the paranepionic substage.



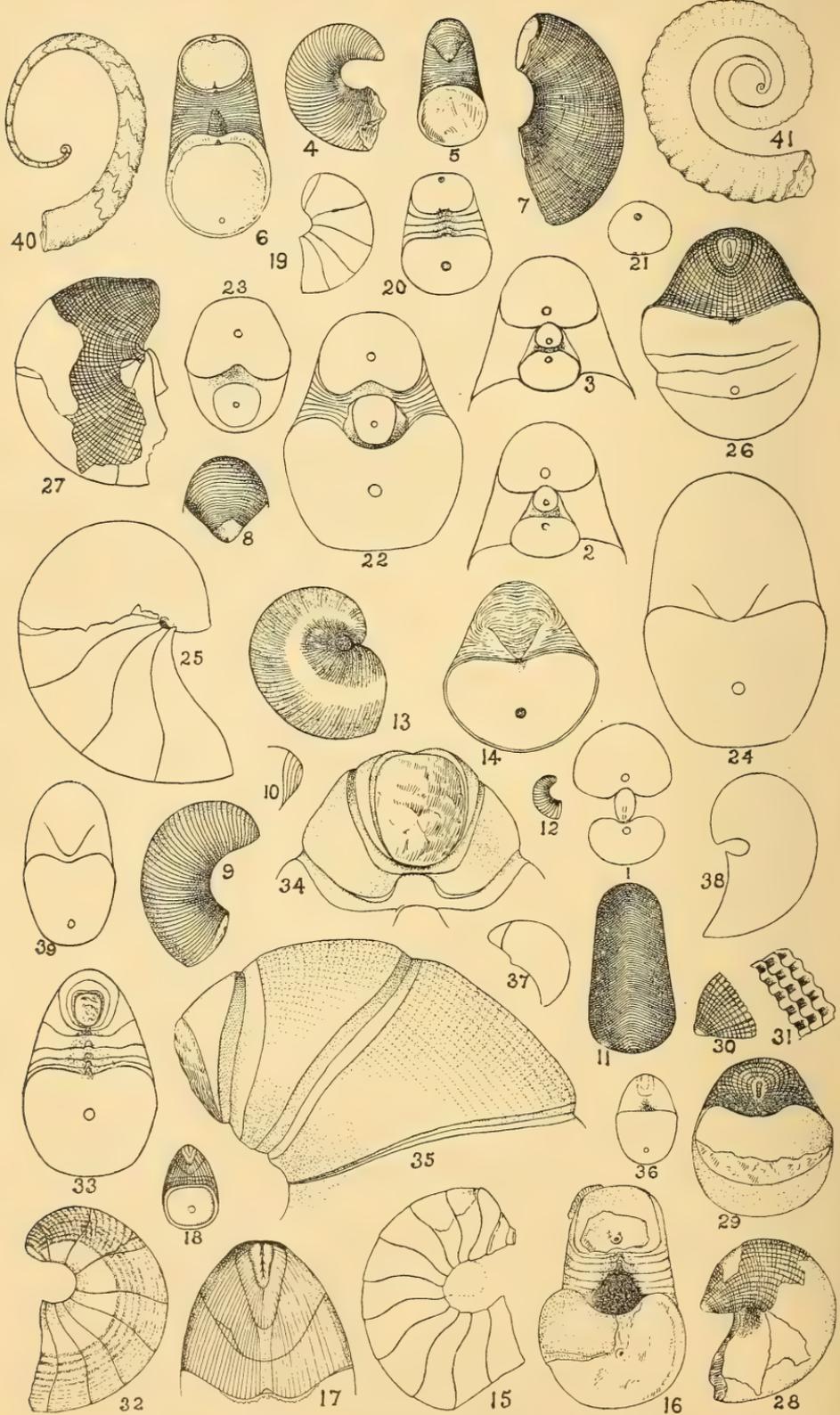


Plate XI (Hyatt).

## PLATE XI.

Figs. 1-3. *Peripetoceras* (Naut.) *Frieslebeni* (sp. Geinitz); Loc., Tunstall Hill, England; Mus. Comp. Zoöl.; Dyas. Natural size. Fig. 1 shows the section through the apex of the conch, the ananeanic volution below and a later age of the neanic stage above. Fig. 2, the cut has passed through the umbilical perforation, the metanepionic above this and the paranepionic below; above the metanepionic is the paraneanic or anephebic substage. Fig. 3, the cut has approached the farther side of the umbilical perforation and shows an older age of the metanepionic and a younger age of the paranepionic with a deeper and better defined dorsal furrow than in Fig. 2.

Figs. 4-8. *Syringoceras* (Naut.) *granulosostriatus*, after Mojsisovic's *Medit. Triaspr.*, Pl. lxxxii, Figs. 7 and 9, Trias. Figs. 4 and 5, nepionic stage enlarged. Fig. 8, more enlarged view of apex, with a cicatrix. Figs. 6 and 7, paranepionic and ananeanic substage with longitudinal striations and beginning of impressed zone after contact.

Figs. 9-12. *Syringoceras* (Naut.) *Linearis*, after Laube; *Fauna St. Cassian Denksch. Akad. Wien*, 1869, Pl. xxxvi, Trias. Fig. 12, natural size. Figs. 9-11, enlarged. Fig. 10, to show more accurately shape of apex. All show nepionic stage and development same as in *granulosostriatus*.

Figs. 13 and 14. *Digonicoceras* (Naut.) *excavatum*, after D'Orbigny, *Terr. Jurass.*, Pl. xxx, Lias. These show the nepionic stage with an impressed zone existing before contact, also the annular lobe.

Figs. 15 and 16. *Cenoceras* (Naut.) *intermedium* (sp. Sow.), Balingen, De Koninck Coll. Mus. Comp. Zoöl.; Middle Lias. Slightly enlarged. These show the large umbilical perforation and sutures, the paranepionic and ananeanic substages. The dorsal furrow is present only in the paranepionic substage and the beginning of the contact furrow is shown also in the shaded area on the dorsum of Fig. 16.

Figs. 17 and 18. *Cenoceras* (Naut.) *intermedius* (?) (sp. Sow.), after Barande and Hyatt, *Syst. Sil.*, Pl. cccclxxxix, Fig. 7; D'Orbigny Coll. Jarden des Plantes; Middle Lias. These show the ana- and metanepionic substages with cicatrix and sutures, but no impressed zone.

Figs. 19-21. *Digonicoceras* sp. ? (similar to *excavatus*), Balingen; De Koninck Coll., Mus. Comp. Zoöl.; Middle Lias. Natural size. Fig. 19 shows sutures, etc., of paranepionic substage. Fig. 20 gives outline of same from dorsum with the dorsal furrow in the paranepionic, the upper outline of this figure is incorrect since the dorsal furrow begins immediately below this. Fig. 21 gives this outline correctly, it being the last of the ananeanic substage at the second suture; in Fig. 21, the venter is placed uppermost for comparison with Fig. 20.

Figs. 22-27. *Cenoceras lineatum* (sp. Sow.), Bayeux; Coll. Duval, Mus. Comp. Zoölogy; Inferior Ool. Fig. 22, natural size, showing umbilical perforation, metanepionic substage below perforation and paranepionic above this, the neanic stage being below the metanepionic volution. The dorsal furrow is well developed in the paranepionic substage. Fig. 23, the reverse of the two upper sections of Fig. 22.

Figs. 24 and 25, views of another specimen, showing the nepionic stage, enlarged 3 diameters, showing the position of the siphuncle ventrad of centre and

dorsal furrow in paranepionic substage. The sutures, of course, belong to the neanic stage. Fig. 25 shows the minute umbilical perforation and the close coiling of the whorl. Figs. 26 and 27, apex of same, enlarged 3 diameters and giving ornamentation of shell and cicatrix. The dorsal furrow begins at the first or gyroceran bend in the paranepionic substage.

Figs. 28-31. *Cenoceras lineatum* (?), *Oolite (Naut.) aratus* of Quenstedt's Coll., Tübingen, from sketches in my notes, showing the nepionic stage with dorsal furrow as in *lineatus*.

Figs. 32-35. *Cenoceras (Naut.) aratus*, Saemann's original specimen; Mus. Comp. Zoölogy; Middle Lias; Suabia. Figs. 32 and 33, enlarged 2 diameters, showing markings on the cast, form of nepionic stage, large umbilical perforation and sutures. The shell probably had longitudinal ridges and bands of growth on the dorsum as well as on the venter. Figs. 34 and 35, copied from *Embryology Ceph.*, Hyatt, Pl. iv, much enlarged and corrected to show ana- and metanepionic substages and annular lobe, which begins in the third suture. The dorsal furrow begins between the third and fourth sutures, the last being the oldest in Fig. 35. The curvature is uniform, gradual, and there is apparently no mechanical cause for its early appearance in this shell.

Figs. 36-39. *Cenoceras (Naut.) granulosus* (sp. D'Orb.), Chatillon; Coll. Boucault, Oxfordian; Coll. Mus. Comp. Zoöl. Slightly enlarged. Figs. 36 and 37, showing extraordinary quick growth of the dorso-ventral diameters in ana- and metanepionic substages and beginning of paranepionic with dorsal furrow in what is probably the fourth septum. Figs. 38 and 39, similar views of another older specimen in paranepionic substage. See also Pl. xii, Fig. 31.

Fig. 40. *Crioceras* (?) *Studeri*, Ooster, after Barrande, Callovian, much enlarged, to show the close-coiled first volution.

Fig. 41. *Ancyloceras* (?) *calloviense*, after Barrande, Callovian, much enlarged, to show the close-coiled young.



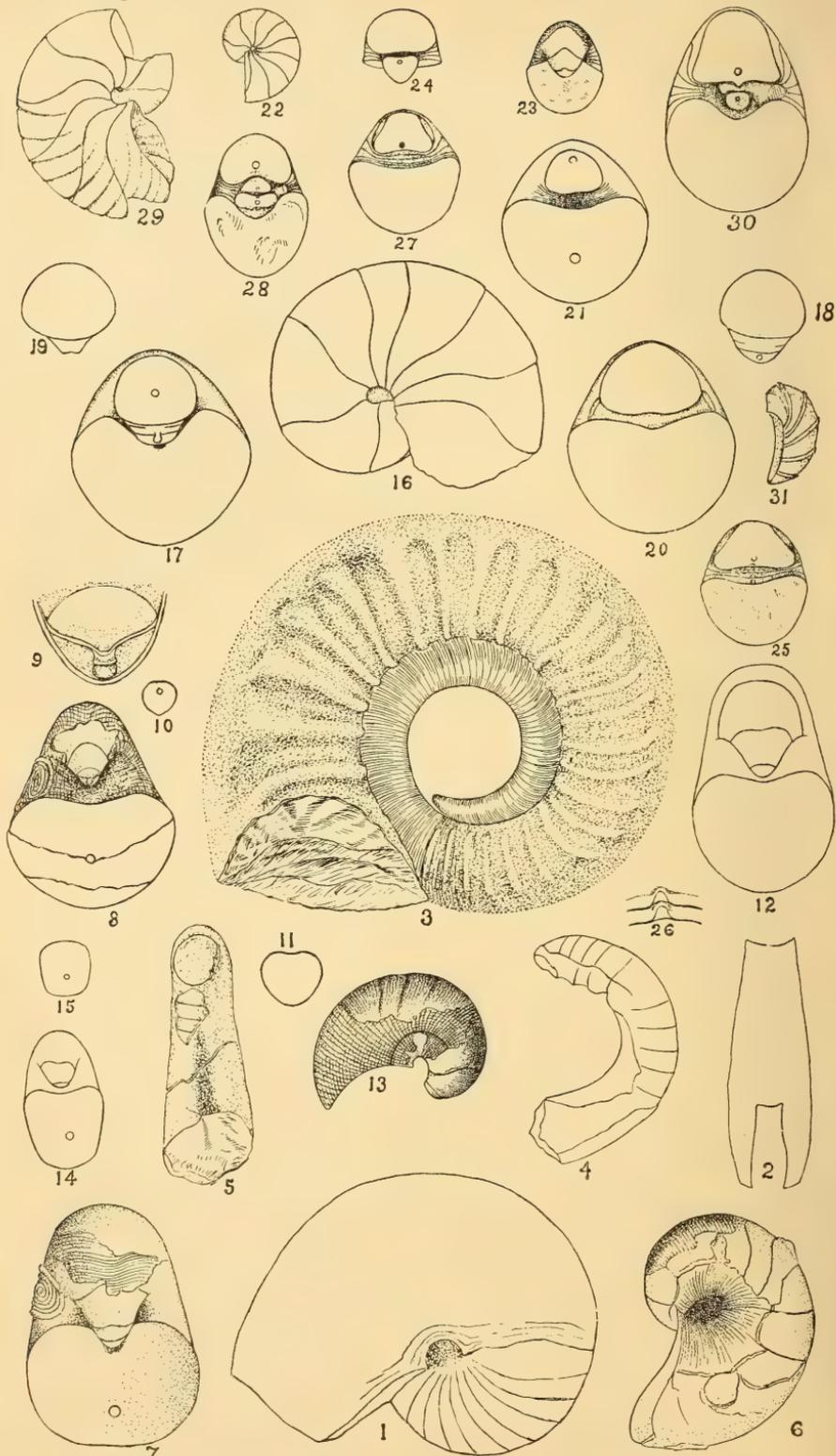


Plate XII (Hyatt).

## PLATE XII.

Figs. 1 and 2. *Diorugoceras* (*Naut.*) *planidorsatum*, after Portlock, *Geol. Rep. Londonderry*, etc., Pl. xxxv, Fig. 1; Carboniferous. Fig. 1, side view, reduced considerably. Fig. 2, section of outer whorl showing how completely the contact furrow is moulded to the form of the whorl.

Figs. 3-5. *Pleuromutilus superbus*, after Mojsisovics, *Das Gebirge um Hallstadt*, i, Pl. xviii, Trias. Fig. 3, reduced one-third, showing the striated nepionic stage, the very large umbilical perforation, free ananepionic substage, also the close-coiled stages. Figs. 4 and 5, lateral, dorsal views of the fragment of what is probably another species reduced one-third, showing an impressed zone as described and figured by Mojsisovics.\*

Figs. 6-11. *Digonoceras rotundum*, Oolite; Coll. Mus. Comp. Zoölogy; no locality.

Figs. 6 and 7, side and front views of nepionic stage and ananeanic substage, natural size, showing especially the large, pear-shaped umbilical perforation and the amount of involution which covers only about one half of the side. The outer part of Fig. 6 still has remnants of the dorsal shell of the enveloping neanic and ephebic whorl and parts of four septa clinging to it. Two older sutures in the paranepionic volution and two younger in the metanepionic volution are also shown and first to the third are seen in Fig. 7, which also shows the narrow ana- and metanepionic substages. Fig. 8, the same broken down, showing the apical chamber and cæum enlarged in Fig. 9. Fig. 10, section of ananepionic substage at first septum. Fig. 11, section of metanepionic passing apicad of second septum and showing early beginning of impressed zone, both have the venter downwards.

Fig. 12. *Cenoceras* (*Naut.*) *clausum*, after Barrande and Hyatt, *Syst. Sil.*, Pl. cccclxxxix; D'Orb. Coll. Jardin des Plantes; Oolite; somewhat enlarged, shows the well-defined impressed zone in the paranepionic substage and the first three sutures.

Figs. 13-15. *Cenoceras* (*Naut.*) *clausum* (?), St. Vigor le Grand near Bayeux, Bronn Coll. Mus. Comp. Zoöl.; Lower Oolite. Fig. 13, somewhat enlarged, showing the shape of umbilical perforation and ana-, meta- and part of paranepionic substages. The amount of involution is shown by the dark line. Fig. 14, front view of same, natural size. Fig. 15, enlarged to show shape of ananepionic substage at first septum, the venter down.

Figs. 16-21. *Cymatoceras* (*Naut.*) (sp. ?), Texas. Fig. 16, side view of nepionic stage, and ananeanic substage with sutures enlarged two diameters. The approximation of the fourth and fifth sutures appeared in several specimens of the young of this species. The third and fourth sutures are too close together in this drawing and the spaces between the fifth, sixth, seventh and eighth, somewhat too wide. The spaces between these last are not so wide as that between the third and fourth in the original, this space being also slightly less than that between the second and third. Fig. 17, section of apex and ananeanic substage enlarged two diameters with the deep zone of contact. Figs. 18 and 19, the appearance of the

\* See p. 547, above.

apex as the grinding plane passed inwards. Fig. 20, same showing the metanepionic and paranepionic, both with dorsal furrows opposed to each other. Fig. 21, section of ana- and paranepionic volutions. This cut passed in the plane of the first septum, truncating the fundus of this and then obliquely across the suture line of the fourth septum. The second suture has a well-defined annular lobe and cone.

Figs. 22-27. *Cymatoceras (Naut.) deslongchampsianum* (sp. D'Orb.); Rouen; Coll. Boucault and Bronn; Mus. Comp. Zoöl.; Cretaceous. Figs. 22 and 23, side and front views, natural size, nepionic stage and ananeanic substage (this shell has faint longitudinal ridges and transverse bands on the casts not shown in any drawings) the sutures and small umbilical perforations are shown. Fig. 24 shows metanepionic outline at second septum and paranepionic between the fifth and sixth septum of the same specimen, both with dorsal furrows. Fig. 25, the reverse of the same specimen. Figs. 24 and 26, part of cast of chambers in the dorsal furrow of Fig. 24, showing the annular lobes. Fig. 27, another specimen showing ananepionic substage at the first septum with a dorsal furrow, and paranepionic also with dorsal furrow between fifth and sixth septa.

Fig. 28. *Cymatoceras (Naut.) simplex* (?); Yeoville, England; Coll. De Koninck, Mus. Comp. Zoöl.; Cretaceous; showing the nepionic volution and part of the neanic stage. The slight subangular, umbilical shoulders which begin to appear in the anephebic substage. The longitudinal ridges and transverse bands are absent on this cast, but this may be due to the state of preservation.

Figs. 29 and 30. *Cymatoceras (Naut.) radiatum* (sp. Sow.); Rouen; Boucault Coll., Mus. Comp. Zoöl.; Craie Chlorite. Natural size. Fig. 29, side view showing the fourth and subsequent sutures with the broad bands and constrictions beginning in the ananeanic substage. In this the eighth and ninth sutures show closer approximation than any of the preceding. Fig. 30 shows the same with the ananepionic substage at the first septum and the paranepionic at the fifth. The dorsal furrow begins immediately between the first and second septum in the metanepionic substage as is shown by the cast of umbilical perforation and by Fig. 1, Pl. xiii.

Fig. 31. *Cenoceras granulosis*, showing the ana- and metanepionic substages with fragment of the dorsal shell and septa of the ananeanic whorl clinging to the venter indicating the amount of involution and the depth of the contact zone.



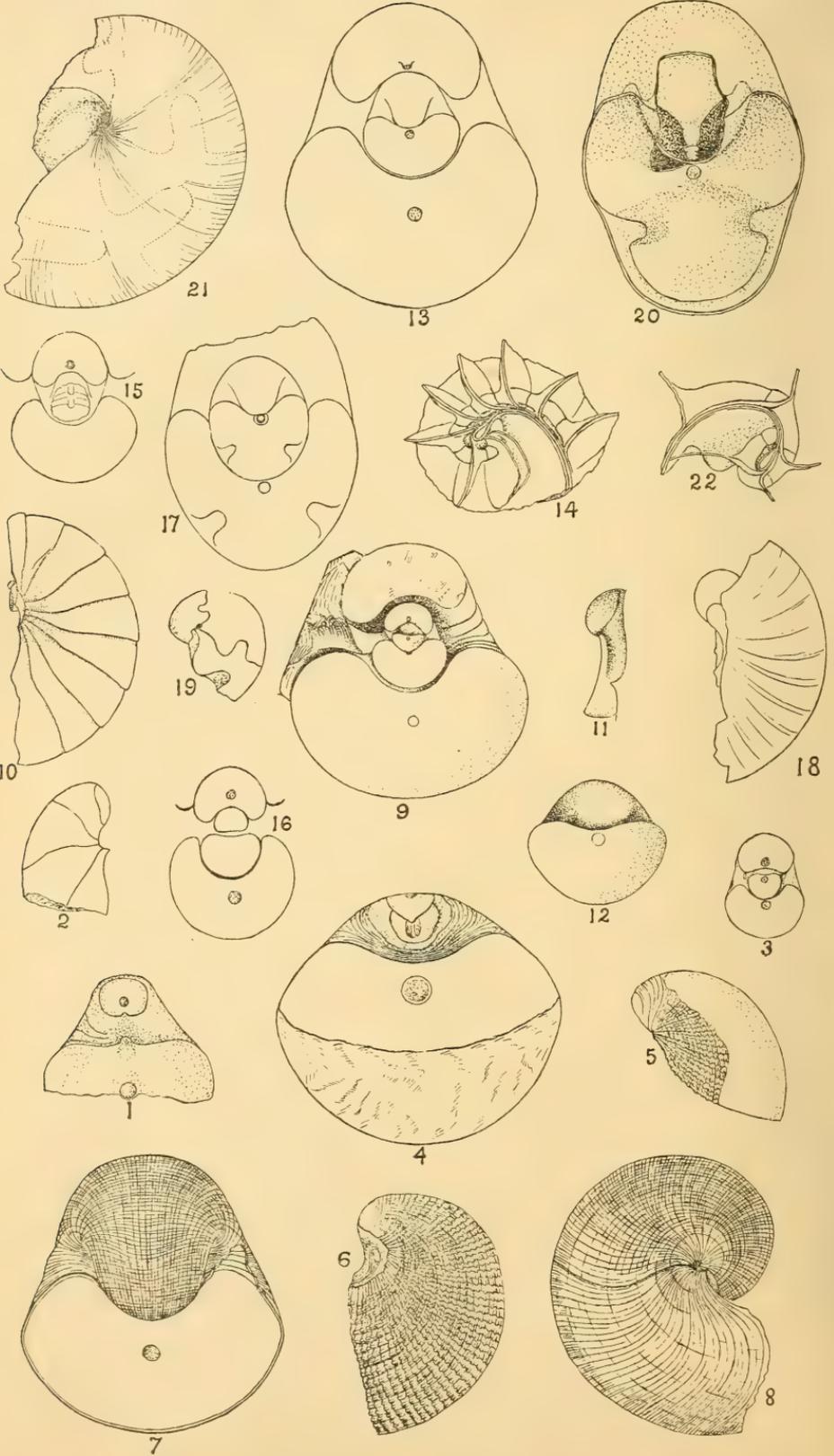


Plate XIII (Hyatt).

## PLATE XIII.

Figs. 1 and 2. *Cymatoceras (Naut.) radiatum*, showing the reverse of Fig. 30, Pl. 12, enlarged to 2 diameters. The beginning of the dorsal furrow is indicated by the shaded area reaching from near the first septum to the edge of the lower or fifth septum.

Fig. 2, side view of same, showing that the dorsal furrow began on the dorsum of the metanepionic substage between the first and second septa and in advance of the gyroceran bend.

Fig. 3. *Eutrephoceras* (sp. ?); Loc., France; Duval Coll., Mus. Comp. Zoöl.; Cretaceous; natural size; showing the dorsal furrow in the meta- and paranepionic substages and section of the ananeanic stage below.

Figs. 4-8. *Eutrephoceras De Kayi*, Dakotah, Cretaceous, preparations by Henry Brooks. Fig. 4, enlarged 6 diameters, and Fig. 5 same, enlarged 4 diameters, view of ana-, meta- and part of paranepionic substages. The citatrix is a double depression and the ananeptic outline is given just beyond this. There is a plate of the nacreous layer ventrad of this and partly covering it, with a shaded area. This spot is evidently the apex of the cæcum seen through the nacre. The two first substages are very short and smooth, but the dorsal furrow is present although exceedingly shallow before the bending begins in the later metanepionic. The umbilical perforation is present, as shown in Fig. 4, but is very small and elongated, comma-like in shape. Fig. 6, enlarged 4 diameters, shows the perforation in an older stage, but it is not correctly given. It is exposed by shaving off the angle of the last septum and the perforation is consequently actually the reverse of what it is in the centre of the umbilicus. This preparation, however, does show accurately the contact of the paranepionic dorsum with the dorsal side of the ananeptic substage and how close the coiling is. Figs. 7 and 8, side and front view enlarged 2 diameters of the meta- and paranepionic substages, the ornamentation becoming less in the latter which is terminated by a permanent constriction in this specimen, and also the anephebic substage in which the longitudinal ridges disappear and bands of growth assume the fine unbroken outlines of the adult. Fig. 7 is erroneous in making too great difference between the ventral lines of growth in the young parts of the whorl. The hyponomic sinus really appears about the middle of the paranepionic substage.

Figs. 9-12. *Eutrephoceras Faxoense*, Faxoe, Denmark; Krantz Coll., Mus. Comp. Zoölogy; Cretaceous. Fig. 9, front view, natural size, showing the cast of the umbilicus continuous with the very small umbilical perforation of the young. Fig. 10, side view of the same specimen. Fig. 11, young with first septum delineated. Fig. 12, front view of same, showing the aspect of the apex and the umbilical perforation, the dorsal furrow apparently beginning as in *Eutrephoceras De Kayi*. Both of these are enlarged 4 diameters.

Figs. 13-16. *Eutrephoceras (Naut.) imperialis* (sp. Sow.); Isle of Sheppy and Isle of Wight; Mus. Comp. Zoölogy; Tertiary. Fig. 13, front view of inner whorls enlarged 2 diameters. Fig. 14, fragment of nepionic or neanic stages, showing the minute umbilical perforation, the absolutely subsorsan position of siphuncle in these early substages. This specimen has a double first septum. Fig. 15, front of specimen from Isle of Sheppy, showing similar position of

siphuncle at about the same age. Fig. 16, another specimen from same locality, showing the dorsal furrow in both metanepionic and paranepionic substages. Both the last are enlarged 2 diameters.

Figs. 17-19. *Aturia Morissi Michellotti*; Baldasserer, Mus. Comp. Zoölogy; Tertiary. Figs. 17 and 18, front and side views of the nepionic and neanic stages enlarged 6 diameters. Fig. 19, nepionic stage, showing the umbilical perforation, seen from the exterior as a small black spot.

Figs. 20-22. *Aturia zizac*, Sow.; Mus. Comp. Zoölogy; Tertiary. Figs. 20 and 21, side or front view of specimen from Dax, Bronn Coll., enlarged ten times, showing apical character, siphuncle, first septum with deep lobes and cæcum. Fig. 22, side view of fragment of another specimen with umbilical perforation, ananeponic substage in section and siphuncle.

#### PLATE XIV.

Fig. 1. *Eutrephoceras De Kayi*. Reduced one-third. Two dorsal sutures, showing the linguæ form, minute, median saddles.

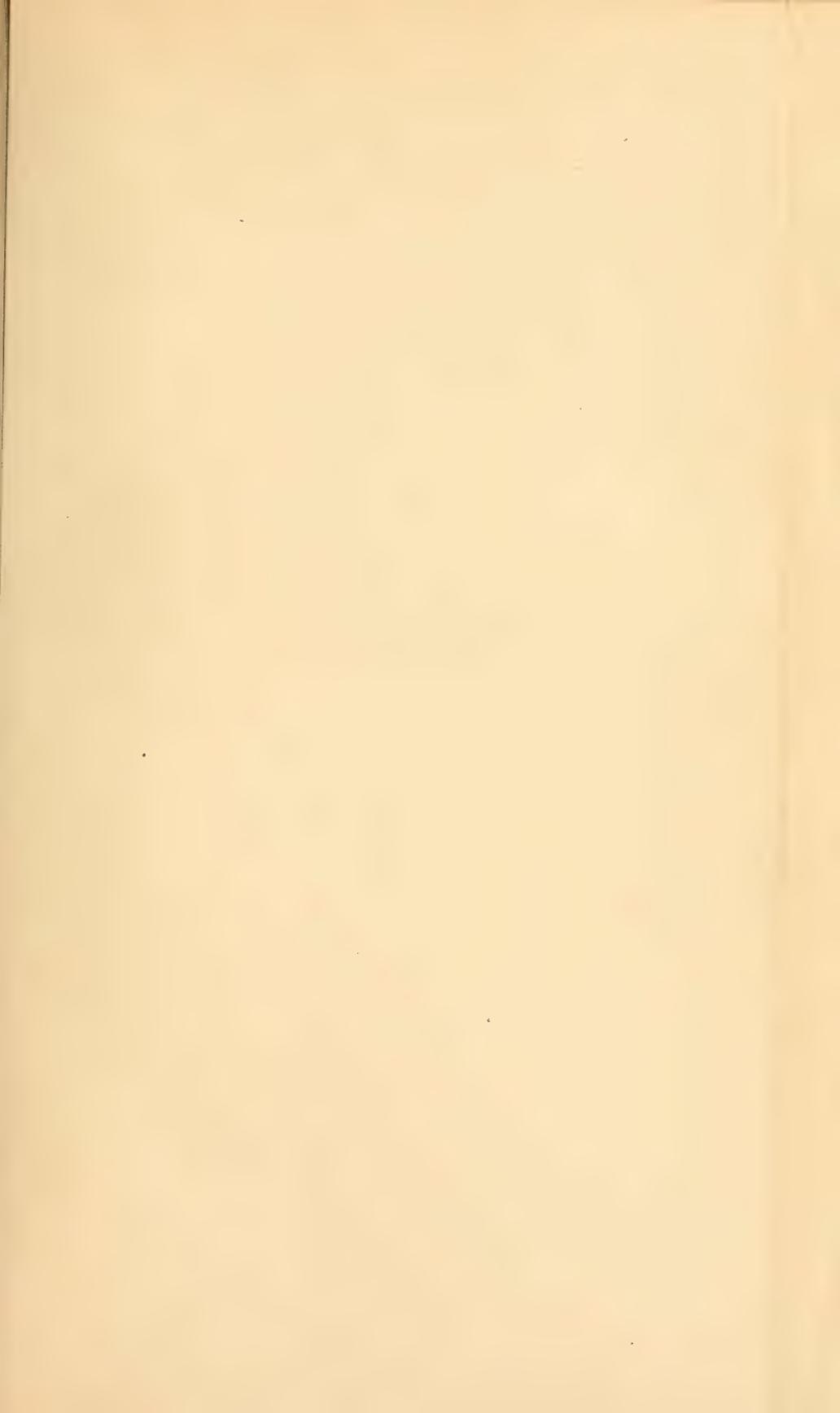
Figs. 2-5. *Barrandeoceras Sternbergi* (sp. Barrande); Schary Coll., Mus. Comp. Zoöl. Reduced one-third. Fig. 2, from Lochkov, variety in which whorls do not touch at all. Fig. 5, section of one, same locality, in which whorls barely touch, showing that it has no contact furrow. Figs. 3 and 4, specimen in which whorls touch in ephebic stage, but become free at the base of the living chamber. This has throughout a flattened dorsum, but no contact furrow. The appearance of a furrow in Fig. 4 is due to compression. These figures show also the narrow dorsal lobes of the sutures.

Figs. 6-12. *Schroederoceras tubulatum*, n. s. Reduced one-third. Coll. Mus. Comp. Zoöl.; Loc., Brevig, Norway; Silurian. Figs. 6 and 7, nepionic stage. Figs. 8-12, ana- and metaneanic substages.

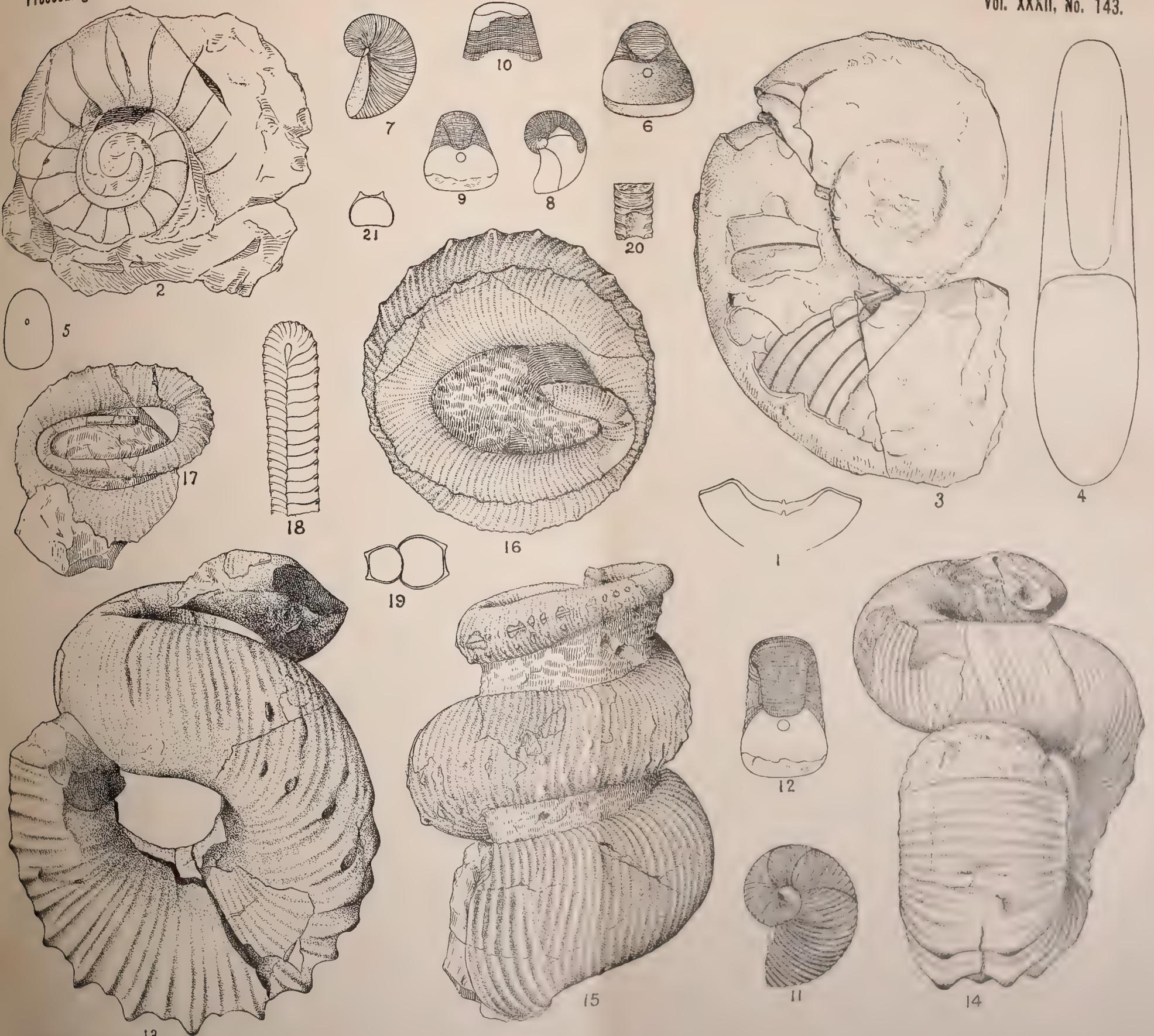
Figs. 13 and 14. *Didymoceras nebrascense* (sp. Meek). Reduced one-third. Loc., near Buffalo Gap, So. Dakota; Coll., Yale University Museum; Cretaceous. Views of the parephebic substage and gerontic stage.

Figs. 15-17. *Emperoceras Beecheri*. Reduced one-third. Loc., near Buffalo Gap, So. Dakota; Yale University Museum; Cretaceous. Fig. 17 shows the earlier stages with Hamites-like whorls from above. Fig. 16 shows the similar apex of Fig. 15 corresponding in age to part of Fig. 17. Fig. 15, side view of Fig. 16, giving the ephebic stage with its tubercles and bifurcated costæ and the parephebic substage with single costæ and no tubercles.

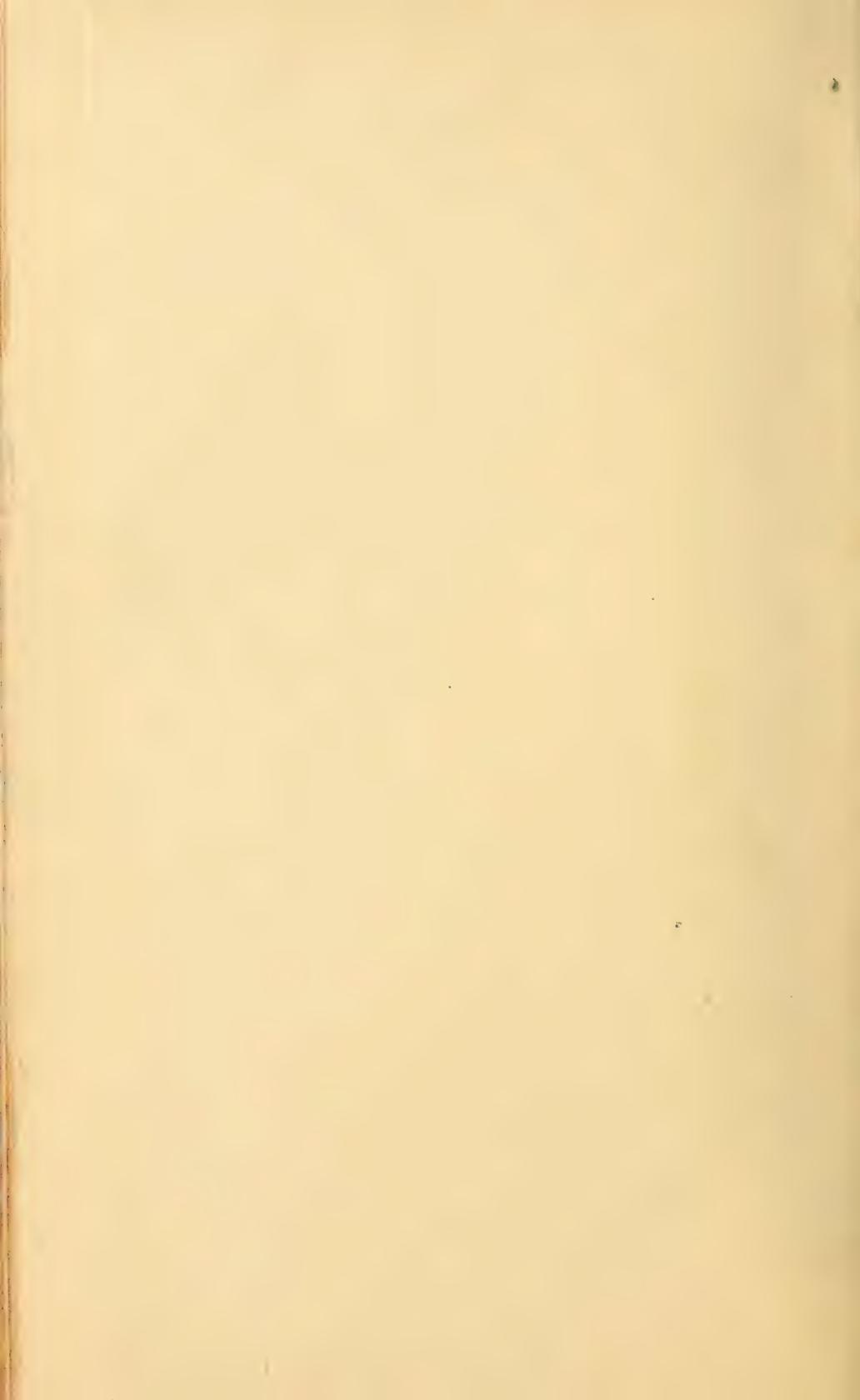
Figs. 18-21. *Ptyhoceras crassum*; Whitfield Coll., U. S. National Museum; Loc., Boulder, Col.; Cretaceous. Fig. 18, side view of ephebic and gerontic limbs, with gerontic umbilical perforation, reduced one-third. Fig. 19, section of same, natural size, showing the gerontic contact furrow. Fig. 20, view of dorsum of gerontic limb, in and just orad of gerontic umbilical perforation, natural size; shows the gerontic dorsal furrow, with dorsal crests in lines of growth and one costation and below the contact furrow. Fig. 21, section of the upper end of Fig. 20, showing the gerontic dorsal furrow.







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