No. 5.— *Fossil Cephalopods of the Museum of Comparative Zoölogy. Embryology, by* Alpheus Hyatt.

The researches recorded in the following pages were originally undertaken in order to ascertain the limits of the embryological period among the typical Ammonites.

During this period, which begins with the ovisac, the different species possess a common form, and are very similar in the characteristics of their septa, siphons and shells. It was at first proposed to give the descriptions only in conjunction with the different groups to which the young belonged; but the intimate connection and importance of the facts, elicited by a general comparison of the young of Nautilus, Goniatites, and Ammonites appeared to demand a separate publication.

The necessary illustrations have been furnished with unstinted liberality by the Director of the Museum, Professor Louis Agassiz. The collections also, which are extremely rich, have been placed entirely at my disposal, and I have been permitted to break up whatever specimens were considered suitable for the present purpose.

As this is my second formal publication upon the Cephalopods in the Bulletin, it is only becoming to correct certain errors which are to be found in the first (No. 5, Vol. I, Bulletin of the Museum of Comp. Zoölogy), under the same general title as this number.

Proper credit was not given in the preface to Professor Edward Suess for having been the first to publish the fact, that the typical forms of Ammonites were capable of generic division, and two of his names, Lytoceras and Phylloceras, should supersede two of those given in that number of the Bulletin, namely Thysanoceras and Rhacoceras.

I have been rather severely criticised by Laube and Zittel for giving Professor Agassiz the credit of having been the first to perceive that the Ammonites were divisible into distinct families and genera, but it will be noticed that this is given to him as a personal matter between an instructor and his student. This I must be excused from withdrawing. But I did know, however, that ever since Professor Agassiz published his French translation of Sowerby's Mineral Conchology, he has regarded the Ammonites, not as a family, as Suess does, but as a large group, perhaps equivalent to a sub-order, and composed not of a few genera, but of several families containing many genera.

The fact that two of the genera were precisely equivalent to those of Professor Edward Suess ought to have secured some credit, at least among his admirers, for the twenty-odd other precisely equivalent genera established by Professor Agassiz and myself; but such has not been the fact.

Either we knew of Suess' publications and patterned after them, only increasing the number of genera, or else the investigation was independent. Besides the fact, well-known to palæontologists in this country, that these investigations began some years before Suess had published anything, there was no object in concealing our acquaintance with his researches. On the contrary a prompt acknowledgment would have been of great advantage, since it would have been easy to show, that, in our much more complete classification, the genera were founded upon the same system of characteristics as those used by Suess to distinguish Lytoceras from Phylloceras.

There has been nothing besides the above in the criticisms advanced except general statements of disapproval, which, of course, cannot be dealt with specifically and are of no importance.

I will say, in conclusion, that I have nearly finished a very thorough review of the same groups without being able to effect any very material alterations.

The same divisions are found to be sharply defined divergent series, and whatever name or value may be given them, they are natural groups; this being so, my object is attained.

This object is, as in the present publication, to obtain some faint insight into the laws of descent of these forms one from another, by means of such indications as may be afforded by a close study of the developmental and adult characteristics, corrected or verified by the observed geological positions of the species.

Every one who has studied the coiled shells of Cephalopods and Gasteropods, is aware that they retain in the interior of the umbilicus the younger whorls, which are necessarily more or less covered up and protected by those of later growth. By breaking away the older whorls, one can therefore eventually arrive at those portions of the involved cone which represent the very youngest periods of growth.

This in Ammonites and Goniatites has been shown to be a minute globular sac. In Nautilus, however, this sac is not retained, but traces of its former existence are apparent on the apex of the first whorl, in the form of a scar or cicatrix. The shell of the neck of the ovisac, in Ammonites and Goniatites, has the same form as the shell of the first whorl, whereas in Nautilus it is evident that the shell of the ovisac roofed over the living chamber, somewhat as in Gomphoceras. The opening into the apex or neck of the ovisac, where it joined the first whorl, was, as shown by the cicatrix, a narrow vertical slit bearing a slight resemblance to the opening of the living chamber in Gomphoceras.

All of the animals of these three groups undergo a true metamorphosis in passing from the globular ovisac into the first whorl.

The first septum occurs at the junction of the ovisac and the first whorl, in both Goniatites and Ammonites, and has an entire abdominal cell with two simple lateral lobes as in Nautilus.

The second septum in the Jurassic species of Ammonites, which alone were examined,* had no positive resemblance to the adult of any species of Goniatites, but the entire, simple sutures and simple ventral lobes have a general resemblance to that type, though the superior lateral lobes are present and undeniably Ammonitic even at this early age.

The second septum of the closely-coiled Goniatites has a much shallower ventral lobe than in Ammonites, and no superior laterals. The sutures resemble those of the adults of the Silurian Goniatites, but the ventral lobe is shallower and broader. The superior lateral lobes which are first seen in the third septum have the sharp outlines which distinguish the Goniatites.

This first whorl, or apical portion of the shell, is closely coiled in Ammonites, more or less involute, and resembles the adults of the typical Goniatites in form.

The form of the first whorl in Goniatites as well as the development of the septa varies excessively in the different species, or even in different varieties of the same species. In some the form and septa must be very similar to those of the straight Nautiloids, such as Orthoceras or Endoceras, while in others we have representatives of the arcuate Cyrtoceras, and finally those which are closely coiled, involute, and hardly distinguishable in external appearance from the young of Ammonites. This variability is, so far as we know, greater in the earlier or Silurian, than in the later or Devonian and Carboniferous

* Species of simpler adult structure and earlier occurrence, among the Ceratites or Clydonites, would probably present an aspect more like some of the adult Goniatites in their young.

species, and prepares the observer to find a common fixed type of form in the young of the Jurassic species of Ammonites, which belong to the same order and are intimately connected by transitional genera.

Everywhere the closest correlation is traceable between the amount of coiling, the amount of involution or envelopment of the whorls, the form of the whorl, and the development of the septa, — the simpler sutures being invariably associated with shallow concave slowly changing septa, an elliptical form, and open coils. The more complicated sutures, whose characteristics change more quickly in course of growth, are combined always with a more or less crescent-shaped whorl, and closely embracing or involving coils, whether found among Nautiloids or Ammonoids.

This agrees with the correlations of the structure and morphology of the adults as worked out by Bronn, Barrande, and others, among Nautiloids and Ammonoids, from the straight Orthoceras to the coiled Nautilus, and inversely, among Ammonoids, from the closely coiled Goniatites and Ammonites to the straight Baculites; the general morphology being readily and accurately expressed as a coiling up of a straight cone and the subsequent uncoiling of the same at later stages of the earth's history. The shells are almost universally classified in accordance with this coiling and uncoiling, with which also the structure of the siphon and septa are more or less correlative.

The siphon in Nautilus, Goniatites and Ammonites terminates, or rather begins, with a blind sac, or siphonal cœcum.

In Nautilus, this occupies a central position somewhat nearer the ventral than the dorsal side, and is enclosed by the shell at the apex of the first whorl. In Goniatites and Ammonites the siphonal cœcum has a cone-like prolongation, which appears to open into the bottom of the siphonal cœcum in Goniatites. The siphon is developed earlier in the last two than in Nautilus, since it is found within the neck of the ovisac.

The ovishell consists, in Ammonites and probably in Goniatites, of an inner lining layer similar to that of the chambers of the whorls, and an outer thicker layer. They both extend entirely around the ovisac, but the outer layer is very much thicker on the sides and abdomen. The inner layer bends inward and forms part of the under side of the first septum. The outer layer overlaps the inner and outer layers of the abdomen and sides of the first whorl, showing that here was the mouth of the ovisac, and that the outer layer of the ovisac corresponded with both the inner and outer layers of the first whorl. Both of the latter are continuous with the outer layer of the ovishell, in the same sense that they are subsequently continuous with each other whenever the growth is interrupted, and an imbricated suture or break is formed.

The shell of the young and mature whorls is composed of an inner and an outer layer, the latter being divided into two portions, the external or colored stratum, and the internal or white stratum. In Nautilus both the layers extend entirely around the shell in the young, but as soon as one revolution of the whorl is completed, the black excretion of the hood replaces the outer layer to a considerable extent on the dorsal or involved side. The outer layer is still present, but is very thin.

In Goniatites and Ammonites the same layers are present, but do not extend around the dorsal side, except in the loosely coiled young of certain species.

In Nautilus, Goniatites, and Ammonites a thin layer lines the interior of each chamber and coats the exterior of the siphon. This alone appears upon the dorsal or involved portion of the whorls in the last two groups.

All the layers, with the exception of the black layer of the hood and lining layer, betray everywhere an imbricated structure which shows that they were deposited by the edge of the mantle from within. The lining layer, and the black deposit of the hood are continuous throughout wherever they occur.

The siphonal cœcum of Nautilus is formed by the funnel of the septum, which projects posteriorly until it comes in contact with the shell of the apex. The funnels of the younger septa are longer than those of the older septa, and the sheath of the siphon which springs from the funnel of the second septum extends posteriorly and lines the interior of the siphonal cœcum, forming a second siphonal cœcum within the first.

In Goniatites and Ammonites the cœcum is formed in a similar manner, but the latter is not lined, the siphonal funnel and sheath of the second septum extending only far enough to close the opening in the first septum.

Subsequently the siphon is composed of the funnel and the sheath which is continuous with it, but has a looser and more porous texture. The sheath is discontinued at the opening of the funnel of the next younger septum, into which it closely fits and thus forms the outer wall of the siphon. Internally is found the corneous layer, which is continuous throughout.

In Nautilus and Goniatites, and in the youngest stages of Ammonites, we find only the parts described above, but in the further development of Ammonites, another is added. At first only a portion, and lastly, nearly the entire thickness of the septum bends in the opposite or anterior direction, forming a loose collar around the siphon, but not built into it, as is the shorter funnel below.

The siphonal cœcum is close to the abdomen in Goniatites and Ammonites, but the siphon, which springs from the neck of the cœcum as it passes through the second septum, diverges nearer to the centre of the whorl.

This position of the siphon, its structure, more especially in the young Nautilus and the prevalence of shallow concave septa, the Nautilian character of the first septum in Goniatites and Ammonites even in the closely coiled young, the prevalence of simply arcuate forms in the young of several Devonian, and the straightened first whorl of the varieties of two Silurian species, the continuity of the layers and their thickness on the dorsal side of the young, are all characteristics which appear to converge towards the structure and form of the siphon and shell in the Vaginati, especially Endoceras (Orthoceras) duplex of De Verneuil and Keyserling.

It is in this group, therefore, or in some closely associated genus that we must look for the ancestors of the Tetrabranchiate Cephalopods.

I select Endoceras rather than Beatricea, which I have always regarded as the prototype of all the Nautiloids, because there still remain several characteristics in the structure of this form which must be more thoroughly worked up, before the affinities can be settled beyond a doubt.

The structure of the septa, and of the siphon in Endoceras is not so irregular or vesicular as those of the shell in Beatricea, but there is a wonderful resemblance of the cup-like internal chambers of Beatricea to a line of siphonal cœca. The young of Endoceras, if this view obtain, would be expected to resemble, or to show some approximation to, Beatricea. It ought either to be alone composed of thick conical septa of the adult siphon, and each of these terminating at the apex in a closed sac, or, at least, the siphon should be larger proportionately in the young, and the true septa have a much smaller comparative area than in the adult.

The outlines and coarser shading of all the figures were drawn with the aid of the Camera Lucida by me, and these were worked over, and artistically finished with the greatest care by Mr. Konopicky, Draughtsman to the Museum. These outlines were often repeated and verified in obscure or doubtful cases, and the camera drawing invariably corrected by the careful study of the more minute structural details. The statement of the number of diameters to which a specimen has been magnified does not show that this power alone was used; frequently in working out the minor details much higher powers were employed, the results being noted in the general outlines already drawn with a lower power.

The objectives employed were made by Tolles & Wales, in their best manner, the glass most relied upon being a one-half inch of remarkably good definition, and working distance made by the first named.

The enlargement of the figures was measured by a direct comparison of the Camera Lucida image, at a distance of ten inches from the eye-piece with the size of the object on the stage as shown by a graduated ruler, or in the higher powers by a stage micrometer.

As others may possibly desire to repeat these observations, I will conclude this preface with a few words upon the preparation of specimens intended for examination.

Those specimens in which the shell is replaced by iron pyrites or in which the matrix is stained with iron, are seldom well suited for the observation of the very earliest period. The centre does not generally, in my experience, break out as well as in those which are fossilized by the ordinary Carbonate of Lime, and they are too opaque. Specimens with which I have been most successful are found in the hard dark blue limestones. The centres of these are usually filled with translucent carbonate of lime even when the older parts of the whorls are opaque.

The first process of reduction may be generally effected by breaking away the whorls with chisels of suitable sizes, care being taken not to strike too near the centre; then the young shell should be bedded in Canada balsam which has not been overheated. If scorched, the balsam is apt to give way in large splinters and fly off the slide, carrying the minute ovisac with it. The removal of the last three or four whorls is best accomplished under a dissecting microscope, with the aid of the long-handled instruments used by dentists. These are chisels of various forms, bent at the ends so that they can be held horizontally; and almost every desirable point can be purchased, or obtained by grinding down those commonly used.

Great care must be taken in grinding down specimens for transparent sections not to get them too thin. After a certain thinness is attained, the carbonate of lime is apt to crack in a very irregular manner, obscuring the structure and seriously enhancing the difficulty of making accurate observations.

The siphon is hardly ever at all points in the same plane, so that the best practice in grinding the first side is not to pass beyond the outer limits of this organ. Then, when the specimen is turned and recemented to a clean slide, the reduction of the exposed portion may be carried forward to any desired level. The whorls are very apt to break off or loosen during this last process, and the delicate crystals of lime on the edges to become fractured, and therefore in most cases it is better to allow a number of the earlier whorls to remain attached to the ovisac as a support for those which are to be examined.

EMBRYO.

It has been customary to consider that one of the differences existing between Goniatites, Ammonites, and Nautilus was to be found in the absence of a globular ovisac at the beginning of the whorls in the two latter. This view is very plainly expressed by D'Orbigny, Guido and Fridolin Sandberger,* and Barrande; but how this mistake could have been made among Ammonites it is difficult to understand, unless indeed the specimens the last-named authors examined, *Amm. lævigatus* and *complanatus* Rein., had really lost their ovisacs.

* "Bei der Unterscheidung der Gattung Goniatites von Ammonites ist dieses Merkmal nicht unwesentlich. Es scheint nämlich, dass den Ammoniten eine in dieser abgeschnürten Kugelgestalt sich erhaltende Anfangselle nicht zukomme. Mehrere wohlerhaltene Arten, unter anderen *Ammonites lævigatus* und *complanatus* Rein. aus den unteren Oolith von Thurnau zeigten schon von der Anfangselle aus regelmässig kegelförmiges Anwachsen ohne jene Abschnurung." — *Die Versteinerung von Nassau.* G. und F. Sandberger. Wiesbaden, 1850-56, p. 59.

Saemann, in Dunker and Meyer's Palæontographica,* has shown that *Lytoceras fimbriatus* had a distinct globular ovisac, and figured the young of this species in comparison with the pointed young of *Nautilus atratus*.

D'Orbigny describes the aspect of the apex of the whorl in Nautilus as an obtuse cone, and in Nautilus lineatus of the Jura, writes of this cone as resembling a Patella. Barrande, in criticising this view, remarks very justly, that the cone must have been at one time the living chamber of the animal, and as this must have extended for some distance, there are no grounds for comparing it with the flattened cone of Patella.

When observed at the bottom of the umbilicus, the ovisac of the Ammonites appears as an oval body, generally more or less denuded of the shell, which breaks away with the matrix.† When the whorls which encompass it are removed, the ovisac is seen to be much larger than these exposed lateral areas, which are merely extreme portions of the narrow sides of the embryonic shell or ovisac.‡ The entire form, when seen from the side, is that of a very broad symmetrical oval, flattened considerably on the abdomen, § and lenticular when viewed from the abdominal or dorsal sides.¶

These outlines may vary considerably in the same species. In some specimens of *Deroceras planicosta* the abdomen is flatter than in others, and often depressed as it nears the sides, giving the latter a remarkably bulging aspect.**

Among the Arietidæ, the species examined, Arnioceras semicostatum,†† and Asteroceras obtusum ‡‡ presented no considerable variation, except such as would naturally result from difference of size in the species.

Even in the abnormal forms, Scaphites and Crioceras, the ovisac fills the fundus of the umbilicus, or, in other words, is closely enveloped by the first whorl. Whether the young of the still more uncoiled genera,

* Vol. III, p. 158, pl. 19, Figs. B, C.

† Plate I, Figs. 7, 8. Plate II, Fig. 9.

‡ Plate I, Fig. 6, A. Plate II, Fig. 7.

§ Plate I, Fig. 4.

¶ Plate I, Figs. 1, 2.

** Compare Fig. 2 with 5, and Fig. 6 with 1 on Plate I.

†† Plate II, Figs. 8, 9.

‡‡ Plate II, Fig. 11.

especially Baculites, have young which are straight or closely coiled, I could not ascertain by direct observation.

The ovisac of Goniatites does not, in the majority of the species, differ very materially from that of Ammonites. It is evidently an elliptic or globose body more or less flattened on the abdominal side as in the typical Ammonites.* It however presents very remarkable differences in the relations of the ovisac to the first whorl and to the umbilicus, and in its variability of form in the same and different species.

Dr. Guido Sandberger figured several species, all of which are reproduced in the first Plate of this paper,† and from these and others, also examined but not figured, he inferred that the species themselves might be distinguished by the differences of the embryos. The figures certainly appear to justify this remark, and my own observations, as well as those of Barrande, though apparently contradictory, are really strongly confirmatory. Barrande found in the silurian of Bohemia *Goniatites fecundus*, and *Goniatites plebius* with two well-marked varieties, and was so fortunate as to obtain also the very youngest stages of growth in each variety of the former. ‡ These are also reproduced on Plate I of this work.§ According to Barrande the ellipticity of the orbit in the adult of one variety is due to the straightness of the first portion of the first whorl, and the regular spiral of the other variety to the close coiling of the young. He also observed and figured the same elliptical form at all stages of growth. This would seem to be sufficient to establish the two varieties as distinct species; but the presence of all intermediate varieties between the two produced here, the similarities of the adult shells, and the occurrence of the same variations in *Goniatites plebius* forbids their separation.

Goniates crenistria, in one so-called variety, has a decidedly rounded abdomen, and the ovisac fills the fundus of the umbilicus, while in the

* Plate III, Figs. 3 4.

† "Diese ist stets stark aufgebläht und wie die Figuren 26 bis 33 (Pl. I, Figs. 11–18) beweisen, bei den verschiedenen Arten oft von sehr characteristischer Gestalt, so das sie in manchen Fällen ein zur Unterscheidung der Species geeignetes Merkmal abgiebt." — Guido Sandberger, *Beob. Über Goniatiten, Jahrbuch der Nassau Verein*, 1851.

‡ Syst. Sil. de Bohême. Cephalopods. Vol. II, pp. 32 and 37. Plates 7, 10, 11, 17 and 5, 6, 7, 241, 242.

§ Plate I, Figs. 9, 10.

other, with a flatter abdomen, it lies against one side of the first whorl, occupying but a very small portion of the entire space.* Here there can be but little doubt of the specific value of the differences which are manifested, not only in the youngest stage, but throughout life, and affect not the symmetry of the orbit of revolution, but the form of the whorl itself.

In all of the seven species observed by Sandberger, as may be seen by his figures † and in the four distinct species observed by me, counting Gon. crenistria as two good species, the differences of the ovisac are very distinct, whereas in several individuals of the same species, Goniatites crenistria, the so-called variety with a flat abdomen, which I have observed, and in several of Go. atratus, no such differences were observed between the different individuals. The slight differences in the amount of coiling between the young of varieties latidorsalis and calculiformis of Go. lamed, figured by Sandberger,‡ were probably therefore unusual among the Devonian and Carboniferous species.

The succession also indicated by the foregoing facts is precisely what might have been anticipated from the general morphology of the Tetrabranchiate Cephalopods.

The range of form has been among the Nautiloids from the straight Orthoceratite through intermediate arcuate genera, to the partially coiled Lituites, and finally the closely coiled Nautilus. Such being the case, if there is any truth in the doctrine of evolution, we must expect to find some reference to the peculiarities of the parent Nautiloid stock in the earlier stages of development among the Ammonoids. And further, as a direct and unavoidable corollary of the above, we ought to find this reference more distinct in the young of the earlier species of Ammonoids, the Goniatites of the Silurian, and less noticeable in the Goniatites of the Devonian and Carboniferous, and, finally, almost obliterated, or, at any rate, still less distinct in the typical Ammonite of the Jura.

So far as the facts have been ascertained, they all point in this direction. The simple Nautiloid-like Goniatites of the Silurian may exhibit an Orthoceratitic or straight form, or be closely coiled in the young of different varieties of two distinct species. A species therefore, on this horizon, may have a range of variation in form, during the earlier

* Plate III, Fig. 7. † Plate I, Figs. 11, 18. ‡ Plate I, Figs. 15, 16.

stages of development, equivalent to that occurring among the adult forms of Nautiloids from Orthoceras to Lituites.

The Goniatites of the Devonian, however, even in such simple species as Go. compressus,* exhibit only arcuate whorls, and in the majority of cases are more or less completely coiled. No elliptical varieties have been observed in the adults, and the variations of form in the young of the same species probably do not exceed what has already been observed. †

Among the typical Ammonites of the Jura, not only is the young of the same species invariably similar, so far as the coiling and form of the ovisac is concerned, but the young of all the closely coiled or normally formed species are also closely coiled and involute or enveloped. ‡

We find in this a perceptible acceleration in the development of the young precisely proportionate to the estrangement, either in time, or in adult organization, of the Ammonoids from their supposed parent stock. There are evidently two tendencies at variance with each other: one strongly reversionary, appearing in the frequency with which the earlier Goniatites repeat the parent form in certain isolated instances in the young of varieties, and in the different species of the later Goniatites manifesting itself in the arcuate cone of the young of Goniatites compressus and others of the Nautilini, and in the closer, though non-involute coiling of the young of other forms. Evidently this tendency is losing its power to affect and modify the organization, or, in other words, its prepotency. The other tendency, which is expressed in the closer coiling of the whorls, and finally in their increasing involution, is decidedly progressive, increasing in power to the final and ultimate extinction of all reference to the ancestral type, except in the internal organization. Here, as will be shown, the siphon for a limited time remains central in the first whorl, and the first septum has a large entire abdominal cell, and simply concave lateral lobes, as in the Nautiloids.

The form, however, of the first whorl of the Ammonoid is like Goniatites, the shell similar, and the second septum has the invariable abdominal lobe, superior lateral cells, and lobes of the simpler adult

* Plate I, Fig. 11.

† As already noticed between Figs. 15 and 16 of Goniatites lamed. Plate I.

‡ Plate I, Figs. 2, 4, 5, 6, 7, 8. Plate II, Figs. 7 - 9, 11.

Goniatites, but not by any means of the simplest Goniatites. The simplest adult Goniatites have no proper lateral cells, but only broad lateral simple curves to the septa, as if the first septum of the Ammonite was modified or broken by a small abrupt lobe on the abdominal side. Contrast this with the development of the septa, and their gradual change in Goniatites compressus, and we see at once that the development of the same parts is very much quickened or accelerated in the typical Ammonite.

That this acceleration of development is due to the prepotency of the same progressive tendency as the closer and closer coiling, and final involution of the ovisac, by the first whorl, can hardly be doubted. Thus, not only in the whole series of Nautiloids are the forms more or less completely coiled and finally enveloping, but in the young Ammonoids this process is repeated, but only as a reversionary tendency of individuals and species, or at most, perhaps, by the group of Nautilini.

In the Arietidæ, and many other groups of typical closely coiled Ammonites, the same process is repeated to a greater or less degree in nearly every series of species, the progress being from a non-involute, or slightly involute, to a more involute form, and even in varieties of species there is occasionally a marked difference in the degree of involution of the adult whorls. Everywhere, throughout the order of Ammonoids, we meet with this constant repetition without reference to the geographical position or distribution of the species.

This increase of involution is, of course, due to the extension of the sides of the whorls inwardly, and is invariably accompanied by a decrease in the lateral or transverse diameter of the whorl, flattening of the sides, and a corresponding elevation of the abdomen.

In those series, however, such as the Dactyloidæ and Cycloceratidæ, in which the amount of involution remains the same throughout, the highest species, such as Dactylioceras Braunianum, and Cycloceras Ægion, or Masseanum, have flattened sides and acute abdomens. These modifications, being the same as those which are correlative with the increasing involution of the species in other series, produce, also, mimetic forms which only need one characteristic, that of involution, to become closely representative of the deeply involved species.

Thus, all the typical Ammonites may be resolved into natural series, in which the different forms in each series are related to each other very much as Lytoceras fimbriatum and others are related to the more involute Phylloceras, and the different series contain more or less representative or mimetic forms due to the resemblance occasioned by the amount of the involution or the characteristics which are usually correlative with the amount of involution. The differences between the series are found in the development of the young, and the structural peculiarities of the shell and septa.

When, however, the organization of the group no longer progresses, but retrogrades by the uncoiling of the whorls in Scaphites Ancycloceras, and Baculites, repeating — as shown by several authors, but notably by Barrande — the earlier forms of the Nautiloids in inverse order, these, though strictly mimetic, are produced by the encroachment of senile characteristics. These are observed in the old age of such species as Amm. Humphriesianus, where the old whorl becomes smaller, more cylindrical, and if growth was continued, must eventually strike off from the regular spiral as in Crioceras or Lituites. This irregularity is found at earlier and earlier stages of growth, and finally affects the whole form as in the completely straightened Baculites. Direct inheritance of senile characteristics is not claimed, but merely that the retrogression of the individual in old age and the retrogression of the group are similar, and both due probably to the same cause, exhaustion of the powers of growth.

There is, however, a notable exception, which can be accounted for only by Professor Cope's law of "retardation," and which, to me, was inexplicable until the appearance of his essay on the Origin of Genera; the two Gasteropod-like genera, Turrilites among Ammonoids, and Trochoceras among Nautiloids. With regard to the latter, there are no certain data; but the former are produced at first in varieties of species, which have, according to Quenstedt's, Oppel's, and my observations, simply prolonged into the adult an individual variation common enough in the young shells. The young of several species of typical Ammonites often assume the spiral, although this is entirely suppressed at a later stage, and the succeeding whorls resume the normal mode of growth and revolve in the same plane. When, therefore, the normal mode of development is "retarded," we find even in the adult this Turrilites-like condition of the young, which is as truly reversional as the Orthoceratitic young of Goniatites fecundus. This happens occasionally in the lower Jura, and finally, after the progressive stage of the whole order passes its climax in the lower and middle Jura, we find the development of a whole group affected by this retardation, and the spiral is common to several generic forms.

The ovisac of Goniatites crenistria differs from that of the Ammonites in the greater breadth proportionally of the abdomino-dorsal axis. The ovisac of G. primordialis, G. retrorsus var., and G. diadema do not seem to differ in this respect. Even the two depressions and the bulging of the sides are as well marked as in the ovisac of Deroceras planicosta.*

The ovisac of Nautilus was not present in any of the seven specimens examined by me. The form of the mouth of this, however, can be inferred from the oval ridge on the apex of the first whorl, and the central scar which marks the former aperture through which the animal probably passed into the fundus of the first whorl.† The outer limits of the area thus marked out are flask-shaped. The lower portion or abdomen, if it were extended laterally, would correspond to the broader abdomen of the Ammonoidal ovisac, and the depressions on either side of the dorsum to the embryonal umbilici. The apex of the whorl rises in a well-defined ridge which marks out this area on the dorsum and the sides. At the abdominal extremity the defining ridge is hardly distinguishable, and the shell rises directly to the cicatrix, which is here the most elevated portion of the apex. The striæ of growth and the longitudinal furrows both cross this area, but are arrested at the edge of the scar. The ridge, when seen from the side, is found to be accompanied by a narrow, shallow, slightly concave band, which at the dorsal end is particularly well marked. The edges of the cicatrix, which is a flattened, corrugated, elongated narrow space, are tumid and more or less elevated.

The ridge appears to mark the line along which the extreme outer edge of the mouth of the ovisac abutted against the apex of the whorl. The lips of the embryo shell were probably inflected as in Gomphoceras, but instead of being convex as in that genus, were probably concave. The projecting edge of this concave area would then have fitted neatly into the shallow channel or area running around the inner side of the ridge, and the concavity have been the mould upon which

* Plate III, Figs. 3, 4, 5. The ovisac differs more when viewed laterally, since the outline of a section through the centre, as in Fig. 5, is more decidedly circular.

† Plate III, Fig. 1, and ideal section last page of the text.

the convexity of the central portion of the scar was formed, the cicatrix itself being left vacant for the passage of the animal.

The abrupt and broken character of the border of the external layer on the edge of the cicatrix, and its crenulated aspect indicate that here is the true location of the former junction of the ovisac and the shell of the first whorl. When we consider how narrow and vertical are the apertures of some of the arcuate Nautiloids of the Silurian epoch, and how closely they approximate to the simplicity of the outline of the cicatrix, this view acquires additional probability, and it seems to be the only one which can reconcile the continuity of the external layer and its markings over this region.

It still remains difficult, however, to account for the passage of the large body of the embryo through the narrow aperture thus made, and future investigations upon the embryology of Nautilus are much needed, in order to settle this interesting question, as well as the true affinities of the form and structure of the embryo.

The cicatrix occupies, as has been described, the true apex of the whorl, as determined by the structure of the shell, but only the lower end, which is curved dorsally, occupies the actual apex; the remainder runs along what appears to be the inner or dorsal side, though this really begins higher up at the dorsal border of the cicatrix.

The absence of the ovisac is due either to its delicacy and the readiness with which it could be broken away from its attachment, or to the advance of the mantle, which in course of growth strikes the cicatrix a little inside of the extreme abdominal end, and then bends up over it, and either absorbs or pushes the ovisac away. Whatever may be the ultimate resolution of the question, one fact is very evident: the embryo of Nautilus differs not only in its form, which is a vertical oval, from the Ammonoids, which is a horizontal oval, but in the mode of its passage into the first whorl.

The whole aperture, or lip, of the ovisac in the Goniatites and Ammonites is united and continuous with the shell of the first whorl, which opens into it at the apex. The siphonal cœcum also has the peculiar pointed cone-like prolongation extending into the ovisac, through the first septum, which shows that the important organ which secreted it differed not only in comparative size, but in shape, and in the earlier period at which it was developed.* The siphonal cœcum

* Plate III, Figs. 2, 5, 6.

of Nautilus was not formed until after the animal had passed its first stage of growth and occupied the first whorl sufficiently long to build the first true septum. Even then this organ had not the size and importance to which it subsequently developed. I have examined the apices of many fossil Nautili without succeeding in finding any sufficiently well preserved to show the original condition of the external shell. One fine specimen of Nautilus Koninckii, from Tournay, had apparently a smooth termination; the longitudinal plications which cover the young shell of the ornamented Carboniferous Nautili reached only a little beyond the second septum. The whorl was here a rapidly increasing cone, the abdomen, however, quite as gibbous as the dorsum, whereas in the adult the latter is the more prominent, the abdomen becoming deeply inflected. The termination of the whorl was very much flattened, so that from the side it had quite a pointed aspect, whereas an abdominal view showed it to be rounded at the extremity.*

Nautilus Koninckii, it will be remembered, is a Carboniferous species with a very large umbilical perforation. In fact, the whorls do not even touch at first. The tip of the cone is free for some distance before the involution brings the whorls in contact. No marks of a cicatrix were discernible.

Saemann's original specimen of Nautilus atratus is the finest I have ever seen, and yet this is only a cast. The apex, however, is formed by a cake of iron, which has a rough, lumpy surface, difficult to account for on the supposition that it was the cast of the smooth interior of an unbroken shell.† The area between the first and second septa is smooth, the abdomen flattened, and a faint median depression is noticeable near the suture of the first septum. This, and the second septum, incline towards the umbilicus at a greater angle than any of the succeeding septa.‡ The point of the external shell is the corner which it makes on the abdominal side, as it passes around the angle of suture. This has been habitually mistaken for the apex, whereas the organic apex is really further inward, and nearly parallel to the first septum, and, in some Nautili, such as Nautilus lineatus Sow., is an almost flattened area apparently on the dorsal side.§ Nothing approaching a cicatrix was actually discovered, and yet, besides the general form, which is similar to that of N. Pompilius, the aspect of Saemann's

* Plate IV, Figs. 7–9.

† Plate IV, Fig. 6.

‡ Plate IV, Fig. 5.

§ Plate IV, Fig. 10.

cast, and the sections of N. lineatus, which I have seen, indicate that it is present. One of these casts has a very thick tumid shell over the apical portion, and the other, which has a thin shell, exhibits a transverse depression just inside of the siphonal cœcum. This shows that the shell not only differs in thickness on the apex, but is more or less corrugated also, as if by a scar.

The oval outline of the area of the cicatrix, slightly flattened on the ventral side, is singularly like the adult of the Nautilus Bohemicus, and others of the Silurian Nautili described by Barrande.* The regular ellipse of the young of the latter, and the flatter cone of the young of the Carboniferous Nautili, is not represented at all in the young of N. lineatus and N. atratus of the Jura.

UMBILICUS.

As the embryo of the typical Ammonites, and the closely coiled Goniatites, such as G. diadema, approaches the beginning of the first whorl, its flattened dorsum becomes depressed or concave on either side as previously described, and when the apex of the first whorl bends dorsally, hollows are formed on either side, closed at the centre. These are the embryonal umbilici.

They do not exist in Nautilus, but their homologues are probably found in the ovisac, as previously pointed out, though they can form no umbilici properly so called. The close coiling of the first whorl forms the umbilici by enclosing these spaces in Goniatites and Ammonites. In Nautilus they can never be so enclosed, owing to the loose coiling of the first whorl. The umbilicus of Nautilus Pompilius penetrates entirely through the whorls, as it does in the group of Nautilini among the Goniatites, where the ovisac does not fill up the centre. The lateral depressions or sinuosities observable on the sides of the outer rim of the scar in N. Pompilius, the homologues of the umbilici of Ammonites, were not observable in N. atratus, since, as previously stated, no well-defined scar was observable among the fossils which came under my observation.

WHORLS.

The whorl of the typical Ammonites, and the closely coiled Goniatites is at first as broad as the ovisac, then rapidly contracts, becoming

* Plate IV, Fig. 6.

considerably narrower.* Before the completion of the first revolution, estimating from the neck of the ovisac until the whorl again touches this point of origin, it reassumes the normal rate of increase.

The increase in the dorso-abdominal diameter appears to be very marked at first, and this gives a peculiarly broad aspect to the sides of the whorl, just beyond the embryonal umbilicus; † subsequently the increase is constant and invariable in all the diameters.

The form of the whorl is notably distinct from what it afterward becomes, and is identical with that of a typical adult Goniatite, and an equally close representative of the young of G. diadema and other closely coiled Goniatites. There is the same broad, even, somewhat flattened curve to the abdomen, and abrupt sides. The retention of this Goniatitic outline is greater or less in different species, and it is necessary to be cautious in estimating the duration of this period of growth. The septa give an accurate measure of the time during which the young animal may be said with truthfulness to have resembled an adult Goniatite in some of its characteristics.

The types I have examined are evidently too far removed from the Goniatites in the structure of the adults, and their development consequently too much accelerated, for any very extended or exact reference, in all their characteristics, at any one period of growth. Such precise identity of the young with the adults of the parent type can only be expected in the Clydonites, or some of the simpler transitional groups, where the Goniatitic stage must necessarily be of longer continuance.

The outline and septal structure of the young are almost identical between the Goniatites and Nautiloids, more especially the arcuate forms of the young with plain concave septa, such as G. compressus, when compared with the arcuate forms such as Cyrtoceras. Sandberger's figures show in section the young whorl of this species, which is a regular ellipse, and has an outline and septa very like Nautilus Bohemicus; the siphon also being at an earlier period undoubtedly abdomino-central, we have here at one stage a close approximation in the general characteristics of the structure.

The umbilical perforation is very contracted and small in Nautilus Pompilius, when compared with the fossil, and differs also in form from

* Plate I, Fig. 6. Plate II, Figs. 2, 11. † Plate I, Fig. 7.

the Palæozoic species. The Nautili of the Silurian, such as Nautilus Bohemicus, Nautilus Sternbergii, Nautilus tyrannus, Nautilus Sacheri, figured by Barrande, have very large umbilical perforations. The Devonian Nautili, like those of the Silurian and Carboniferous, all belong to the group of Imperfecti, and have large umbilici, showing the entire spire. What is the exact size of the umbilical perforations I cannot state, but doubtless it is in the majority of the species large, and the young whorls rounded as in the Carboniferous and Silurian members of the same group.

The Carboniferous forms are distinguished by their highly ornamented and varied adult shells, as well as by their exceedingly large umbilici. Nearly all of these DeKoninck * has pointed out are characterized by a large umbilicus, showing the entire spire. Even the Nautilus oxystomus, a species in which the whorls are considerably involute, has an umbilicus, and at first a rounded whorl, which subsequently becomes hexagonal and then lanceolate in transverse sections, and involute. The umbilical perforation in this species is much smaller than in those species with non-involute whorls. The Museum has among other treasures the entire collection of DeKoninck, and I have been able to verify these observations.

The species of the Trias and Permian I have been unable to examine. But of the two species figured by King,† N. Freislebeni, and N. Bowerbankianus, one has a closed, or what is generally called a closed, umbilicus, i. e. with probably, as in the modern N. Pompilius, a small perforation. N. bidorsatus of the Muschelkalk also has a form like many of the Jurassic species, and a much smaller umbilical perforation than is common in Carboniferous species. Other species of the Muschelkalk, such as N. mesodiscus, N. Sauperi, N. reticulatus, are as completely coiled, and as involute as any of the Jurassic and succeeding formations. It is probable, therefore, that the earliest general change in the size of the umbilical perforation will be found to take place in this formation.

The Nautili of the Jura, as pointed out by Pictet, ‡ approximate closely to the existing species in the adult stage, and, as DeKoninck has shown, their umbilici are comparatively closed. The young of two

* Animaux Fossiles, p. 544.

† Permian Fossils of England, p. 219.

‡ Pictet, Traité élémentaire de Paléontologie, 1845, Vol. II.

species are figured by D'Orbigny, and these are decidedly in advance of the circular and very slowly increasing whorls of the young of the Carboniferous and Silurian Nautili, and the umbilical perforations are much smaller. Barrande says of the umbilical perforation, "Au centre de la spire, il existe une vide ou perforation, qui est remarquable par sa constance, et son étendue dans les Nautiles paléozoiques. Nous retrouvons cette perforation, quoique très-réduite, dans les espèces fossiles des époques postérieures et même dans les Nautiles qui vivent dans nos mers." The Jurassic shells belong almost wholly to the Striati, a group with longitudinal ridges or plications on the whorls.

The young of Nautilus lineatus of the Jura presents an umbilical perforation quite as small as that of the modern Nautilus. The whorl, however, does not make the graceful curve of Nautilus Pompilius, but bends inward more abruptly, and instead of touching the apex of the whorl first, it strikes the dorsal ridge of the area of the cicatrix, fitting itself to its flattened surface.* The result is an irregularity in the curvature of the dorsum at this point, which appears to be abnormal, but is probably characteristic at least of the species, since I found it in two different specimens.

This fact, however, as well as the figures of the young given by various authors, shows that in the Jura the whorling probably becomes, in several species, as close, and perhaps closer than in the modern Nautilus; certainly, in all those forms which, like Nautilus lineatus, are very involute in the adult.

The Radiati of the Cretaceous are, as a whole, more deeply involute than the Striati of the Jura, though not differing as respects the size of the umbilical perforation. The earlier age at which the involution begins is particularly noticeable, and the consequent prevalence of forms which increase in size more quickly than the majority of Jurassic species may be assumed with confidence, though the material at my command does not enable me to substantiate this statement by actual observation made upon the uncovered young.

It is founded, however, upon the fact which appears to be universal among Ammonoids and Nautiloids, that the earlier a species begins to become involute, the quicker must be its increase in size. Involution, indeed, is only one method of expressing the expansion of the shell inwardly by the growth of the sides over the umbilical area, and it is

* Plate IV, Fig. 10.

evident that this, when it occurs early in life, must, as in the modern Nautilus, occasion a more rapid spreading of the sides at the apex than is to be found in the Striati of the Jura. This, of course, does not exclude the effect of the spreading of the sides independently of involution, as in Nautilus excavatus Sow. of the Jura; but this is not generally so well marked in the young as in this species, and has no bearing upon the question, which concerns only the prevalence and early development in time of involution, as it may be observed in full-grown specimens.

The Lævigati of the Tertiary appear to come no nearer to the existing Nautili than the Radiati, except in their smoother shells. The group of Aganites or Nautili, with deep lateral lobes like those of Clymenia, form a distinct genetic series, but they are no exception to the rule. Nautilus aganiticus, gravesianus, and sinuatus of the Jura are all less involved than either Nautilus aturi, zic-zac, lingulatus, or Morrisii, and others of the Tertiary.

Another peculiarity, the concavity of the dorsal side, is earlier developed in the closely coiled young of Jurassic, Tertiary, and existing Nautili than in the Palæozoic forms. Barrande, among the Nautilini of the Silurian, treats this characteristic as one which is due to the involution of the whorls. His figures show that it is very slight, and arises at a comparatively late period, and only after the whorls come in contact. It does not exist at all in Nautilus vetustus, which is a very loosely coiled whorl. The conclusion here also seems to be inevitable that a characteristic, at first fluctuating, and pertaining exclusively to the older periods of growth, becomes more embryonic in the later species of the same genetic series. In this instance also we have, as the result of this law of acceleration, a characteristic which is at first dependent upon another characteristic, the involution of the whorls, becoming incorporated in the organization, and finally manifesting itself independently, in the growth of each individual, before the whorls touch each other. It is certainly universally present at a very early period in the young of the Jurassic and succeeding periods, though absent in many of the Carboniferous forms.

These exceptions may be said to prove the rule, for species, such as N. Koninckii, in which it is absent, have their backs convex instead of concave, because the abdomens of the whorls which they involve are concave instead of being convex.

The dorsal concavity in the young of Nautilus atratus is marked at the very commencement of the whorls by the flattening of the elliptical outline of the second septum.* In Nautilus Pompilius, however, the dorsum is flattened at an earlier period, the concavity affecting the conformation of the first septum.

Sandberger † and Richard Owen ‡ both allude to the Goniatitic stage, and also to a subsequent Ceratitic period. Sandberger's recognition of these periods of development, though not quoted by Owen, has priority in point of time, and is much fuller and more comprehensive. He also shows that Hauer really first called attention to them by his figures of Amm. floridus. § Sandberger, however, failed in seeing their full significance, since he most emphatically denies that these transformations show any affinity between Goniatites and Nautilus in the following words: "Obgleich ich die letztere Thatsache" (the simple Nautilian characters of the septa of young Goniatites) "keineswegs für einen weiteren Nachweis vewandschaftlicher Verhaltnisse von Goniatites und Nautilus geltend zu machen gedenke und angesehen wissen will." Owen describes the transformations of an Ammonite, only in order to show that they were simpler in the young than in the adult, and that the young of the same species at different periods of growth had been by different authors referred respectively to Goniatites, Ceratites, and Ammonites.

The so-called Ceratitic stage exists only in the septal sutures, and will be referred to further on.

After the Goniatitic stage is completed among the typical Ammonites the outlines of the whorls assume no general form, but vary according to the group or genus in which the shell is found.

SEPTA.

The first septum of the typical Ammonite is situated at the junction of the first whorl and the ovisac. It has deep, entire, simple lateral lobes on either side, and a prominent abdominal cell as in Nautilus.||

The dorsal side was not so accurately observed. It is probable,

* Plate IV, Fig. 6.

† Oberhessische Gesellschaft für Natur-und-Heilkunde, 1858.

‡ Palæontology: Second edition, p. 99.

§ Cephalopod, von Bleiberg. Plate I, Fig. 14.

|| Plate I, Figs. 2, 5.

however, that the lines "X" delineated in the interior of the specimen of Deroceras planicosta, Plate I, Fig. 6, show the junction of the first septum with the dorsal side of the whorl. They are in the proper position with relation to the external suture, and it is difficult to imagine any other structure to which they could belong. I failed to find anything similar in other specimens, and the original was accidentally lost after the figure had been drawn, while transferring it from one glass slide to another.

The huge size and depth of the abdominal cells of the first septum has no exact parallel, so far as I am aware, in any known adult Cephalopod. The pouch-shaped lateral lobes also appear to be peculiar. The sutures, however, vary considerably in the young of the same species. In some specimens inferior lateral cells* appear on the sides, and the lateral lobes are not so high, the abdominal cell, also, varying proportionally in breadth and depth. These lateral cells, however, do not exceed the strict Nautilian limits, and remind the observer of the slight inferior lateral cells of Nautilus Pompilius, both in position and in outline. Often, however, they occur so exactly on the edge of the embryonal umbilicus, and the descent into the lateral lobes is so abrupt that the observer confounds the suture with the projecting edge of the first whorl.† When such a specimen is viewed from the side by transmitted light, and the ovisac is transparent, as it frequently is, the shell appears to be pointed as in Nautilus, and the ovisac absent. When, however, a few specimens are completely broken down, and the ovisac and first septum laid bare, the error is easily corrected.

In section, the first septum appears to blend with the wall of the siphonal cœcum.‡ The enclosed transparent spaces, however, as indicated at 1 e, 2 e, Plate II, Fig. 1, between the siphonal wall and the inner side of the shell proper, probably represent all of this septum which obtains along the median line. In other specimens which I have studied this cannot be so plainly made out, and I should still be in doubt if these transparent spaces had not been enclosed by the lining layer of the shell. They can be compared in other respects also with the succeeding septa, which they resemble in position, size, and the peculiar spreading or fan-shaped sections of the sutural portions or junctions. The texture of the septum seems to be very distinct, but the drawing

* Plate I, Figs. 2, 5.

† Plate II, Fig. 7. Plate I, Fig. 4.

‡ Plate II, Fig. 1, 1 e.

necessarily exaggerates its transparency as well as the opacity of the siphonal wall. They cannot really be distinguished at their borders, the one from the other, but in every case the true calcareous septum blends with the brown of the wall of the siphonal cœcum. This may be the effect of fossilization, since, in other instances, at a later age, there was no difficulty in distinguishing the two at their junctior

The second septum* has a very distinct, deep, broad ventral lobe, divided by a ventral cell and siphonal fissure, deep superior lateral cells with shallow superior lateral lobes and inferior lateral cells equally slight, the inferior lateral cells beginning to appear upon the border of the whorl. Thus, when seen from the front, this septum has an appearance which leads the observer to suppose that it is interrupted.† An abdominal view,‡ however, readily corrects this mistake, especially in section where the continuity of the suture is readily defined, and a lateral view of the succeeding septa shows the divided ridges of the ventral cell very plainly. § These two ridges normally form one cell. The fissure is probably due to the prolongation of the siphonal funnel. This is a collar-like inflection of the septum, directed posteriorly, the circular extremity resting upon the sheath of the siphon. This funnel has a shallow channel on the ventral side, which is found in Nautilus also. When, therefore, the siphon is near enough to the shell, this channel divides the ventral cell; otherwise, it ceases to depress the septum before arriving at the edges, and leaves the suture entire.‖ These facts also demonstrate another, of some importance, that the ventral cell is no adventitious product of the near approach of the siphon to the ventral side in Goniatites and Ammonites, but an independent characteristic, constantly present in the latter, but absent from many species of the former. This conclusion is substantiated by a specimen, two septa of which are figured below.¶ No abdominal channel or gutter was present, and the abdominal cell was left entire.

The species in which the gutter is absent, among the Goniatites, have a simple ventral lobe, as many of the Nautilini, Goniatites discoideus Hall, and Goniatites Patersoni Hall. In some, however, as pointed out by Barrande in Goniatites plebius, the ventral prolongation of the funnel deepens the ventral lobe itself. This is due, perhaps, to the extensive

* Plate I, Figs. 4, 5. Plate II, Figs. 7, 8.

† Plate I, Figs. 1, 0.

‡ Plate I, Fig. 2.

§ Plate II, Fig. 8.

‖ Plate II, Figs. 10, 0.

¶ Woodcut on last page of text.

development of the funnel in Goniatites, which contrasts with the slighter proportional development of this part in Ammonites.

Leaving the funnel to be more fully described in treating of the structure of the siphon, we can proceed to the dorsal side of the second septum. This suture is precisely similar to the ventral side in the number of the lobes and cells, though these are shallower and narrower, as might be expected from the more confined limits within which they are necessarily distributed. The young Ammonite in the second septum, therefore, really possesses, like the simpler forms of Goniatites, — the Nautilini, which almost exclusively occupy the Silurian epoch, — only large lateral lobes, which, with their duplicate dorsals, make four in all, together with one dorsal, one ventral, and two inferior lateral lobes.

These last occur upon the edge of the whorl, and are therefore filled, at first, only by single lateral projections of the animal's body. They, by growth, become duplicated on the ventral and posterior sides ; but, at this stage, they are single. The sutures of the second septum, therefore, possess one pair of median lobes, the ventral and dorsal ; two pairs of superior lateral lobes, and one pair of inferior lateral lobes, making eight in all.

Six is the number which has always been attributed to the young Ammonites, and also the normal forms of Goniatites, though differently counted. The external lateral lobes were counted by D'Orbigny and others separately from their duplicatures on the dorsal side ; very inconsistently, however, the dorsal lobe, which is plainly only a duplication of the ventral, was enumerated as a separate lobe. In this way observers have found only two external inferior, and two external superior lateral, with one external, and one internal median lobe, making six in all. D'Orbigny was strictly correct, so far as he went, in assigning six lobes to the young Ammonite, though at fault, with the exception of the ventral lobe, in not observing their counterparts on the dorsal side.

The third and succeeding septa * on the first volution differ only in the fuller development of these same lobes and cells ; on the early part of the second volution in Deroceras planicosta, and on the latter part of the first whorl in Arnioceras semicostatum, however, the increase in breadth of the whorls exceeds the normal increment of growth of the lobes and cells. When this takes place, the inferior lateral lobes no longer occupy their old position on the umbilical border, but retire with-

* Plate I, Fig. 4. Plate II, Figs. 7, 8.

in, and the inferior lateral cells appear.* The whorl continues to enlarge, and finally these also retire to make way for the first auxiliary lobes. This occurs in Deroceras planicosta upon the last quarter of the second volution; but in Arnioceras semicostatum the development is much accelerated, the first auxiliary lobe appearing on the first quarter of the second volution. The first auxiliary cell succeeds these lobes in the latter species, certainly as early as the second quarter of the third whorl, and in the former they are delayed until the second quarter of the fourth.

The peculiar minor lobe dividing the superior lateral cells, the first decisively Ammonitic characteristic assumed by the sutures, is fully expressed in Arnioceras semicostatum, on the latter part of the third volution, while in Deroceras planicosta the minor lobes are hardly apparent on the latter part of the fourth.

Further than this it is not my present purpose to carry the history of the development of the sutures. From this point, or rather after the first two whorls, the sutures should be studied in connection with special series and groups of series.

D'Orbigny, who studied more thoroughly than any other author the mode of apparition of the auxiliary lobes upon the umbilical side, decided that they were due to the increase in breadth of the whorl, and the facts here recorded confirm the accuracy of his statements.

My observations do not lead me to recognize the so-called Ceratitic period of other writers. If there is anything peculiar to the Ceratites, it consists in the presence of an indefinite number of small, club-shaped, serrated lobes. No corresponding features exist in the young Ammonite, not even in Amm. floridus, as figured by Hauer. The smooth and deeply sinuous sutures of the young Ammonite, such as Arnioceras semicostatum, have a faint resemblance to those of the adult of Goniatites Hyas, from Rockford, Indiana, and to some adult Clydonites or young Ceratites. These are mere similarities, however, which do not impress the observer as anything more than mimetic changes, such as are observable everywhere between the structures and forms of distinct, but genetically connected series. The fundamental characteristics of the simpler and earlier-occurring Nautiloids and Goniatites are very distinctly repeated in the young Ammonite, but beyond this comparisons can only be safely made by tracing series downward. I have succeeded, by the aid of the

* Plate I, Fig. 8. Plate II, Fig. 9.

splendid material accumulated by Professor Agassiz, in doing this with considerable certainty for the Arietidæ, Liparoceratidæ, Cycloceratidæ, and somewhat less completely for several other families of typical Ammonites.

Goniatites has the first septum very similar to that of the typical Ammonites, but on the ventral side a deep siphonal fissure occurs, owing to the near approach of the conical prolongation of the siphonal cœcum to the ventral side.* The sutures of the first septum follow the cone in two specimens of Goniatites diadema, but in both the necessarily violent removal of the shell probably carried away the outer side of the siphon.

Barrande's observations show that this frequently occurs in the adult, when the whorls of the Silurian Goniatites are torn apart in order to expose the ventral side. The broken edges of the upper part or neck of the siphonal cœcum, in both the specimens alluded to, as in the one figured,† make continuous sutures along the abdomen from the first to the second septum, and this could hardly be accounted for under any other conditions.

A comparison of sections of this part of Deroceras planicosta and Goniatites diadema ‡ show that in both the same conical prolongation exists, and has about the same relation to the shell. In the former, however, the cone ceases to be an integral portion of the siphonal cœcum, and the invariable continuity of the suture of the ventral cell is due to the manner in which the first septum bends inward to form the floor of this part only, instead of being more deeply inflected to form the cone, as in Goniatites.§ Both are normally entire, but in Ammonites alone, owing to the structure of the cone, is this apparent in all specimens. The suture of the second septum in Goniatites diadema is continuous; the neck of the siphonal cœcum not being so close to the shell, it is not easily obliterated, and the dark line of the suture is readily traced across the siphonal area. This septum has entire outlines, a shallow broad ventral lobe, and superior lateral cells, with narrower, but still very well marked lateral lobes near the embryonal umbilicus. ‖ The dorsal sides of neither of these septa were observable on account of the opacity of the specimens.

* Plate III, Figs. 3, 5, 6.

† Plate III, Figs. 3, 5, 6.

‡ Plate I, Figs. 3, 4. Plate III, Figs. 5, 6.

§ Plate II, Fig. 1, 1 c.

‖ Plate II, Figs. 3, 4.

Comparing the first septum with the corresponding septum of Deroceras planicosta, it is noticeable that the ventral cell and the lateral lobes are deeper and narrower in the latter; a characteristic liable, probably, to considerable variation, since it accords with the larger size of the neck of the ovisac, and the consequently greater spread of the sutures in Goniatites diadema.

The suture of the second septum differs far more from its representative in the young Ammonite. The ventral lobe of the latter, with its siphonal fissure, is represented by an entire shallow lobe; the superior lateral cells have their counterparts in wide, shallow, evenly curved sutures, unbroken by any superior lateral lobes. This comparison, and the abrupt introduction of the superior lateral lobes in the third septum of Goniatites diadema,* also show plainly that the superior lateral lobes do not arise, as do the inferior lateral and auxiliary lobes, from projections of the body, which appear first as single lobes upon the edge of the umbilicus, subsequently becoming double (i. e. divided into dorsal and ventral, *vis-à-vis*,) by the spreading of the sides of the whorls. On the contrary, they are derived from the direct growth of a lobe which bisects the large entire superior lateral cell, and divides it into superior and inferior lateral cells. The inferior lateral lobes are present in both. The outline of this suture in Goniatites diadema is very like that of the adults of Nautilus atratus and similar species among the Nautiloids which have sweeping lateral and shallow abdominal curves.

The next, or third septum of the young Goniatites diadema introduces the superior lateral lobes as a minute angular indentation, not at all similar to the rounded superior laterals of the young Ammonites. The development of the sutures is more accelerated in the growth of the latter than of the former, since here we have two septa with Nautilian characteristics, in place of one among the later-occurring and more complicated Ammonites. When the young Goniatites diadema is contrasted also with those of its own group, we find some interesting resemblances. The Nautilini never develop superior lateral lobes, the Retrorsus group, Magnosellares of Sandberger, not until a very late stage of growth, and in some varieties, as shown by the masterly researches of the last-named author, these lobes are very slight, even in the adults. I have not examined the young of other species and

* Plate III, Fig. 4.

groups with more complicated sutures. This additional evidence is not necessary, however, to show that within the Goniatites there is still greater acceleration displayed between the young of different groups in the development of the lobes and cells, than can be found between the young of the latter and the typical Ammonites. This also corresponds with the scope of the modifications observable in the adults of the entire division between the simple Nautilini, and the Genuifracti or Serrati, or the range of variations in the adults of the same species, as exhibited by Goniates retrorsus and others. No such variability of the sutures exists among typical Ammonites, excluding the allied divisions of Ceratites. Thus, in the adults as well as in the form of the young and the amount of involution, we find greater fixity resulting from the acceleration of the development as we rise higher in the type. This continues until senility or the decline of the type again produces something similar among the aberrant uncoiled genera of the upper Jura and the Cretaceous. The fourth, and succeeding septa of the young Goniatites merely increase the divergence from the common type, the rotund ovisac, and first septum, and the history of these later stages will undoubtedly be found to be characteristic of, and highly useful in the definition of special groups.

The first true septum of Nautilus has exceedingly shallow lateral inflections of the sutures, and a ventral cell of corresponding curvature. These could hardly be termed lobes and cells, so slight are they, if it were not for the greater intensity of their expression in the second and succeeding septa. A very important feature of this first and all the succeeding septa, is the dorsal lobe. This has been previously noticed by De Montfort,* who founded his genus Bisiphites upon this feature, and by other authors, as an adult characteristic of many of the fossil and recent Nautili. Its developmental history has not, however, been followed out, except by Quenstedt.† This observer described only its later stages, and its disappearance in the adult. He appears also not to have noticed that, in the adult, a slight inflection remains in the suture after the lobe in the septa ceases to exist. Barrande describes the sutural lobe and the corresponding conical depression of the septa, but considers that they may be independent of each other. They are, however, so closely connected in the extreme young, that the sutural

* Conchyl. Syst. 1808.

† Petrefactenkunde Deutschlands, Ceph. p. 55.

inflection, which is alone retained in the adult, should be regarded as a remnant of the more complete lobe of the young. In the Aganites group, the lobed and its accompanying sutural inflection are present whenever the siphon funnel is not too close to the dorsal side. When this occurs, as in Nautilus zic-zac, the lobes of the septa are not developed, but the sutural inflection appeared to be distinctly marked. Whether this was really persistent, or whether the depressions I saw were due to the violent removal of a portion of the funnel, was not satisfactorily determined. The dorsal lobe of Nautilus Pompilius impinges against the internal portion of the upper end of the cicatrix, just as the siphonal cœcum does against that of the lower end, and is apparently the result of the passage of some organ or part from the ovisac into the shell, but the entire outline of the first septum in the young of Nautilus atratus, N. Koninckii, is conclusive against such a supposition.* It is evidently only another of the same kind as those characteristics already cited, which are developed earlier in later species of the same genetic series, according to the law of acceleration of development. When compared with the small area of the first septum of Nautilus Pompilius, it is seen to be a large and very well marked lobe. The size, however, does not increase proportionally with the growth of the shell and the area of the septa, and thus in the adult it becomes comparatively insignificant. During the younger stages, also, it modifies not only the sutures, but forms a decided conical depression in the septa themselves, so that the latter bend posteriorly at their junctions with the dorsal side of the shell. The lobe in the suture, however, is formed higher up, just under the cone of the next older septum. This is due to the great extension of the septa of Nautilus on the dorsal side, which reach so far that they are overlapping or imbricated. This cone disappears on the first quarter of the third whorl, and the septa, instead of bending posteriorly into a lobe, are simply rectangular with a minute depression on the surface. This, however, speedily disappears, and a slight ridge, evidently marking the trace of some organ or part, makes its appearance. This is found first bisecting the sutural lobe, and seems to extend continuously underneath the septa built upon the inner surface of the dorsal side of the shell. The septa, after the appearance of the ridge, lose their rectangularity, and become evenly concave, the narrow,

* Plate IV, Figs. 5-9.

shallow depression in the edges of the suture being the only remnant of the dorsal lobe.

The second and succeeding septa of the young Nautilus Pompilius differ in the possession of a narrow ventral cell upon the median line. This subsequently loses its prominence, but is not wholly lost in the general expansion of the cell; even in the adult there is a slight rising of the suture as it approaches the median line of the abdomen on either side. The first septa of Nautilus Pompilius, as might be supposed from the form of the whorl, are remarkably broad from side to side, and slightly inflected on the dorsum on either side of the posterior inflection or deep dorsal lobe previously described.

In the Clymeniæ the dorsal lobe exists, and it may be observed at an early stage, very large and distinct even in the simple sutures of Clymenia lævigata. Sandberger's researches show that it is a common characteristic of all the species of this Devonian group. The siphonal funnel of the Clymeniæ, which occupies the bottom of this lobe, is evidently entirely independent of the lobe itself, as in the case of the ventral lobe of Goniatites and Ammonites. The homology of the dorsal lobe in the young Nautilus with that of the adult Clymeniæ, can hardly, therefore, be considered doubtful. It occupies the same position, and has a similar conical form, with an accompanying broad, deep, and rounded sutural inflection. This is especially marked in the Aganites group of the Tertiary, where the siphon is variable in position, and sometimes close to the dorsum occupying the area of the dorsal lobe, as in Nautilus zic-zac, and in other species more central. Here we have an additional reason, besides that previously found in the earlier occurrence of the Goniatites, for separating the Clymeniæ including also Aganites as a distinct genetic series from the Ammonoids, notwithstanding the ventral lobe of Clymenia pseudogoniatites.

The young Nautili of the Silurian, as figured by Barrande, have shallow concave septa, and a more or less shallow outline in accordance with the elliptical or circular shape of a section of the young. This is especially noticeable in the figure of Nautilus ellipticus by Barrande.*

At a more advanced age all the species except Nautilus vetustus have an elliptical outline more or less flattened on the abdomen. They also possess, in the adult, a narrow ventral cell, like that of the young Nautilus Pompilius, on the third and succeeding septa. The Carboniferous

* Op. cit., Plate XXXII, Fig. 1.

species, which have similar cone-like young, have also similar septa. Nautilus Koninckii * at least, has septa, which differ from the more advanced stages of the young of Nautilus Bohemicus, possessing a faint dorsal cell, or rather subangular outline to the dorsal side of the septum. The suture of the first septum was observed upon one side, though obscured on the other, and this evidently possesses decided, though very shallow ventral and dorsal cells, with correspondingly slight lateral lobes. The septa were elliptical in outline, with the dorso-ventral axis longest, as in the Silurian Nautili, though they speedily reverse this in course of growth, the transverse axis becoming the longest in the adult. The dorsal lobe appears first in Nautilus Barrandei, Hauer,† or at least has not been described or seen in any species occurring earlier, though it is a characteristic not likely to escape observation, and was well known to Barrande, Sandberger, and others who have worked up the Nautili of the earlier formations. The developmental history of the septa of the Jurassic species shows a decided acceleration in the septal characteristics. Saemann's original specimen, when thoroughly cleansed,‡ showed that the outline of the first septum was an ellipse, slightly flattened on the ventral side, correspondingly with the flatness of the external outline, and nearly parallel with the area of the cicatrix.§ Sections of two different specimens of Nautilus lineatus show the same characteristics. The first septum of Saemann's cast has an entire cell on the dorsal side, as in the young of Nautilus Koninckii of the Carboniferous, though in accordance with the shape of the dorsum it is much broader, and this cell is still more prominent in the second septum, and broken by a dorsal lobe. The second septum crosses the central axis of the spiral at a different angle from the first septum, and is not, therefore, parallel with the area of the cicatrix. The dorsal lobe is very distinct in the third septum, and is supplemented by a decided though shallow inflection of the large dorsal cell forming a shallow supplementary lobe, such as has been already described in Nautilus Pompilus. The concavity of the dorsum becomes apparent between this and the second septum.

* Plate IV, Figs. 7, 9.

† Haidinger's Naturw. Abhandl. Ceph. von Hallstadt. By Hauer. Vol. III.

‡ It was covered with a thick coating of iron-rust, which obscured the sutures, and entirely concealed the first septum, which was consequently omitted in Saemann's figure of this specimen.

§ Plate IV, Figs. 5, 6.

The lateral lobes are only very faintly marked, as is also the ventral cell. In the next three septa all these features are intensified, but in the sixth and seventh septa a change takes place. The ventral cell becomes flattened, and forms a transition to the slightly concave ventral cell of the eighth septum. After this period the concavity becomes deeper, and the shell, by growth, increases the depth and size of the other lobes and cells which have been described, but otherwise does not materially change them.

Thus the Jurassic Nautili, with a shallow lobe instead of a cell on the abdomen, do not possess this characteristic in the young, but have the usual projecting cell of the Silurian Nautili. Their septa also resemble, at the earliest period, those of the same forms when considerably older, but this outline changes in the second septum. The development is also accelerated in another way than by the earlier appearance of the Silurian characteristics. The increased involution, as previously shown in the small size of the umbilical perforation, and tendency of the whorls to spread inward, causes the second septum to advance its outer or ventral edge, and make a sharp angle with the first septum. The antero-posterior axis of the whorl, in other words, curves suddenly instead of slowly, as in the Silurian and Carboniferous Nautili, and the first septa are not consequently parallel either with the mouth of the ovisac, as indicated by the area of the cicatrix, or with each other.* The second septum resembles the first, however, in its shallowness, and is a transition to the third, which crosses the whorl at the same angle as the older septa, and also resembles them in its deeper concavity, and the shape of the dorsal cell and lobe. The acceleration of the development shows itself very decidedly in the modern Nautilus. The outline of the first septum of Nautilus Pompilius is broader, but otherwise the suture is identical with that of the third septum of Nautilus atratus, and like that has the same trend as the older septa, and is deeply concave. Its breadth, also, is due to the accelerated rate of growth of the young, as are also the absence of any stages corresponding to the first and second septum of Nautilus atratus. The outline of the area of the cicatrix is very similar to that of the first septum in Nautilus atratus, and this shows that, in all probability, the neck of the ovisac resembled in shape the apex of the first whorl in the Jurassic Nautili.

* Plate IV, Fig. 10.

SIPHON.

The siphon has been so much studied and so fully described that at first sight it seems impossible to add anything to our knowledge in this direction. The structure, however, in many of the most essential features has been either misinterpreted, or only partially understood, on account of the disuse of the microscope in palæontological researches. The siphon in Nautilus Pompilius * begins with a closed cœcal prolongation of the first septum. This is circular in outline, apparently flattened at the bottom, and rests directly upon the lower end of the cicatrix. The ventral side is somewhat inclined, the dorsal more or less abrupt, the cœcum swelling out below the septum in the specimen examined. Above the first septum the siphon expands, becoming much larger. The walls, as well as the bottom of the cœcum, are lined internally by an extension of the sheath, which is continuous with the siphonal funnel of the second septum. There is also in the figure on Plate IV a layer lying between the internal corneous layer of the siphon and the sheath. The walls of the third septum are continuous beyond the mouth of the siphonal funnel of the second septum, and seem also to coat the inside of the cœcum, but I have been unable to verify this observation upon other specimens, and prefer to consider it doubtful.

The structure of the outer wall, or sheath of the siphon, differs from that of the septum itself, in being of a looser and more granular texture. This, in the specimen examined, was more marked upon the dorsal than upon the ventral side, between the apex and the first septum, as well as between the latter and the second. At the third septum, however, this difference is not so noticeable; the denser portion of this septum, or the siphonal funnel, extends posteriorly nearly as far on the dorsal as on the ventral side. As previously described, the siphonal funnel rests upon the looser-textured wall, and is really continuous with it. The difference in texture merely results from the quicker formation of the latter, while the animal is passing from one septum to the next in age, and the quieter deposition of the former while the animal is taking its periodic rest, and building up a septum.

The siphonal funnel is always spoken of as belonging to the septum, and not to the siphon proper. This is true of the adult, but not of the

* Plate IV, Fig. 4, R.

young. The siphonal cœcum is entirely made up of the funnel of the first septum. The funnels of the second and third septa are excessively long, but in the fourth a decided decrease in this respect is noticeable, and on the fifth septum it assumes very nearly the short aspect of the same part in the full-grown shell. The lips of the funnel incline inward, resting upon, and surrounded by, the looser-textured wall of the siphon, which reaches exteriorly considerably beyond the lips of the funnel in the young, and in the adult sometimes to the bottom of the septum itself. Barrande describes the length of the funnel as exceedingly variable in the Silurian Nautili; but this does not appear to be true among the modern forms. I was unable to determine whether the funnel in the Jurassic Nautili was longer in the young than in the adult. It is probable, however, that, as in other characteristics, this will be found to have acquired greater constancy, as we proceed in time; in fact, the funnels of the young Nautilus Pompilius, invariably longer than those of the adult, show that the length has not only become more constant, but has even been reduced, in accordance with the law of acceleration, to an embryonic characteristic.

Sandberger and Barrande, who have studied the siphonal funnel more than other authors, use a somewhat different terminology, the former speaking of it as a funnel and the latter as a conical neck. I prefer Sandberger's term, because it seems to me to express the form quite as well as the latter. In all the species that I have examined, whether Nautili, Goniatites, or Ammonites, the aperture is always somewhat wider than the bottom, and one side, the ventral, inclined, the opposite being more abrupt.

In other Nautili, however, the funnel form is more distinctly expressed, as in Nautilus zic-zac. Here the structure which I have described, the continuity of the outer layer of the siphon or sheath with the septum, is most plainly expressed. The siphonal funnels in the adult extend posteriorly, as in the young Nautilus, to the opening of the next younger funnel. They become narrower posteriorly, until near the junction, and then a tumid band plugs up completely the siphon, some distance outside of, or posterior to, the flaring sides of the funnel. In other words, the funnels set into, and not upon, each other, like a pile of the necks of broken bottles, when the septa are fractured in order to expose them to view. The shell of the funnel throughout is of the same close, pearly texture, except the swollen band at the junction. When this is more closely examined, it is seen to be composed of two portions, the tumid external sheath of looser granular texture, and the narrowing neck of the funnel. Thus the tumid band is really, though so narrow, the representative of the external sheath of the siphon in Nautilus Pompilius, and performs the same function of uniting the siphonal funnels, and protecting the continuous horny layer of the interior. In other Nautili, such as Nautilus lineatus of the Jurassic, the siphonal funnel becomes a ring or section of a cylinder, flaring or inclined outward both above and below like an eyelet.

Inside of the funnel and the sheath in Nautilus Pompilius is a layer, which is also of a loose texture similar to the sheath, and inside of this, the continuous dark corneous layer. The intermediate layer has not been previously observed, and I have unsuccessfully endeavored to find it in the siphon of the adult. The condition of the specimen was such that I cannot now be sure that it is really a distinct layer.

The sheath in the adult is not simply of a loose granular texture, but looks more like the rough surface of a sponge pierced with holes, which are visible with an ordinary magnifier in desiccated specimens. Externally, the sheath is covered by the lining membrane of the chambers, and has a pearly aspect in many specimens. The thickness of the sheath and its color vary greatly. In one specimen it was so excessively thin and porous, even in the adult, that the color of the corneous layer shone through. At an older stage, however, it assumed the usual opaque aspect. Viewed from the interior, it is usually smoother, pearly, and shows broad bands, probably bands of growth. If so, the animal must progress neither quickly from septum to septum, as supposed by Owen, nor slowly and constantly, as described by Valenciennes, but probably with many intermediate periods of arrest marked by the deposition of these bands.

The siphonal cœcum of Nautilus lineatus* occupies a different position from that of Nautilus Pompilius. The cœcum lies against the inner side of the area of the cicatrix near the centre in Nautilus lineatus, and both sides swell out under the first septum as on the dorsal side of the same organ in Nautilus Pompilius. The siphon between the first and second septa makes a curve like the central portion of the letter S, first inclining ventrally, and then bending again towards the centre. The position

* Plate IV, Fig. 10.

of the cœcum nearer the centre accords with the situation of the first septum, and its parallelism to the area of the cicatrix, but it is still, as in the recent Nautilus, considerably nearer to the ventral than to the dorsal side. Owing, however, to the position of the first septum with relation to the angle or apex made by the bending of the external shell around the ventral edge of the first septum, the cœcum is not so near the so-called apex of the whorl as in Nautilus Pompilius. In other words, it lies nearer the centre of the actual apex, the centre of the cicatrix, and farther away from the apparent apex, or angular termination of the outline, than in Nautilus Pompilius. The peculiar abrupt curves which it subsequently makes are due partly to the abruptness of the ventral side of the cœcum, and partly to the angle at which the first septum lies with relation to the second. All of these characteristics are thus shown to be dependent upon the altered or accelerated development of the septa in the young of Nautilus Pompilius, which causes the first septum to assume a position and other characteristics similar to those of the third septum of Nautilus atratus and lineatus. Another fact in the same direction is the ventral position of the cœcum in the Jurassic and existing species, as contrasted with the central siphon of the young of the Silurian and Carboniferous Nautili. The extreme variability of position of this organ among the adult forms of the Silurian of course renders this characteristic somewhat doubtful, but it is a curious fact that we should find it so strictly accordant or correlative with the other characteristics already described. It must evidently be added to our other list of characteristics, which though at first variable, become in course of time fixed and invariable, through the action of the law of acceleration.

The siphon of Goniatites differs in a remarkable manner from that of Nautilus. It has a long conical termination which penetrates the first septum, and lies so close to the abdomen as to form a very decided fissure, probably due, however, as previously explained, to the removal of the shell. Otherwise the siphonal cœcum would be open on the abdominal side, which it does not seem to be when seen from the side, and covered by the shell. The cœcum above is flask-shaped, the neck of the flask lying between first and second septa. The first septum forms the round bottom of the flask and the closed conical prolongation; the second septum, the neck and part of the body of the upper portion. The neck, however, continues to decrease in size until it reaches the third septum. The siphonal funnel is apparent even in the first septum, as may be seen in the ventral view of this part in Goniatites diadema, on Plate IV, where the sutures incline posteriorly at their junction with the cœcum. Thus, instead of being entirely out of the ovisac as in Nautilus, whether recent or fossil, the siphonal cœcum is to a considerable extent developed within the ovisac. In other words, this part is developed and completed later, as is also the first true septum, of which it is an integral part, in the existing Nautilus, than in the fossil Goniatites, certainly as early as the Carboniferous and perhaps earlier. I should expect, however, to find some change in this respect in the Silurian forms of Goniatites.

The cœcum is made up of the same elements, if we consider that the internal corneous element has probably been destroyed in the course of fossilization.

The siphonal funnel at a later age becomes more distinct, and is not confounded with the sheath of the siphon as it is in the first and second septa, and perhaps the third also, but this last fact could not be determined satisfactorily. At a later stage the funnel is very distinctly seen, and, as described by Guido Sandberger, is continuous on the ventral side, though it lies almost its entire length against the shell. Barrande has described this occurring in the same manner in the Goniatites of the Silurian, and thus accounts for the appearance which deceived Von Buch. This author supposed that one of the main distinctions between Goniatites and Nautili lay in different positions of the siphon. He removed the shells of certain Goniatites and Ammonites, and apparently exposed the siphon lying in immediate contact with the shell, whereas he had really torn off the ventral lip of the siphonal funnel with the shell. Barrande, on removing the shells of Goniatites, found that this frequently occurred, and thus established the truth of Guido Sandberger's observations.

The posterior edges of the funnel * rest in and upon the siphonal sheath very nearly as in Nautilus Pompilius, and this sheath, also, as in the latter, connects the siphonal funnels of adjacent septa, as described in Nautilus.

The siphonal cœcum of Ammonites possesses very nearly the same form as in Goniatites, but is, in the species examined, perhaps somewhat flatter dorso-abdominally. It has the same position, but yet no difficulty was experienced in removing the shell without disturbing the cœcum,

* Plate III, Fig. 8, P.

or breaking the continuity of the suture of the first septum on the abdomen. The prolongation into the ovisac was not discernible on the abdomen, except in one specimen, and from the side not so distinct as in Goniatites.* The figures of this portion, owing partly to the great thickness of the specimen, and to its more attenuated structure, were completed with great difficulty, and only after repeated observations. By the use of dark ground illuminations and a powerful condenser, the cœcum extending below the first septum was seen from the abdominal side in Fig. 5, Plate I, though the walls seemed broken and partly destroyed; the cone, however, was not made out. Longitudinal sections of several specimens gave substantially the same results as the single one figured. The cœcum is formed as in Goniatites by the siphonal funnel of the first septum, but the conical prolongation does not open into the cœcum,† and its interior is filled either with a succession of other cones, or by a number of pillars stretching across its interior. The peculiar aspect of this portion in the specimens examined has suggested an explanation of this remarkable modification. When the first septum was formed, it may have been composed entirely of the thin membraneous layer on the ventral side of the cœcum, and the first thick layer at *y* in the figure; as the siphonal sheath was built up or thickened, it was carried forward on the ventral side, the different successive layers or partial septa from *y* upwards, marking the resting-places in this transit until at 1 *e* the first septum was completed. Whether this be so or not, the conical part of the cœcum has not, as far as my observations go, any decided connection with the cœcum when closely examined in section, though when seen from the side, as in Plate I, Figs. 3, 4, a connection appeared probable.

Von Buch pointed out the anterior direction of the so-called siphonal funnel of Ammonites, and has been followed by all authors since his time. The use of the microscope, however, readily detects here a very curious error. The anterior siphonal funnel of Ammonites is not identical with the true funnel of Goniatites and Nautilus, but an additional organ.‡ In the adult nearly the whole thickness of the septum bends in an anterior direction, reversing the shape of the lips of the funnel.§ In the young, only a small part of the septum bends anteriorly, and the funnel is partially maintained, while in the very youngest stages no such

* Plate I, Figs. 3, 4.
† Plate II, Fig. 1 y.
‡ Plate II, Fig. 4,
§ Plate II, Fig. 5.

anterior extension is apparent.* In all cases this anterior deflection of the septum forms an open collar surrounding the sheath. The lining membrane of the chambers, of course, surrounds it as well as the sheath, but otherwise it cannot be considered as connected with the sheath. The difference between Ammonites and Goniatites consists, then, so far as the adult siphon is concerned, in the possession by the former of a more completely rounded siphonal cœcum and the siphonal collar. Besides the earlier development and different form of the siphonal cœcum in the Goniatites and Ammonites, as compared with Nautilus, we find extensive differences in the formation of the siphonal funnel. This, instead of lining the interior of the cœcum by its extension from the second septum, as in Nautilus, only reaches the mouth of the opening through the first septum, and in the succeeding septa, instead of reducing the length gradually, the funnel becomes at once, in the third septum, very short and distinct from the sheath. They all three, Nautilus, Ammonites, and Goniatites, agree, however, in having, during the earlier stages of development, a siphon formed by a cœcal prolongation of the first septum. The large size of this cœcum, as compared with the area of the first and second septa, is also an important fact in this connection.

If there is any truth in the application of embryology to the solution of the problem of evolution, or even of the relative rank of forms, it is evident that in either sense the true prototype of the Cephalopods must have these characteristics, namely, a large siphon, composed of circular prolongations of the septa, or siphonal funnels closed at their posterior ends. Consulting the development of the simpler Nautilus, we see also that these siphonal funnels should set one into another, like a pile of cups, or cones, and the septa be concave and very shallow, as in the Jurassic and Carboniferous species. The conditions are partially fulfilled by the genus Endoceras, whose septa are shallow and concave, and the siphon consists of a series of cones, placed one within another, and closed at the posterior extremity. These cones are not strict siphonal funnels; the funnel portion really only extends from the opening of one septum to that of the next, and the cones, which are evidently the homologues of the sheath of Nautilus, are built against the continuous wall thus formed, as partitions in the siphon itself. These are the characteristics of the adult only, and it can be reasonably anticipated that the young of Endoceras would exhibit a

* Plate II, Fig. 1.

siphon composed wholly of cœcal prolongations of the septa themselves.* The discovery of the adult corresponding to the young of Endoceras is yet to be made, and even the young of Endoceras has, I believe, never been described. A fragment of an Endoceras, the Orthoceras duplex of Verneuil and Keyserling, can be even more closely compared with the young of Nautilus, than our American species. In this the septa bend posteriorly, forming extraordinarily long funnels. Instead of simply connecting adjoining septa, as in the ordinary forms, the funnel overlaps and extends just twice as far, to a point opposite to the second younger septum, posterior to that from which it takes its rise.† This compares with the tendency of Nautilus to increase the length of the funnel in the young, and the slighter distinction which exists between the texture of the sheath and the siphonal funnel itself, until at the earliest period, the siphonal cœcum is wholly composed of the siphonal funnel closed at the posterior end. Evidently a similar method of development is to be anticipated in Orthoceras duplex, and as the funnels extend so far, we ought also to find more than one cœcum. That is just as in the young Nautilus Pompilius we find that the sheath of the second septum extends into the siphonal cœcum and is closed, forming really a second cœcum; so, in the young of O. duplex the siphonal funnel of the second and third septa at least will probably be found fitting into the siphonal cœcum, and closed at the bottom.

I have industriously examined the young of Orthoceras in order to ascertain whether they too had any close resemblance to the adult of Endoceras; so far, however, my search has been fruitless, probably owing to the unfitness of the forms which have come into my hands for microscopical examinations. In the group of the Vaginati to which Endoceras belongs, it is common to find the huge siphon filled to a greater or less extent by calcareous deposits, differing considerably from those filling the living chamber and the septal chambers. Barrande, with his masterly grasp of facts, has demonstrated that these deposits are made by a posterior prolongation of the body of the visceral sac, and are not the result of fossilization. Barrande, also, considers the cones of Endoceras to have been deposited in a similar

* If, indeed, any septa remain in the extreme young.

† De Verneuil and Comte de Keyserling, Russie et l'Oural. Vol. II, Plate XXIV, Fig. 7.

manner, and attributes the spaces between them to the suddenness with which the animal arose from one resting-place to another, which did not permit the secreting surface to fill up the entire tube. Whether this is the true explanation or not does not here signify, since the main points of structure are the same, and the siphon is closed, according to both authorities.

Barrande has also, in his immortal work on the Silurian Cephalopods of Bohemia, given, with his customary fulness and accuracy, a complete analysis of the elements of form and structure among the Nautiloids. He has, however, settled upon Ascoceras as the prototype, regarding the Vaginati as the nearest allies of Ascoceras. In describing the structure of Ascoceras, this author acknowledges the existence in the young of simple concave shallow septa, pierced by a true siphon, which opens into the bottom of the living chamber, as usual in all the Tetrabranchiata.

On one side of the living chamber a series of septa are built up, whose sutures reach only partially around its circumference, and the septa themselves in the interior are equally incomplete. The imperfect septal chambers thus formed do not open into the living chamber, but are closed by the bent edges of the septa, whose free internal borders bend posteriorly until they come in contact with each other. These posterior prolongations are, in Barrande's opinion, the equivalents of the siphonal funnels of the Vaginati, many of which group have siphons open on one side, and constructed not unlike this large posterior prolongation of the living chamber in Ascoceras. There would be not the slightest hesitation in accepting this opinion, if it were not for the siphon and perfect septa existing in the young. This, according to the laws of development, as they are now understood, would constitute the Ascoceras a degraded type, one which like the Cirripeds among Crustacea, had developed into a structure simpler and of a lower zoölogical rank, than if the growth had been arrested at a comparatively early period. This would meet one of Barrande's principal reasons for considering Ascoceras as lower than the Orthoceratites, which is, that it certainly could not be placed above them, and really possessed, in its immense, incomplete, adult siphon, or posterior prolongation of the living chamber just described, a much simpler structure than any of the other Nautiloids. There is probably but little doubt that the Ascoceratites, as claimed by Barrande, have all the elements of structure found in subsequent forms besides their greater simplicity, but this can be accounted for best by considering them as forms having a truly retrogressive development, what has usually been described as a retrograde metamorphosis.

The types of Ascoceras which I have seen are much too imperfectly preserved to enable me to speak from my own knowledge of the nicer points of structure described by Barrande, but that author's unsurpassed and minutely accurate figures supply all deficiencies. One peculiarity of the structure appears to be very unfavorable to the view here presented and is so considered even by the author himself; this is the want of connection between the young siphon and the supposed larger siphon of the adult. The first of the imperfect septa bends posteriorly, as do the others, but is not, however, discontinued when it reaches the last of the entire septa of the young. It is prolonged over the surface, and is really a complete septum, not pierced by any siphonal opening. We cannot imagine any normal progressive mode of growth by which the minute so-called siphon of the young Ascoceras could be changed into the huge visceral prolongation of the living chamber of the adult, without some of the intermediate steps of this change being visible, and some connection maintained with the siphon of the young. Barrande also states that in no instance has he found any more than one of the perfect elliptical septa of the young preserved; that over this he has observed the striations and markings of the external shell; and further, that the so-called minute siphon, or elliptical funnel, penetrates this septum. Now this condition is precisely what we should expect to find, if a portion of the exposed lower end of the Ascoceras, or area of the first septum represented the scar left by the ovisac on the apex of the whorl, as in Nautilius Pompilius. This would not only account readily for the presence of the striæ of the shell upon the exterior, but also for the projecting end of the so-called siphon. The latter would then represent the siphonal cœcum, which, as in Goniatites and Ammonites, penetrated the first septum, and by the removal of the ovisac had been left exposed.

Of course this explanation can only be considered as a suggestion calling for a re-examination of some of Barrande's fine specimens, and is quite as likely to be overthrown as to be confirmed by such a process.

Whether this be so or not, the young Ascoceras was evidently, as described by Barrande, in possession of a siphon, or the representative of one in the young, and occupied the entire cavity of the living-chamber; whereas, it subsequently lost this siphon, and built up a portion of the living-chamber with imperfect septa, leaving a cylindrical hollow, which was evidently occupied by the visceral sac, thus plainly retrograding in structure, and undergoing retrograde metamorphosis, like Orthoceras in the young, and perhaps somewhat similar to Endoceras, or others of the Vaginati in the adult.

THE SHELL.

The shell of the young Nautilus, at the apex of the first whorl, consists of two layers, an imbricated internal nacreous layer, and a layer of denser texture.* The internal layer is at first a single plate deposited at the apex. The zones subsequently secreted overlie this internally on both the dorsal and ventral surfaces, and from this point the imbricated structure is maintained throughout. This shows that the internal layer is entirely deposited from within, and probably by the border of the mantle. Whether seen in transverse or longitudinal sections, it presents the crenulated aspect common to nacreous shells. It is considerably thicker on the dorsal side, owing to the longer time which the mantle must take in passing a given point on the dorsal or inner side of the spiral. This thickness is increased by the manner in which the septa extend and overlap their borders on the same side, though in the figure this is not shown, because the cut extended through the side of the dorsal lobe. Subsequently, as the whorl grows larger, this difference between the absolute thickness of the shell decreases, and in the adult they are about the same on either side.

The external layer is quite thin on both surfaces in the young, but becomes also rapidly thicker on the dorsal surface, and assumes a denser and more opaque structure than the interior. A break in this layer on the dorsal surface just before it completed the first revolution, and came in contact with the apex,† shows that this layer was probably also deposited by the border of the mantle. At this point the layer is

* Plate IV, Fig. 4.

† The break is marked by a very faint line in the figure, near the angle of the umbilical perforation. This has accidentally been made too slight in the drawing; the break is much thicker and more decided.

imbricated, and the direction of zone the same as those of the internal layer.

When the first revolution is completed, the hood begins to deposit the dark layer on the external surface of the ventral side of the first whorl, and the true external layer becomes very thin, and is often hardly definable, appearing in the section as a very faint band next to the black deposit of the hood. On the ventral side, however, it steadily increases in thickness. It is this layer also which attains such an excessive development, and composes the principal part of the shell, close to the umbilical border. The brownish color of the exterior does not seem to be distinct, but rather to be intimately blended with this layer. A faint tinge is visible before the completion of the first volution, probably beginning somewhere between the fourth and fifth septa, which gradually extends in breadth and thickness, until it assumes the aspect which distinguishes the adult. The bands on the sides, however, were not observed in the young.

Valenciennes has fully described these three parts in the adult, distinguishing the internal and external layers, and also the outer colored portion of the last, which, however, he described as a distinct layer. He regarded the two last as confined to the exposed sides and ventrum of the adult, and for this reason attributed their production to the ventral arms of the animal. I am at a loss, however, to account for their imbricated structure, precisely similar to the internal layer, or for the presence of these layers upon the dorsal side of the young, unless they have been deposited from the interior by the edge of the mantle, as were the zones of the internal layer. The replacement of the mantle-edge by the hood when the first revolution was completed, as shown by the appearance of the black deposit, would, if this view were accepted, account for the very slight traces of the external layer left on the dorsal side after the hood came in contact with the apex of the first whorl. A fine specimen of Nautilus Pompilius in the possession of the Museum, with the contained animal in an excellent state of preservation, has been examined, and the structure of the mantle-edge confirms the view here taken. The entire mantle-border is thickened, as described by previous authors, but the edge on the sides and ventrum has a somewhat different structure from that of the dorsum. The edge is tumid and divided, as in the Lamellibranchiata, into lips, containing in the channel between them a brownish substance, probably the remains of the animal matter which colors the external layer. This brownish matter is friable and not a consistent horny membrane or epidermis. The mantle-edge on the dorsal side, however, is thin and lies posterior to the hood described by Owen and Valenciennes which secretes the black layer. That on the ventrum is much thicker, with tumid border and one channel. Farther down on each side, and corresponding to the increased thickness of the shell, the border becomes exceedingly thick with two channels, an outer and an inner, each still partly filled with soft matter, evidently unformed shelly excretions, whereas the dorsal border has no such material left in its channel.

Barrande states that the dark layer of the hood is wanting in the Silurian Nautili, and this accords admirably with the continuity of all the layers on the dorsal side in these species, and also in the slightly involute Carboniferous Nautili, which I have examined. Like the size of the umbilical perforation, and the concavity of the dorsum, the presence or the absence of the dark layer and the extent of the external layers depend upon the greater or less closeness and increasing constancy of the involution of the whorls. It could not be inferred from this, however, that the fold of the mantle or hood was absent or present in the same proportion. The black deposit simply indicates, so far as we know, the secreting power of the hood, and shows that this organ came in contact with the whorls, but nothing more. The external layer is visible with a common hand lens in Nautilus lineatus of the Jura, and exhibits characteristics similar to those of Nautilus Pompilius.

Lining all of the chambers, and the exterior of the siphon, is an exceedingly thin membrane, which upon the septa, and the sides of the shell proper, though not upon the siphon, is generally, but not invariably, connected with an equally thin layer of nacre, and in the desiccated specimens; they may be observed peeling off together. Even in Jurassic fossil shells, it is distinct and easily traced, probably owing to its connection with the nacreous deposit described above.

The same layers are traceable in the ventral and lateral sides of the shell of Goniatites. All the layers * consist of imbricated plates, laid on internally. There is in many specimens a dark-colored layer, equivalent, however, to the external layer of Nautilus, and like that, invested by a layer which corresponds to the smooth, colored layer of Nautilus Pompilius. In one specimen, figured on Plate IV., I was for-

* Plate IV, Fig. 11.

tunate enough to find in section all these parts, where a transient mouth had been formed, and the deposits continued from this break. Here all of these layers are decidedly imbricated; even the thin external colored zones show their imbrications in its external portion as zones of growth, evidently due to internal deposition. Keyserling has described and Sandberger figured what they have called the wrinkled layer, lying between the involved ventral and the dorsal side of the shell of the next whorl. This I have not seen, nor succeeded in detecting anything analogous in the specimens I have examined. The figures of Sandberger, however, are known to be very accurate, and the wrinkled layer is plainly shown, limited to the involved portion of the whorl, and not extending outside of these limits. The specimens I have examined with success are all young, and it may be that this layer is absent from the younger periods of Goniatites. Besides the two layers there is, as in Nautilus, an internal lining, layer, or fossilized membrane, visible in some specimens, and this, with the prolonged edges of the septa, appears to be all that is deposited on the dorsal side. Not only the external layer is wanting on the involving dorsal side, as in Nautilus, but the internal also.

The shell of Ammonites also consists of two layers * besides the internal lining layer, which both here and in Goniatites, may be often seen to pass between the septa and the shell, as it really does also in some instances in Nautilus.† It is evidently due to the mantle, which deposits a film upon the surface whenever it rests for a sufficiently long period in any one chamber of the whorl. I was also unable, in the young, to observe any deposit similar to the wrinkled or black layer of the Nautilus or Goniatite. ‡ Only the internal lining layer of the chambers thickened by the edges of the septa is deposited on the enveloped region or dorsal side as in Goniatites.

The shell in Ammonites, as in Goniatites, also extends over the ovisac on the abdomen and the sides. This, at first, led me to suppose that here, at least, it was deposited by the arms of the animal, as in Argonauta, and as supposed by Valenciennes, for the external layer in Nautilus. But nothing in the structure of the shell itself confirms this

* Plate IV, Figs. 1, 2, 3.

† Plate II, Fig. 1.

‡ The wrinkled layer undoubtedly exists in the adults of several species, especially in Amaltheus margaritatus, as described by Sandberger.

view. The ovishell of Deroceras planicosta, as figured below,* is composed of two layers, — the internal lining layer, and an external thicker layer, which is not continuous with any of the layers in the shell of the first whorl. The internal lining layer bends internally, and coats the inner side of the first septum. The external layer is very thin upon the dorsal side, and was perceptible only by the aid of a fifteenth. The increase in thickness of the external layer is quite abrupt upon the abdomen, but not so abrupt as upon the sides, especially at the edges of the embryonal umbilici.† The external layer reaches beyond the neck of the ovisac, overlapping the edges of the layers which compose the apex or beginning of the first whorl. These are evidently the product of the mantle-edge, and show that the external layer of the ovisac must have been secreted from the interior by the body of the embryo. The shell of the whorls consists at first of two layers, besides the internal lining layer of the chambers.‡ These, unlike the external layer of the ovisac, to which they collectively correspond, are absent from the dorsum. The presence of the external layer on the dorsum, and its extreme thinness there, as compared with what it is upon the abdomen and sides of the ovisac, is a characteristic also of the adult of Nautilus.

The absence of all the external layers, however, from the dorsal side in Goniatites and Ammonites, appears to begin at the earliest period in the closely involved species. The septa upon that side in the latter, from the first to the sixth inclusive, extend their borders considerably, and build up quite a dense thick layer, which, however, ceases with the seventh septa. § After this, only the lining layer, probably accompanied by a thin nacreous deposit, is found on the dorsal side. A close examination of the layers showed everywhere indications of arrests of growth, and the formation of more or less permanent mouths, ‖ or zones of growth, always, however, imbricated as in Goniatites and Nautilus. The last formed, beginning inside of the edges of the earlier deposited zones, a structure entirely at variance with the supposition that any portion of the shell was laid on from the exterior.

Comparisons have also been made with the shell of Argonauta, which

* See woodcuts on last page of the text.

† Plate II, Fig. 3.

‡ See last page of the text.

§ Plate II, Fig. 1, and last page of text.

‖ Plate IV, Fig. 1.

is known to have been, partially at least, deposited by the enveloping arms of the animal. The shell consists of three layers; the inner and outer layers have a similar structure. These two are composed of minor plates or zones of variable lengths, but these are never imbricated, they are simply laid one upon another.* The median layer is very irregular when seen in longitudinal section, showing thicker and thinner portions, the thicker being somewhat more opaque than the thinner parts. In a transverse section, this layer presents a similar aspect, but the structure varies from a smooth, even shade, to a granular aspect. When viewed from above, this layer presents a reticulated aspect, due to the presence of numerous white opaque thread-like lines of growth. These are parallel with the lips of the shell, notwithstanding their minor irregularities, and may be, in some instances, followed for a considerable distance across the whorl. Especially when they represent the former edge of some one of the numerous mouths, marking the periodical arrest and renewal of the growth. They bend posteriorly on the abdomen, and anteriorly on the sides, and are covered everywhere by the internal and external layers which possess no such marks of growth. There are no marks of an imbricated structure, and the absence of lines of growth from the external and internal layers, as well as their presence in the median layers, shows also that the structure is entirely distinct everywhere from the shells of either Nautilus, Goniatites, or Ammonites. It is evident that the internal layer is deposited by the body of the animal internally, the median layer by either the mantle-edge, or by the anterior edge of the abdominal arms, externally, in successively thicker or thinner, but more or less irregular zones, and lastly, the external layer probably by the inner side of the expanded portion of the arms.

* Plate IV, Figs. 12-16.

CAMBRIDGE, June 5, 1872.

Figure I.

Deroceras planicosta. Two septa showing the siphonal funnel, **P**; the dorsal lobes, **H**; and the ventral cell, **J**.

Figure II.

Deroceras planicosta. Shell of embryo. d′, lining layer; **X**, external layer; d″, median layers of the apex of first whorl, an internal transparent and a thicker darker layer, both overlapped by **X**; d‴, external layer of first whorl next to dark layer of d″; d, additional layers deposited by the dorsal portion of the body of the animal in passing from neck of ovisac to seventh septum; 1e, first septum.

Figure III.

Nautilus Pompilius. An ideal outline of the ovisac and apex of first whorl. **A**, ovisac; 1c, first whorl; **W**, shoulder formed by the external ridge of the cicatrix; **X** shows where the shell of first whorl connected with the shell of the embryo, and also where it is always found broken. The two dotted lines from **X** show the area of the scar itself as seen from the side; **T** is the line of involution showing the extent to which the apex is enveloped at the first revolution of the shell.

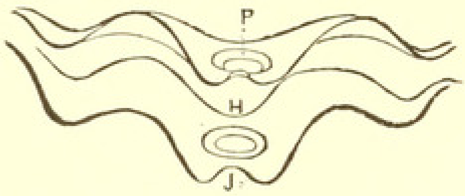

Fig. I.

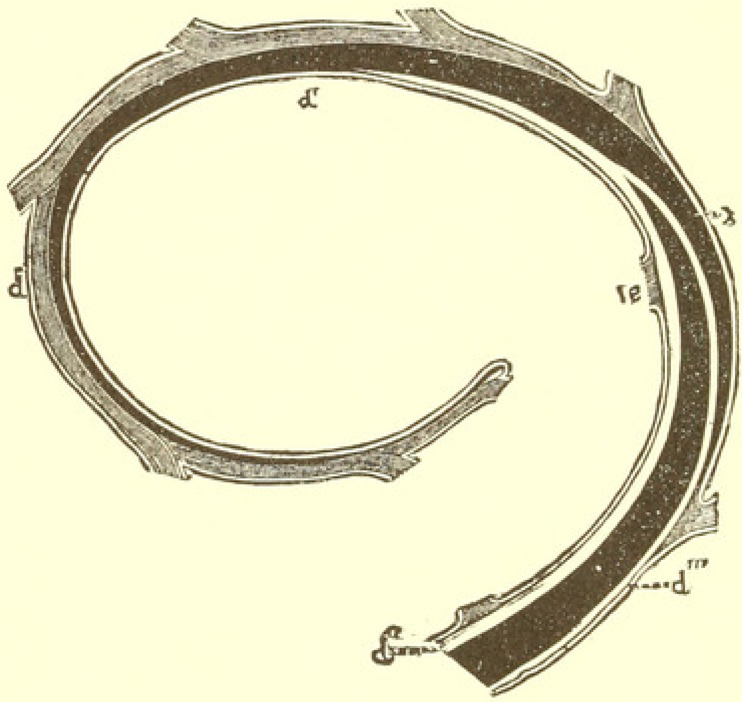

Fig. II.

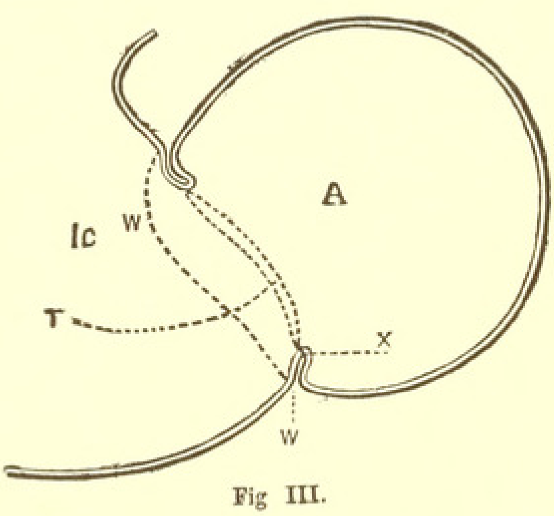

Fig III.

EXPLANATION OF SIGNS USED IN THE PLATES.

A. Ovisac.
B. Ovishell.
C. Whorls.
1c. First whorl.
2c. Second whorl.
D. Shell.
d′. Lining layer.
d″. Median layer.
d‴. External layer.
d+. Black deposit or layer of the hood.
E. Septum.
1e. First septum.
2e. Second septum.
F. Abdominal lobe.
G. Lateral lobes.
g. Superior lateral lobes.
g″. Inferior lateral lobes.
g‴. Auxiliary lateral lobes.
H. Dorsal lobe.
h′. Superior dorsal lobe.
h″. Inferior dorsal lobe.
h‴. Auxiliary dorsal lobes.
h̄. Minor lobes.
J. Abdominal cell.
K. Lateral cells.
k′. Superior lateral cells.
k″. Inferior lateral cells.
k‴. Auxiliary lateral cells.
L. Dorsal cell.
l′. Superior dorsal cells.
l″. Inferior dorsal cells.
l‴. Auxiliary dorsal cells.
M. Marginal lobes.
N. Marginal cells.
O. Siphonal fissure.
P. Siphonal collar.
P̄. Siphonal funnel.
R. Siphonal cœcum.
S. Siphon.
s′. Horny layer of siphon.
s″. Accessary layers of siphon.
s‴. Sheath.
U. Embryonal umbilicus.
y. Cone of the siphonal cœcum.
X. General mark.