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AT

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ON THE ORIGINAL CONNECTION OF THE EASTERN AND WESTERN COAL-FIELDS OF THE OHIO VALLEY.

By N. S. SHALER.

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DIRECTORS OF THE KENTUCKY GEOLOGICAL SURVEY.

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NOTES

ON

THE TAXODIUM DISTICHIUM,

OR

BALD CYPRESS.

By N. S. SHALER.

NOTES ON THE BALD CYPRESS.

Every fact that serves to show a relation between the circumstances that surround an animal or plant and its peculiarities of structure has a certain importance to naturalists. It may aid in the solution of the great problems they now have in hand. I therefore venture to make a record of certain facts concerning the habits of the swamp cypress (*Taxodium distichium*) of our Southern States which seem to me to be important. The observations have been made at various times during the last ten years, but principally in connection with the work of the Kentucky Geological Survey, in the district west of the Cumberland river.

It requires but little attention to this species to make it plain that it is subject to great changes of conditions, arising from the peculiar character of the soil in which it lives. The condition of the low lands where it finds its station may bring it into any one of several widely divergent conditions of soil, with very slight variations of position. I wish to trace the effects of these changes of condition upon the peculiar projections from the roots, which are commonly known as knees. These excrescences of the roots have received so little attention from naturalists that it will be necessary to premise an account of their variations by some statement concerning their nature.

Along the main roots of the Taxodium, as it exists in the swamps, we have a series of projections which at first appear as slight tuberosities on the upper side of the root. These projections are formed somewhat irregularly, but they frequently occur at intervals of no more than two or three inches along the crest of the root. The result of these frequent excrescences is that the root is vertically flattened, presenting in transverse section an elliptical shape, the vertical axis being double or treble the length of the horizontal axis. Certain of these tubercles grow more rapidly than the others, and present a curiously dentate appearance; so that the root, seen transverse to the length, reminds one of the jaw of a saurian reptile. This likeness is enhanced by the fact that the projections are at first sharply conical and slightly bent back towards the main stem of the tree. The young knees grow very rapidly until they lift themselves to the height of from two to ten feet, and are well above the level of the swamp waters; they then increase in diameter, while they cease to grow in height. Their tops lose their conical shape, and become knotty, or carunculated. During the process of growth, the summits of these knees are exceedingly bud-like and vascular, always presenting a considerable surface of fresh bark. The rupturing of the outer bark layers, as the growth goes on, serves to give the bulbous top of the knee the look of an opening bud. The gnarled and knotty growth of the old knees, which have ceased to increase in height, serves also to expose the fresh inner bark over considerable surfaces of the carunculated head that crowns the knee.

The height of these knees varies a great deal with the different positions occupied by the trees that bear them. Generally they do not rise more than two or three feet above the level of the main root; but at times they rise to four or even ten feet above its level. Observation has led me to believe that the height of the knees is in good part determined by the average height of the waters in the swamp, the knees endeavoring to attain a level which will bring their more vascular parts above the surface of the water as it stands in the season of most active growth of the tree, which occurs between April and July. If we take any swamp area occupied by these trees, and examine carefully the development of the cypress in its various parts, we shall see the evidence bearing on this point. In the first place, we shall find the cypress on the higher grounds, near the edges of the swamp, which are not overflowed save in the winter season, growing with fair luxuriance, but quite without knees. The small tubercles along the roots may be visible on close inspection, but they do not rise above the bed of leaf mould. As we go into the wetter parts of the swamp, these knees begin to appear; but it is only when the water stands a good part of the year about the roots that they become a striking feature. The deeper we penetrate into the swamp, the higher the knees rise above the surface of permanent water, and the more abundant they are about the trees. In all cases the top of the knees, when their upward growth is complete, rises above the level of the ordinary spring and summer flooding of the swamps. One other fact is needed to complete the chain of evidence. Whenever the level of the swamp water is raised above the top of their knees, the trees die. A very conspicuous instance of this is afforded by the extensive tracts of land which were flooded by the subsidences that accompanied the earthquakes of 1811. Whenever this sinking brought the tops of the cypress knees below the level of the permanent water, the trees all died. The great areas of Reelfoot and the adjacent lakes are still covered by the stately columns of these trees which were killed in this way two thirds of a century ago, and their submerged knees are still traceable, so that there cannot be any doubt of their position; yet other specimens, in which the knees were nearly buried, still survive.

In various mill-ponds in this district, where artificial flooding of the swamps has brought the permanent level of the water above the top of the knees, the trees have speedily died. This connection between the flooding of the knees and the death of the trees to which they belong is well recognized by the people of the country. They do not hesitate to determine the height of the summer waters by the altitude of the crests of the knees.

It seems to me that these facts, — viz., the failure of the knees to develop when the trees grow on high ground; the development of the knees when the roots are in permanent water; the rise of the knees above the permanent water level, and to a height varying with that level; and finally, the destruction of the trees whenever the level of permanent water rises above the top of the knees, — incontestably show that there is some necessary connection between them and the functions of the roots when the latter are permanently submerged.

It is not unreasonable to conjecture that this function of the knees is in some way connected with the process of aeration of the sap. It is a well known fact that the roots of most plants are intolerant of continuous immersion in water. It seems likely, therefore, that some process connected with the exposure of the sap to the air takes place in these protuberances. This hypothesis is supported by the fact that the knees remain quite vascular, and that the process of their growth assures the constant exposure of considerable surfaces of newly formed bark on the upper part of the knee, a circumstance that would favor the aeration of the sap. The woody part of the knee is also very soft and spongy, differing very much from the ordinary wood of the tree.

It is clear that we have in this tree a singularly variable accommodation to the changeable conditions it encounters in its different stations; and the readiness with which the variations are brought about must remain a matter of surprise to any one who knows the small amount of flexibility in this respect shown by most of our forest trees. I do not know of another case among them where the variations arising from the change of position of the trees occur with the immediateness and distinctness that they do here. In the chestnut-oak, for instance, the bark of the swamp variety becomes smoother and thinner, and contains less tannin, than in the highland forms; but the changes are relatively slight and quite irregular, never presenting the close relation to the conditions of environment that is given in the case of the cypress knees. It has been shown also, by the researches of Mr. DeFriese, assistant in charge of the timber studies made by the Survey, that the hemlock is never found in Kentucky on any other soils except those produced by the decay of sandstones and conglomerates, or more than a few hundred feet from running water, which serves probably to give a certain dampness to the air; but narrowly limited as this species is, it does not give anything like the clear proof of the immediate effect of conditions on the characters of an organic form that is afforded by the swamp cypress. It is doubtful if, in all our American forest trees, another instance can be found where a slight change of surroundings can bring about such important modifications of the conditions of life as in the case of the cypress.

These processes termed knees evidently serve very much to extend the area over which the tree can maintain itself. There can be little doubt that by it the tree has gained access to at least thirty thousand square miles of area in the southern part of the United States, from which it would otherwise have been debarred.

I have been unable to find any account of other species of trees having such knee-like processes. Several species of our ordinary timber trees are apt to make nodulose projections from their main roots; and when they grow in swampy ground are apt to keep their roots rather near the surface; but none of them have developed such specialized structures as are found in the Taxodium, and none of them have anything like the power of adapting themselves to such varied conditions of humidity. So far as is known to me, the Taxodium is the only tree that is able to occupy positions varying from very wet swamps to rather dry uplands. It is not too much to say that its range of station, so far as actual conditions go, is about double that of any other forest-tree belonging to the North American flora.

It is a well known fact that the ancestors of our Taxodium can be clearly traced back to the time of the miocene tertiary. At that time a closely related species was living in Greenland, and its kindred have been traced in Northern Europe and elsewhere; so that this genus has long been a tenant of this continent. Among these ancient cypresses there are some, particularly Taxodium dubium Sternb. sp., which are very nearly related to our existing forms; like it, they seem to have been tenants of swamps, as is sufficiently proven by the fact that their leaves and delicate extreme branches are found in the coal beds of the miocene time. It seems probable that the American varieties have descended from some one of these ancient forms—most likely from T. dubium. Further back, in the Carboniferous flora, we find a number of conifers, from some one of which this genus may be descended. I have been unable to find any evidence of the existence of these knees in the recorded observations of those who have studied the ancient species of Taxodium. Though this failure to observe them in the fossil form may not be taken as evidence that the knees are of modern origin, it certainly suggests the interesting question whether this may be the case, and makes it very desirable that the observers who may hereafter encounter fossil species of this genus should endeavor to determine the presence or absence of these processes. The fact that the ancient species were swamp-dwellers makes it likely that the knees were present.

From the existing distribution of this tree, it seems to me that it has probably been driven from an association, on the elevated lands, with the other trees of the forests in the Mississippi Valley, and has found a refuge in the swamps; and that but for this special adaptation to different conditions afforded it by the knees, it would have been altogether driven out by the deciduous vegetation of the country where it is found. It is clear that this last remnant of a great lineage of forest trees is no longer able to maintain itself in the contest with forms with which it, in miocene days, associated on something nearer equality. Although its seeds are borne in vast quantities on to the elevated ground that borders the swamps, we never find it in the woods where it would have had to struggle with the other trees. This arises from no incapacity to live and flourish upon the soils of the uplands, for I know many very flourishing trees growing in a variety of open grounds in gardens and lawns in various parts of Kentucky. In many gardens and arboretums in Europe it has proven a hardy and rapid growing tree. Its rate of growth on the elevated terrace deposits at Frankfort, Kentucky, has been much more rapid than the average of our forest trees. Trees fifty years old have there attained a height of sixty feet and a diameter of eighteen inches. We must ascribe its incapacity to maintain itself in the existing forests of the Mississippi Valley to some unknown influence of the other trees upon its functions.

In the miocene and pliocene times this genus was one of the most wide-ranging of all the forest-trees. Oswald Heer cites it from Switzerland, Germany, Austria, France, Italy, Spitzbergen, Siberia, Kamtschatka, and the Alutian Islands.* The circumstances in which we find its remains in these ancient formations are such as to make us suspect that it shared the ground with many forms with which it no longer willingly grows. In eocene and pliocene times it seems to have mingled its leaves in the forest beds with the ancestors of our poplars, beeches, walnuts, oaks, persimmons, &c., &c. To-day we find none of the species of these genera growing in the same localities where the Taxodium flourishes. It may be suggested that the fossil remains we find are those of species that did not occupy the same stations, but were brought together by floods in their common burial places. I do not think that this hypothesis explains their association. The deposits now making in our cypress swamps do not contain such minglings of the leaves of a wide area as we find indicated in the fossils of the Greenland miocene beds. If they were fossilized, we should not find, as explorers have found in the Greenland beds, the entire leaves of beeches, persimmons, and half a dozen other forms that now belong on higher ground, mingled with twigs and leaves of the Taxodium in the same square yard of space.

It seems to me that we are led by these facts to the conclusion that the association between the ancestral Taxodium and those of the other forest trees whose descendants now occupy the uplands alone, was once much more intimate than it is at present. This intimacy of association may have been brought about by the less definite limitation to particular stations of the trees that made up our ancient forests, or by the greater range of the Taxodium in the olden days. As experience goes to show that the Taxodium will still live and flourish on a great range of soils, and that it does not require access to moisture more than most of our forest trees, while there is good reason to believe that the other forest trees are much less tolerant of swamp conditions, I am disposed to think that the greater part, at least, of the change of habits has been in the cypress itself; that it has gradually

* Flora Fossiles Arctica: Zurich, 1868, p. 12.

given up its wider place in the forests, and limited itself to the swamp areas, where it has no struggle to maintain with other trees. It may be remarked that the limiting of the Taxodium to a narrow station, if such a limitation has occurred, would find its parallel in the conditions of many of our other coniferous trees. The white pine (*Pinus mitis*) in Kentucky is circumscribed within very narrow boundaries, and only maintains itself at a disadvantage against the vigorous deciduous woods. The same may be said of the hemlock, which is limited to stations that are really unsought by our other trees. The western part of the United States affords an even more remarkable example of the narrow limitation of a tree that once was very widely distributed. The Sequoia gigantea is a noble representative of a long lineage of trees that once ranged throughout the Northern Hemisphere, and now is limited to a very small area on the Pacific coast. It seems certain that in Kentucky the conifers are fighting at a disadvantage against the deciduous trees, which are gaining upon their ground; and it seems not unlikely that the conifers, as a whole, are losing ground and giving place to the more varied and more plastic deciduous forests. Loss of adaptation to varied conditions is a common phenomenon in all organisms of which we have an extended geological history.

A similar narrowing down of the field occupied by the form is seen also in the somewhat kindred conifer, the sequoia, and in a less degree in many of the old associates of the Taxodium in Europe and Asia. Yet this limitation to a narrow geographical range is not quite parallel to the peculiar exclusion of the Taxodium from the upland forests of the continent. I am unable to point to any source of weakness that is the basis of this restriction. The cypress is a very rapid grower even on the uplands. It easily overtops and makes head against the timber on the edge of the swamp whenever a chance specimen may secure a foothold. The seeds are plentiful and easily grown, the young trees appearing vigorous from the beginning of their growth.

There is yet another problem connected with the conditions of the Taxodium that is worthy of note. The trees are often found growing from the center of permanent pools of water, where it is hard to suppose that they could have originated save from seeds. I have not been able to find that they ever spring from the roots of other trees. A careful search of many specimens has not shown the trace of root-budding, and many other observers have failed to find any case of this kind. It is very hard to imagine any coniferous seed sprouting at the depth of a foot or more below the surface of water, and growing until it lifts itself above the water surface. It seems to me that the hypothesis that they spring from root buds is highly improbable, for I have several times found young and thrifty specimens growing up from permanent water at the distance of several hundred yards from any other tree of the species. I am told that the tree may be readily propagated from twigs, provided they are of the new wood, and are immersed in water or soft mud, and are kept in the shade. Such twigs are often broken from the branches of the trees by the wind, aided perhaps by the collision of boughs against each other in high winds. The extreme branches are much more brittle than those of any of our other conifers known to me; and this, together with the readiness with which they root, makes a special method of propagation peculiarly suited to the conditions of growth under which the species live. I am not aware that the power of sending out roots from twigs exists in our other conifers. I am inclined to believe that the planting of these trees in water too deep for the germination of seeds is generally brought about through the fallen branches rather than by means of seeds or buds from the roots.

PRESENT DISTRIBUTION OF THE TAXODIUM DISTICHIUM.

As this species is the last remnant of what was once a very cosmopolitan genus, it is worth our while to consider its present limitations of the form. I shall therefore give a brief synopsis of the present limits of the species as far as I have been able to ascertain them.

Although singularly limited in its station, the swamp cypress nevertheless endures a wider range of climate than many of our forest trees that occupy a great range of soils and of exposures. The northernmost point where it now exists is central New Jersey. In this district it is apparently in its decadence—the individuals few and much smaller than those which lie buried in the swamps of that district. Its northern limit in this district does not seem to depend upon its endurance of cold, as it is not killed by much lower temperatures than it finds in the swamps of New Jersey. No trace of this species has ever been found in the ancient swamps that are so frequently excavated in New England, although they are said to be abundant in New Jersey. This leads us to the conclusion, that since the last glacial period it has never extended farther north along this shore than the last-named district.

Southward from New Jersey we find it sparsely distributed until we come to the district south of the James river. Here we enter upon extensive forests of this tree, and it appears afterwards at any point affording favorable conditions for its growth along the whole Atlantic coast.

In Virginia it does not occur much beyond the limits of the swamps that lie within a height of fifty feet above tide-water. The swampy borders of the inland streams are not occupied by it. In this region it struggles very little beyond the limits of the shore swamps.

In the Carolinas its westerly extension somewhat increases, yet its limitation to the region within about one hundred feet above tide-water remains a marked feature.

In Georgia the limits of the species are again forced nearer to the sea by the greater general height of the surface of the country.

In Florida the species is said to be common throughout the length and breadth of the peninsula.

In Alabama and Mississippi the cypress follows all the stream borders much farther into the uplands than on the Atlantic slope. It is common in all the swamps in those States.

In Tennessee the species is limited to the district west of the Tennessee river, and to the borders of that stream in the lower part of its course. I have been unable to find that it extends above the level of the Muscle Shoals.

In Kentucky the limitation of this species is even narrower than in Tennessee. It is not common except in the district west of the Tennessee river. It is rarely found on the Ohio river above the mouth of the Cumberland. On the Tennessee and the Cumberland rivers it is found in the swamps near those streams to the State line or a little beyond. On the Green river it is occasionally found, but I have never seen it in the shape of connected forests. East of the Green it is unknown to me, and on that stream it does not extend above the junction of the Barren river.

North of the Ohio the cypress occurs in the swamps of southern Illinois and southwestern Indiana; but its northward extension along the rivers of those States seems to be very limited, though I have no means of tracing it in detail.

Along the main Mississippi it does not extend much above the junction of the Ohio.

West of the Mississippi the extension of this species is much more limited than on the eastern side of the river.

I have no knowledge of the species on the Missouri river, or any part of Missouri, except near the Mississippi.

The whole of the swamp districts of Arkansas, Louisiana, and Texas afford it congenial stations; and it probably occupies larger areas in those States than in any others.

Beyond the limits of the United States its extension is difficult to determine. It is not found in the West India Islands, and I have no information of its occurrence along the Mexican shore.

The economic uses of the timber are as yet limited. The larger knees are occasionally taken for well-buckets. When of the fullest growth they are hollow, their cavities being large enough to contain a gallon or two of water. They are also occasionally used as bee-hives, though they are generally much too small to serve this purpose.

The tree itself has long been used for the purposes to which the other coarser coniferous woods are applied. The wood is easily worked, and though rather brittle, is used for clapboards and other house-building purposes. It is fairly enduring both above and below the ground level. As yet but little of it has found a market save in the rural districts of the Lower Mississippi. With the progressive destruction of our forests, and the consequent increasing scarcity of coniferous woods, the resources offered by this species will doubtless be largely drawn upon. The supply offered by this tree bids fair to remain important for many years. It now exists on not far from thirty thousand miles of surface within the United States. At almost all points within the areas where it is found it grows with rapidity and to great size, and it is more generally accessible to water transportation than any other timber tree. The ground it occupies is usually irreclaimable, or of difficult subjugation. There is, therefore, no better nursery for timber than these swamps. If, as is likely, the artificial planting of these trees can be easily managed, there can be no doubt of the profitableness of their culture. Lands suitable for such purpose can be bought for a few cents per acre. Much of it is still Government land that can be acquired under the law regulating the sale of swamp lands. Besides thé advantage of cheap lands and easy transportation, these forests have a perfect security from the devastations of fire, which are so serious a hindrance to the profitable cultivation of most of our economic woods, especially the conifers. It needs no argument to show that a cypress swamp is perfectly secure from this danger. I do not believe that in our ordinary swamps the trees could be placed nearly as close together as the trees in a pine woods.

All our cypress swamps commonly have a good deal of their surface occupied by pools and sloughs, where the water is too deep for the trees, or by hummocks, where the land is too high to afford the best stations for this species. I am inclined to believe, however, that it can be safely estimated that the trees may be planted twenty feet apart, or about one hundred to the acre, and that they will, in twenty years, attain a size at which they begin to be merchantable. The tree is probably adult at sixty years, attaining then an average diameter of about three feet, and a height of about ninety, although it continues to grow until, in favorable positions, it attains a height of one hundred and fifty feet, and a diameter of seven feet or more. With the increased height, it rapidly becomes of less merchantable quality. I am satisfied that the trees may be grown to the full size that utility requires at no greater distances than forty feet apart, or about twenty trees to the acre. The spaces between may be occupied by the younger trees, for the young cypress is tolerant of the densest shade.

It seems to me not unreasonable to estimate that an area of planted cypress would yield not less than one adult tree annually to each two acres of surface, besides the immature trees removed in thinning; and that the economic value of the trees is likely to be as considerable as those of our white-pines. Including the young trees, I believe that our swamps, after twenty-five years of care in securing the planting of the cypress seeds, could easily be made to yield an average return of two dollars per acre; and if a large area were controlled by one management, the expense of planting and care would be very small.

There is a general belief that the cypress tree exercises a destructive influence on the malarious exhalations of the swamps where it plentifully abounds. By the peculiar impenetrability of its shade, which is far denser than that made by any other of our American trees known to me, it greatly diminishes the evaporation of the swamps where it abounds, and thereby serves to keep the waters of the morass nearer the same level throughout the warm season. Where they grow very thickly their knees, their plentiful and slowly decaying leaves, and the falling débris of bark and limbs, make a sponge that retains the water throughout the year, so that decay takes place very slowly, and a thin peaty mass is formed. It is a well known fact that peaty swamps, owing to the absence of decay or to the antiseptic vegetable acids developed in such swamps, or to other causes, are rarely, to any great extent, malarious. The great peat swamps of the North are wholesome, while a new-drained pond may give ague germs in abundance. I am therefore disposed to think, that, as this cypress favors the formation of peaty matter in the swamps, its extensive planting would do much to diminish the malaria of those areas. Moreover, in common with all our coniferous trees, the cypress exhales a certain balsamic vapor that perhaps serves, to a certain extent, to better the quality of the air for man's use. This purifying power seems to extend to the roots as well; for while the water from an ordinary earthy swamp is unfit to drink, that from a cypress swamp is exceedingly potable, and is sought for use on ships, as it does not putrefy as seemingly purer waters do.

It may be too much to hope that the malarious nature of the swamp lands along the Western and Southern rivers may be, at least in part, taken away by the careful extension of this tree; but I am satisfied that it is the only American tree to which we can look for any considerable amelioration of the malarious conditions that now render extensive regions in the Mississippi Valley unfit for the occupation of man. None of the species of the Eucalyptus can be expected to flourish in the region north of Louisiana. I am disposed to doubt the great febrifugic power of this much talked of tree, and to question whether it does more than hinder the ground from becoming a good nidus for spores by keeping it permanently covered by a mass of leaves that are filled with gummy matters. Such deposits are probably prejudicial to the peculiar plants that produce the malarial spores, while, at the same time, they favor the retention of permanent moisture that also tends to prevent the production of malaria.

I have before this called attention to the fact that it is not the wetness of the swamp areas that favors the production of malaria, but the alternation of wetness and dryness with the changing seasons. Whatever operates to arrest, to any considerable degree, these changes of water level in the swamps will contribute, in the same proportion, to the diminution of the malaria generated there.

At present the course of events is leading to a considerable reduction in the number of cypress trees in our Western swamps. Although the business is manifestly in its beginning, there are some hundreds of thousands of cypress trees cut out of the swamps of the Mississippi Valley each year. As there is no replanting, the result is to give an advantage to the worthless and malaria-breeding cottonwoods, pin oaks, and other swamp trees, or to leave the swamp open to the festering heat of the sun in case these species cannot crowd into the places made vacant by the removal of the cypresses. The extension of this process will convert into unshaded pools a great many swamps that are now made comparatively wholesome by the deep shade that this tree secures to them.

ON THE ORIGINAL CONNECTION

OF THE

EASTERN AND WESTERN COAL-FIELDS

OF

THE OHIO VALLEY.

By N. S. SHALER.

ON THE ORIGINAL CONNECTION OF THE EASTERN AND WESTERN COAL-FIELDS OF THE OHIO VALLEY.

Among all the debated matters concerning the development of American geography, perhaps none have been the subject of a more extended discussion than the question of the original relation of the several coal-fields of the carboniferous era that lie within the Valley of the Mississippi. On the one side it has been maintained that those areas were originally parts of one and the same field, owing their separation to the wasting they have received; on the other, that they were, from the beginning, distinctly separated areas, and have had their physical and vital problems as individualized as are those of widely separated seas.

It has been especially contended, and this with a great deal of vigor and effect, that the eastern and western basins of the Ohio Valley, commonly known as the Appalachian and the Illinois fields, were, at their time of formation, separated from each other by the ridge known as the Cincinnati axis.

A careful study of this problem in the State of Kentucky, where alone exists the data for its solution, has served to convince me that there is a considerable error involved in this generally accepted opinion, an error likely, if it continues unassailed, to confuse all our notions of the geological history of the continent. I shall therefore set forth in brief the nature of the evidence that has led me to the opinion that these coal areas, lying to the east and west of the Cincinnati anticlinal, were not only originally united into one area, but were actually connected down to a very recent time, in the geological sense of the word.

A reference to the geological map of Kentucky, published by the Survey, will show that these two fields have now their nearest escarpments within less than eighty miles of each other. It will also show that there are many over-outliers, which are clearly relics of a once continuous field, which diminish the gap between these coal basins, so that at one point it is not over forty miles between the outlying remnants of either field. Standing upon the heights of either escarpment, the eye ranges over the intervening country to the outliers on the other side. A little observation shows us that if we but protract the plane given us by the upper surface of the two fields across the intervening space, we would replace the beds in the gap that separates them. This suggestion of original continuity that is made to the eye on simple inspection, is abundantly borne out by other evidence, which I will now proceed to consider, taking up the several series of facts in the following order:

1st. The physical evidences of a continuous sea or swamp over the whole of Kentucky at the several stages of the carboniferous period.

2d. The vital evidences of a similar unity of the physical conditions at the before mentioned time.

3d. The evidences of the amount of wear to which this district has been subjected since its last continued depression below the level of the sea.

The evidences of a physical nature going to prove the former existence of any particular series of deposits in any area where they are no longer found, may differ very much in different conditions, but are in the main limited to two classes of facts. In the first place, we may have the débris of ancient deposits lying in variously distributed ruins in the region where the beds they represent have long since been destroyed; in the second place, we may have a given district showing by its topography, inherited from a more ancient time, that it has had its drainage system formed in beds other than those which now cover its surface.

Searching over the district that lies between the ragged borders of the eastern and western coal-fields, I have found at many points the most unquestionable indications of ruined carboniferous beds. In the very centre of the Muldraugh-hill escarpment of the Subcarboniferous series, the beds of lower St. Louis limestone are covered by the waste of a conglomerate that is no longer in place. This waste consists not only of a great quantity of detached pebbles of quartz, but also of considerable slabs of a coarse ferruginous sandstone with like quartz pebbles, the slabs with their angles unrounded, and evidently not transported by water. This waste, occurring upon the high summits and not upon the lowlands, puts it beyond a doubt that it is the waste of a conglomerate that once capped these hills. The character of this conglomerate is quite unmistakable; no one familiar with the geology of this district can doubt that it is from the Subcarboniferous conglomerates, the millstone grits of many geologists. The lower lying rocks of our Kentucky series are so well known as to make it quite impossible to suppose that there is any other conglomerate for which this could be mistaken. At certain points traces of vegetable impressions may also be found in these deposits. They are very indistinct, but quite resemble the impressions so common in some parts of the conglomerate series, both in the eastern and the western fields. Associated with this débris, when found along the Muldraugh-hill district, we have a quantity of the waste from the St. Louis lime stone, the uppermost purely calcareous member of our Subcarboniferous limestone series. This association is strongly confirmatory of the idea that this conglomerate is that of the coal period.

The whole of the Green river basin in the counties of Adair, Green, Metcalfe, and parts of others, has its hill-tops covered by the beds of the Warsaw division of the St. Louis group. From this level to the base of the coal-bearing series, where that is left in the region, to the east of this district, is not over one hundred and fifty feet. In the district to the west, the thickness of the St. Louis is greater, being about two hundred and fifty feet on the average. Above the St. Louis the Chester sandstone, which is the transition series from the deep sea limestones below to the land beds above, is perhaps about one hundred feet thick. In its upper part we have some thin coal seams, one of which is about eight inches thick, and is found over an extensive section in the western coal-fields; so we are safe in asserting that there is only required to be restored to this district of the upper Green river a total thickness of from two hundred to two hundred and fifty feet to return the carboniferous horizon to it. Is it likely that this thickness of deposits has disappeared from this region? It seems to me that we are forced to give an affirmative answer to this question. It needs but a glance at the conditions of this district to make it clear that it is wearing down with great rapidity compared with other parts of the Mississippi Valley. We know, from the labors of Humphreys and Abbott, that the erosion of the Mississippi Valley is now going on at the rate of one foot in seven thousand years. As this erosion is in the main proportionate to the amount of rainfall, it is doubtless about twice as great in this section of the Ohio Valley as it is over the whole Mississippi drainage system. I am satisfied that one foot in three thousand five hundred years is not too much to allow for the ablation of the surface of this region. At this rate the destruction of the three hundred feet of beds which I believe have been wasted from this district between the coal-fields since the conglomerate continued over the Cincinnati axis, would have required not far from one million of years. No geologist who has attentively considered the evidences of duration given us by many geological facts can doubt that far more than this time has elapsed since the beginning of the tertiary period. The best computations of the duration of time represented by that period, — those made by Mr. James Croll, — assign a duration of over four million years from the beginning of the eocene to the present day. It would require not more than half this time to take away a section which, if restored to this district, would give us the drainage surface within the beds above the level of the conglomerate. Without setting too much value on the estimates of the duration of the tertiary period, we are certainly safe in saying that the time that has elapsed since the close of the carboniferous period must much exceed five millions of years; yet this period, probably but a small part of the age that has elapsed since our coal-beds were laid down, is sufficient, at the present rate of erosion, to have taken away something like fifteen hundred feet of strata from this region. It is therefore necessary for us to suppose that the carboniferous strata originally extended over this region; or else we must arbitrarily, and without a trace of affirmative evidence, suppose that while the carboniferous series was not deposited in this region, the trias, the jurassic, or the cretaceous beds were laid down, and since their deposition utterly wasted away, leaving no débris to mark their former occurrence in these parts. One or the other of these suppositions is necessary. The geological reader can safely be left to choose between them.

While I regard the physical evidence of the original extension of the carboniferous deposits across the upper Green river district from the eastern to the western fields as practically complete, it is necessary to add that it cannot be inferred from this that the whole of the Cincinnati axis was so covered by the formations of the carboniferous series. As is evident from a mere inspection of the Cincinnati axis, the two extremities of the ridge are geologically much higher than the intervening district. The amount of the central deflection is several hundred feet, and it is through it that we have complete proof of the former connection of the two coal-fields by a coal-bearing belt of not less than fifty miles in width. The question of the former extension of the coal over the Cincinnati and Nashville ends of the axis must remain, for the present, an open question. I will only assert here that there is much evidence to be found to support the affirmative side of this question. At various points in the great area of the exposed Cincinnati-group beds,—which I am disposed to term the Kentucky dome, from the fact that while a part of that area extends beyond that Commonwealth, its centre and the larger part of its area are within its borders,—we find the waste of a pebbly deposit such as cannot be referred to any other than the conglomerate of the coal series. At one point in the southern part of Campbell county, about eighteen miles south of Newport, I found in a valley elevated one hundred feet or more above the Licking river, and some miles from its present bed, in the alluvial deposit such as borders all our smaller streams, a quantity of fragments of bituminous and cannel coal. Although for years the neighboring farmers had gathered these fragments, there was no difficulty in finding a dozen pieces averaging five or six cubic inches in size from the low bluff along the small stream. They were fairly well preserved, owing their resistance to decay to the fact that they were coals of a somewhat dense nature, and were bedded in a rather impervious clay. With them were occasional fossils of the Subcarboniferous horizons, and some pebbles of the millstone-grit age. I was at first disposed to refer these deposits to the action of the Licking river flowing at higher levels, but a careful search along the banks of this stream up to within a few miles of the edge of the coal-field has failed to bear out this idea; for fragments of coal are exceedingly rare in its alluvium, and where they occur they are very much rounded, while those in this high-lying alluvium in this small elevated valley are rather angular. At a point in Taylor's creek, just above Newport, there was exposed some fifteen years ago, in the stratified gravel-beds at about high-water mark of the Ohio, a thin bed of much comminuted bituminous coal, about one inch thick, and extending several yards along the freshly excavated bank. These beds lie near the mouth of a small stream the head waters of which are about fourteen miles north of the other above described locality of coal débris. I have reports of various similar localities in central Kentucky, showing a curious amount of coal waste over the Upper Cambrian or Siluro-cambrian area of the State.

On account of these peculiar patches of coal period débris in central Kentucky, I am now disposed to suggest that it is possible that a part at least of the coal series wrapped over the Kentucky dome, covering it with a thin coating of beds which have since been brought to utter ruin by the action of various agents. In order to avoid the charge of inconsistency that may be brought against my position on this point, I must endeavor to reconcile this view of the condition of the Cincinnati axis during the coal period with what I elsewhere held concerning the physical history of this important mountain fold. I have long been satisfied that the Cincinnati axis began to lift itself above the sea floor very early in the Upper Cambrian period. The fact that in the horizon of the calciferous sandstone we have an abundant supply of very saline brines, is of itself proof that at the time of this horizon there was, from time to time, an exposure of the deposits making on the old sea floors above the surface of the sea. Again, in the horizon of the Cincinnati group, we have a repetition of the evidence of shallow water or low-lying islands.

I am inclined to think that there can be no reasonable doubt as to the extreme antiquity of this axis. It is to be remembered, however, that the subsidence of the continent at various times in its history has been great enough to have entirely submerged this low axis beneath the sea. A sinking of the continent by twelve hundred feet would bring the ocean over the top of this axis, though it might not have any distinct effect upon the altitude of the axis as determined by its other relations. There can be little doubt that during the formation of the Black, or, as I have termed it in the Kentucky reports, the *Ohio Shale*, the whole of this Cincinnati axis was deeply buried beneath the sea. The entire absence of pebble beds in the deposits of the Waverly and higher Subcarboniferous beds is an equally strong argument against the exposure of this axis during the time when they were being laid down. Nor in the time of the millstone grit, when pebbles were swept by strong currents in a lifeless sea from the mountains of Carolina, and possibly from the Laurentian Hills as well, far and wide over our ocean floors, do we find a trace of the waste this axis would have given if it had been above the level of the sea. There is, therefore, no reason to look upon it as forming a natural barrier between the eastern and western districts of Kentucky in the times immediately anterior to the coal period. It is far more reasonable to suppose that while this axis was traced out in our rocks from an early age, it was not until after the close of the carboniferous period that it took on its present form, and became so dome-shaped in the region about Nashville and in the district of which Lexington is the centre and summit. This is clearly the view that is most reconcilable with the present conditions and the record of ancient conditions which is sent down to us in the physical record of the rocks.

The biological evidence which we may derive from the rocks about the Cincinnati axis does not favor the idea of its having been a barrier during any stage of the carboniferous time, from the base of the Waverley to the highest coal-bearing strata. The only level where we find evidence of its having been a distinct barrier is in the time between the upper Cincinnati beds and the base of the Black Shale. During this time, when the upper hundred feet of the Cincinnati series was depositing, and during the whole of the Niagara and Corniferous periods, the Cincinnati axis gives us evidences that it was a distinct ridge, rising to or above the surface of the sea; but from that time down to the last of our records of the ancient seas it appears to have been always merged in the uniform oceans or swamps of those days. The fossils of the subcarboniferous period do not, so far as I have been able to examine them, indicate shore-lines along this axis. It is true they differ on the two sides of its central line, but this difference seems to me to indicate the steady deepening of the sea from its eastward shore-line towards what is now the centre of the Mississippi Valley.

The conclusions which I believe we are forced to accept from the evidence the rocks afford may be briefly summed up as follows:

1st. That the Cincinnati axis was about the level of the sea during a part of the Hudson River, Medina, and Niagara epochs.

2d. That during the subsequent ages, down to and including the carboniferous series, the axis was probably of no importance as a physical or zoölogical barrier.

3d. That the coal-period swamps, and the seas into which they from time to time sank down to receive their burial in the drifting sands and muds, extended over the most if not the whole of this axis.

A study of the evidences of a former connection of the eastern and western coal basins in Kentucky affords us some data for estimating the former extension of these deposits in the other parts of the Ohio Valley.

It is clear that an erosion scarcely more considerable than that which has taken place in Kentucky would have sufficed to separate the basin of the Appalachian region from that of Michigan.

Allowing for an erosion rate of one foot in seven thousand years, which is now about the average of the Mississippi Valley, the loss of strata in a million of years would be about 150 feet. Assuming that this region has been subjected to erosion since the close of the carboniferous, and allowing only this low rate of decay to the rocks, at least fifteen hundred feet, and perhaps twice this amount, have gone off of the region which remains between the Appalachian and the Michigan field.

As this region north of the Ohio has been the seat of considerable glacial action, we cannot expect to find evidences of the former presence of the coal-measures such as we have noted in Kentucky. In Kentucky the glacial sheet did not affect more than a few hundred square miles of its area in the northern part of the State, so that nearly every hill-top retains some evidences of the deposits that have disappeared by erosion. No such relics of eroded strata can be looked for in any glaciated region.

Accepting fifteen hundred feet as the minimum of erosion that must have taken place in this district since the time of the coal-measures, it is clear that the larger part of the region east of the Mississippi, which now has beds below the carboniferous exposed at the surface, must have been at one time covered by the coal-measures. All the coal-fields from Iowa, Kansas, and Missouri must have been connected together and joined with the Appalachian coal-field.

Whoever will watch the process of erosion as it now goes on upon the carboniferous strata of this region, will easily see that the wearing away of these beds goes on more rapidly than it does in any other deposits of the Ohio Valley. This is shown on the topography of the district, which is marked by the very deep erosion of the smaller streams. The sandstones and shales above the conglomerate beds of the millstone grit are singularly incapable of resisting the action of running water. The streams that drain this district pour out torrents of sand in their times of flood. This sand being composed principally of quartz, is easily transported by flood, waters. The granular character which it gives the rocks of the country favors the absorption of water, which, under the action of frost, breaks up the beds with great rapidity. In the coal-measures there are none of those dolomitic limestones which, in the lower parts of the palæozoic beds, interpose such enduring resistance to the action of water. Accepting the determinations of the erosion rate given by the sediment carried by the Mississippi river, it seems to me reasonably certain that these carboniferous strata are now wearing down at the rate of one foot in about three thousand years, or about twice as fast as the average erosion of the valley in which they lie. On the supposition that only ten million years have elapsed since the erosion of this country began, there must have been something like three thousand feet of erosion upon the carboniferous section.

When we add to these considerations the fact that the present erosion rate is probably much less than it was during the greater rainfall of the glacial period; and further, that the time that has elapsed since the carboniferous period is in all probability twice as long as that we have estimated, — we see how great is the probability that the coal-measures once covered all the surface of the continent, from the western plains to the Atlantic, and north to the position of the great lakes.

There are several important conclusions which follow from this evidence of the former wider extension of the coal-measures. The most important of these is that the uplifting and down-sinking of the sea, or of the continent, which brought about the rapid changes in the nature of the deposits of the coal time, must have affected, not portions of the continent, but nearly the whole of its area. This much increases the difficulty of the problems brought us by the conditions of the carboniferous period. It is not possible to discuss them here; they will, however, be treated in the final report on the geology of Kentucky, which is now in preparation.

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GENESIS

OF

THE ARIETIDAE.

BY

ALPHEUS HYATT.

WITH FOURTEEN PLATES

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In accordance with the rule of the Institution, requiring the formal approval by selected experts of every Memoir offered for publication in the Smithsonian "Contributions to Knowledge," it was submitted for examination to CHARLES A. WHITE and to WILLIAM H. DALL; by whom it was also strongly commended, and it has been accordingly accepted for publication in the series of "Contributions."

S. P. LANGLEY,
Secretary Smithsonian Institution.

SMITHSONIAN INSTITUTION,
WASHINGTON, D. C., February, 1889.

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LIST OF CUTS IN THE TEXT.

PREFACE.

IT is a common mistake to designate my classification as "embryological." It will be found by those who read these pages, that the whole life of the individual, and all its metamorphoses, have been deemed essential standards for the estimation of affinities. Even the degradational metamorphoses of old age are used as characteristics of value in the generic descriptions; it is properly speaking an ontological classification.

The researches were conducted almost wholly in Museums, because it was found impracticable to study stratigraphical superposition in the field. This part of the work has already been accurately done by local geologists, and my notes were largely made upon their collections. More extended studies might have made the work more accurate than it is, but this was not possible for me.

I desire to record my deep sense of obligation to the late Prof. Louis Agassiz, under whose direction my studies upon the Arietidæ were begun. His instruction and advice were none the less valuable because we differed in theoretical views; to him I owe the methods of observation which are used in all my work.

His son, Alexander Agassiz, has also laid scientific men in this country under heavy obligations, and this essay could not have been completed or published but for his sympathy, and for the liberal manner in which he has sustained by large personal sacrifices the collections and the cause of scientific research in the Museum of Comparative Zoölogy.

Professor Langley, Secretary of the Smithsonian Institution, has shown the greatest consideration and courtesy, and in undertaking the speedy publication of this memoir after the Museum of Comparative Zoölogy had been obliged for want of funds to postpone its issue indefinitely, has saved the results from becoming antiquated before they were made public.

My principal studies outside of this Museum were made in the Museum of Stuttgardt, and there I received unwearied attention and help from Prof. Oscar Fraas, and the use of superb collections. Professor Quenstedt of Tübingen gave me the benefit of much valuable information, and threw open his collections without reserve, and I am indebted for similar favors to Prof. Guido Sandberger at Würtzburg, Prof. Karl Zittel of the Museum at Munich, and to Professor Mösch at Zürich. The late M. Barrande, Professor Gaudry and his assistant Dr. Fischer of the Jardin des Plantes, Professor Hébert and his assistant M. Munier-Chalmas of the Sorbonne, Paris, were equally kind and liberal. I desire also to thank M. Collenot, M. Bréon, and Dr. Bochard, for their kind attention and the free use of the collections at Semur. Professor Owen and Dr. Henry Woodward of the British Museum, Mr. Etheridge of the Geological Museum, the authorities of the Bristol Museum, and Dr. Thomas Wright, gave me similar opportunities for study, and Mr. Marder at Lyme Regis assisted me in the field. Prof. Jules Marcou has materially aided the work by the loan of rare books not obtainable elsewhere, and I am also indebted to Prof. J. D. Whitney for similar loans from his library. Professor Emerson of Amherst has given me valuable information, and the use of his collection. I was unfortunate in finding the curators of collections either absent or sick at Hanover and Heidelberg; but in all practicable cases ample opportunities for study were given me, except at the Museum of York, England, where unyielding regulations prevented access to the interior of the cases, and my identifications there were consequently made without handling the specimens. I am also indebted to Professor Cope and Dr. John A. Ryder for the results of investigations which have thrown much light upon vexatious questions of theory, and which have not been properly represented by quotations in the text of this work, the general remarks having been necessarily cut down to the narrowest possible limits.

The essay on "Fossil Cephalopods in the Museum of Comparative Zoölogy"[1] was written in large part as an introduction to this monograph, but for obvious reasons has not been used. The following conclusions, copied with some emendations and corrections from that essay, may be useful, however, in giving the reader a view of the theoretical opinions entertained by the author.

1. *Law of Morphogenesis.* — We have endeavored to demonstrate that a natural classification may be made by means of a system of analysis in which the individual is the unit of comparison, because its life in all its phases, morphological and physiological, healthy or pathological, embryo, larva, adolescent, adult, and old (ontogeny), correlates with the morphological and physiological history of the group to which it belongs (phylogeny).

2. *Organic Equivalence.* — All new characteristics, even those which are purely mechanical reactions of the tissues, arise in a similar manner, as reactions due to the exciting agency of the more general or more localized physical causes. They are therefore necessarily, and because of this mode of origin, the corresponding organic, or suitable complementary equivalents of these physical causes, both structurally and functionally.

3. After their origin, however, and during their subsequent history, organic equivalents or characteristics are divisible into two categories: those which become *morphological equivalents*, and are essentially similar in distinct series, and those which are essentially different in distinct series, and may be classed as *morphological differentials.*

4. *Morphological Equivalence.* — In the different genetic series of a type derived from one ancestral stock there is a perpetual recurrence of similar forms in similar succession, which are usually called representative and often falsely classified together, though they really belong to divergent, genetic series.

[1] Proc. Am. Ass. Adv. Sci., XXXII., 1883.

5. These forms and their similar characteristics are not derived by direct inheritance from the common ancestor, in which all the forms are necessarily similar and primitive, but originate everywhere independently of hereditary influences in the different series, and also in all formations independently of chronological or chorological distribution.

6. This evolution of similar morphological changes in the forms of different genetic series must be regarded as the similar reactions or efforts of a common organism in direct response to similar generally distributed physical causes active in the same habitat, and are therefore necessarily similar to each other, though in different genetic series. As a whole, they may be said to express the general tendencies of modification, due to the efforts of the common-radical and common organization while spreading in all directions and in different genetic lines to respond to similar physical causes, and meet their requirements with suitable changes. They are, therefore, structural equivalents of each other in different series, and functional equivalents of the general requirements of the environment or habitat, or, in other words, purely *physical selections*.

7. *Morphological Difference.* — Differentials are absent in the first members of series, on first appearance in their descendants transient, but afterwards tend to become invariable, or fixed in the stock or series, being perpetuated by direct inheritance in successive generations, species, etc. They finally often disappear in the retrogressive or highest and last occurring members of each series, or in aberrant forms when on the same level.

8. They have no determinate mode of succession, but are usually more or less isolated modifications, and arise first in individuals or varieties, but afterwards become characteristic of species, and finally of the major part of the direct line in species, or descendent series.

9. They are, therefore, strictly adaptive, variable characteristics, and not directed in their occurrence or development by any more or less invariable law of successive modification, as are the morphological equivalents. We have failed in finding any differentials of great importance whose prepotence as hereditary characteristics could not be accounted for by the law of use and disuse in connection with habits. The differentials of small series, species, genera, and families, which we have not been able to analyze thoroughly, may be due to the action and reaction of individual animals upon each other, or, in other words, to natural selection.

10. Differentials, therefore, can be separated from other characteristics of the same parts by careful observation and close analysis of their behavior in series, but cannot be specifically predicted from the study of other series; whereas, morphological equivalents can be predicted with the same certainty as the recurrence of cycles in physical phenomena. Thus we can say of any new series of Nautiloids or Ammonoids, that, the habitat remaining similar, they will, whenever or wherever found, tend to develop arcuate, coiled, close-coiled, or discoidal and finally involute forms in progressive series, and reverse this process in retrogressive series.

11. *Acceleration in Development.* — All modifications and variations in progressive series tend to appear first in the adolescent or adult stages of growth, and then to be inherited in successive descendants at earlier and earlier stages according to the law of acceleration, until they either become embryonic, or are crowded out of the organization, and replaced in the development by characteristics of later origin.

12. *Geratology.* — Modifications which tend to appear in the old age of the individual of progressive series correlate with the modifications taking place in pathological series of all grades, and in geratologous and retrogressive forms of all kinds, however progressive they may be in certain characteristics. Geratologous forms, therefore, show that the development of retrogressive characters has been stimulated so as to take the place of the hereditary progressive, thus either partially or completely replacing them. Partial replacement is often accompanied by the early development of hereditary progressive characteristics.

13. *Acceleration in Degeneration.* — Geratologous forms may, therefore, be the highest members of progressive series, or the terminal members of retrogressive series, and the stimulation of the development appears to take effect upon both progressive and retrogressive characteristics; thus producing, at the same time and in the same animal, first, the earlier development of some of the progressive characteristics combined with geratologous characteristics; secondly, the earlier development of geratologous characteristics and their fusion with larval characteristics, which occasions the complete replacement of progressive characters, and occurs only in the extreme forms of retrogressive series, and in parasites.

14. The law of acceleration in development seems, therefore, to express an invariable mode of action of heredity, in the earlier reproduction of hereditary characteristics of all kinds, and under all conditions. In progressive series it acts upon healthy characteristics, and appears to be an adaptation to favorable surroundings, and in retrogressive series upon pathological characteristics, and is probably an adaptation to unfavorable surroundings, usually leading to the extinction of the series or type.

15. *The Three Phases of Development.* — In following up series, it has been found that the development of ancestral forms is simple and direct (Epacme); that of their more specialized descendants becomes gradually indirect (Acme), acquiring complicated intermediate or larval stages; and that of the terminal retrogressive or geratologous and pathological forms becomes again more or less direct (Paracme.)

16. The introduction of adaptive larval stages into the history of individual development in any series appears to be due to the direct exciting action of the surroundings, and their absence or subsequent suppression to some physical agency, changes of habit, or protection, or pathological causes. All of these causes must, however, be considered as similar in their effect upon the young. They are stimulants, producing acceleration or excessively rapid development of the ancestral progressive characteristics, or of the retrogressive, or primitive larval characteristics inherited from the progressive forms.

17. This agreement in the mode of development of the individual according to its position in the history of the group completes the correlations which exist between the history of the individual (ontogeny) and the history of the group to which it belongs (phylogeny). Using Haeckel's nomenclature, the three periods of ontogenesis, Anaplasis, Metaplasis, and Cataplasis, correlate with the three periods of phylogenesis, Epacme, Acme, and Paracme. In addition to this general correlation, we now find that during the epacme of a group the development of individuals is anaplastic or progressively direct; during the acme of a group, metaplastic or progressively indirect; and during the paracme of a group, cataplastic, or retrogressively direct. We have also found, that, in the history even of small groups, the epacme, acme, and paracme may often succeed one another in geologic time, and show similar correlations, so that we can often distinguish epacmic faunas, acmic faunas, and paracmic faunas in chronological succession. In series, also, epacmic forms, acmic forms, and paracmic forms, either in series of species or varieties, may occur in geological succession in different faunas, or in zoölogical gradation in the same fauna.

18. *Law of Variation.* — The action of physical changes takes effect upon an irritable, plastic organism, which necessarily responds to external stimulant by an internal reaction or effort. This action from within upon the parts of organisms modifies their hereditary forms by the production of new growths or changes, which are, therefore, adapted or suitable to the conditions of the habitat, and are therefore *physiologically and organically equivalent* to the physical agents and forces from which they directly or indirectly originated. In so far, then, as causes and habits are similar, they probably produce representation or morphological equivalence in different series of the same type in similar habitats; and in so far as they are different, they probably produce the differentials which distinguish series and groups from each other.

19. The radical and epacmic forms of the Arietidæ probably originated in the Northeastern Alps, and migrated from thence southerly and westerly into Italy, and also in another direction westerly into South Germany and the Côte-d'Or. In these last two faunas new series of acmic forms arose by modification, and these and the paracmic forms which seem to have arisen in the same basins flowed back into the Northeastern Alps, and thence into Italy, during Bucklandian and later times. They were also distributed from these two basins to all others to the north and south of them in Central Europe. The Northeastern Alps and the South German and Côte-d'Or basins constitute a Zone of Autochthones for the Arietidæ, and other faunas to the north and south of these are what we have called Residual Faunas.

The materials in the Museum of Comparative Zoölogy consist of various collections made in England by Damon, Marder, and Wright; Boucault's famous collection from the Côte-d'Or, containing several of D'Orbigny's types, and in part named by him, or by direct comparison with his collection; a special and very large general collection, especially rich, however, in South German species, purchased from Dr. Krantz; a valuable exchange from the Museum at Stuttgardt named by Professor Fraas; Professor Bronn's collection labelled by him; a number of valuable species, principally from Belgium, from L. de Koninck's collection; a similar lot presented by Prof. J. Marcou, from various localities in Europe; and others not sufficiently important to be mentioned here.

ALPHEUS HYATT.

CAMBRIDGE, April, 1889.

GENESIS OF THE ARIETIDÆ.

I.

INTRODUCTION.

Origin and Characteristics of Suborders.

THE succession of forms among the silurian members of the genus Mimoceras indicates that true gyroceran shells occurred among Ammonoidea, differing from the similar forms among Nautiloids only in the possession of a globular protoconch and a small ventral lobe. In some silurian and devonian Anarcestes these permanent adult stages are repeated in the development of the young Those in *Mimoceras compressum* are truly cyrtoceran, or open curves at first; and in others, as in a variety of *Anarcestes fecundus* described by Barrande, they are straight.

The next stage of growth is a loose-coiled or gyroceran form, like the adult of Mimoceras. These stages can only be accounted for as hereditary tendencies of growth in a type which is being rapidly changed from a primitive ancestral straight form with simple sutures into a close-coiled nautilian shell.[1]

Branco[2] describes and figures a specimen of Bactrites with a protoconch similar to the very peculiar ovoid protoconch of *Mim. compressum.* He quotes Beyrich, who gave him this specimen, as authority for the view that Bactrites is connected with Mimoceras as Baculites is with the normal Ammonoids of the Cretaceous. This idea was first published by Quenstedt in his "Die Cephalopoden," and it is quite possible that Bactrites of the Devonian may be a degraded form of Mimoceras, but in that case the latter is also a degraded form of Anarcestes, or transitional between it and Bactrites. To establish this proposition, forms of Mimoceras and Anarcestes should be produced in which uncoiling occurred in adults after a close-coiled stage of growth had been passed through. Such degraded forms are common in the Jura and Cretaceous, and enable the observer to connect Baculites with the normal coiled Ammonoids of the same formations. Whether this be so or not, the straight Bactrites-like young of some forms of Anarcestes, the gyroceran young of others of the Goniatitinæ, and the gyroceran adults and young of Mimoceras, indicate the derivation of Goniatitinæ to have been from silurian straight shells similar to Bactrites, if not directly from that genus itself.

[1] Genera Foss. Ceph., pp 303, 304, 309, Proc. Bost. Soc. Nat. Hist., XXII, 1883.

[2] Zeitsch Deutsch Geol. Gesell., XXXVII. p. 1.

We pointed out in "Embryology of Fossil Cephalopods,"[1] that the loosely coiled stages prevalent among Nautilinidæ were repeated in the early stages of development in some of the Goniatitinæ and in the later Ammonoids. This repetition was indicated by the form of the embryo which was flattened and depressed, and also in the first sutures and in the embryonal umbilici. These last are two conical or flattened depressions on either side of the protoconch, at its junction with the apex of the conch. They were accounted for as remnants of the umbilical perforation found in the young and adults of Mimoceras and all coiled Nautiloids.

In our "Genera of Fossil Cephalopods" we narrowed this generalization by comparing the first whorl of the embryo in the close-coiled Goniatitinæ and in all Ammonitinæ with Anarcestes, thus bringing the affinities of all the Ammonoidea to a focus in the silurian genus Anarcestes. These and other similar observations, published before and since the work quoted above, have been founded upon the law of acceleration formulated also in the Preface of this monograph, pp. v, vi, Art. 11 and 14.

Dr. Branco's extensive and accurate researches[2] have shown that all of these opinions, though founded upon a few specimens only, were sound, and that the law of acceleration can be relied upon as a working hypothesis. Though treating us otherwise with more than just appreciation, this author failed to notice that we had used the law of acceleration in development, or made our inductions with the view of demonstrating its truth as a working hypothesis, and consequently attributed the discovery of this law to Würtenberger.

Among Nautiloids the straight shells in each series appeared first; they were succeeded by the cyrtoceran, gyroceran, and close-coiled. Among Ammonoids there is only one series — Bactrites, Mimoceras, and Anarcestes — which is parallel with any one series of the many occurring among Nautiloids. The open-whorled stages of the young of Anarcestes and other Goniatitinæ represent a transitional and highly accelerated development. This transitional character is also indicated by the fact that, except in Mimoceras and some species of Anarcestes, the occurrence of the gyroceran form, even in the young, is sporadic. It occurs, as demonstrated by Barrande, in one variety of *Gymnites fecundus*, and not in the other. Sandberger has shown similar though less marked variations in the young of *Anar. subnautilinus*, and Branco has described the embryo of var. *vittiger* of the same species as close-coiled. Other examples might be given, but it only remains to notice Branco's doubts of the accuracy of our drawings of the young of *Gon. atratus* and *Gon. Listeri*. Both of these were found by him to belong to his close-coiled division of the Asellati of the Carboniferous. Our drawings were made with a camera. The details they contain show, better than any defence we can make, that they were also closely studied by the author, and often corrected before being placed upon stone. They indicate that primitive gyroceran forms of young are occasionally found even among the highest forms of carboniferous Goniatitinæ.

[1] See especially articles "Whorls" and "Umbilicus," Bull. Mus. Comp. Zoöl., III. No. 5.
[2] Paleontogr., 1880, 1881, XXVI., XXVII.

The depressed semi-lunar whorl appears first in the adults of Anarcestes. It is subsequently found in the young as a stage immediately succeeding the more cylindrical whorl of the gyroceran stage, when that occurs. In very close-coiled forms, the latter may be omitted, or be only slightly indicated, and then the anarcestian whorl appears at the beginning of the apex. In fact, this tendency in Latisellati, and especially in Angustisellati, affects the shape of the protoconch which is excessively depressed in the embryos of the higher suborders.

We have, therefore, considered it convenient to designate the anarcestian form of whorl as the primary radical of the Ammonoidea, reserving the terms primitive and transitional radicals for the straight and gyroceran modifications as they appear in Bactrites and Mimoceras.

The different series of the Clymeninæ and Goniatitinæ, and the Arcestinæ, often begin with, and maintain persistently in full-grown shells, the primary radical form. The Ceratitinæ, Lytoceratinæ, and Ammonitinæ, on the contrary, have this depressed form but rarely, except in their protoconchial stage, — and at the beginning of the apex or true conch, while it remains in what we have called the goniatitic stage of development.

The Clymeninæ of the Devonian begin, when zoölogically arranged, with discoidal forms having depressed semi-lunar anarcestian whorls. These depressed whorls are exchanged in the higher forms for compressed discoidal whorls, and these in turn for compressed involute whorls. The suborder includes several genera and in each there occur examples of this mode of succession, or rather procession, of forms, forming parallel series.[1]

The sutures of the genera Beneckia, Longobardites, Lecanites, Norites, Meekoceras, Hungarites, and Carnites show them to be true Ceratitinæ. We should, with our present information, be disposed to include these, and all the genera mentioned by Mojsisovics as belonging to his group of *Ammonites trachyostraca*, in the Ceratitinæ, distinguishing them by their well-known and peculiar sutures from the Arcestinæ, Ammonitinæ, and Goniatitinæ.

The more or less compressed whorl, which in section can be described as helmet-shaped, is the natural successor of the depressed anarcestian whorl both in the growth of individuals and in the evolution of series of species. We have considered this in the work quoted, therefore, as the secondary radical.

The secondary radicals[2] are prevalent in the Ceratitinæ, as shown by the extensive researches of Mojsisovics in the remarkable and masterly treatise above quoted. They completely replace the primary radicals as generators of series in the Trias, except in the paleozoic survivors of the suborder Arcestinæ. So far as the sutures are concerned, however, the Ceratitinæ, though distinctly characteristic of the triassic faunæ, are like the Goniatitinæ. The young of Longobardites is really a Goniatite, similar to Prolecanites.

[1] Genera of Fossil Cephalopods, Proc. Bost. Soc. Nat. Hist., XXII, p. 312.

[2] We formerly included (Gen. Foss. Ceph., p. 324) in secondary radicals some quadragonal whorls like those of the adults of Xenodiscus; but we are now disposed to consider this an error, arising from not having observed that the young of these forms often possessed, during earlier stages of growth, the secondary or helmet-shaped whorl. This evidence shows that, in the most ancient periods as well as in later times, quadragonal whorls were derivative modifications of the compressed helmet-shaped secondary radicals.

Norites is considered by Mojsisovics as allied to Pronorites, a genus of Goniatitinæ, and by Griesbach, Zittel, and the author as allied more nearly to another genus of the same suborder, Sageceras. Throughout the group the lobes and saddles form a simple series in which very little differentiation is observable except in the highest forms. The ventral lobe is very broad and short, and the siphonal saddle broad and shallow. The survival of prolecanitian characters in these outlines is apparent the moment we dispense with the denticulations of the lobes and reduce the sutures to their primitive outlines. The Arcestinæ of the Dyas are known only by one species, described by Waagen, *Cyclolobus Oldhami*,[1] which has whorls of the anarcestian shape. It is an involute species, and there may be others of this genus in the same formation, not yet discovered, which have more discoidal whorls.

According to our mode of translating the affinities of the forms, they arrange themselves as follows. Popanoceras of the Dyas, as the direct descendant of Prolecanites, inherits the tendency to have lobes and saddles of very nearly the same size, with lobes having trifid or bifid terminations similar to those of the young of Monophyllites, and also transitional to the sutures of the dyassic Cyclolobus, the most ancient of the true Arcestinæ. If we are right, the young of this last form, when examined, will be found to be similar to *Popanoceras antiquum* at a stage when its sutures have not yet acquired marginal lobes.

The siphonal saddle in these forms and in true Arcestinæ is small, often attenuated, and the ventral lobe large and often broad. The remaining lobes and saddles are more nearly of the same size, numerous, and formed a gradually lessening series inclining towards the umbilicus. The same aspect is common in the simpler shells of Megaphyllites and Monophyllites, but in these the large phylliform saddles, with entire outlines at their bases, exhibit closer approach to the Prolecanitidæ. Arcestinæ, therefore, retain in their sutures the proportions of paleozoic forms of Goniatitinæ which have numerous lobes, but depart from them in having more complicated and ornate marginal digitations. The series, with some exceptions, have involved whorls which can only be considered as parallel with the more involute shells of silurian and devonian Anarcestes. With respect to its forms and the smoothness of the shell this series is a survival of purely paleozoic modifications.

The Lytoceratinæ form a separate phylum, distinguished usually by the absence of true pilæ (ribs), the larval form and characteristics of the adult shell, and the leaf-shaped marginal saddles of the sutures. Lytoceras, in its smooth or unpilated shell, rounded abdomen, peculiar siphonal saddle, and phylliform marginal saddles, appears to be a more progressive form of the same genetic series as Megaphyllites and Monophyllites of the Trias. Even the peculiar coarse striations of the shells of these genera are often repeated among the Lytoceratinæ of the Jura.

Megaphyllites of the Trias is evidently closely allied to Monophyllites. The siphonal saddle is similar to that of Monophyllites, and the marginal

[1] *Arcestes priscus*, Waagen, is probably also a species of Cyclolobus. Geol. Surv. Ind., Salt Range, ser. 13, I. i. pl. ii. fig. 6.

saddles are phylliform. The young of *Monophyllites Suessi*, Moj.,[1] of the Trias, has sutures similar to the adults of *Popanoceras antiquum*[2] and *Kingianum* of the Dyas,[3] which are true Goniatitinæ. The sutures of Popanoceras are in their turn transitional between Monophyllites and the more normal Goniatitinæ of the genus Prolecanites.

Triassic Ammonoidea have shallow ventral lobes and very prominent broad siphonal saddles, thus giving the first lateral saddles the aspect of being adjuncts of the siphonal saddle. In consequence of the more direct descent of Lytoceratinæ of the Jura from primitive forms, their sutures persist in retaining triassic outlines, having usually short abdominal lobes, large siphonal saddles, with the superior laterals apparently set upon their sides, the larger lobes expanded and profusely branching at the top, the saddles expanded and profusely branching at the base, the auxiliary lobes and saddles more numerous and more nearly equal to the larger lobes and saddles than in Ammonitinæ. Neumayer has demonstrated trumpet-like apertures in *Lyt. immane*.[4] The frilled and elevated ridges in shells of many forms indicate that these are perhaps not uncommon in this group.[5]

The normal forms of the Ammonitinæ, the Arietidæ of the Lower Lias, can be united to the genus Gymnites through Psiloceras. Gymnites can be traced back to the Goniatitinæ through Arcestes of the Trias and Cyclolobus of the Dyas. The Ammonitinæ do not, therefore, come directly from the Goniatitinæ, as do the Lytoceratinæ, but are probably direct offshoots of the lower Arcestinæ. The Ammonitinæ include not only the typical jurassic and cretaceous forms, but also the allied radical genera Schlotheimia and Psiloceras of the Lias, and Gymnites and Ptychites of the Trias.[6]

In Gymnites of the Trias, the primary radical is exchanged for the more compressed discoidal secondary radical, but still smooth shell, which is also characteristic of Psiloceras of the Lias. The sutures are correlatively modified, and begin to assume the aspect and proportions of the true Ammonitinæ. The siphonal saddle is more prominent, but still retains in many species the pointed aspect derived from the Goniatitinæ. The narrow first lateral saddles are apt to appear like adjuncts of the siphonal saddle, owing to the great size and breadth

[1] Mediterr. Triasprov., pl. lxxix. fig. 4 a e.

[2] *Arcestes antiquus*, Waagen, Salt Range, Pal Ind., ser. 13, I. i. pl. i. fig. 10.

[3] Russia and Ural, M. V. K., II. pl xxvii. fig. 5.

[4] Mojsis. et Neum., Beitr., III., 1883, 1884, pl. xx.

[5] Schlonbach, Paleontogr., XIII. p. 169, pl. xxvii. fig. 3, describes *Amm hircicornis*, one of the Lytoceratinæ, having a series of prominent flaring ridges indicating permanent apertures of similar form. The slight, blunt rostrum is a notable characteristic of these apertures. Unfortunately, very few have been preserved, possibly owing to the fact that they were in most species, as in the two mentioned, thin flaring ridges, easily destroyed. We can only suggest, therefore, that this form of rostrum might have been peculiar to this suborder.

[6] In "Genera of Fossil Cephalopods," in 1883, we expressed this opinion as follows: "This genus (Cyclolobus) is very important, since it enables us to show the gradations by which the Prolecanitidæ approximate to Arcestes, Ptychites, and Monophyllites." Mojsisovics, with new materials from Spitzbergen, has lately demonstrated the correctness of this opinion in part, and gives conclusive evidence of the probable derivation of Arcestes and Ptychites from Popanoceras Arkt Trias Fauna, Mem. Akad St. Petersb., XXXIII. No 6, p. 66, pl xv.

of the first lateral lobes and the shortness of the ventral lobe. The aspect of the second laterals in many species, and the gradation from these into the auxiliary lobes, show that they retain the more primitive aspect of the earlier forms in this part of the sutures.

Ptychites of the Trias has sutures similar to those of Gymnites, and the modified aspect of marginal lobes and saddles in both genera shows that, in spite of a near approach or resemblance in the sutures to many Lytoceratinæ, they cannot be considered as so nearly related to them as to Cyclolobus.

Mojsisovics says that the evidence of genetic connection of *Psiloceras planorbe* and *Gymnites incultus* rests alone upon the resemblances of the auxiliary lobes and saddles, and that the resemblances in form only occur between the discoidal Gymnites and the most involute Psiloceratites, the former being indeed much more involute than the most involute of the Psiloceratites. The genus Halorites of the Trias is regarded by Mojsisovics as the probable ancestor of the Arietidæ.

We cannot recognize that there are any very marked differences in the amount of involution or form between *Gym. incultus* and *Gym. Palmai* when compared with *Psil. planorbe*, and the resemblances of the sutures are exceedingly close, especially when the species of Psiloceras of the Mediterranean province are studied. The aspect of the shells in the three former are very similar, while in the types of Halorites already cited by Mojsisovics, *Hal. Ramsaueri, semiplicatus, decrescens,* and *semiglobosus*,[1] they are very distinct. The range of form in Halorites embraces highly sculptured shells, altogether triassic in aspect. Neumayr's[2] and Wähner's[3] researches entirely confirm the position here taken and show that Psiloceras possessed a series of involute shells. Psiloceras and Gymnites, therefore, appear to be two parallel genera of the same group, in each of which discoidal forms give rise to more involute shells. *Gym. incultus* may be traced into the more involute *Gym. Humboldti*, and the still more involute *Gym. Credneri.* The adolescent young of *Gym. Palmai*, Mojsis.[4] and *incultus*[5] show less involution than the adult, and we may confidently expect that some correspondingly still less involute discoidal ancestral forms will be found. Mojsisovics has not yet published his observations in full, and his evidence is therefore not completed; but, so far as we now know, the derivation of Psiloceras seems to have been from Gymnites as a common ancestor and not from any forms of the Ceratitinæ like Halorites or its allies.

Mojsisovics has said, that out of his group of *Ammonites leiostraca* the genus Phylloceras alone persists and is but little changed in the Jura; whereas the *Amm. trachyostraca*, or Ceratitinæ, are more largely perpetuated, though much changed, in the true Ammonitinæ. Our view differs, since we consider all groups of the Trias to have been discontinued in the Jura except the Lytoceratinæ. It is probable that a close affinity existed between Psiloceras and Gymnites, and the former is a modified Triassic survivor in the Lias; but the constant reappearance of the psiloceran form in the young of undoubted Arietian

[1] Amm. Gattungen, Verhand. Geol. Reichs., 1879, No. 7.

[2] Unterst. Lias, Abhandl., Geol Reich., VII.

[3] Unt. Lias, Mojsis. et Neum., Beitr., III.

[4] Med. Triasprov., pl. lvii. fig. 2

[5] Ibid., pl. liv. fig. 3.

species shows that we must reckon it among the Arietidæ. The genus Schlotheimia is also a purely jurassic series, though undoubtedly triassic in respect to its sutures. The young of *Schlotheimia catenata* is an almost exact reproduction of the form described by Mojsisovics as *Ægoceras Buonarotti* in "Jahrbuch Geologischen Reichsanstalt,"[1] and afterwards referred to Celtites in his "Mediterranean Triasprovinz."[2] The pilæ cross the whorls on the abdomen in the same way, and the general aspect of this discoidal shell is similar. It seems quite likely that this is a young shell of some species, and until its exact affinities can be determined it is of no great value. At present it would be difficult to say with any certainty to what genus it might be referred. Mojsisovics was evidently in doubt, since he states that it may be a young form of some species of Balatonites. The resemblance to the young of *Schlot. catenata* may be due to a purely pathological deformation, since the crossing of the abdomen by the pilæ occurs from disease in many species of the Arietidæ and other keeled groups of the Jura, notwithstanding the fact that it is normal in others. These facts, and the gradations of form between Schlotheimia and Psiloceras presented by the genus Wæhneroceras,[3] and by the young of this last genus, lead us to think that Schlotheimia was derived from Psiloceras. The Ammonitinæ of the Jura, so far as known, show no special traces of their prolecantian descent, except in the discoidal shells and phylliform sutures of the genera just mentioned, and in the embryonic and generalized goniatitic characters of the apical stages of the shell. The ventral lobe of the Ammonitinæ is deep and narrow, the siphonal saddle small but more or less dentated by marginal lobes and saddles. The lateral saddles are broad and not so deeply divided by marginal lobes as in the Lytoceratinæ, the lobes are narrower at the tops than in that suborder, and the saddles consequently narrower at their bases. The great size and small number of the lobes is also a marked peculiarity. The superior lateral saddles and lobes are especially remarkable for size, and the auxiliary lobes and saddles much less important and more unequal as compared with the lateral lobes and saddles than in Lytoceratinæ. The marginal lobes and saddles are as a rule short and pointed, and the saddles rounded, but not phylliform. Possibly another distinction will eventually be demonstrated in the more constricted and rostrated apertures of many of the Ammonitinæ. The characteristics of the embryos and of the earliest stages do not yet seem sufficiently well known to be used in this connection.

The Ammonoids, therefore, according to our views, are not divisible into two grand divisions, but have six suborders: the Goniatitinæ, of the Silurian, Devonian, Carboniferous, Dyas, and Trias; the Clymeninæ of the Devonian; the Arcestinæ of the Dyas and Trias; the Ceratitinæ of the Dyas and Trias; the Lytoceratinæ of the Trias, Jura, and Cretaceous; and the Ammonitinæ of the Trias, Jura, and Cretaceous.

Unfortunately, there is not space enough within the necessary limits of this monograph to discuss the classifications of Mojsisovics, Fischer, and Zittel,

[1] Vol. XIX., 1869, pl. xv.

[2] Page 120, pl. xxix.

[3] A new genus described in this memoir.

and the embryological divisions proposed by Branco.[1] The classification given above was necessary in order to introduce our remarks upon the Ammonitinæ, and show clearly why we limited this suborder as defined above; any further discussion would lead us too far away from the immediate objects of this memoir.

Nomenclature of Stages of Growth and Decline.

In a paper read before the Boston Society of Natural History, November 16, 1887, the author discussed the classification of the stages of growth and decline, dividing them as follows: —

1. The earlier stages, embracing the ovum (monoplast, Lankester), the monoplacula, and the diploplacula, were considered under one term, Protembryo, because of their parallelisms with the single and colonial Protozoa.

2. The next, or blastula stages, were classified under the head of Mesembryo, on account of their resemblances to the Mesozoa; the latter being those forms usually included in the sub-kingdom of Protozoa, but which have true ova and spermatozoa, and can be therefore separated as one-layered, spherical Blastrea, closely parallel with the blastula, and precisely intermediate between Protozoa and Metazoa.

3. The gastrula stages were considered as referable to true Metazoa, and were styled accordingly the Metembryo.

4. The earlier planula or ciliated stages were regarded as indicating a still very remote ancestral type, in common with Semper, Lankester, and Balfour, and were termed the Neoembryo.

5. The later ciliated stages — those which show the essential characters of the type to which the embryos belong — were classified as the Typembryo; ex. the veliger, nauplius, etc. The typembryos were considered as the last of embryonic stages, and those which followed were regarded as true larvæ on account of their more demonstrable connections with well known forms. It was found by applying this classification to the fossil Cephalopoda that the protoconch of Owen was the shell of a univalve typembryo, which must have been a veliger not very widely removed in structure from the similar shells of the embryos of Gasteropoda and Pteropoda.[2]

The principal difficulty of the application of this view lies in bringing the wrinkled and curious forms which occur upon the apices of some Nautiloids into

[1] Mojsisovics, Med. Triasprovinz; Fischer, Manuel de Conchyliologie; Zittel, Handbuch der Paleontologie; Branco, Paleontogr., XXVI., XXVII.

[2] Robert Tracy Jackson, a pupil of the author, in an essay now in preparation ("Phylogeny of the Pelycypoda"), shows that the typembryo stage of mollusks is limited to an early period characterized by the existence of a shell-gland and the plate-like beginnings of a shell. Later veliger stages, he says, are referable to the class or phylum of Mollusca, to which the embryo really belongs, and he names them "Phylembryo" stages. The "prodissoconch" is a name given by Jackson to the embryonic, bivalvular shell of Pelycypoda, which is the equivalent of the protoconch of cephalous mollusca. The completed protoconch of the cephalous mollusca, and prodissoconch of Pelycypoda, Jackson considers as a stage later than that at which the phylembryonic characters are emphasized, and as the close of the embryonic shell period. His paper will give types of these and other stages considered in the several classes of mollusks.

exact relations with the indubitable protoconchs occurring upon the apices of the conchs of Ammonoids and Belemnoids. The wrinkled lump above referred to is unquestionably a part of the shell. It is not only closely attached, but the longitudinal striæ of the apex of the true conch are continuous upon the proximate parts of the lump. It had an aperture which must have remained open until the body of the veliger had entirely left the interior of the protoconch, and was then closed by the apical plate. There is a cicatrix upon the apex of the conch, which is invariably concealed by the lump when it is present, and in some examples we observed the fracture of the outer layer of the shell on the apex of the conch and outside of the ordinary boundary of the cicatrix, which could only have been caused by the violent removal of the lump. The wrinkled and contracted aspect of the lump when preserved can be accounted for by assuming it to have been composed of conchiolin. This also accounts for its almost invariable absence, since such an organ must have been easily lost or destroyed. The lumps must consequently be regarded as the remnants of conchiolinous protoconchs having elongated and narrow apertures; but probably they were, when in a living condition, much larger and more oval, and more similar to the protoconch of the Ammonoids. The continuity of the striæ from the conch to the protoconch also shows that the conch was built out from the aperture of the protoconch, layer after layer, and the concentric markings, and form of the apex, which correlates with that of the scar, sustain this idea. The figures on the following pages are less perfect than several other examples studied by the author since these were drawn. They do not show the passage of the external longitudinal striæ from the apex of the conch on to the surface of the protoconch.

A living chamber among recent and fossil Nautiloids marked a period of rest after a stage of growth. The septum, therefore, was not built until the animal arrived near the final steps, or had altogether stopped building out the sides of that part of the shell in which it lived. At any rate, we can say without risk of error that the septum was the final step, or one of the final steps, in the construction of a living chamber.

6. The first living chamber, or the first larval or næpionic[1] stage of a Nautiloid was, therefore, represented by the apex of the conch in that order; but the first septum and siphonal cæcum did not exist at this stage, which is represented by a straight or slightly curved widely spreading cone, — in fact, the empty apex of the conch. The length of the first living chamber has not been ascertained; but that it was short seems probable from the form of the cone in Nautilus. Doubtless this remark does not apply to the earliest forms of closely coiled shells, in which the cone was much slenderer than in existing Nautilus, and the first living

[1] Νήπιος, infant, or young animal. The term "silphologic" was used for this stage in the article above quoted. This literally means "grub" stage, and it is not strictly applicable to a normal progressive stage of development. Grubs, caterpillars, and the like, among insects, are degraded or retrogressive developments, as compared with the normal, probably hereditary Thysanuriform larvæ of what are commonly called the lower orders of Insecta. Studies of insects lately made have convinced us of the truth of this opinion, first published by Friedrich Brauer, and of the need of changing this term to the one used, and of reserving silphologic as a general term for retrogressive stages, such as one finds in the larvæ of Coleoptera, Lepidotera, Hymenoptera, and Neuroptera.

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chamber perhaps longer in proportion. The entire absence of a cæcum, and of all signs of a siphon, may be inferred with probable certainty in this first stage; and we proposed, in the paper referred to above, to name it the Asiphonula. This form may indicate the previous existence of a common univalve ancestor for the Cephalopoda which resembled the Pteropoda. Certainly the aspect of the calcareous protoconch of Ammonoids and Belemnoids favors this idea, first suggested by Von Jhering; and the asiphonula adds another argument, since it has no siphon or true septum. The young of the Pteropoda, especially the ancient forms, had calcareous protoconchs in most forms; but doubtless there are more primitive shells in which the protoconchs had the more primitive, embryonic, conchiolinous stage of development. The evidence, therefore, is not conclusive, but it justifies the supposition that Cephalopods and Pteropods had originally some common ancestor, a true shell without septa or siphon, and possessing a protoconch, which might have been conchiolinous.

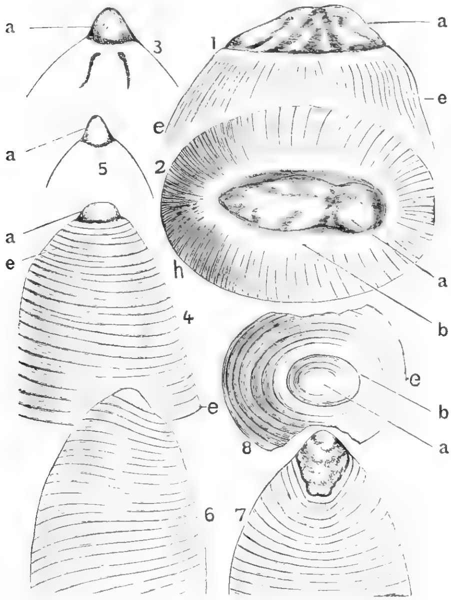


Fig. 1–3. Apex and protoconch of *Orth. elegans*, Münst., from the side, below, and in front. In Fig 2 the fine striæ really cross the shoulder of the apex (b), and reach to the protoconch (a). Named by Klipstein, Loc. St. Cassian, Coll. British Museum.

Fig. 4, 5. Apex and protoconch of another specimen mounted with the first on the same card. Named by same, Loc. same, Coll. same.

Fig 6–8 Views from the side, front, and below of the same parts in *Orth. politum*, Klipst. The shading on the protoconch of Fig. 8 does not indicate structure; this protuberance is smooth. a, protoconch; b, shoulder of the area of the cicatrix. Named by same, Loc. same, Coll. same.

There is, however, another group, the Scaphopoda, which may claim to be considered in this connection. According to W. K. Brooks, the veliger is represented by the adult of Dentalium in several of its leading characteristics, and this must be regarded therefore as the most generalized type of the true Mollusca. It is quite possible that the asiphonula may have retained some of the characters of the veliger, and may have resembled Dentalium or some common ancestor, and may have descended from this form without having passed through any pteropod-like ancestral modification. The peculiar resemblances of the young of some of the Goniatitinæ and the adults of Tentaculites among Pteropoda may be entirely due to homoplasy, and not to homogeny.[1]

[1] These terms were first used by Lankester (Jour. Micr. Sci., XVII., 1877, p. 436). They express phenomena with which naturalists have long been familiar, "homoplastic" meaning representation and independent origin of similar characters, and "homogenous" meaning genetic connection. See also previous use of terms Heterology and Homology for the same phenomena by Cope, in his masterly essay, "Origin of Genera," Proc. Acad. Sci. Phila., 1868, and "Origin of the Fittest," p. 95.

It is obvious that we cannot account for the nautilus-like ventral saddle of the earlier sutures of the Ammonoids, the calcareous shell of the protoconch, the cœcal stage, the absence of the collar in the lower Goniatitinæ and in the young of the higher forms, the often central position of the siphon in the young, and many other characters, unless we admit a probable derivation of the Goniatitinæ from some straight microsiphonulate form of Nautiloid. It is, therefore, highly probable that the pteropod-like aspect of the young of some Goniatitinæ may be a purely homoplastic character, and be meaningless so far as the genesis of the group is concerned.

7. The next or second of the næpionic stages was represented by a living chamber, which was completed by the building of the first septum with its attached cæcum, indicating the primitive beginnings of a siphon. This stage we styled the Cæcosiphonula, and we have considered the possession of a cæcum to be an indication of the former existence of an ancestor having a central series of cæcal pouches. These may have had functional communication in some forms by means of an endosiphon, as in the Endoceratidæ, and in others, either belonging to this family or to a more primitive group, they may have been closed cæca.

8. The next næpionic stage was ended when the second septum was built in the modern

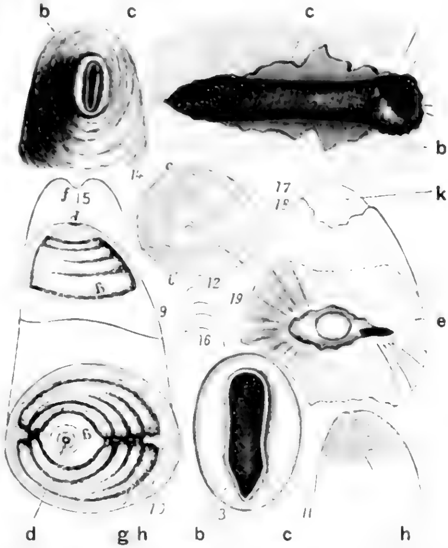


Fig. 9, 10. Views from the side and below of the plug which the animal of *Orth. truncatum*, Barr., habitually built on the exterior of the broken or truncated end of its shell. The last suture is shown in Fig 9, and the internal shadowy markings are apparent in both figures at a, g. These, however, in Fig. 9, are too far removed from the exterior. When the outer layer of the plug is penetrated, they are seen to be a part of its structure. The side view is also defective in the drawing of the pseudo siphon (d). There should be three distinct steps indicating three layers. The external crenulated striæ of the plug appear at h. Loc. Bohemia, Coll. British Museum.

Fig. 11, 12. Views of the same from the side and below, to show the external markings of the plug (h), which contrast strongly with the perfectly smooth shell above the septum of truncation and internal striæ (l) which appear when the outer layer is fractured No septa ever occur in the plugs These figures are introduced in order to meet M Barrande's objections (Syst. Syl, Pl. 488), that the examples of what we have called the protoconch and apex of the true conch were in reality plugs similar to those of *Orth truncatum.* There is no need of making any remarks; if our figures are correct, we are right in our statements It may, however, be well in this connection to say that M Barrande has done us the honor to make use of a number of our figures, including in part the above

Fig. 13–15. Views of the cicatrix and apex of *Orth. anguis*, Phill, after the shedding or removal of the protoconch as it usually occurs, leaving the cicatrix uninjured. Fig. 13 shows the area of the cicatrix much enlarged, b, conch or apex forming a smooth shoulder; and c, depressed surface of the cicatrix Fig 14, view less magnified of apex, Fig. 15, section of same Loc. Dublin, Coll British Museum

Fig. 16 Apex of *Orth. anguis*, Phill, natural size, with first three sutures

Fig. 17. Apex of same species after the probably violent removal of the protoconch, showing the fractured shell (h), and the unusual aspect of the cicatrix This and Fig 16 are types Loc Yorkshire, Coll. British Museum

Fig. 18 Front view of Fig. 19 The broken line (k) is hypothetical It indicates the possible outline and position of the cæcum, supposing the oval area in the centre of Fig 19 to have represented that organ

Fig 19 Apex of *Orth. politum* from below The protoconch has also been violently removed, and the opening plugged, apparently from within The dark spot on the right seemed to be a rupture in the external surface The oval shade in the centre indicated an internal structure, which may have been the cæcum in the first air chamber Loc St Cassian, Coll. British Museum

Nautilus, and in the vast majority of all known fossils of the order so far known to the author this stage had similar characters. The siphon was larger at this stage than subsequently, and possessed a prolongation which reached down into and lined the primitive cæcum. This closed pipe was however more or less cylindrical, and formed a transition to a cylindrical, open, siphonal tube, when compared with the cæcum on the one hand and the siphon of the succeeding septa on the other. The second septum was prolonged apically into a funnel, and this was continuous with a true porous wall, which formed the remainder of the pouch. We have already pointed out the probability that this wall was the homologue of the calcareous sheaths or endocones which filled the interiors of the siphons of Endoceratidæ. There is, therefore, as previously stated by the author, a structural though highly concentrated and much modified remnant of the adult siphonal elements of an Endoceras still preserved in this stage, even in the existing Nautilus, and we propose to name it the Macrosiphonula.

9. The next næpionic stage in living Nautilus was the third living chamber and third septum with its siphon. The siphon has a true funnel, and the siphonal wall attached to it is less swollen out, and seems, upon re-examination of the junctions at the opening of the funnel in the second septum, to be discontinuous. If we are correct, this stage has a small siphon consisting of the usual funnel and tubular porous wall, as in the vast majority of all Nautiloids and Ammonoids. We proposed to name this, according to its aspect and structure, the Microsiphonula. The microsiphonula, though a næpionic stage in the modern Nautilus, did not always occur among larval stages, but had in common with the macrosiphonula a traceable beginning in the adult stages of ancestral types. The genesis of the two forms of siphon may be studied in the Endoceratidæ. In this family Cyrtocerina had a siphon, which continually increased in size, probably throughout life, though more forms need to be described before one can be assured of this as a fact. There is no doubt, however, that the next form, Piloceras, had what we can safely call a macrosiphon of typical structure until very late in life. The large shells collected in Newfoundland by the author had siphons of great size, which were only slightly contracted or remotely approximated to the tubular condition of the Orthoceratidæ in the adolescent and adult stages.

This and other changes occurring in the adolescent stages induced us to distinguish them by a special term, Nealogic. The adolescent or nealogic stages, therefore, and the stages of the adult, or, as we have named them, the Ephebolic stages, in Piloceras show for the first time a tendency to contract the siphon or approximate to the microsiphonula, but they never had a true microsiphon. The contracted siphon in these forms, as in the other genera of this family, always had the holochoanoidal or complete funnel reaching from one septum to the next, and a series of conical concentric *endocones*, or sheaths, as they have been called by others, which stretched from the ends of the funnels, and were the homologues of the porous walls of the segments of the siphon in Nautilus.

The terminations of the endocones were prolonged into a central tube, or endosiphon, which we have previously described, and which probably served as a functional siphon in these shells. Gerard Holm[1] first called attention to the interesting character of the young stages of the siphon in Endoceras, and has shown this organ to have been very large even in the young, having not only a cæcal beginning, as in other forms, but in several species having a swollen or macrosiphonulate form which endured throughout several septa. In specimens now in the Museum of Comparative Zoölogy, at least six septa were built before any signs of contraction began to appear. In other cases figured by Holm the siphonal cæcum, though very large as compared with that of Orthoceras, was attached to the first septum, as in all the shells so far known from that group, and occupied only the first air-chamber. We should suggest to those having materials for study, that the shells having this last character are very likely not true Endoceratites, but perhaps the young of species of the genus Sannionites, which, according to the classification followed by the author, is a genus distinct from Endoceras, because the species possess a much slenderer siphon. Whatever the fate of this suggestion, it is plain that transitional series exist in this group between Sannionites and Cyrtocerina or Piloceras, and that gradations occurred also in Piloceras, which show that contraction of the siphon began first in adults, and then, according to the law of acceleration, was inherited in the nealogic stages of immediate descendants, and finally became næpionic in the smaller siphoned species of the genera Endoceras and Sannionites. This tendency to contraction in the diameter of the siphon indicated the beginning of a series of transformations which accompanied a decrease in size of the fleshy siphon, and other correlative transformations, such as the decrease in length of the funnels, and the contraction and straightening out of the calcareous endocones, so as to form the walls of a tubular siphon. In other words, as the siphon contracted, the functional endosiphon formed by the open and extended tips of the endocones was finally brought into line with the funnels, and together with them formed the microsiphon, which is consequently a degraded modification derived from the funnels, endosiphon, and endocones of the Endoceratidæ. The Orthoceratidæ and all the remaining forms, with some notable exceptions which we shall take up and describe in future papers, had a microsiphon. The whole microsiphon formed a continuous open tube of narrow diameter, reaching from the last septum to the næpionic septa, which represented the macrosiphonula. Doubtless the duration of næpionic stages will be found to vary somewhat in ancient forms, but the indications, so far as known, are in favor of the theory that the vast majority of even ancient forms had a microsiphon, which was developed comparatively early in the life of the animal.

The nealogic stages of succeeding groups would be very interesting if there were space to describe them, but we shall have to illustrate this part of our work among the Ammonitinæ. The protoconchs of Ammonoidea, including the genus Bactrites, had, as remarked above, globose forms with calcareous shells, and these shells were continuous with the apex of the conch, but the aspect of the junctions was quite distinct from those of Nautiloids. The constriction between them and the apex was very slight in the uncoiled young of the

[1] Dames et Kayser, Paleontol. Abhandl., III., Part I.

more primitive forms of several silurian and devonian species of Goniatitinæ, and this is notably the case in Bactrites which has a straight shell. In these primitive forms the apertures of the protoconchs must have been less contracted than in most Nautiloids.

The apex of the conch did not expand so fast as in Nautiloids, but was more nearly of the same diameter as the neck of the protoconch, and often remained tubular for a considerable portion of the næpionic period. This was especially evident in the more open whorls of the anarcestian larvæ, figured by Sandberger, Barrande, and Branco. Among the close-coiled forms of paleozoic species, and in still later occurring genera, the protoconch itself became depressed, and a deep dorsal constriction resulted from the abruptness with which the apical part of the conch turned in upon the inner (dorsal) side of the protoconch.

The calcareous nature of the shell, the depressed form and transversely constricted aperture, and the closer union of protoconch and conch among Ammonoids, separated the young apparently so widely from those of Nautiloids, as to lead Barrande, Munier-Chalmas, and Branco to deny that transitions occurred between them. Another distinction of importance was, that the aperture of the protoconch was closed, not by an apical plate, but by the first septum. In other words, the asiphonula of Nautiloids disappeared as a distinct næpionic stage, and the cæcosiphonula took its place in the development of the young among Ammonoids. This fact led Branco in his masterly work on the early stages to assert, in common with Barrande and Munier-Chalmas, that the protoconch of the Ammonoids was the homologue of the apex of the conch and first air-chamber in the Nautiloids. Certainly the calcareous shell and the position of the first septum and cæcum appear to be in favor of their view.

On the other hand, the student of embryology will be slow to admit that the resemblances of the protoconch in Ammonoids to the veliger shell has no meaning. If it have any meaning at all, and can be compared with the protoconchs of the Cephalophora during the veliger stage, then during the whole of that stage the typembryos of Ammonoids, like all other veligers, could not have had a siphonal cæcum or siphon. This is insured by the emptiness of the protoconch, the siphonal cæcum being present only in the aperture, and not penetrating far back into or resting upon the first formed plate of the protoconch, as in the first air-chamber of Nautiloids.

Another argument in favor of the view here advocated is the general fact, cited in the paper quoted above, upon the "Values in Classification of the Stages of Growth and Decline," that the typembryos, to which class of forms the veliger belongs, cannot be said to have the essential characters of any specialized division, like the Cephalopoda, but have to be compared with remote and generalized types from whom their principal characteristics were inherited.

The authors quoted above, holding the view that the protoconch was the homologue of the first chamber and apex of Nautiloids, necessarily rejected our theoretical explanation of the presence of the first septum and cæcum in the aperture as due to acceleration of development.

Nevertheless, this explanation still seems to us correct, and we have now a new point to make in its favor. If the protoconch of Nautiloids was an empty conchiolin shell and represented the veliger stage, it most certainly could not have been the ancestral form from which the calcareous tendency of the same stage in Ammonoids was derived. The characteristics of the asiphonula of Nautiloids are, however, just what are needed to fill the gap. The apex at this stage in Nautiloids is rounded and calcareous. The tendency to deposit calcareous matter could therefore have been inherited from an ancestor corresponding to the asiphonula, and which we will name the Asiphonophora. The Asiphonophora must have had a calcareous shell acquired as an adaptive character, without internal calcareous septa or a siphon. This form could not have been by any means so far removed from the ancestor of the veliger as the immediately following ancestor of the macrosiphonula, which we have named the Macrosiphonophora. This must have had septa and a central axis of cæca, or at any rate at least one septum and a cæcum.

The characters of the Asiphonophora, when transmitted to the Ammonoids according to the law of acceleration, would have been inherited earlier than in Nautiloids, would therefore have affected the growth of the protoconch, and would have necessarily produced the calcified shell of this stage in Ammonoids. The fusion of the protoconch with the conch in all Ammonoids was the immediate result of this process, and in this way the more tubular form and freer connection of the protoconch with the true conch, and the constant adhesion of the former to the latter, can be explained.

The disappearance of the asiphonula as a distinct stage in the young of the Ammonoids appears to us, therefore, not an argument against the derivation of the Ammonoids from Asiphonophora, but in favor of this opinion. In fact, it seems to us that, in order to disprove it, opponents will have to find a cicatrix upon the apex of the protoconch in the Ammonoidea. According to the uncompromising attitude of those who insist upon the naked facts, and are hostile to explanations, the protoconch is the apex of the conch in Ammonoids, and the absence of any cicatrix upon the tip of this is a difficulty they can only surmount by asserting that the general and special homologies we have traced, and all the embryological and nepiological correlations, are purely homoplastic, and do not indicate the derivation of the Ammonoids from any form of Nautiloid. They must also explain away the similarity of the protoconch in external aspect to the veliger shell in Gasteropoda, since this is an earlier stage than that of the apex of the true conch in Nautiloids, Ammonoids, and all cephalous mollusks. Can any of these gentlemen tell us why the cicatrix does not appear upon the protoconch of Ammonoids, and explain at the same time how that shell came to be similar to the veliger shell in the Cephalophorous Mollusca on the one hand, and the apex of the conch of Nautilus on the other?

It must be observed, also, that we do not insist that the primary radical of the Ammonoids, Anarcestes, was necessarily descended directly from Endoceras, but that it had probably come from a prototype like the veliger, possibly, as suggested by Brooks, from a class now only represented by the genus Dentalium. The next step, according to our translation of the evidences, must have been the Asiphonophora, which may have been more of a Pteropod or Scaphopod than a Cephalopod. So far as the shell goes, there are no similarities to the peculiar shell of Dentalium, but perhaps more to that of a Pteropod.

The next step in this line of genesis must have been the ancestral generator of the characters of the cæcosiphonula, which we propose to call the Cæcophora, a form which must have been a reality in some shape, and in some species doubtless had the characters of the cæcosiphonula in its ephebolic stages. This class of forms, though having septa and a central axis, which we might have to consider as a primitive siphon, was nevertheless quite distinct from those which followed.

The next link in the genealogical tree must have been the ancestor of the peculiarities of the macrosiphonula, and this is luckily a well known form. The Endoceratidæ enable us not only to see that the previous train of induction is legitimate, but to connect our line of hypothetical forms with the next in the evolution of the group. The Endoceratidæ are true Macrosiphonophora, according to the nomenclature adopted here, and are transitional to the more highly specialized and stable modification which had what we have termed the microsiphon.

When this organ came into being in the direct line of change, the evolution of the forms also changed its character. The more rapid or accelerated modes of change were replaced by slower processes. The changes occurring in the types preceding, and including the Endoceratidæ (Macrosiphonophora), were, if we can judge by the abrupt transitions of the genera in this family, more rapid and more important in their effects on structures than was the rule subsequently. This is also shown in the structural changes taking place in the embryos of Nautiloids and Ammonoids, as compared with the slow and comparatively slight changes of the subsequent stages of growth. The rapid acceleration of the macrosiphonulate character during the evolution of the Endoceratidæ, the still more rapid acceleration which took place in the evolution of the microsiphon among Ammonoids, and the fusion, through acceleration in development, of the characters of the asiphonula with the protoconch, all bear witness to the truth of this induction.[1]

The næpionic stages in ancient asellate forms of the Ammonitinæ, as has been shown above, may be considered as indicating the primitive radical, the straight orthoceran, and the gyroceran, or loosely coiled nautilian shells; but in

[1] We have already traced the more rapid evolution of the ancient forms of Cephalopoda, and need not go into the matter any further in this monograph than to state that these facts accord with the law announced in Genera of Fossil Cephalopods (Proc. Bost. Soc. Nat. Hist., XXII. p. 262), which reads as follows: "These facts, and the acknowledged sudden appearance of all the distinct types of Invertebrata in the Paleozoic, and of the greater number of all existing and fossil types before the expiration of paleozoic time, speak strongly for the quicker evolution of forms in the Paleozoic, and indicate a general law of evolution. This, we think, can be formulated as follows: *types are evolved more quickly, and exhibit greater structural differences between genetic groups of the same stock, while still near their point of origin than they do subsequently.* The variations or differences may take place quickly in the fundamental structural characteristics, and even embryos may become different when in the earliest period, but subsequently only more superficial structures become subject to great variations." See also Foss. Ceph. Mus. Comp., in Proc. Am. Assoc. Adv. Sci., XXXII., 1883, p. 338.

all other forms, especially in the devonian latisellate and triassic angustisellate embryos, the tendency to become closely coiled, and to inherit the depressed primary radical whorl of Anarcestes, produced the Goniatitinula, and affected even the protoconch. The protoconch through heredity becomes depressed fusiform by lateral expansion in the Angustisellati, and the embryonic nautiloid character of the first septum in the asellate forms and its tendency to form a broad ventral saddle in the latisellate and a narrow ventral saddle in the angustisellate embryo is correlative with this progression of form.

The goniatitinula is a true larva, corresponding to adults within the order. We use the term because it is the characteristic larval form of the Ammonoidea, which was introduced at first among adult Goniatitinæ, and in the higher forms of this group became, by acceleration, fused with the microsiphonula.

The remarkable researches of Branco enable us to state that this progression in complication of the embryo in form and sutures has no counterpart in the parallel series of any pre-existing series of adult shells, except among Nautiloidea; consequently the angustisellate peculiarities of the ventral saddles and deep lateral lobes characteristic of the latisellate and angustisellate embryos of the Devonian and Trias were not due to inheritance from primitive adult radicals, but were later modifications originating in the cæcosiphonula from close coiling. They were correlative with the earlier or accelerated development of the depressed whorl, and the quicker growth in bulk of the whorl. Similar tendencies have been observed repeatedly in different progressive series of Nautiloidea. Thus, wherever we have been able to trace the series of species from a straight, or loose-coiled, to a close-coiled nautilian form, this as a rule has more complicated sutures. The universal result of such progressive specialization among the adult forms of Nautiloids is closer coiling, due to quicker growth in bulk of the whorl, and is accompanied also by the evolution of a larger ventral saddle. It is not surprising that similar mechanical results should follow in the septa of the embryos of Ammonoidea, when similar changes in the mode of growth occurred through the accelerated inheritance of the depressed anarcestian radical whorl, and closer coiling in the cæcosiphonula.

Branco has observed the shortening of the larval stages in the Latisellati as compared with the Asellati, and the still greater acceleration of development occurring in the Angustisellati, and the correlation of these with the general progress in complication of the sutures of the adults of the same divisions in time. This confirms our previously published opinions of the relation of embryos and adults, and also agrees with those here published regarding the inheritance of the primary, radical, smooth form in the depressed embryos of Latisellati and Angustisellati, and the correlative evolution of the sutures and coiling.

The microsiphonula appeared in the Ammonoidea with the second septum, in what is morphologically the second air-chamber when compared with Nautilus, though actually the first existing in the apex of the true conch. This microsiphonula is also an accelerated form, since the siphon becomes very rapidly or even abruptly attenuated. The collar or distinctive organ of the siphon among the normal Ammonoids was not formed until later, though the precise period has not been ascertained in any one form, so far as we know. The microsiphonula occurred, as might have been expected, earlier than the true goniatitic stages, or goniatitinula, in those species which had the nautiloidean stage with ventral saddle also prolonged into the second septum, as in the Asellati figured by Sandberger, and *Gon. atratus* figured by Branco. The goniatitinula became distinguishable when the first ventral lobe appeared. This was undivided, as in the lower Anarcestes and in the Magnosellaridæ among Goniatitinæ. This stage is prolonged through one or more septa in the higher Goniatitinæ, and also in the Lytoceratinæ and Ammonitinæ, and the whorl also at this time strikes one as similar to Anarcestes, or depressed semilunar in section, as stated above, and in these the goniatitinula is completed.

The duration of the næpionic period can in a general way be described as coincident in extent with the duration of the smooth shell, which is always found at the centre of the umbilicus, however much the shell may be subsequently ribbed and ornamented. This period would of course include many more transformations than the goniatitinula, especially among the higher and later occurring species of the Mesozoic.

Haeckel designated all of the progressive stages which succeeded the true ovarian stages and included the næpionic and nealogic stages, and their structural relations, under the term Metamorphology.[1] This term is, however, somewhat indefinite and artificial when limited in this way, since the ovarian stages are necessarily of very different duration in distinct groups, and cannot be considered as the natural limit of the embryologic period. We should, as above stated, be disposed to think that some such limit as here proposed would be nearer to the true one, namely, to consider the typembryos as the last of the true embryologic stages. This nomenclature would enable an author to give an approximate idea of the stage at which the metamorphologic stages began in any type. Thus, they would have begun in Nautiloids with the asiphonula, and in the absence of this among Ammonoids with the cæcosiphonula. In the absence of this last, if it is absent among the lower Sepioidea, the metamorphologic stages, according to the same rule, would begin with the first stage immediately succeeding the protoconchial stage. Whenever this last is absent, as it certainly is among the highest of the Sepioidea having meroblastic ova, then its equivalent stage, which represents what is left of the veliger, should be taken as the last of the embryologic stages.

As has been noted above, the næpionic period is always smooth, and is visible at the centre of the umbilicus in most discoidal shells, and the demarcation is therefore visible between this and the nealogic period; but, as can be observed on most specimens, an attempt to separate the characters of the latter from the characters of adults is attended by greater difficulties. It is, however, essential to distinguish the category of ephebolic or adult characters from the nealogic, because in each form of any series there are usually found certain novel characters, which appear for the first time in that particular series. These make their first appearance almost invariably during the ephebolic period.

[1] Morph d. Organismen, II p. 22.

The ephebolic characters are as a rule inherited or homogenous within the special series in which they originated, but are not transmitted from one series to another except through the medium of the nealogic stages of what we have called the *tertiary radicals*,[1] and they are not, so far as we know, ever concentrated in the earliest larval or næpionic stages; they occur too late in the history of types.

We classify in the nealogic and ephebolic stages such characters as follows: the sharply defined ridge-like pilæ and tubercles, the channels with their lateral ridges, and keels, and especially the hollow keel, the highly developed rostrum of the higher suborders, especially Ammonitinæ, the lateral lappets of the apertures, and the branching marginal lobes and saddles of the sutures of suborders above Goniatitinæ. Speaking in a general way, we should include in these categories those progressive characters which appear late in the life of the shell among the higher suborders, and at the acme of their development in time, which are not found in the stock of discoidal radical forms. When the shell began to assume the ribs or pilæ, as we prefer to call them, the nealogic period may be said in a general way to have been entered upon. It has been found that these stages of growth indicated genetic relationship with radical forms, which were not infrequently merely different genera or species within the limits of the same family, and often occurred on the same or only slightly different horizons. The nealogic stages of the higher Ammonoids, Ammonitinæ and Lytoceratinæ, have not the constancy and general importance of the næpionic stages, but are transient in the history of the types, appearing and disappearing in the same limited series of forms. They consist of the less important modifications which first appeared in the adolescent or adult stages at a late period in the history of a type, and were then inherited in the nealogic stages at earlier ages in successive species of the same series, according to the usual action of the law of acceleration. The nealogic category cannot be as definitively separated from the characteristics of adults as from those of the larvæ. Their first appearance in adults indicated the establishment of a new species in any given series, since they are invariably differences so far as their predecessors and congeners in the same series are concerned. However much they may represent or reproduce the characters of species in other series, they are essentially differentials as regards the adult stages of ancestral species of the same series. Thus the nealogic characters are as a rule ephebolic, and not nealogic, in origin among the Cephalopoda, and usually become nealogic through inheritance. We shall have frequent occasion farther on to call in the evidence of the ephebolic stages, and to show, as in the Endoceratidæ, that, as a rule, characteristics originated in this stage of growth, as indeed must have been the case with the cæcum and the microsiphon.

At the termination of the progressive stages, which ended with the full development of the ephebolic characters, the first stage of decline, or the geratologic period, began to make its appearance, and became more and more apparent as the specimens advanced in age. It was found that, as has been observed

[1] See, for secondary and tertiary radicals, p. 22 *et seq.*

in other animals, especially in man himself, the decline was marked by degradation of certain characters, and the number of parts undergoing degeneration was gradually increased, until finally the whole of the body was more or less affected.

This period has been frequently described by the author in previous publications, and will be more fully described farther on. It is necessary now only to call attention to the fact, that the geratologic or old-age period can be naturally subdivided into two quite distinct stages. The first, or Clinologic stage, included the retrogressive transformations during which *the nealogic and ephebolic characters became resorbed one after another, usually in reverse order to the succession in which they were introduced during the progressive stages of growth.* The size of the whorl also, sooner or later according to the species, showed retrogression during this period. All of these retrogressive tendencies reached their extreme expression in the last and final stage of the ontogeny of the individual. In this stage the spines, pilæ, and often the keel and channels, when present, were lost, and the size of the whorl was so much reduced in all its diameters that it became more or less rounded, whatever the angularity of the whorl during the ephebolic period. This stage we have designated by the term Nostologic, on account of the likeness to its own næpionic period, which was finally acquired by the smooth, almost rounded whorl after the loss of its progressive characters.

Geratology, or the study of the relations of these old-age stages, shows, as we shall try to demonstrate farther on, that the clinologic characters can be used to predict the degradational modifications which appeared in any series of ornamented shells when placed under such unfavorable conditions that their descendants became degraded, and series of more and more retrogressive forms were gradually brought into existence. A number of such series have been traced by several authors, and they usually end with a perfectly straight form. This form terminated the phylogeny of the series in a manner comparable to that in which the nostologic stage terminated the ontogeny of the individual. It is usually separated also by a gap from all other species, which has not yet been fully filled by intermediate species. This nostologic adult form, the so-called genus Baculites, is not only comparable in this way and by means of its smooth and compressed cylindrical whorl with the last stage of ontogeny, but it is also a very complete reversion to the aspect of the earliest radicals of its own class, the Orthoceratite and Endoceratite.

This nomenclature is similar to that originated and published by Haeckel, and at first sight may appear to many naturalists as identical; but it is really only complementary. It is based upon strictly structural and morphological grounds, whereas Haeckel's nomenclature[1] was entirely physiological. This eminent author regarded the ontogeny of an individual as a cycle divisible into three periods; first, the progressive stages of Anaplasis, or those of progressive evolution; secondly, the stages of fulfilled growth and development, Metaplasis; thirdly, those of decline, Cataplasis. He also appreciated and gave full weight to the general physiological correlations which are traceable between the history of a group and

[1] Morphol. d. Organismen. II. pp. 18-23.

the life of an individual, and in accordance with these ideas designated the progressive periods of expansion in the phylogenetic history of a group as the Epacme, the period of greatest expansion in number and variety of species and forms as the Acme, and the periods of decline in numbers of species, etc., as the Paracme.

Haeckel used also the term Anaplastology for the physiological relations of the stages of progressive growth and those of the epacme of groups, Metaplastology for those of the adult and the acme of groups, and Cataplastology for those of the senile stages and the paracme of groups. These terms seem to cover the same ground as those we have employed, but they were in reality chosen for the purpose of classifying physiological relations. Thus the anaplastic relations of the næpionic and nealogic stages to the phenomena occurring during the epacme of groups, the metaplastic relations of the ephebolic stages to the phenomena occurring at the acme of groups, and the cataplastic relations of the geratologic stages to the phenomena occurring during the paracme of groups, are the functional relations of the structural modifications occurring in the ontogeny of individuals to those which are characteristic of the phylogeny of groups.

Theory of Radicals and Morphological Equivalence in Progressive Forms.

The simpler characters of the sutures in the adults of more ancient forms, as compared with the more modern species of the same series, has been noticed by Würtenberger, Zittel, Neumayr, Waagen, and Branco,[1] in different groups of Ammonitinæ. The first is very decided in his statement, that the Ammonitinæ he has studied form perpetually diverging series, which spring from certain common ancestral forms.

The constant repetition of discoidal and involute forms in series, which are otherwise distinct in respect to their sutures and minor characteristics of development and shell markings, produces a similarity in the succession of the forms. It is practicable to compare the evolution of discoidal into more involute forms of any one series with a similar genetic procession in any other series. Thus in the General Summary, Plate XIV., we can compare the discoidal forms of *Ver. Conybeari*, Fig. 20, with *Arn. tardicrescens*, Fig. 26, *Cor. rotiforme*, Fig. 30, and *Ast. Turneri*, Fig. 36, and in the same way the involute forms of *Ast. Collenoti* with *Oxyn. oxynotum*, *Greenoughii*, and *Lotharingum*; and these comparisons also hold good for *Schlot. Boucaultiana*, and the terminal forms like *Wæh. Emmerici* and *Psil. mesogenos*, which are also involute. In exceptional series the whorls do not become more involute in the higher species, but are nevertheless modified in those characteristics which usually accompany and correlate with increase of involution. Thus the lateral diameter of the whorl decreases, the sides become more and more

[1] Würtenberger, Stammesgesch. d. Amm., Darwinistische Schriften, Nr. 5, Leipzig, 1880, p. 91. Zittel, Ueber Phylloceras tatricum, Jahrb. d. k. k. geol. Reichsant., 1869, p. 65. Neumayr, Die Phylloceraten d. Dogger und Malm, Ibid., 1871, pp. 347, 348; also, Zeits. d. deutsch. geol. Gesellsch., 1875, p. 866. Waagen, Die Formenreihe d. Amm. subradiatus, Benecke's Geognost. paleont. Beitr., II. p. 202. Branco, Paleontogr., XXVI., XXVII.

convergent outwardly, and the abdomen narrower, though the shell may still remain discoidal; ex. Caloceras and Coroniceras, Plate XIV. Fig. 11–16, 28–32.

The Ammonoids of the Lias also have a tendency to produce keels, ribs, etc. in addition to the parallel procession of the forms just described. Thus, when we study the parallelisms occurring in different series or genera of the Ammonitinæ in the same family or group, we find that equivalent species in different series are due not only to the increasing involution of the whorls, but also to the development of similar structural characteristics. Most palæontologists are not aware of these facts, and therefore are apt to consider species of distinct series as closely allied. It is usual, for example, to classify all the species of the Arietidæ having quadragonal whorls, deep channels, prominent keels, and well developed pilæ, as species of the same genus, Arietites,[1] whereas they are more closely allied to *Psil. planorbe*, their radical ancestor, than they are to each other. Errors of this kind are common, and have been still more general. Thus most modern improvements in taxonomy in all the branches of the animal kingdom have consisted in doing away with classifications made by the association of representative forms, or, as they are here called, *morphological equivalents*.

The Arietidæ sprang from discoidal species of Psiloceras, having smooth shells and phylliform sutures. Other groups occurring later in time are traceable to forms of more advanced structure, so far as the shape and ornaments of the whorl and the sutures are concerned. In every case, however, *progressive groups* have been traced directly to forms having discoidal shells. The discoidal radicals of different series have been invariably found to be nearly related to each other, and to preceding discoidal radical types, while their descendent species are divergent, and essentially distinct. However closely they might have resembled each other as morphological equivalents, they possessed the homogenous differential characteristics of their own genetic series.

I have elsewhere noted the facts tending to establish the probable existence of a continuous line or radical stock of types or species.[2] The paleozoic primary radicals are similar to Anarcestes; the mesozoic or secondary radicals are like *Dinarites Mahomedanus*, *Ceratites Sturi*, Gymnites, and Psiloceras; they occur largely in the Trias, and are species with discoidal but rather compressed smooth shells. The tertiary radicals, though discoidal, may be highly ornamented with pilæ and spines, and have sometimes very broad or coronate whorls; they occur largely in the Jura.[3] The primary and secondary radicals, if we follow Haeckel's nomen-

[1] Zittel's Handbuch d. Pal., I. p. 455.

[2] Gen. of Foss. Ceph., Proc. Bost. Soc. Nat. Hist., XXIII., 1883, pp 323–325.

[3] Tirolites and Tropites are acmic or tertiary radicals occurring in the Trias. They are certainly coronate forms, with pilæ, tubercles, and open umbilici. If any one will compare the young of Balatonites or Tropites with the adults of the smooth species of Dinarites and Ceratites as figured by Mojsisovics, he will be able to see that the radical stock is a definable series of forms, with characteristics not only shown in the adults of simpler smooth genera and species, but necessarily repeated in the young of more modified species, like Balatonites, Tropites, etc. It must be remembered, however, that all forms will not have the smooth, compressed secondary radical reproduced in their young; many of them lost this, or had it only very slightly, since it was replaced by the broader-abdomened tuberculated tertiary radical, as in the young of *Trachyceras aon*. The young of Tropites has a form and sutures similar to those of *Glyphioceras diadema* of the Carboniferous, and the stock of tertiary radicals may therefore be said to have begun even in the Paleozoic.

clature, are epacmic, and the tertiary are what we should call acmic radicals. *Cæl. Pettos* is an excellent example of an acmic radical in the Jura. It stands morphologically and chronologically at the centre of the affinities of the group of Dactyloidæ and Stephanoceratidæ, that is, of the larger part of the oölitic Ammonitinæ. It is, in its relation to these, and to the characteristics of their nealogic stages of development, an epacmic radical, but with regard to Psiloceras, and more ancient secondary radical forms, it is a tertiary or acmic radical. It has a flattened abdomen, very divergent sides, like those of *Steph. coronatum*, and similar acmic radical forms, and a line of coarse tubercles along the sides. Though altogether distinct from Psiloceras, it is also a perfectly discoidal form. The direct descendants of *Pettos*, which belong properly to the stephanoceran and allied groups, are also discoidal forms, though the series often have involute species, such as *Macr. macrocephalum*, etc.

Tertiary radicals in what we propose to call the Pettos Stock, or Spinifera, according to the evidence of the younger stages and the characteristics of adults, have but one row of large spines in adults, and whorls which are very gibbous or trapezoidal in section, that is, with abdomen broader than dorsum. The whorl may sometimes be smooth, with only one row of lateral spines, but is usually strongly pilated, the pilæ being single on the sides and as a rule bifurcated only on or near to the abdomen. The sutures have a more or less close resemblance to those of *Der. Dudressieri*, or *Cæl. Pettos*. The line of descent being broken, we shall, in the imperfect list below, give some forms having two lines of tubercles. These, however, have young which, until a late stage, show only one outer line of lateral tubercles, as in the adults of the two species cited above. *Steph. nodosum* of the Lower Oölite is the tertiary radical of that genus, and of Macrocephalites, Sphæroceras, Morphoceras, Reineckia, Cadoceras, Quenstedioceras, Aspidoceras, Oleostephanus, and Pachydiscus. All of these genera have some forms which are either closely similar to the radical in the adult stages, or else have young with a nodosum-like stage. *Peltoceras athleta* has a similar history, though it is like Dactylioceras in its nealogic stages, it has two lateral rows of large spines, and is similar to *Asp. perarmatum* in the adult. The huge coronate forms of the Upper Jura, like *Oleostephanus Gravesianus*, etc., and the single-spined forms like *Aspidoceras Edwardsianus*, and shells like *Asp. perarmatum*, *Rupellense*, etc., with two rows of spines, are obviously in the line of stock forms. In fact, one can select from the discoidal shells of these groups a more or less closely allied series of stock forms, from each of which a separate genus or series of genera arose, until we find in the Cretaceous a new beginning in *Hoplites Royerianus* and *Cornuelianus* for the species of that large genus, and of Acanthoceras, Pulchellia, and possibly Holcodiscus and Costidiscus.

The cretaceous group, with nodose keels or lines of tubercles in place of a keel, also belong to the Spinifera, but they form a separate phylum connected, in common with such forms as *Acanthoceras mammillare*, with the Hoplites series, and their radical is also *Royerianus*. The radical of Cosmoceras, *Cos. Taylori* of the Lias, is a species with two rows of spines allied to *Deroceras armatum*, and the adult characteristics of this species are repeated in the young stages of the normal forms of that genus. Würtenberger has come to similar conclusions, and has traced a large part of the same genera back to the same origin in the work quoted above. We differ in details, and in the way in which we treat the stem of stock forms, but these differences will probably disappear after further researches have been made. His book is full of the evidences of careful work, and we do not feel disposed to offer any criticisms until there is an opportunity to publish our own observations in detail. The young forms of the Spinifera in the later næpionic stage, have a very close resemblance to the young of Tropites before the keel appears, and also an obvious reference to Tirolites of the Trias, and to the more remote and possible ancestor, *Glyph. diadema*, in the Carboniferous.

Per. Defranci is the radical of all of the species of the large genus Perisphinctes, and has no tubercles in the adult, but in the young there is a prolonged stage like the adult of discoidal cœloceran species, and in still younger stages a pettos-like stage. This genus embraces a very large number of species which have been traced out by Würtenberger, and referred by him to a species closely allied to the one quoted above in the Lower Oölite. The absence of tubercles, and the rounded form of the whorl in this group, and the frequent absence of the trapezoidal form and tubercles even in the early stages of many species, show that it is distinct from the Spinifera. We propose to designate it by the term Plicatifera.

The tertiary radicals of the keeled groups, the Carinifera, as we propose to call them, have also close structural relations, but are modifications of what we have called the quadragonal form. Nevertheless, in the young and the adults there is a tendency to reproduce the tertiary radical of the Spinifera. This is to be seen in Wähner's figures of *Caloceras* (*Arietites*) *Coregonense*,[1] and that keen observer describes the resemblance of the young just before the keel appears to *Cœl. Pettos* of the Middle Lias. Similar facts can be noted in the young of other forms of the Arietidæ, but the keeled stage acquires prepotency in the Arietidæ. Their quadragonal, keeled, and channelled forms began in Caloceras, and from this genus sprang the similar tertiary radicals of the later Jura. The radical stock is continued by such species, as follows: *Amaltheus Hawskerense*, *Phymatoceras enervatum*, *Hildoceras Walcoti*, and *Harpoceras Sowerbyi*, which last has a modified quadragonal form until a late stage of growth in some varieties. *Oppelia hecticus* also has in some varieties a quadragonal form until a late stage, though not so discoidal as most of the preceding. In the Cretaceous, there is *Schlœnbachia tricarinatus* and *Westphalicus*, which are true stock forms of the Cariniferæ.[2]

Haploceras, Desmoceras, Silesites, Pictetia, and the like, have tertiary radicals similar to the typical forms of Lytoceras, and belong therefore to the Lytoceratinæ.

[1] Mojsis. et Neum., Beitr., VI., 1888, pl. xxii.

[2] It should be noticed in this connection that the characteristics of the so-called pettos-like young of the earlier occurring species of the Carinifera are favorable to Mojsisovics's view that the Arietidæ sprang from Halorites. This genus is closely related to Tropites, and the form and sutures of the young of several species in the Arietidæ certainly show affinities for Tropites. On the other hand, as we have maintained above, the affinities and gradations of all the species of the Arietidæ lead us back into Psiloceras, and the alliance of that genus with Gymnites seems to be closer than with any other in the Trias.

Cal. tortile, Cal. laqueum, and *Schlot. catenata,* in the Plicatus Stock of the Arietidæ, are more closely allied to one another and to *Psil. planorbe* than are the morphological equivalents among their descendants to one another. However closely the descendent involute forms may simulate one another, their næpionic and nealogic stages are generally distinct, and indicate the series with its peculiar differential characters. *Arn. miserabile* or *semicostatum,* and *Agas. lævigatum,* are more nearly related to each other and to *Psil. planorbe* in the Lævis Stock than are any of the descendent morphological equivalents. There are several forms closely representative of one another, and apparently almost identical, among these morphological equivalents. Thus the adults of *Ver. Conybeari* are apparently very closely allied to *Cor. bisulcatum,* and to some forms of *Ast. Turneri* and *Arn. ceras;* but all of these are more distinct in their nealogic stages than in the adults. The Arietidæ present in this respect a similar picture (Summary Plates) to that of the whole group of the fossil Cephalods. Thus the adults of the earlier and simpler radical species, from which the later and more complicated forms must have been derived, are more closely related in structure than any of their adult descendants. The Cyrtoceratites, Orthoceratites, Gyroceratites, the Nautilini, and the anarcestian Goniatites of the Silurian, are more nearly related in structure and development, in the similarity of the adult sutures, the absence of pilæ and tubercles, and the mode of growth, than are their direct descendants, the genera of the Nautiloidea and the Ammonoidea in the Carboniferous and Jura.

The Nautiloids and the Ammonoids had morphological equivalents, but close parallelism is not constant or frequent, and occurred principally among later forms. We have elsewhere discussed this question, and need only notice well known cases; such as the extraordinary likeness of Clydonautilus to the higher forms of Goniatitinæ due to its divided ventral lobe, of Centroceras to Agoniatites, and of Subclymenia to Agoniatites, and also the better known example of the Clymeninæ of the Devonian and the Aturia group of the Tertiary. Such cases of morphological equivalence are disposed of by the use of the convenient expression, that these are mere analogies. This expression, however, fills nothing but a verbal gap. It neither explains parallelisms, nor the confusion they have occasioned and still occasion in our classifications, nor the constant tendency of straight shells to become coiled and of already coiled discoidal shells in progressive series to become involute, to whatever series they may belong, or wherever they may be found, thus producing morphological equivalents in great numbers.

The only comparison that represents all these relations to my mind is that of a number of divergent branches united at their bases or radical ends into a common trunk. The branches are composed of groups, which, though distinct, and having differential characteristics, are nevertheless similar in the forms produced, and in the order of procession of these forms.

The equivalent forms of the larger branches would be admitted to have originated independently of the direct influence of inheritance. We think that this is also true in the smaller series, since in no case can the similarities of the equivalents, however close, have been derived or carried across the genetic lines of descent from an equivalent representative species of one branch to that of another. Nor could the similarities of such forms have been derived in any series from the radical species, because involved whorls, keels, channels, etc. did not exist in the discoidal stock forms. Parallel series and equivalent forms, also, occur often in such zoölogical and geological relations that any sequence or descent of one from the other is improbable; as, for example, Aturia of the Tertiary, and Clymeninæ of the Devonian; or Centroceras of the Devonian, or Subclymenia of the Carboniferous, and Agoniatites which began in the Silurian.

These facts speak with great force for the continuity in descent of the discoidal shells, and for the existence of a primitive trunk line of generalized radicals, beginning with the earliest times and lasting into the Jura. The universality of the phenomena leads at first to the supposition that we can account for morphological equivalence of species in different series by some invariable law of growth, such as is evidently the cause of the more exact parallelisms which occur between different individuals of the same species. We might consider each species as representing a hereditary grade of structure in the development of a series, just as any period in the life of an individual would represent a stage of development inherited from some ancestral form.

We were led into this error at first, but it is an inadmissible supposition in the light of the facts given above. These show, that the representative forms are absolutely new forms in their respective genera or groups, possessing characters not found in the stock or chronological trunk of discoidal radicals, and their resemblances are therefore homoplastic, and not homogenous.

There are also many kinds of series among fossil Cephalopoda, and in some of these forms similar to those of the Ammonoids and Nautiloids are not produced, as in the Sepioids and Belemnoids. In these orders entirely new modifications accompanied equally complete changes in habits and habitat. The crawling and shell-covered, littoral, radical Orthoceras has in these orders become changed into a swimming and predatory mollusk, the shell having become internal. It seems evident in these cases, that the forces of the surroundings and new habits deflected the Sepioids and Belemnoids from the more normal course taken by the Nautiloids and Ammonoids, and thus made the repetition of form or equivalence in the shells impossible, except very rarely, and then only in a very limited sense. Such, for example, are the similarities which exist between the internal shell of Spirula and the external shell of Lituites, or between the pseudo shell of the female Argonauta,[1] and the true external shell of one of the compressed Ammonitinæ, like Cosmoceras or Hoplites.

The disappearance of the siphon in the Sepioids, and the naked young of the existing forms of this order, show that too much weight can hardly be given to the modifying and eventually controlling influence of changes of habit, or, what is the same thing, the effects of the surroundings in any new habitat, whether

[1] See Evolution of Cephalopoda, Science, III., No. 52, 53, 1884; Foss. Ceph. of Mus. Comp. Zoöl., Bulletin, I., No. 1; Proc. Am. Ass. Adv. Sci., XXIII., 1883, p. 341.

sought by the animal or forced upon it by geologic changes. Professor Cope,[1] in his masterly work on the "Origin of the Fittest," and in pamphlets previously published, described "homologous" and "heterologous" series equivalent to what we have called homoplastic and homogenous series, and gives numerous instances from all departments of the animal kingdom of exact and inexact parallelisms sustaining the position taken above. This eminent author discusses at length the location of growth force due to use or habits, and shows this to be an efficient cause of modification, thus bringing out clearly and demonstrating a new law of variation. His opinions with regard to "mimetic analogy" in external and internal characters differs only in so far as we have preferred to use the term morphological equivalence, because we thought it expressed more exactly the phenomena of homoplasy. He says (p. 96), "I believe such coincidences express merely the developmental type common to many heterologous (homoplastic) series of a given zoölogical region." With regard to the effects of habit, we should also refer to Cope's remarks (p. 198), and examples with which he explains the origin of generic characters in the ossification of the cranial walls in the Batrachia, and the origin of horns among Ruminants, as due to habits of defence, concluding (p. 200) that the use of the angles of the parts in question (the head) would result in a normal exostosis of a simple kind in the frogs, or as horn cores in the Ruminantia. Waagen, in his "Jurassic Cephalopoda of Kutch,"[2] has made a valuable contribution to the facts in tracing several parallel series of Lytoceratinæ in India and Central Europe. "The most important facts which result from the investigations explained in the present volume are these two: first, that in Kachh, in the same manner as in Europe, developmental series exist, which are in part identical with the European ones; and second, that the succession of the identical species in time during the jurassic period in Kachh has been governed by exactly the same laws as have been observed in Europe."

"For facts (parallel series[3]) like those mentioned, which would be augmented by a good many instances if other groups of Ammonites were as well known as Phylloceras, the only explanation is, that the changes of form in the organic world were dependent upon laws which were innate in them and had not to rely exclusively on outer circumstances. The latter factors, as struggle for existence, geographical separation, etc., certainly influenced the production of forms greatly; but the fundamental law upon which these influences acted very likely was not the law of variation, as stated by Darwin, but the law of development, or the tendency of the organisms to produce an offspring varying in a certain well defined direction. If this law be true, the time will come when we shall be able to indicate *a priori*, with tolerable certainty, what species a given form can or might produce."

[1] Origin of Genera, Proc. Acad. Nat. Science, 1863; Methods of Creation, Ibid., 1871, p. 229; and Origin of the Fittest, p. 95 *et seq.*

[2] Paleontol. Ind., Juras. Fau. of Kutch, I. Ceph., pp. 242, 243.

[3] Waagen's parallel series end in the evolution of identical forms or species from or through different species. We have never met an example of this kind which did not admit of explanation as the result of migration. Waagen's remarks, however, apply to parallel series in general, whether the forms ultimately evolved are the same, or merely resemble one another more or less closely.

We reproduce this conclusion in full, though, as may be seen by reading the preceding pages, we differ essentially as to the causes that produced parallelism between different series in the same or different localities. Nevertheless, Waagen agrees with us in rejecting the doctrine of natural selection as a fundamental cause of parallelism, and has also stated in 1875, from independent observations, the possibility of doing what we have been putting in practice ever since 1866; namely, predicting what sort of species would be found as descendants of certain given forms, and then subsequently finding them. This experience has also been shared by Professor Cope, who makes similar statements of his own observations among fossil and recent Batrachians and Reptiles. The method pursued by both of us differs from that ordinarily used by naturalists in predicting the existence of new forms, in that it relies upon the action of the law of acceleration, and the constant recurrence of similar forms in different series of the same stock, or, as we have explained above, upon the law of morphological equivalence.[1]

Theory of Radicals and Morphological Equivalence in Retrogressive Forms.

There are certain species among complicated acmic forms which became the ancestors of uncoiled degenerate series, that can be properly termed nostologic forms on account of their complete reversion to the uncoiled forms of the radical groups among Nautiloids. These were not confined to any special class of forms, though more frequent among the higher than among the trunk stock of radical forms. They are what we have called geratologous radicals. Thus Lobites of the Trias must have sprung from some geratologous radical among the Goniatitinæ; and Hauer's Cochloceras with its turrillites-like whorls, and the straight Rhabdoceras, both have sutures which indicate derivation from some genus like Helictites or Choristoceras among Ceratitinæ of the Trias, ribbed shells with very simple sutures.[2] Choristoceras, also, had discoidal species in the Rhætic beds.

We treat these forms as probably degradational, because of their simpler ornamentation and sutures, and also because the similar uncoiled shells among Gasteropoda and among Ammonitinæ may be followed until they grade into closely coiled and more complicated shells, from which they probably arose.[3] The geratologous forms have a most important bearing on the conclusions reached in this essay. They terminate the geologic history of their suborders, just as the Turrillites and Baculites, and others, appear as the final forms of Ammonitinæ. They were also coextensive with the existence of the cephalopod type, and were evidently liable to be evolved at any time in their history, and to increase in

[1] The law of acceleration and of morphological equivalence has been stated in the Preface, pp. iv. and v.

[2] These lines were written before Zittel's superb work, "Handbuch der Paleontologie," had appeared, in which (p. 431) he associates these forms in exactly the same order. Although his text does not allude to the genesis of the forms, his mode of arrangement shows that he probably had the same idea in mind.

[3] Parallelisms of Individuals and Order among Tetrabranchiate Mollusks, Mem. Bost. Soc. Nat. Hist., I., 1866-67, and Proceedings of same, I., 1866, p. 302. Genetic Relations of Stephanoceras, Proc. Bost. Soc. Nat. Hist., 1876, XVIII. p. 380. Also Genesis of Tertiary Species of Planorbis at Steinheim, p. 8.

numbers whenever conditions became unfavorable to the evolution of normal progressive forms. The degenerative nature of the uncoiled Ammonitinæ and Lytoceratinæ of the Cretaceous has been very generally recognized. They were regarded as diseased forms by Von Buch and Quenstedt, and Neumayr's discovery of the prevalence of simpler sutures even in the normal forms of the Cretaceous has completed this wonderful picture of wholesale degradation. It can be confidently stated, that the well known cretaceous genera of uncoiled shells, Crioceras, Ancyloceras, Ptychoceras, Hamites, and Baculites, are the morphological equivalents of similar forms occurring earlier in the Jura, but that they are not their lineal descendants. The series of *Cosmoceras* (*Amm.*) *bifurcatum* worked out by Quenstedt,[1] and studied also in detail by the author, had shells which became gradually uncoiled. Quenstedt named the uncoiled forms Hamites, but has correctly traced them to the coarsely tuberculated species *Cos. bifurcatum*. There is also a finely tuberculated specimen, *baculatus*, with a broader abdomen, which does not otherwise differ from *bifurcatum*. To this last he is disposed with good reason to refer an arcuate and a straight baculites-like shell. This same tendency is observable among the shells of the Planorbidæ at Steinheim.[2] Among living shells of a closely allied, if not identical, species of Planorbis at Magnon,[3] similar but exaggerated and evidently diseased forms occur, and the physical conditions are such that we can attribute the tendency to the unfavorable and abnormal nature of the surroundings.

We have previously pointed out, that such uncoiled shells could not have had the same habits as closely coiled ones. The appearance of a rostrum in the Ammonitinæ indicates that they had become exclusively crawling animals, in consequence of the disappearance of the ambulatory pipe or hyponome. In the shells of uncoiled Ammonitinæ the rostrum though smaller is still present. Scaphitoid, ancyloceratoid, hamitoid, and ptychoceratoid shells, to whatever genera they may be eventually referred, have one peculiarity in common, the living chamber is bent backwards, forming a shepherd's crook. The absence of the hyponome and the presence of the rostrum in these forms show that they could not have been swimmers, like the modern Nautilus with its large hyponome and corresponding sinus in the aperture and in the striæ of growth along the outer (ventral) side of the whorls. The shepherd's crook added to the rostrum in the living chambers of the shells mentioned above indicates not only a wide departure in habits from the close-coiled Nautiloids, but also from the close-coiled Ammonitinæ, since such creatures could not have crawled with facility. They must have been stationary, either hanging among the branches of plants and feeding upon them, or living with their lower portions buried in the ground and cleaning the surrounding surfaces for their food. Other suppositions might be made, but all hypotheses would involve a wide departure from the habits of their immediate ancestors, and from those of their morphological equivalents, Lituites, Gyroceratites, or other uncoiled Nautiloids, none of which have the reversed shepherd's

[1] Der Jura, p. 400, plates lv., lxxii.; Amm. Schwab. Jura, p. 576, plate lxx.

[2] Gen. of Plan. at Steinheim, Summ. Pl. ix.

[3] Ann. Soc. Malacol. Brussels, VI., 1871, Planorbis complanatus (forme scalaire), by M. Leos Pire.

crook in the living chambers or the rostrum. These cases also illustrate Dohrn's theory[1] of change of function, and the effects produced upon organs thereby, which has been of the greatest use in our researches. Semper's researches and experiments[2] explain changes in organisms in the same way, as probably caused by changes in the surroundings which have led to the adoption of new habits, and the consequent modification or suppression of already existing organs, and sometimes to the building up of entirely new organs or parts. It is interesting to note, that our investigations, though necessarily confined to purely morphological phenomena, have led to theoretical results similar to the conclusions of Dohrn, Semper, and others.

We can account for the existence of the parallel series on the basis of the following law of relation to the surroundings:

The response or reaction of the forms of different series to the action of the ordinary surroundings in the same habitat produced progressive morphological equivalence, when the external influences were favorable to growth.[3]

The enviroment may assuredly be assumed to have been favorable in the case of the parallel series of normal forms of the Ammonitinæ and other chambered shells, whether occurring in India or Europe. The diversity of these causes was very considerable, but it was not of such a nature as to imply a change of habitat, or any fundamental change not favorable to the growth of the shell. The average size of Goniatitinæ is considerably below that of the Ceratitinæ, and these in turn, as well as the Lytoceratinæ and Ammonititinæ of the Trias, are smaller as a rule than the same suborders during the Jura and earlier Cretaceous. The steady increase in size in all the progressive series of the Arietidæ culminating in the huge shells of Coroniceras shows this very plainly, as may be seen upon consulting the Summary Plates, and the same is true of Planorbidæ at Steinheim.

When the environment, however, became unfavorable to growth, we find retrogression and retrogressive equivalence. Lobites is a genus of small species; Choristoceras, Cochloceras, and Rhabdoceras are also smaller than most of the Ceratitinæ. The deformed species of the bifurcatus series are smaller than the *normal bifurcatus*. All of the scaphitoid shells are notably smaller than their congeners, and though there are many large Crioceratites, Ancyloceratites, and Baculites, there are, so far as we know, no exceptions to the rule in cases which have been traced to close-coiled forms. Retrogression is also exhibited in the decreasing size of the retrogressive forms of Agassiceras, Asteroceras, and Oxynoticeras.

In the pathological species with extremely retrogressive forms there is an evident exhaustion of the normal powers of growth and development, and premature senility. This is shown in the uncoiling, destruction of the ornaments, and often also by the retention of næpionic and nealogic characteristics in adults. The form and sutures of straight shells in the Jura and Cretaceous, for example,

[1] Der Ursprung und der Princip des Functionswechsel, Leipzig, 1875.

[2] Wachsthum's Beding. d. Lym. stagnalis, Verhandl. d. Wurzb. phys. med. Gesell. N. F., IV.; also Naturl. Existenzbedin. d. Thiere, Leipzig, 1880; and Animal Life, etc., Appleton's International Scientific Series, 1881.

[3] See also Preface, pp. iv. and v.

differ but little at any age. The four or six lobes of the young are retained throughout life, and have comparatively simple margins. The adult, however, is not similar to a true larval form except in the same sense that an old whorl is similar to its own young, or the toothless gums of an old man are similar to the same parts before the teeth appear. The Baculites are not as a rule strictly tubular whorls, as in the næpionic stages of other Ammonitinæ, but are generally more or less compressed in the adults, like the aged whorls of close-coiled shells. The development skipped the normal progressive stages of the proximate close-coiled ancestors, and, like syphilitic children, these shells had no proper adult stages, but assumed senile, degradational characteristics while still young, and are, as we have said above, purely nostologic forms.

The law of evolution for geratologous forms seems therefore to be as follows: *The response or reaction of the forms of different series to the action of the ordinary surroundings in the same habitat produced retrogressive morphological equivalence, when the external influences were unfavorable to growth.*

We cannot account for the number of uncoiled Ammonoids in the Upper Cretaceous, their wide distribution, and the undeniable fact, that they were the members of an order then rapidly nearing extinction, unless we imagine the general conditions of life during this period to have become unfavorable. The unfavorable causes produced in the forms of the groups as a whole similar modifications to those caused by the unfavorable effects of the local surroundings in *Cos. bifurcatum*, and other shells in more limited localities during the jurassic period.

The bifurcatus shells and the uncoiled cretaceous Ammonoids are not isolated individuals, — like the turrillitic deformities of Ammonitinæ figured by D'Orbigny under the name of *Turr. Boblayi*, *Valdani*, and *Coynarti*, or the planicostan deformities figured in *Cor. rotiforme*, Plate III. Fig. 7–13, and the scalariform Planorbidæ of Magnon, or multitudes of similar instances known to every student of these fossils, — but series of varieties, species, and genera. These can only be accounted for as the result of hereditary tendencies acting upon races and species, through successive generations, for periods of time more or less prolonged.

The evidence is very strong, that Baculites, Scaphites, etc. of the Cretaceous are not necessarily species of the same genus, but probably always polyphylettic in origin. The Baculites of North America have so close resemblance to those of Europe, that they are usually considered as allied species; but there are indications in the peculiar nodular markings and great size of many species, which lead us to think that they originated from American stocks. Several species of American Scaphites have common characteristics in the sutures, and in the aspect of the ribs and tubercles, and the abdomen, which suggest affinity with Placenticeras. Meek's plates of Scaphites, published in his Invertebrate Paleontology,[1] exhibit common characteristics so far as the sutures are concerned, especially the large size and length of the first lateral lobes, but he gives no figures of the tuberculated young of *Placenticeras placenta*, which make this comparison closer. The *Amm. Mullananus* on Plate LVIII. Fig. 1, 1 a, from Upper Cretaceous, Chippeway Point, near Fort Benton, has exactly the form in some

[1] U. S. Geol. Survey of Territ., Hayden, IX., plate xxxiv., and Placenticeras on plate xxiii.

examples; also the sutures, Plate VI. Fig. 9, of the young of *Scaph. ventricosus*, Plate VI. Fig. 7 b, 8–8 b, of the same locality; the pilæ, the involution of the whorls, and the sutures are also similar. It differs only in possessing the scaphitoid living chamber, which is well marked. This group of Scaphites are stouter, and have different sutures from Placenticeras.[1]

In Europe *Stephanoceras refractum*, the *Amm. refractus* of authors, is a true Scaphites, but no one thinks of calling it Scaphites, and it is usually referred to the group of normal Ammonitinæ, in common with several other distorted forms. In an article on "Genetic Relations of Stephanoceras,"[2] we discussed the affinities of this and similar distorted forms, trying to show the former existence of a general tendency to imitate the scaphitoid mode of growth in *Stephanoceras Gervilii, microstomum*, and *platystomum*. These species rebuilt a living chamber at each arrest of growth, which was eccentric, having a flatter curvature, and being smaller than the included whorl. This living chamber was also resorbed at each period of renewed growth, as in Scaphites.

The well known form *Amm. vertebralis* Sow., of the Upper Jura, was described by Quenstedt as a diseased scaphitoid form, derived from *Amm. cordatum*, and this conclusion has also been confirmed by my own observations. *Stephanoceras bullatum*[3] has a shell which is precisely like typical Scaphites in the form and aspect of the last whorl, but does not depart from the spiral as in Scaphites. It is, in other words, intermediate between Scaphites and the normal closely coiled Ammonitinæ of the Stephanoceran group. The *Amm. microstomus impressæ* of the Upper Jura is figured by Quenstedt as a form of *Steph. microstomum*, to which it has a close similarity, although smaller, and the author concentrates his knowledge of the relation of these forms in one sentence, "Scaphites sind haufig nur kranke Ammoniten," — Scaphites are often only diseased Ammonites. This statement, which was also Von Buch's opinion, requires a qualification, since they are not simply sick or diseased Ammonoids, occurring sporadically like occasional distortions, but races or stocks with cataplastic tendencies inherited and increasing in successive generations.

The distribution, affinities, and cataplastic nature of these forms indicate local origin, but during the cretaceous period unfavorable conditions prevailed so generally that series of them were produced independently, and apparently simultaneously, in many localities in Europe and in this country. Thus, equivalent series of nostologic forms, like Scaphites, Ancyloceras, and Baculites, arose in groups of species, which were not genetically connected with one another, but more or less closely with widely separated and distinct genera of the progressive Ammonitinæ and Lytoceratinæ.[4]

[1] These remarks, however, are considered to be simply suggestions, which the author purposes to follow out and publish with proper details.

[2] Proc. Bost. Soc. Nat. Hist., XVIII., 1876, pp. 370–384.

[3] Die Ceph., p. 61.

[4] Zittel, in his admirable "Handbuch der Paleontologie," I. pp. 440–446, adopts Neumayr's opinion as to the connection of the typical cretaceous genera of Hamites, etc. with the Lytoceratinæ, founding his belief in their genetic connection upon the sutures and smooth shell. On pages 481, 482, he confirms Neumayr's and Uhlig's opinion of the variety of genera from which the more ornamented shells of Ancyloceras, Crioceras, etc. had been derived

Neumayr was the first to trace systematically the uncoiled forms of the Cretaceous to several groups and distinct species of normal close-coiled Ammonitinæ,[1] thus confirming Pictet's isolated but suggestive observations on *Acanthoceras angulicostatum*, and declared that Acanthoceras, Olcostephanus, and Hoplites were the radicals of the uncoiled forms previously included under a number of generic names by D'Orbigny and other authors, and also traced the genera Hamites and Turrilites to an origin in Lytoceras. Uhlig[2] holds views similar to Neumayr, tracing most of the Crioceratites to Hoplites, but considers that Olcostephanus, Acanthoceras, and Aspidoceras had also crioceratitic derivatives. Our conclusions, therefore, are in accord with the results of the researches of Quenstedt, Neumayr, and Uhlig upon the same class of forms.

The Ammonitinæ of the Lias and Oölites in extreme old age, as a rule, lost the tubercles, pilæ, and often the keel, the whorls became smooth, and decreased in size, tending to take on a rounded or triangular outline in section, according to the group in which the species belongs. Thus, in Plate I., Fig. 24 and 25 show the changes which took place in the old whorl of *Cal. raricostatum*, and Fig. 1 and 2 the similar effects in the old age of *Cal. carusense*. The whorl in both became rounded, and lost its ribs, etc. On Plate V. Fig. 8, 9, may be seen the old age of *Cor. Gmuendense*, and on Plate VI. Fig. 1, 2, the similar old age metamorphoses of *Cor. trigonatum*. In these last the quadragonal whorl of the adult became trigonal, instead of being rounded by senile degradation as in the first instance. On Plate X. Fig. 1–3, there are illustrations of individuals of *Ast. obtusum*, which can only be accounted for as the results of premature old age in this species, since the young until a late period of growth are identical, and both Professor Fraas of Stuttgardt and the author have identified them under this name.

These changes are all due to the loss of power in the old animal, which can no longer maintain its normal rate of increase in size as it grows. Thus the smaller discoidal whorls of Caloceras with low keels became rounded, and the quadragonal whorls of the keeled and channelled Coroniceras became trigonal. The latter is really a stage of reduction in size, intermediate between the quadragonal form and completely degenerate rounded whorl of extreme age, but, so far as is now known, this last stage was not reached by the progressive forms of the Arietidæ except in Oxynoticeras.[3]

Notwithstanding the evident loss of power, and the consequent and well marked changes taking place in the old whorl of many species of Vermiceras,

[1] Zeits. deutsch. geol. Gesell., 1875, pp. 871, 875, 921, 935, and subsequently with Uhlig in Paleontogr., XXVII.

[2] Denksch. Acad. Wien, 1883, XLVI. p. 258.

[3] One of the finest illustrations of the effects of senility upon the shells of the Ammonitinæ of the Jura is given by Waagen (Geol. Surv. of India, Ceph., Jurass. Fauna von Kutch, pl. xi. fig. 1). In a large specimen of *Perisphinctes aberrans*, the old whorl became smooth, greatly reduced in size, rounded, less involute, and finally exhibited a series of heavy folds on the sides. These senile folds are also common in the old of many forms of the Upper Jura, but are rarer and smaller in the Oölites and Lias. They may be due to prolonged arrests of growth, and the decline of the power to resorb the thickened edges of the apertures, after each period of rest. But, whatever the cause, they certainly indicated a loss, not an increase of strength. This is shown by the degradation in size and form of the whorls in such examples as are given below in the descriptions of *Cor. Bucklandi*, *Cor. trigonatum*, *Ast. obtusum*, and especially *Oxyn. Lotharingum*.

Coroniceras, and Asteroceras, the stages of decline in individuals are not usually attended by such complete metamorphoses in these normal progressive forms as in Oxynoticeras and many others among the jurassic Ammonitinæ. The keel persisted, and is generally still visible even in extreme age, though often greatly reduced in size; the whorl also usually continued the same rate of growth so far as dorso-abdominal diameter is concerned. It therefore appeared to increase in size throughout life when viewed laterally, even in very large individuals of Vermiceras, Coroniceras, and Asteroceras. It is to be anticipated, in some very rare cases of exceptional longevity even in these species, that the keel would be absent and the whorl would become rounded. This happened in senile specimens of *Oxyn. Lotharingum,* which apparently possessed less power of resisting the effects of extreme age. This is a very interesting fact, since Oxynoticeras is the paracmic series of the Arietidæ, and according to our views would be likely to exhibit strongly marked degradational characters.

It is obvious that the decrease in the size of the whorl, if continued long enough in old age, must have finally caused the last whorl to strike off from the regular line of the spiral, as in the Crioceras. We searched the collections of Europe during the year 1873 for a specimen of a normal species of large size and sufficiently advanced in age to refute or confirm this view, and finally found one, through the aid of Professor Mösch, in the Museum under his charge at Zürich. This was a large fossil of the Neocomian from Sentis, in which the adult whorls were ribbed, but the outer whorl old, smooth, and contracted to such an extent that at a short distance from its termination it was separated by a distinct gap from the abdomen of the next inner whorl. Professor Mösch was impressed by this fact, and gave this specimen, which he considered a new species, the manuscript name of *Amm.* (*Scaphites*) *umbilicus,* which it probably still retains.

I have examined all the figures of M. Barrande, anticipating the finding of some marks of senility in individuals among the lower types of Nautiloids, and have not been disappointed. M. Barrande classifies the form of the siphon as "the cylindrical, the nummuloid, and the mixed"; and though he nowhere, so far as I can find, describes these metamorphoses of the siphon as stages of development, yet this was probably his real view, since in all his figures, sufficiently complete to show the young, when the siphon is nummuloidal in the adult it is cylindrical in the young.[1] Barrande's figures also exhibit clearly the degradation of the nummuloid siphon, and its return during old age to the cylindrical form;[2] but I cannot find that this eminent author regarded these metamorphoses as having been caused by senility.

[1] *Phrag. simplex,* pl. xix. fig. 9, *Gomph. Belloti,* pl. xxxii. fig. 6, *Phrag. perversum,* var. *subrecta,* pl. c. fig. 11–17, *Cyrt. Logani,* pl. clxxxii. fig. 2–10, and *Cyrt. indomitum,* pl. clxiii. fig. 5, all show the development of the nummuloid siphon from the smaller cylindrical tube of the young, or else it has a lessened diameter approximating to the cylindrical condition in the young.

[2] *Cyrt. rebelle,* pl. clxiv. fig. 7, exhibits the change during growth of the siphon, which transforms it from a nummuloidal to a cylindrical tube, and causes the shifting of the position from close proximity to the convex side to near the centre of the last formed septum. *Orthoc. docens,* pl. ccl. fig. 7, exhibits a similar series of metamorphoses, but the siphon remains at the centre of the whorl.

Degradation in the ornaments, markings, etc., occurred, but is less marked and rarer on account of the frequent absence of the shell. Prof. James Hall has figured cases of senile degradation[1] in Orthoceras, and we have ourselves seen several similar examples.

We have not been able to trace any remarkable changes in old age among the silurian, devonian, or carboniferous goniatitinæ. The dyassic and triassic forms of Ammonoidea with highly ornamented shells have not, as far as known, exhibited cases of senile metamorphosis in any noticeable abundance, and there is a marked absence of these in Mojsisovics's plates, although a few are figured.

There is an easily observed increase in the effects of old age upon the last whorls of the shell in the Jura. Every group, however, does not show the effects of senility equally. There are not only less remarkable metamorphoses in the radical genus Psiloceras, but also less in the Arietidæ, as a whole, than in the Ammonitinæ of the Upper Jura. This retrogression correlates directly with the increasing prevalence of geratologous uncoiled shells in the Cretaceous. There is, therefore, among Ammonoidea a general progress up to the Jura, which is definitely expressed in the life of the individual as well as in the life of the type, and a general decline in the later Jura and Cretaceous, which is also definitely expressed in a similar way. Geratologous types and forms are also less frequent among the paleozoic and earlier mesozoic than in later mesozoic series. *Individuals apparently had greater strength as individuals in these earlier periods, senile metamorphoses being less marked in their old age.* The phenomena presented by radical types also accord with this statement. If we pick out those types which were the progenitors of series, they appear to have been less affected by degradational changes than the more specialized forms which arose from them. This fact, however, as we have often stated, corresponds directly with the more complicated organization of derivative forms, as contrasted with the simpler structures of radical forms. There are more characters introduced in the adults of specialized derivatives, and the necessary disappearance and degradation of these marks the old age of the individual in such types with more obvious modifications.

As we have stated above, however, geratologous metamorphoses do occur even in Orthoceratites, and series of Nautiloidea. The Lituites of the Phillipsburg (Canada) and Fort Cassin limestones,[2] which we are now studying, and the Lituites and Trocholites described by Holm,[3] have in their youngest stages forms which indicate derivation from nautilian shells, thus proving that they are not radical forms, but degenerate uncoiled derivatives of prepaleozoic or paleozoic stocks of close-coiled Nautiloids, of which they are the last survivors. Trochoceran species belong to several different genera, and are all degenerate forms.

[1] *Orthoc. fusiforme*, figured in Nat. Hist. of New York, Paleont., I., pl. xx, fig. 1, is a very large specimen, with the last three sutures nearer together than the preceding, and this generally indicates advanced age among Ammonitinæ. The increasing width between the folds in the shell of *Orth. crotalum*, Hall, Paleont., V., pt. 2, pl. xliii, fig. 1, 2, 6, though characteristic of the living chamber, as described by him, probably became permanently characteristic of the senile stages. Very large specimens of Endoceras not infrequently show approximation of the sutures and less distinct annulations than in the adult stage, though this does not appear to be an invariable accompaniment of age, as in the Ammonitinæ.

[2] Whitfield, Bull. Am. Museum, New York, I., No. 8.

[3] Dames et Kayser, Pal. Abh., III., pl. i. and v.

Ascoceratites, Discoceratites, and Ophidioceratites also indicate lost faunas, in which such types had their now unknown, but progressive progenitors.

Notwithstanding, however, these geratologous series and the facts already stated, the shells of the surviving stocks of Nautiloidea were not usually so perceptibly changed in old age as the more specialized shells of Ammonoidea. So far as known, the shell of a nautiloid, whether fossil or recent, though it may lose tubercles and perhaps become somewhat changed, neither becomes very decidedly depressed nor decreases perceptibly in the involution of its whorls during old age. This remarkable exhibition of persistent growth force in individuals, when taken in conjunction with the slight senile metamorphoses of the smooth radical types of the Ammonoidea and the persistence of the keel in the normal progressive forms of the Arietidæ, the persistence of Nautiloidea until the present time, and the absence of nostologic series in Nautiloids of the Mesozoic and Neozoic, all show how complete is the correspondence between the ontogeny of individuals and the phylogeny of the groups to which they belong.

Alcide d'Orbigny drew attention to the old age of the individual among Ammonitinæ in his "Paléontologie Française." He divided the life of the individual into five periods, distinguishable from each other by the external characteristics of the shell; namely, the first period, or "période embryonnaire," during which it is smooth and the abdomen round; the second period, or "première période d'accroissement," which is marked by the advent of the tubercles, or ribs and keel, if there are to be any upon the adult shell; the third period, or "dernière période d'accroissement," during which the tubercles or ribs and the keel are fully developed, and the whorl takes on its adult configuration; the fourth period, or "première période de dégénérescence," during which the ribs or tubercles begin to separate more widely and become depressed; and the fifth period, or "deuxième période de dégénérescence," when all these ornaments are obsolete, and the exterior is smooth again as in the young.

The recapitulation in which he sums up the results of this remarkable series of observations is equally truthful and instructive. The following paragraph conveys the sense of the original, though its piquancy and force is lost in translation. "These modifications are not due to chance, but to decided regularly occurring periodical metamorphoses, which affect the larger number of the Ammonites, and which invariably operate in a regular order of succession. In fact, each one, though smooth in the youngest period, covers itself at a later time in the course of growth with tubercles around the umbilicus, afterward with ribs, striations, or tubercles upon the back (abdomen). It is then in the adult stage. Having arrived at the maximum of external complication, all of these ornaments begin to show signs of alteration; it (the shell) degenerates; its striations and dorsal (abdominal) ribs first disappear; then follow its lateral ribs or tubercles, and in old age it becomes fully as simple externally as it was during the embryonic period."[1]

[1] There are apparent exceptions to this law, as observed above, in the heavy folds of the senile stages of many forms in the Upper Jura, and some in the Lower Jura. The young of these forms, which have not yet been investigated closely, will, however, probably explain this discrepancy by showing that the senile folds correspond with larval folds, as is the case in Oxynoticeras of the Lias.

The accomplished author of the "Paléontologie Française" denied that the internal parts were affected by old age, "ne montrent qu'une complication toujours croissante et jamais de dégénérescence." This error was corrected by Quenstedt who pointed out that the closer approximation of the sutures in large individuals was due to senility, and the author is now able to record that he has either observed or seen figured similar cases of approximate sutures, indicating senile degradation in all of the different forms of chambered shells, except in Belemnoids, which have not yet been investigated.

D'Orbigny and Quenstedt were both satisfied with noting the details of the old stage in the individual, the diseased aspect of certain forms, and their reproduction of the characters of their own young and of those of older forms, but did not attempt to explain the wider meaning of these parallelisms. In former papers we have asserted that the close similarity between the smooth, straight Baculites of the Cretaceous, the extreme nostologic form of the Ammonoids, and the smooth, straight Orthoceras of the Cambrian, the common radical from which both Ammonoids and Nautiloids sprang, is parallel with the resemblances which exist between the nostologic or oldest stages of the individual and its own young.

This resemblance between radical and geratologous forms in smaller groups, like the Arietidæ, was slighter, and often consisted merely in the smoothness of the shell, or loss of the keel, or decrease in the amount of involution of the whorl. *Ast. Collenoti* and *Psil. planorbe* both have the compressed helmet-shaped outline of the whorl in section, and are smooth, though *Collenoti* exaggerates this form, or is more involute and flatter than *planorbe*. The most remarkable cases of geratologous reversion in the Lias are found in *Oxynoticeras Lotharingum*, in which the old whorl loses its keel, and exactly reassumes through degeneration the compressed helmet-shaped aspect of the adults of *Psil. planorbe*. Even this extreme example among Arietidæ, however, is not in any sense an uncoiled shell. It is very nearly a complete parallel with the smooth keelless proximate radical form Psiloceras, and may therefore be termed a nosologic species. It barely attains this extreme rank in degeneration, whereas other species, such as *Ast. Collenoti*, which retain the keel and do not decrease in size of whorl, are only clinologic approximations.

The resemblances which occur between the young and old of the same individual in the same parts and organs take place because the organs lose their power to exercise the functions which distinguished them in the adult, and becoming useless, are either partly or wholly atrophied and resorbed.

The Three Modes of Development.

The likeness between the younger stages of growth and the senile stages of decline in the same individual is, as we have just shown, due to the disappearance in old age of the specialized ephebolic characteristics acquired in the progressive nealogic and adult stages of growth. In groups the resemblances between radical and geratologous forms is occasioned by a similar suppression in the latter of the more specialized ephebolic characteristics which arose in the group during its acme of evolution in time.

We now propose to take one step more, and try to show that this tripartite correlation in the development of the individual and in the evolution of the type correlates with a similar cycle in the modes of development of the individual, which we have classified as the direct radical, or anaplastic mode, the complex, or metaplastic mode, and the direct geratologous, or cataplastic mode. We are thus carrying to definite conclusions and confirming by application the laws announced by Haeckel in his "Morphologie der Organismen,"[1] and by the author independently with regard to the ontogeny of the Cephalopoda, in his essay on the "Parallelism between the Individual and Order in Tetrabranchiate Cephalopods."[2]

Haeckel was a strong advocate of the general efficacy of natural selection as a motive force of far greater importance in the evolution of types than has been granted in this and other publications by the author, and did not give as much weight to the correlations between the ontogenetic and phylogenetic cycles. If these have the correlations here claimed, then we can see that a theory like that of natural selection, which does not recognize the action of some law which has affected both the individual and the type in the same way, cannot be reconciled with the observed facts in the evolution of forms. A theory of evolution must necessarily, while admitting the origin of new characters by external causes, also recognize the limitations due to the force of heredity in conserving the type. It must admit fully the plasticity of organisms, and the power of external conditions to effect fundamental changes in structure by means of internal reactions,— that is, through the action of either conscious or unconscious effort,— but not deny to heredity its fullest effect in the tendency of like to produce like. It should emphatically deny that heredity tends to produce like with variations, or that there is any such thing as a tendency to variation which is inherent and not produced by external forces. It must recognize not only the three physiological phases of epacme, acme, and paracme, but that all the phenomena of evolution accord with this cycle. It should show that not only the general physiological phenomena, but also the relative strength of the individual, as testified by the slight effect of old age upon the shell in the oldest and simplest types, and the more rapid evolution of paleozoic as compared with mesozoic types, and of geratologic types at the termini of each special group of forms in time, are strictly in accord, and testify to the existence of a common law governing and producing cycles. It must also recognize that there is a growing stability in types, and less important structural variations at the acme of a group than during its epacme or paracme; and that its habitat was freer at first than it was subsequently during its acme.[3] The struggle for existence between species, if there were any at first, (which we do not believe,) must have been very slight compared with what it became during the crowded acme, and

[1] Vol. II. pp. 18, 22, 320.

[2] Mem. Bost. Soc. Nat. Hist., I. p. 195 *et seq.*, and Proc. of same, X., 1866, p. 302.

[3] See Genera of Fossil Cephalopoda, p. 261, and Fossil Cephal. Mus. Comp. Zoöl., p. 339.

this shows conclusively the comparatively small influence of natural selection except during the acme of groups.

Another series of facts in favor of the views here advocated is to be found in the cycle formed by the modes of development. The more ancient and simpler forms of Cephalopoda, like Orthoceras and most of the earlier forms of Nautiloidea, had a direct mode of development, during which the individual passed through certain well marked changes; but these were less numerous and not so crowded together as in types with more complicated development. The young and adults of the same individual among straight radical shells differed comparatively little in form and ornamentation. The siphon in Piloceras, and in some species of Endoceras, for example, was comparatively little changed in adults from what it had been in the young, and Cyrtocerina as described above, probably remained completely macrosiphonitic throughout life.

When closer coiling was introduced and more concentrated development occurred, as in the higher Nautiloidea and Ammonoidea, we found, as one of the results, the omission of some hereditary stages. As we have said above, the first air-chamber disappeared in Ammonoidea, having become fused with the protoconch, which stage acquired through this earlier inheritance a tendency to secrete a calcareous shell, and in consequence of this fusion the cæcosiphonula was also carried back and appeared earlier in the life of the shell and animal.

The næpionic or true larval stages, as we have said above, became more accelerated in the angustisellate young of the Lytoceratinæ and Ammonitinæ, and the succeeding or nealogic stages were introduced with a profusion of ornaments and increased complications in the outlines of the sutures, curves of the septa, structure of siphon, increased involution, and changes of structure and form in the whorls, which multiplied the metamorphoses and made the different stages of growth more distinct than in the Goniatitinæ and Nautiloidea.

The complex mode of development of the normal acmic forms, due to the introduction of these new characteristics, is easily perceived in most of the Ammonitinæ, even without breaking down the whorls to examine the young. The ornaments and pilæ on the exposed sides of the whorls show this in most species of the Jura with sufficiently discoidal shells.

The paracmic forms, and especially the degenerate uncoiled species of every group, exhibit a return to the direct mode of development, and a lessening of the variety and number of structural changes. These suppressions became, as we have described them above, so well marked in all the straight baculites-like forms, that a tyro cannot fail to notice the fact. The smooth, slightly compressed whorl retained nearly the same form throughout life, the sutures retained the primitive number of næpionic lobes, and the marginal digitations were comparatively simple even in adults.

Similar phenomena occurred in every group. Thus in the Arietidæ the radical *Psiloceras planorbe* had the anaplastic or comparatively direct mode of development, while the descendent species in both these genera had more complicated, metaplastic transformations, due to the introduction of a quadragonal form, with keels, channels, etc.[1] The metaplastic mode of development of the progressive forms was again exchanged in the still higher and more specialized but degenerate and geratologous forms, like *Ast. Collenoti* and the Oxynoticeran series, for the cataplastic mode. The young more closely resembled the later stages, and passed into them with less abrupt transitions, because of the action of the law of acceleration, and the consequent omission of ephebolic characteristics. The same process took place in each genus of the Arietidæ, more or less according to its place in the cycle, and in our descriptions of the species and series the evidence will be given.

Law of Acceleration.[2]

Whenever the character or form, whether healthy or pathological, became fixed in the organism, it became at the same time subject to the law of acceleration. Its previously transient and sporadic appearance ceased, and a series came into being having this character, whatever it might be, constantly reproduced in earlier stages of the species.

The fixity of many characters on first appearance may be reasonably doubted, but not their subsequent tendency to acceleration. The hollow keel of *Oxyn. oxynotum* is a novel character, and it seems to be present in every mature specimen of the species. Nevertheless, in this and in all cases like this, there is a dearth of evidence of a positive nature, and some specimens may yet be found which did not possess it. There are however, examples without number like the variable first appearance of the abdominal channel in Schlotheimia, of the keel in Caloceras, and of the pilæ in Arnioceras and Agassiceras. The young had fold-like pilæ in Schlotheimia, which crossed the abdomen. The single channel which was subsequently produced is a progressive stage, arising partly from the suppression of the folds along the median line, and partly from extra growth of the pilæ on either side of the abdomen. Sometimes the suppression of the pilæ along the median line of the abdomen never took place, the abdomen remaining completely pilated throughout life. This occurred as a sporadic or varietal ephebolic character in *Schlot. catenata*, but in the higher, later occurring, and more

[1] See Chapter III. of this memoir.

[2] I have used the term Law of Concentration in several recent essays, instead of, as formerly, "Law of Acceleration," because my attention had been attracted to phenomena which showed that an animal having accelerated development of characteristics did not necessarily have a quick development, but on the contrary might grow, so far as time is concerned, even more slowly than others of its own group. It became essential, then, to get rid of the impression, which I had held in common with some other embryologists, that an animal which skipped many characteristics of its ancestors, or of its own type, had necessarily a quicker growth and development. Undoubtedly, in many instances, especially where acceleration is due to pathological causes, such is the result; but this does not occur in all cases, or perhaps necessarily in any case. In trying to introduce this idea I went too far, and in substituting the term "Concentration" for "Acceleration" made a change which was not an improvement. In this memoir, therefore, I have returned to the older and more appropriate term which stands at the head of this section. The term "abbreviated development" is often used, as it has been by Balfour, for extreme examples of acceleration, and it also implies no necessary relation of time. This term, however, was not invented to express a law of development, and its author did not take into consideration the fact, that such cases are only the extreme expression and the necessary result of a universal law of organic evolution.

compressed, involute forms like *Schlot. Charmassei*, the suppression, so far as we know, always occurred in normal forms at some nealogic stage, and the presence of a channel is constant even in the young. If the pilæ again crossed the abdomen, thus obliterating or obscuring the channel, during the life of the same individual, it occurred as a degradational character in the senile stages. Extreme cases of degradation in species did not occur in Schlotheimia, but if there had been any such nostologic forms, they would have inherited this tendency to obliterate the channel during the nealogic stages. The law of acceleration of development was quite as effective in its action upon geratologous as upon progressive characters, as will be seen when we treat of this class of characters farther on.

Besides the examples given above of the inheritance of characters in larger and smaller series, we add the following in order to make our meaning still clearer. The form, shape, and characteristics of the secondary radical, *Psil. planorbe*, are prominently shown in the young of Arnioceras, Plate II. Fig. 10–15, and in the Embryology of Cephalopods, Plate II. Fig. 9, 10, until a late period of the growth of the shell, but are less noticeable in the young of the descendent species, *Cor. kridion*, in which indeed they are perceptible only in the transition form between this species and *semicostatum*. Most of the specimens have young like that figured on Plate III. Fig. 2, and are stouter than the flat discoidal *Psil. planorbe*. These and the young of other species of Coroniceras inherit the stouter quadragonal whorl and peculiar ribs and tubercles, the keel, and the channels, at earlier stages of their growth than those in which they first appeared in ancestral shells, as may be seen by comparing *Arn. semicostatum* with the young of Coroniceras, Plate III. Fig. 19, and Fig. 5, 6, 8–10.

One of the most convincing examples of the law of acceleration which we have studied can be illustrated by using Wright's book, "Lias Ammonites."[1] He shows the latæcostan form of the young on Plate XXXIV., and in Fig. 4–6 the adult of *Androgynoceras hybridum*, his *Ægoceras heterogeneum*. A more accelerated form is shown on Plate XXXV. Fig. 4–6, in which the young are similar to latæcosta for a less prolonged period of their growth. Wright's *Ægoc. Henleyi*, Plate XXXIII., is also a specimen of the same species with a prolonged latæcostan stage of growth. *Lip. Henleyi*, figured by Wright as *Ægoc. striatum*, Plate XLIII., is also highly accelerated, and most of the specimens have young shells with no traces of their latæcostan ancestry, reproducing only the characteristics of the adult whorls of *And. hybridum*. *Lip. Bechei*, also figured by Wright, Plate XLII., is still more accelerated in its mode of development, since the young has no resemblance to the adult of *And. hybridum*. From the smooth stage of the nepionic period of growth it passes abruptly to a stage in which the shell resembles the adult form of *And. Henleyi*. The whorls at this stage show the specific characters of the adult of *And. Henleyi*; they are too involute and too heavily ribbed and tuberculated in proportion to their size to be compared with the adult of *And. hybridum*.

Würtenberger's book is devoted to the exposition of this law of heredity

[1] Paleontological Soc., XXXII., 1878

among the Ammonites. This author, in his "Studien über die Stammesgeschichte der Ammoniten,"[1] traces the Armatus or Aspidoceras stock of the Upper Jura to the Planulati; that is, to the genera Cœloceras and Dactylioceras, which last I had previously described and traced to an origin in *Deroceras Dudressieri* of the the Lower Lias.[2] His work is a summary of evidently extensive observations upon the Ammonites of the Upper Jura, all of which he traces directly or indidirectly to the Planulati. Whether he can sustain this opinion will be questioned by some until he has published his plates. He has, however, studied the series according to proper methods of analysis, and should be given the credit of the doubt. We also, though the author fails to notice the fact, have traced *Pelloceras athleta* to the same species in the Lias, *Amm. annulatus* Quenst., and published the remark[3] that they were genetically connected by intermediate forms. Our observations, therefore, closely accord upon this very important species, and we also agree in the view that most of the jurassic genera we have included in the Spinifera and Plicatifera can be traced to *Cœl. Pettos* as the probable radical.[4]

In his fourth chapter Würtenberger gives the history of the evolution of the Lallierianus series, in which he traces degeneration in the lobes and saddles, showing that changes of all kinds appear first on the outer (adult or senile) whorl of the ancestral forms, and encroach more and more on the inner (younger) whorls in descendants. Neumayr[5] considers that Würtenberger was the discoverer of the law of acceleration in development, and this author states that he first published his new discoveries in "Ausland" of 1873, — about five years after the appearance of precisely similar statements in such scientific periodicals as the Proceedings of the Philadelphia Academy, by Professor Cope, and the Proceedings and Memoirs of the Boston Society of Natural History,[6] by the author. Professor Cope has lately republished his discoveries in a volume entitled "The Origin of the Fittest," and in these masterly essays those who are interested may get a full view of his mode of explaining this law, and will find very complete series of illustrations of the character and meaning of parallel series and other related phenomena.

The decision as to who discovered the law of acceleration is only historically interesting; but it is of general importance that so many persons agree, and that an eminent paleontologist like Neumayr, who has studied such phenomena among fossils, considers the law to be true in its application, as tested by him, with some exceptions. He does not state the exceptions, however, and they cannot be discussed. The opinions of Würtenberger and Neumayr that some species inherited characteristics at later stages than those in which they occurred in any ancestral species or pair, seem at present to rest upon the insecure basis of the apparent need of this assumption in order to account for acceleration as

[1] Ernst Gunther, Leipzig, Darwinistische Schriften, No. 5.

[2] Non-reversionary Series of the Liparoceratidæ, etc., Proc. Bost. Soc. Nat. Hist., January, 1872, and Appendix to the same, with a geological table, Ibid., May 20, 1874.

[3] Proc. Bost. Soc. Nat. Hist., Appendix to Non-reversionary Series of the Liparoceratidæ, 1874, p. 33.

[4] See above, pp. 23, 24.

[5] Zeitsch. d. deutsch. geol. Gesellsch., p. 868.

[6] See above, page 28, note 3, and Proc. Bost. Soc. Nat. Hist., 1870, pp. 72, 73.

being due to the law of natural selection. We do not deny the existence of such examples; we are only anxious to hear of their existence, and to be able to examine the evidence.

Weissmann[1] also seems to have been unacquainted with the same literature, and claims the discovery of the law of acceleration for Würtenberger. Weissmann's interpretations of the phenomena were in part very similar to our own. He rejected Würtenberger's theory of the origin of acceleration through the action of natural selection, and states that it is due to the innate law of growth, which rules every organism. In many places he explains this law of growth as a mechanical law, and the origin of variations as due to the innate response of the organism to external forces exciting it to suitable changes. This law of variation through mechanical causation is identical with that advocated by Cope, Ryder, and the author; but with regard to this there can probably be no controversy about priority. Dr. A. S. Packard has shown that such views are essentially rehabilitations and improvements upon Lamarck's theory of effort, and he has appropriately named us the Neo-Lamarckian school.[2]

This eminent author (Weissmann) has apparently abandoned this position in his later works. He claims that the protoplasmic basis of organisms is alone the vehicle of heredity, and substantially imperishable or continuous; that all variations taking place in the organisms, unless they affect this basis so as to modify the ovum, are not inherited; that the variations of males and females are, when inherited in the offspring, the originators of new characters through the new combinations which necessarily arise, and he also regards natural selection as the prime agent in the preservation and perpetuation of these variations.[3] We have been unable to find any characters which were not inheritable in some series. The behavior of all characteristics which have been introduced into any series of species shows them to be subject to the law of acceleration, in whatever way they have originated, whether primarily as adaptive characters, according to our hypothesis, or by natural selection and through the combination of the sexual variations, as supposed by Weissmann. All of the degenerative changes took place in retrogressive series, in precisely the same way as is described above for progressive changes. Thus, the degradational characters and uncoiling became noticeable in the old of individuals and of species first, and then appeared, in obedience to the law of acceleration of development, at earlier stages in succeeding or derivative forms, until finally they entirely replaced the normal progressive characteristics of the nealogic stages. A straight Baculites-like modification could not have been produced by the unfavorable surroundings directly from any close-coiled form; it must have arisen from the intermediate arcuate and crioceran modifications. If this be true, heredity must have played its part even in the extreme modifications of abnormal geratologous series, however improbable this may seem.

[1] Studies in the Theory of Descent, Eng. ed., transl. by Meldola, I. pp. 274, 277.

[2] Standard Natural History, edited by Kingsley, Introduction; and also Cope's "Origin of the Fittest," in which see index, Lamarck.

[3] Continuitat der Keimplasmas; also Ueber der Vererbung; see also, as in favor of the views here advanced, Kolliker's criticism, Karyoplasma und Vererbung, Zeit. Wissensch. Zool., XLIV., 1886.

We would also suggest that the phenomena of parallelism, or the evolution of similar forms in different series which can be predicted, is obviously contrary to any law which does not assume that adaptive characters are equally inheritable with differentials. Again, the minuteness and slight importance of some differentials, like the collar of the siphuncle in Ammonoids, which are nevertheless persistent throughout several geologic periods and constant in every series, do not appear to be accounted for by Weissmann's hypothesis. This collar appeared first in the adults of the Goniatinæ, and became engrafted in the early stages by the law of acceleration, like other characteristics. It should be remembered also that parallel series were continually evolved, while this differential remained comparatively unchanged, and that the alteration of the entire form of the whorl by involution, and the evolution of complicated from simpler radical sutures took place over and over again in different series arising from the same stock. How could males and females have combined to produce similar series of variations, and also unimportant but still persistent differences? How could a characteristic of slight importance to the life of the species have made a deep and lasting impression on the ovum, while others of obviously greater moment to the organism were transient in different series?

There is one phase of the law of acceleration which requires to be dwelt upon as the best means of conveying its full meaning to those not yet accustomed to note its action in their researches. It expresses the mode by which the continual replacement[1] of the older by newer and later acquired characteristics takes place in every genetic series, and therefore *explains the mechanism of gradation, whether progressive or retrogressive. Changes in environment, which introduce new adaptive characteristics in the nealogic or adult stages, necessarily add these to the hereditary stages of the younger periods of growth, and thus shorten the development of the latter by direct replacement.*

Heredity, as is well known, can continue for indefinite periods to reproduce a useless part or organ, provided it does not interfere with the growth and normal development of useful structures. When interference occurs, as is well known to all physiologists, their resorption is a normal process, due to the fact that they have become through disuse merely passive stores of food for the more active worker cells.

Though species sometimes pass through more than one horizon, they are, as a rule, limited to the levels upon which they first appear. This fact, and the frequent differences in the sediments, which often correspond to differences in the faunas, indicate that the different varieties or species characterizing distinct horizons are more or less directly due to the changes in the surroundings, which occurred in passing from one geologic level to another. We can fully understand the phenomena of acceleration in development only when we begin by assuming that the characteristics last introduced in the history of any type were more suitable to the new conditions of life on the horizon of occurrence of the species, than those which characterized the same stock in preceding horizons. These characters would then necessarily, on account of their greater usefulness and

[1] Genesis of Planorbis at Steinheim, p. 28.

superior adaptability, interfere with the development of the less useful ancestral stages, and thus tend to replace them. The necessary corollary of this process would be the acceleration of the previously existing nealogic stages in direct proportion to the number of new characters successively introduced into the direct line of modification during the evolution of a group.

The importance of this law becomes more apparent when consideration is claimed for it as a working hypothesis for the explanation of such obscure problems as occur among insects. The complicated metamorphoses of the Hymenoptera, Diptera, and some Coleoptera, for example, in which feetless and headless larvæ appear, can be attributed to acceleration, like the more normal examples among fossil Cephalopoda. They illustrate the suppression of ancestral thysanuriform stages, which when present in the active larvæ of lower orders indicate that all insects were derived from some ancestor possibly similar to the adult of such forms as Lepisma or Campodea. This gives new interest to the theoretical views of Brauer and Sir John Lubbock, who first pointed out the næpionic characteristics of the adults among Thysanura.

It seems to us equally applicable to the explanation of the medusaless metamorphoses of the fresh-water Hydra, as compared with the marine Tubularia in which the medusa stage is prevalent, and also to the accelerated development of the pelagic medusæ, Geryonia and others, in which the hydra-like stage has vanished.

In Tænia, also, the earlier stages are so accelerated that the secondary sac, furnished with cutting blades, worked by special muscles, and used for digging through the tissues, is still called an ovum by many naturalists, though it is morphologically the remnant of an active form producing the young Tænia by an involution or bud from its walls. The ancestors of Tænia must first have acquired a cercaria or nurse form with cutting blades, and then, the evolution having reached its highest progressive acme, the reverse process of resorption through acceleration began. The constant exercise of the blades by the cercaria and the use of a horny case for the ovum caused these to be retained, while the other characteristics of the cercarian stage disappeared, or else like the blades became more or less fused with the ovarian stages.

Perhaps the most remarkable instance of the loss of progressive characters correlating with a highly accelerated mode of development is man himself;[1] and his example will serve a good purpose in making clear what we mean by a geratologous retrogression, which is often evidently due to a great change in habits, bringing about specialization in certain parts, enlarging and prematurely developing them at the expense of many of the normal progressive characters of the ancestral type. The Caucasian type, in losing the prognathism of the Anthropoids, which is certainly a highly specialized characteristic of the adult forms among the apes, has in a morphological sense made a step backwards instead of forwards. The larger size of the brain as compared with the lower part of the face and jaws is also an embryonic characteristic of all the Vertebrata, even

[1] See Cope, Origin of the Fittest, pp. 11, 12, 147, 148, chaps. viii., ix., also Haeckel, Gen. Morphologie, II. p. 446, and Anthropogenie, for similar views.

fishes and birds at an early stage exhibiting this peculiarity. Dr. C. S. Minot[1] has declared, upon similar grounds, that there was nothing in man's structure which justifies us in considering him as morphologically a higher animal than the more specialized Mammalia. Though not willing to indorse this statement as a whole, it is in part true.

Notwithstanding the increased functional power of the brain, the loss of certain characters which once marked the progress of ancestral structures remains to be accounted for. In fact, as suggested by Professor Shaler, the body and its organs exhibit the evidence of having belonged originally to a horizontal type, and in accommodating itself to a vertical position has succeeded in adapting its parts to meet new and more complex conditions, and a new position with relation to gravity, without having made very essential changes in hereditary structures. Man is a walking simian biped, or, as Cope describes him, a "pentadactyle plantigrade bunodont."[2] Nevertheless man is also a highly specialized type. The extraordinary development of the legs, the increased size of the big toe, the differentiation of the feet, the broadening out of the chest and sigmoid curve of the backbone, the differentiation and shortening of the arms, the changes in the pelvis, and other correlative specializations, have probably been introduced through the exercise of the parts in an upright position, as was originally pointed out by Lamarck.[3]

There is, of course, a vast gap to be bridged between man and *Oxynoticeras oxynotum*, but they are none the less types belonging to the same general category of geratologous forms. They have arisen suddenly, and present alike the commingling of degenerative and specialized characters. Such geratologous species show us that any form having a highly accelerated development, and producing suddenly some new and unexpected characteristics, as, for example, the hollow keel of Oxynoticeras, or the peculiarities of man's structure, may have, in association with these, many retrogressive characteristics.

The extreme example of Baculites-like shells are very distinct from these, and show us that the development of geratologous characteristics may sometimes take place without the introduction of new characteristics. In such cases, the adults may resemble their own young more completely than in man, or in other examples given above, and may be similar in aspect to the primitive radical of the whole group, as is Baculites when compared with Orthoceras. Such considerations and others given above have led us to compare this class of forms in which degeneration is complete with the oldest stage of decline in the individual, and we have accordingly placed them in the same category as nostologic forms. This serves to distinguish them from partially degraded forms, which can be called geratologous, or from forms that resemble the first senile stages of the individual, and can be termed clinologic forms.

In order to account for high degrees of specialization, and their tendency to

[1] Amer. Assoc. Adv. of Science, August, 1881.

[2] Origin of the Fittest, p. 266, referring of course to the retention in the organization of ancient ancestral characters.

[3] Philosophie Zoologique, I., Pt. I., chap. viii., Quelq. Observ. rel. à l'Homme.

extreme acceleration in development, the author, in a previous paper,[1] imagined the special means of protection often afforded to the young in such types to be the efficient cause. But the Marsupialia are not the most highly specialized mammals, nor are some of the penguins the most specialized birds, and yet both protect the young in pouches. Distoma and many other parasites are highly protected, and yet in these we find exceedingly long and complicated adaptive series of metamorphoses, with a high degree of protection in some cases, and in others more accelerated modes of development with less protection, as in Tænia. Balfour in his "Comparative Embryology" subsequently adopted the same explanation in order to account for cases of "abbreviated development," some of which he noted, but without, however, recognizing them as due to any general law or tendency of development, or making quotations of Cope's, Packard's, or the author's researches in this direction.

The Diptera and other insects, whose larvæ are placed in protected situations where soft foods abound, and have consequently lost their useless jaws, eyes, legs, and hard chitinous covering, and in some cases even the differentiated segmentation of their ancestral forms, are very remarkable examples of acceleration in development. Doubtless the supply and kinds of food, and perhaps protection, may have had much to do with these changes, as pointed out by several entomologists. The constant correlation of habits and structure in larvæ is, however, independent of protection; and it is evident that such a limited cause could not have produced, *as an effect*, the universal tendency of acceleration. The hypermetamorphosis of some insects and parasites also shows that protected habitats, or special maternal organs for protection, are not essential to acceleration, since the most complicated and indirect modes of development occur as in Sitaris, where the young are protected during certain stages and unprotected at others.

Acceleration occurs whether an animal is protected or unprotected, whether furnished with one kind of food or another, in all sorts of habitats, and whether it belongs to a progressive or retrogressive series. This can be supported by many examples among recent animals, described by other authors than those specially interested in proving the truth of this law.

With regard to the accelerated forms of shell-covered Cephalopods, they are usually, if belonging to the geratologous category, smaller, narrower, or less gibbous, and sometimes much compressed, as in *Ast. Collenoti* and in Oxynoticeras, when compared with their immediate progenitors. The more cylindrical whorls of Lituites, Ophidioceras, etc., and the compressed cylindrical forms Crioceras, Hamites, or Baculites, show facts of the same nature. All of these more compressed or more cylindrical shapes were obviously not adapted to the office of accommodating living young; they indicate in a very positive manner that there was less space within their whorls, and consequently less protection for the young, than in the more gibbous shells of congeneric normal forms. It is obvious that no special provision for protection existed for the young in such shells, or in *Stephanoceras refractum*, or Scaphites, which did not also exist in the normal forms with complex modes of development from which they were derived.

[1] Genesis of Planorbis at Steinheim, p. 29.

There is also no ground for assuming exceptional protection in the cases of dwarfs, which have accelerated development of retrogressive characters, as, for example, in those of *Ast. obtusum*, which we shall describe in detail farther on.

Origin of Differentials.

Differentials are essential characteristics, which distinguish one group from another, and, unlike morphological equivalents, are apparently directly inherited in successive generations of the series from the distal or proximate radicals. Thus the distinct stocks of the Nautiloids, Ammonoids, Belemnoids, and Sepioids, may be followed without difficulty. The Goniatitinæ, Arcestinæ, Lytoceratinæ, Ammonitinæ, and Ceratitinæ, among Ammonoids, are examples of suborders less easily separated. Vermiceras, Coroniceras, Amaltheus, Oxynoticeras, and Asteroceras are examples of genera affording still greater diagnostic difficulties. In all of these the differentials can with certainty be considered hereditary, since after their introduction in the earlier members of a group they are perpetuated, not only in the earlier species or forms, but more or less even among the most aberrant and geratologous members of the group. Differentials are often described as invariable, but this is an inaccurate expression, which is not in practice trusted by any naturalist of the present time. They are perhaps, when compared with other characters, relatively constant, but in all complete series necessarily pass through stages or phases of evolution. On first appearance, they are apt to be more or less variable within the limits of the species in which they originate, then they become constant in descendent forms of the same series, and finally in extremely geratologous (nostologic) forms they may be in large part or wholly obsolete.

The close-coiled character of the young was certainly a differential among Ammonoidea, but this became constant only in the mesozoic forms. The contraction which marked the tendency to reduce the size of the siphon was not very important at first, and was variable in position among the Endoceratidæ. It was, as has been said, probably fixed at the first septum in Sannionites, and became perhaps invariably fixed at this stage in the Orthoceratidæ, assuming in them the aspect which subsequently also characterized the close-coiled nautilian shells, and the entire stock of the Ammonoidea and Belemnoidea. The contraction in these orders defined or cut off the primitive cæcum from the parts of the siphon formed subsequently, and its invariable occurrence at one place in the næpionic history of such a vast number of forms is very important in its bearing upon the mode of origin of other and less important differentials.

There is no explanation of the introduction of these characters which permits us to separate them, as belonging to a distinct category, from characters which are adaptive. Nor can we say that any of them more deeply affected the ovum than any other characters. They were simply the earliest in time, and made their appearance in adults first as ephebolic characters, and then as suitable characters were inherited, and, being replaced in due course of time by newer modifications, were gradually forced back through the nealogic stages until they secured representation in the næpionic stages. This seems to be a reasonable explanation of the observed phenomena; but that the characters, as in Weissmann's theory, singly or in part could have affected the ovum when they first appeared, does not seem to be sustained by the facts. The examples cited above of the transmission of the characteristics of the asiphonula and cæcosiphonula to the typembryo of the Ammonoidea give similar evidence with regard to the origin of embryonic characters, and are directly against Weissmann's position.

Barrande and Munier-Chalmas have tried unsuccessfully to prove the absolute invariability of differentials among fossil Cephalopoda by means of the great apparent differences between the embryos of Nautiloids and Ammonoids, but the discovery of a protoconch in Orthoceratidæ has demonstrated their error,[1] and we confidently anticipate the discovery of some form in which the protoconch will exhibit intermediate characters.

The rostrum in the Ammonoids contrasts decidedly with the central sinus of the same region of the aperture in Nautiloidea, and is a differential of importance, which ought to be mentioned here. The rostrum of the mesozoic forms indicates that the Ammonoids did not possess the ambulatory pipe or hyponome[2] of Nautiloids, which causes the ventral sinus in the aperture and striæ of growth in that order. As noted above, they could not have been swimmers in the same sense as the existing Nautilus, and they must have been for the most part strictly littoral crawlers. The habit of crawling as a slower mode of progression combined with varied habitats of shallower waters, may have been the cause of the higher specialization and greater variety of forms and structures which they exhibit. The change from a ventral sinus to a rostrum in the aperture began among the higher Goniatites during paleozoic time, and is shown by the narrower ventral sinus of the aperture, and in the lines of growth on the shell. This sinus also is more distinctly marked, and is present oftener, in the devonian forms of Goniatitinæ than in the carboniferous species.

The Clymeninæ of the Devonian have very small ventral sinuses in many forms, and in others the hyponome may have been absent. The specimens observed by the author have not as a rule exhibited the lines of growth with great clearness, but many of Gümbel's figures give the striations, and in some species they pass straight across the venter. The Ammonoids of the Trias are apparently completely transformed, the rostrum and the ventral saddle in the lines of growth indicating the constant absence of a hyponome.

As the ambulatory hyponome disappeared, all the sutures became more complicated or ammonoidal, and, in correlation with the greater lengthening of ventral and dorsal lobes, the central zone of the septum changed from concave to convex. When one tries to attribute the origin of convexity in the septa, or the multiplication and lengthening of lobes, or the marginal digitations of the sutures among ammonoids to fortuitous variations, he finds at once that their history in the groups of the order is correlative with the phenomena of morphological equivalence. As was long ago observed by Von Buch, and

[1] Science, III., No. 52, 1884, p. 126; and also above pp. 10, 11.

[2] See Foss. Ceph. Mus. Comp. Zool., Proc. Am. Ass. Adv. Science, XXXII., 1883, p. 340; also Science, III., No. 52, 1884, p. 123; and above, p. 29.

by several naturalists since his time, the complication of these characteristics increases in each group of Ammonoidea, in strict accord with the amount of involution of the whorls of the shell. The reason for this correlation is easily given. Involute shells have broader sides and must necessarily have a larger number of lobes and saddles, or, if these do not increase in number, then they must necessarily deepen and have more profuse marginal digitations. Origin through fortuitous variation is consequently inadmissible, since one can predict the changes which are to occur under certain specified conditions.

On the other hand, the assumption that these characteristics are advantageous differences, acquired through the struggle for existence, seems to be ruled out by the same facts. Characters and differences which were shared by many series, whether living and contending in the same horizons and localities, or occupying distinct horizons and widely separated localities, must have been due to causes which modified the forms by acting from within the organism. The external causes, as pointed out by several authors mentioned above, could not have had such similar effects, since they were assuredly diverse on distinct horizons and in different localities. The only cause of modification which could have produced similar change in different groups must have been the efforts — either as voluntary or involuntary mechanical reactions, or both[1] — of the animals in response to the requirements of the surroundings in the same habitat. As has been said above, all external marks of similar reactions in the animals themselves, such as parallel forms and characters, tend to disappear when the habitat has become changed. That the differentials we have been treating of are of the same nature as parallelisms, in so far as those appearing in one series resembled those appearing in other series, or in so far as they correlate with such characters, will not, we think, be doubted by an experienced observer.

While it is extremely difficult to account for the lengthening of the lobes, or the multiplication of marginal digitations, by means of natural selection, it is not difficult to understand that these complications might have been the result of the habit of holding the comparatively large shell high above the arms. The branching of the posterior ends of the lobes would tend to give greater steadiness of carriage to the shell, and the efforts of the animal to use these organs while crawling would probably tend to increase them in size and length, and in the complication of the outlines. The length of the rostrum was not great in most forms of Ammonoidea, but in some groups it was quite prominent, as in the Amaltheidæ. Its length in all groups, together with its position, was, however, sufficient to show that the shell must have been carried while crawling more elevated above the arms than in Nautiloids, and therefore in a position bringing greater strain upon the parts of the mantle most used in balancing this organ.

Waagen[2] with his usual keenness has observed, that the annular muscle could not have served solely for holding the Nautilus within the shell, but must

[1] Henslow in his interesting book, "The Origin of Floral Structures," (Appleton's Intern. Sci. Series, 1888, p. 88,) takes somewhat similar ground, and says that "the forms and structures of flowers are the direct outcome of the responsive power of protoplasm to external stimuli." Also pp. 123, 147, 333–337. See also quotation from Packard's "Cave Faunas of North America," p. 52, note 1, of this memoir.

[2] Ansatz d. Haftsmusk. b. Naut. u. d. Amm., Paleontogr., XVII. p. 190.

have been also useful as an air-tight band around the animal, fastening the mantle closely to the shell. The very slight impression made in the inner surface of the living chamber shows that this muscle was not very strong, nor very useful for purposes of prehension, and we are disposed to agree with Dr. Waagen's remark, and even perhaps go a little further. Finely preserved casts of the living chambers of Ammonoids, from Solenhofen and other places, do not afford traces of this annular band, and it seems to have been of a similar nature, but of not so great importance in this order, as the pallial muscles among the Lamellibranchs. The animal of Nautilus was probably held in its shell almost exclusively by pressure, and this band of muscles perhaps served to secure the posterior parts from being disturbed by the movements of the outer parts of the body while the animal was using its hyponome. The supposed muscular band of *Oppelia steraspis*, figured by Waagen,[1] runs forward on the sides much nearer to the lateral edges of the aperture than in Nautilus. This fact also indicates that the Ammonitinæ could not have used the fore parts of the body in the same way as the Nautiloids.

The convexity of the central zone of the septum is certainly a differential among Ammonoids when compared with Nautiloids, but it is in strict correlation with the arising and lengthening of the dorsal, ventral, and lateral lobes, especially the first two, and is therefore concomitant with the increasing complication of the sutures, the closer coiling, and the greater involution of the whorl in this order. We have already given the details sustaining this view in our Genera of Fossil Cephalopods, and need only refer here to the cases of Pinnacites (p. 311), in which the septa are double concaves on account of the ridges formed by the large lateral saddles, and the family of the Primordialidæ (p. 316). "While still in the broad-whorled anarcestian stage, the septa are nautiloidean or concave, but when the deep ventral" *and dorsal*[2] "lobes and large lateral saddles are formed, the septa become ammonitoid or convex along the median line." It becomes, therefore, necessary to look upon this differential character as also attributable directly to the habits of the animal, and due to the efforts of the Ammonoid to respond to the requirements of its surroundings.

The persistent ventral position of the siphon is a constant differential among Ammonoids. Even the nostologic series of the Jura and Cretaceous, which yielded so readily to physical changes, becoming uncoiled and departing in many of their characters from the normal ancestral types, still retained the ventral position of the siphon. Although there was considerable lateral variation in the position of this organ in some species, it remained, so far as known, always external or ventral.

The size of the siphon becomes a matter of considerable importance in this connection, and must be considered as throwing some light on this obscure point in the history of the Cephalopoda. The siphon was a far less important organ among the later than among the earlier Nautiloidea. It was also smaller, as may have been already gathered from what we have said above,[3] in the adult

[1] *Op. cit.*, p. 193, pl. xi fig. 1.

[2] These two words should have been inserted, but were accidentally omitted.

[3] Pages 12–17

or ephebolic stages of a Nautiloid, than in the young of the same individual. The ancient primitive radicals like Piloceras and Endoceras had huge siphons, and were macrosiphonulate, whereas in all the remaining forms it was quite small or microsiphonulate. The siphon was also far less important and smaller among the Ammonoidea as a whole than among Nautiloidea, since there were no macrosiphonulate forms in this order. It was also, as has been stated above, much larger and more important in the typembryos, and in the earlier næpionic stage among Ammonoids than subsequently in the growth of the same individuals.

This organ was also far less important, and smaller and less perfectly formed, among the Belemnoids than among Ammonoids, and finally among the Sepioids it became reduced to a mere rudiment, being distinguished with difficulty in the internal shell.

We can therefore say, with some confidence, that the siphon became reduced in size and importance during the progressive period of evolution or epacme of each group of the Cephalopoda, and also followed a parallel course during the development of the individual. When one reviews the various positions, decreasing size, and lessening importance of the siphon in the various groups of Cephalopoda, he becomes aware that these characteristics correlate with each other, but they do not seem to be dependent upon any other character. They are, however, correlative with higher specialization. Thus, in Nautilus, the position of the siphon is variable; in Ammonoids, a more highly specialized type, it becomes more invariable, and always ventral in nealogic stages; in Belemnites which remain straight, and in those more or less coiled, like Spirula, the siphon is also constant, but on the ventral side of the shell. It seems, therefore, that fixity of position is not dependent upon close coiling, but is purely a condition of specialization, and is an accompaniment of the decrease in size and importance of the organ. The fixity and preservation of this differential character, one of the most important in distinguishing the Ammonoids, could not have been due to natural selection, since an organ invariably tending to become of less importance in every order could neither have been advantageous, nor have offered a favorable lever for this law to work with.

Specialization has in all cases appeared to us to be due, *not to natural selection, but to physical selection*, or the production of suitable modifications by the action of forces which changed in a similar way large numbers of the same species, perhaps nearly all the individuals in the same locality or same habitat, within a comparatively limited period of time.[1]

[1] See in this connection the interesting researches of Dr. A. S. Packard, in the Memoirs of the National Academy of Sciences (IV., Pt. I., p. 137 *et seq.*), in which this untiring investigator deduces similar conclusions with regard to the action of physical surroundings upon cave animals. He also repeats after these new and profound studies the assertion made in former publications, that natural selection does not appear to him to be a cause of modification or of the preservation of variations, but the result of the action of other factors.

Dr. Packard's own words are as follows: "Such a phrase as 'natural selection,' we repeat, does not to our mind definitely bring before us the actual working causes of the evolution of these cave organisms, and no one cause can apparently account for the result." The causes are "change in the environment," "disuse of certain organs," "adaptation," "isolation," and "heredity operating to secure for the future the permanence of the newly originated forms as long as the physical conditions remain the same."

"Natural selection, perhaps, expresses the total result of the working of these five factors, rather than

We do not intend to dispute entirely the action of natural selection and the influence of the struggle for existence, but simply to deny the applicability of the law to the more important modifications and series of modifications which have occurred in the history of animals, taking the fossil Cephalopoda as a type.

We have in former papers conceded the preservation of differentials to the law of natural selection, rather on account of the apparent logical necessity of thus accounting for the invariability of minute differences, like the ventral position of the siphon, the siphonal collar, the short funnel, the convexity of the septa and ventral lobe of Ammonoids, and the divergence of the type from the common stock of Nautiloids which these characteristics indicated, rather than from any firm conviction derived from analytical study.

We think now that the changes in the surroundings acted upon the plastic organism, inducing it to make efforts to accommodate itself to new conditions. Effort, being a reaction from within upon a common organization, necessarily produced similar series of modifications whenever the surroundings were not changed so completely as to lead the phylum away from the original type on lines of extreme divergence. Thus parallelisms occurred between the differentials of the Nautiloidea and Ammonoidea, they were less apparent in Belemnoids, which are more remote in habitat, and may be said to have been almost wholly absent in Sepioids, which are still more remote in habitat, as pointed out above. It passes without saying that the differentials are in many cases new modifications; and, if our position is true, they are adaptive characters, correlative in the Nautiloids with their mixed habitat as swimmers and crawlers, in the Ammonoids with their habitat as reptant forms, in the Belemnoids with their intermediate habitat as leapers or bottom swimmers, and in the Sepioids with their habitat as surface swimmers. The simple lobes and saddles, keelless abdomens, and abdominal sinuses in the shells of the Nautiloids, the dendritic or deeper lobes and saddles and keels and rostra of the Ammonoids, the straight internal shell with its peculiar structures and the guard of Belemnoids, and also the degenerate broad internal shell or pen of the Sepioids, are plainly of this nature. Effort working alone upon a common organism could, of course, not produce such results. It is evident that it must have been assisted by the continuous action of physical surroundings. The law, therefore, as referred to in the Preface,[1] seems to be, that, in so far as causes and habits are similar, they probably produce representation or morphological equivalence between different series or forms of the same type in the same habitat, and in so far as they are different, they probably produce the differentials which distinguish series and groups from each other.

being an efficient cause in itself, or at least constitutes the last term in a series of causes. Hence Lamarckianism in a modern form, or, as we have termed it, Neolamarckianism, seems to us to be nearer the truth than Darwinism proper or 'natural selection.'"

These words are so nearly our own views, and so valuable to us as confirmations of the theoretical results given in the text of this memoir, that we regret not being able to quote still more largely from this thoroughly scientific and philosophical writer.

[1] Page vi No. 18.

II.

GENEALOGY.

General Remarks.

THE Arietidæ are divisible into three parts or stocks, the Psiloceran, the Plicatus, and the Levis Stocks. Each of the last two were probably derived from different varieties of the single species *Psil. planorbe*, or its geographical affine in the province of the Mediterranean, *Psil. caliphyllum*.[1] Psiloceras can consequently be appropriately designated as the Radical Stock of the Arietidæ, and, as stated above, this genus is also a surviving member of the radical stock of the whole order of the Ammonoidea. It may also be considered as the first branch of the Arietidæ.

The Plicatus Stock has four genera or series, Wæhneroceras, Schlotheimia, Caloceras, and Vermiceras. The first and second depart widely from the normal Arietidæ, and they can be considered together, as if forming a second distinct branch. Caloceras and Vermiceras, especially the latter, are distinctly arietian in aspect, and may be classed together in another or third branch of the family tree.

The Levis Stock has five genera or series, Arnioceras, Coroniceras, Agassiceras, Asteroceras, and Oxynoticeras. The first two are derivatives of the same radical species, and can be closely associated as a fourth branch of the family. Agassiceras and Asteroceras cannot be so closely associated with Oxynoticeras, on account of the wider divergence of the adult characters of the last genus, but they are apparently derivatives of the same radical species, and can therefore be joined, forming a fifth branch. Oxynoticeras thus becomes separated from the rest of the Arietidæ as a sixth branch composed of one genus.

The Plicatus Stock can be followed from Psiloceras into a series of forms having transitional characters, Wæhneroceras, and ending in the production of the peculiar series Schlotheimia, having characteristics widely divergent from those of the normal forms of the Arietidæ in their pilæ, and in their single-channelled keeless abdomens. The sutures retained the peculiar phylliform or psiloceran character. In another direction, the same stock built up in part the normal Arietidæ, producing by gradual modification the vermiceran series. Caloceras, though truly arietian in aspect, was nevertheless much like Psiloceras, especially in its sutures. The latter lost their complicated psiloceran characters in Vermiceras, and became simpler in outline, or typically arietian.

The Levis Stock had no such complete transitions to Psiloceras, and began its modifications at a later time in the Lower Lias, springing at once into the true

[1] See Summary Plates xi. to xiv., which should be studied in connection with these "General Remarks."

arietian type in the form and sutures of Arnioceras, and from this the typical genus of the family, Coroniceras, was evolved. The keel, double-channelled abdomen, straight geniculated pilæ, and less complicated sutures of both genera, are similar to those of Vermiceras in the Plicatus Stock.

This normal type was rapidly departed from in the next branch, in which the highly aberrant compressed *Ast. Collenoti* appeared. This aberrant tendency was still more decidedly brought out in the more rapid production of similar, but more compressed and involute, forms in Oxynoticeras. In this, also, the highest specialization was reached by the introduction of a new structure, the hollow keel, as a nealogic and ephebolic characteristic.

The smooth variety of *Psil. planorbe*, and its immediate congener, *Psil. caliphyllum*, were of course the most primitive forms which occurred in the Lias, and we can treat the whole of the two stocks as a connected group arising in Central Europe from the smooth variety of *planorbe*, though, as a matter of fact, this is probably artificial. The actual process of the evolution of the second branch, and probably of Caloceras, as will be explained in Chapter III., took place in the basin of the Northeastern Alps, and the forms found in Central Europe were migrants. When arranged naturally the genera appear as in the Summary Plates, as an assemblage of distinct and more or less divergent series.

We have considered each separate genetic series as a genus, because it was necessary to do this, or else use a cumbersome trinomial or quadrinomial descriptive nomenclature. Even with the aid of binomials, we have not been able to speak of any series under one name as a single species. Had this rule been adopted, i. e. to treat each series as a single species, the opinions of paleontologists are not now in its favor, and probably no one would have followed us in practice, however much disposed theoretically to praise our conservatism. Even Quenstedt in his most recent work has proposed names for the different groups of Arietidæ all ending in "ceras." They are highly appropriate euphonically, but for the most part are open violations of the law of priority in nomenclature and not systematic in arrangement, though supported by observations and a wealth of accurate illustrations which are of the highest importance to all students of this branch of science.

We have tried to show, in the Introduction and in other parts of this essay, that the metamorphoses of a normal individual in all its stages is a trustworthy index of the morphogenesis of its group, and that a group of species tended to have a cycle of forms corresponding to these metamorphoses. *The unit of classification is, therefore, not the species, but the genus; in other words, it is the smallest natural group which is genetically connected, and in which a more or less complete cycle of forms or species may be traced.* The genus may also be further defined as an independent group of species, which must always be represented by a distinct diverging line when represented graphically in a geological diagram or genealogical table. In such examples the genus becomes a series of forms, having a distinct line of modifications traceable to the adult radicals, and more or less present in the nealogic stages of their descendants. It has differential characters, but these may be, as in the case of Coroniceras with relation to Vermiceras, much obscured by morphological equivalents, and in such series the closest study of the structural gradations becomes the only sure guide.

As a rule, a series also runs through a gamut from the discoidal forms to the involute, but not always, because there are series like Caloceras having no involute forms, and no one species of Vermiceras or Arnioceras is more involute than another. Nevertheless there is a decided development of the quadragonal whorl in Vermiceras, which, as shown in the series of species in Coroniceras and Asteroceras, and during the development of the individual in all normal forms of the Arietidæ, is usually an intermediate stage to the future genesis of compressed and involute shells.

In such a system, also, certain radical forms which do not show the usual morphogenetic cycle may occur, as was the case with Psiloceras before the more involute forms of that genus[1] were discovered in the Mediterranean province. These may have a closely allied and inseparable series of varieties,[2] which cannot be distributed into the different genera arising from them. In such cases, the radical may be considered as an undeveloped series, and separated as a distinct genus, though it consist of but one species with well marked varieties.

A species is a definite step, or gradation in the morphogenetic cycle of the genus, and is distinguished by its form, amount of involution, sutural and other adult and senile characters, and the more or less accelerated development of the nealogic stages. In the descriptions, it will be noticed that the ephebolic characters of the ancestral form, though it may be a closely allied species, are nevertheless often accelerated in the nealogic stages, and the ephebolic stages then acquire some peculiar distinctive differentials. The aberrant pathological forms, and dwarfs of the same species, may often have more accelerated development than the normal forms, and sometimes simulate distinct species. These, as well as the normal varieties of species, have connections with other species which can only be properly estimated with sufficient materials and accurate study. After having secured the genealogy of a series, the species can be determined and separated, but until this is done, the work does not rest upon a secure basis. The possession of a keel, or channels, or a line of tubercles, or increased involution in the adult whorls, may distinguish one species from another in the same series; but the same differences may make the shell appear to be identical with a species occurring in another genus, and thus confuse the classification unless the genesis of the characteristics has been traced.

The order adopted for illustrating the series in the Summary Plates is the result of following out genetic lines, and therefore presents forms in their approximately natural relations, though necessarily having no reference to chronology. The species are connected by lines indicating their natural affinities, and show the relations of the series; but the title, Summary Plates, fully explains the necessarily abbreviated and more or less artificial nature of the arrangement. Comparison with Genealogical Table V. will serve to correct any erroneous impressions which might arise from the study of these plates, in so far as the species of Western Europe are concerned. Those from other localities, also figured in the Summary Plates, will be found by reference to the descriptions.

[1] Summ. Pl. xi. fig. 11–13. [2] Summ. Pl. xi. fig. 1, 2; Pl. xii fig. 1.

RADICAL STOCK.

Psiloceras caliphyllum, as supposed by Neumayr, may have been the radical discoidal and smooth form from which *Psil. planorbe* originated. It is a very close ally of this species, differing only in the sutures, and these, like those of other members of the genus in the Northeastern Alps, are phylliform, and have, as we have said, a triassic aspect. Although we are disposed to share Neumayr's opinion that *Psil. caliphyllum* is the radical of all the Arietidæ, we think, nevertheless, that the evidence of the forms and sutures favors the theory that the Levis Stock of the Central European province all sprang from *Psil. planorbe*. The sutures of the normal Arietidæ of Central Europe have less complicated margins than those of Psiloceras and Caloceras of the same province; but these in turn are as a rule less complex than those of the same genera in the Northeastern Alps. The Arietidæ, therefore, can be characterized as having degenerated in respect to the sutural margins of the septa. The degeneration of the sutures in *Psiloceras planorbe* and in *Cal. laqueum* and *Verm. spiratissimum* enables one to see that this tendency was general even in the Plicatus Stock; and it is probable[1] that the Plicatus Stock, with the exception of Vermiceras, all originated in the Northeastern Alps from *Psil. caliphyllum*.

The degeneration of the sutures is due to an arrest of development followed by the retention of nealogic characters, and is purely degenerative. This is, however, accompanied by the evolution of a new character, an increase in the depth and narrowness of the abdominal lobe, in the typical Arietidæ.

PLICATUS STOCK.

Wæhneroceran Series.

The interesting forms discovered in the Mediterranean province, and described by Wähner in his "Unterer Lias,"[2] show that the closest affiliation existed between Psiloceras and the schlotheimian group. The genus Wæhneroceras,[3] described farther on, contains species like *Wæhn. extracostatum*, *curviornatum*, *Panzneri*, etc., which are transitional between Schlotheimia and the true plicated species of Psiloceras.

Schlotheimian Series.

In this series[4] the number of forms having the pilæ crossing the abdomen with a peculiar forward bend, especially in *Schlot. catenata*, enable the observer to see that a direct connection by transitional forms must have occurred between this and Wæhneroceras. The similarities are, however, not so close as to be traceable in a series of connecting forms, and one is still left in doubt whether the evolution of this series took place in an earlier formation than that of the Planorbis bed, or in that bed itself.[1] Suspecting that the nealogic stages of *Schlot.*

[1] See Chapter IV.

[2] Mojsis. et Neum., Beitr., II., 1882

[3] Summ. Pl. xi, fig. 7-10

[4] Summ. Pl. xi, fig. 3-6

catenata in varieties having the most discoidal forms and the pilæ crossing the abdomen without a channel would throw some light on this problem, we begged Professor Emerson to give us some specimens of this species from the Markoldendorf basin for examination. After making several preparations of those kindly sent in reply to this request, the inner whorls and all stages up to the adult were studied. The young to the diameter of 6–8 mm. resemble closely the older nealogic stages of *Wæhn. curviornatum*[1] and *circacostatum*, as figured by Wähner.[2] The pilæ are slightly bent forward on the abdomen, are fold-like, as in Psiloceras, and without the sharp bend and tongue-like forward projection which are the primitive indications of a tendency to form a median ventral channel. This tongue-like projection is formed in the next stage, and the pilæ, which have in the mean time become very sharply defined and prominent on the sides and abdomen, also exhibit a slight flattening or decided depression, in most forms, along the median line of the abdomen. It is evident from these facts that Wähner was right in considering the species of the wæhneroceran series as transitions to Schlotheimia.

Caloceran Series.

This series is divisible into two subseries.

First Subseries. — The direct connection of the plicated variety of *Psil. planorbe* with *Caloceras Johnstoni* (*torus*, D'Orb.) has long been insisted upon by Quenstedt, and in his collection the intermediate types are found. There is (1) a *plicatus* with whorls slightly narrower dorso-abdominally than is usual in this variety, and somewhat more prominent folds; then (2) one with the same form, but still narrower dorso-abdominally, and for this reason with a blunter and rounder abdomen; then (3)[3] a young one of this form precisely similar to the *Johnstoni*. These show that *Johnstoni* is an offspring of the plicated *planorbis*, in which the more gibbous sides, narrower whorls, and rounder, broader abdomens of the young of that form are retained throughout life.

From *Johnstoni* one can pass by gradations into *Caloceras tortile*.[4] First, the typical *tortile*, with young until a late stage, having rounded abdomens and the aspect of the narrower and smoother forms of *Johnstoni*. These become angular on the abdomen at various ages, without producing a true keel. Secondly, those which introduce a slight keel upon the elevated abdomen, but which subsequently disappears in the increasing angularity of the abdomen in the senile stages. Thirdly, those which introduce a keel, then a squared or quadragonal form of whorl, like that of *Caloceras laqueum*. Fourthly, those which are of very large size, similar in all their stages, except in the angular abdomen, to the stouter forms of *Johnstoni*, and like these becoming rounded in extreme old age.

The first variety grades into *Cal. Liasicum*, which has rounded, gibbous whorls in the young. This has a keel only at a very late stage, or may not

[1] Summ. Pl. xi. fig. 7.

[2] Unt. Lias. Mojsis. et Neum., Beitr., XII., Pl. xv., xvi.

[3] The larger one (2) was fortunately a broken specimen, and showed precisely the same form as (3) in the young.

[4] Summ. Pl. xi. fig. 14; Pl. i. fig. 12-14.

have any, though, as in the keelless tortilis form, the abdomen may become elevated, or very slightly subangular. Wright's figure[1] admirably illustrates such an individual. The Sironotus variety figured by D'Orbigny has a more compressed form and an earlier development of the keel.

Second Subseries. — *Caloceras laqueum* has many varieties. First, those which develop the keel at a very late period of the growth, and grade into the third variety of *Cal. tortile.* With these we find, as sub-varieties, some which, either immediately before or at the time when the keel is developed, change by growth the general form of the whorl. The abdomen may become elevated, as in the first senile stage of some varieties of *tortile*, or depressed, assuming the aspect of *carusense* or *spiratissimum.* Secondly, those which develop a keel at a comparatively early stage, and either retain the rounded sides, or become subquadragonal and approximate in form and pilæ to *Ver. spiratissimum.*[2]

The senile whorl had metamorphoses, which produced an elevated or narrow abdomen, similar to that of *Cal. tortile* at the same stage, though in some varieties the sides were flatter, and there is a nearer approximation to the true trigonal outlines of the old of Vermiceras.

The young of *carusense*[3] repeated the characteristics of the intermediate forms, but generally produced the keel at earlier periods. These are also lowest in geological position, and pass into other varieties, occurring later geologically, which are of much larger size. In all these larger specimens[4] the form is noticeably subquadragonal in the adult, and also has a keel, and sometimes faint channels. There is a tendency in old age to produce a rounded whorl, with an elevated angular abdomen in the clinologic stage, resembling the same part in the old age of the prominently keeled varieties of *tortile* and *nodotianum.* In the large variety of *carusense* we also find some forms which in their clinologic stage have *flattened* and *convergent sides*, with a keel and slight channels. In other words, there are some specimens which show a tendency in old age to change the subquadragonal form of the adult, very much as in the genus Vermiceras. In this species, also, the sutures were observed in one case of extreme age to lose the differentiated proportions of the adult, and partially retrograde, becoming similar to those of Psiloceras.[5] The young and the adult of many specimens of the *raricostatum* variety of *carusense*[6] are inseparable from the same stages in the extreme of variety *a* of *raricostatum*,[7] with the exception perhaps of slight differences in the marginal digitations.

The typical *raricostatum*,[8] however, is not similar to *Cal. Liasicum*, being extremely broad transversely, and having a very immature gibbous whorl, which can be called subquadragonal only in variety *b*. In old age,[9] even the broad whorl of the typical variety diminished in transverse diameter, the abdomen became more elevated, and the keel and pilæ obsolescent, until finally a fragment of the old whorl cannot be distinguished from the same stage of *Cal. tortile* or *nodotianum.*[10]

[1] Lias Amm., Pal. Soc., I. p. 316, pl. xvi.
[2] Summ. Pl. xi. fig. 22.
[3] Summ. Pl. xi. fig. 15.
[4] Pl. ii. fig. 1-3.
[5] Pl. ii. fig. 3, 3 a.
[6] Pl. i. fig. 16.
[7] Pl. vi. fig. 15.
[8] Pl. i. fig. 25 a.
[9] Pl. i. fig. 24, 25.
[10] Compare section of old *nodotianum*, pl. i. fig. 10, with section of old *raricostatum*, fig. 25.

Cal. nodotianum,[1] as found at Semur, has two varieties. One of these resembles the subquadragonal varieties of *Cal. carusense* until a late stage of development with somewhat flattened sides, similar pilæ, keel, and faint channels. Afterwards it assumed the more acute form of whorl characteristic of its own species. *Cal. sulcatum*[2] is transitional to *Cal. Deffneri* in its characters, but is not very closely allied. The sutures of *Deffneri* and its young form as seen from the side appear to justify the position given it as the extreme form of the caloceran series. In the Mediterranean province *Cal. Johnstoni* also occurs, and exhibits transitional characters similar to those of the same species in Central Europe. The pilæ are coarse, like those of the young in Psiloceras, and there is the same tendency to an elevation of the abdomen, as in the same species in Central Europe. Our remarks upon the subseries of this genus in the Northeastern Alps are open to the objection that they were made upon the drawings of Neumayr and Wähner, but our inferences do not differ widely from those of either of these writers, except in the names given to the genera and in the rejection of the name Arietites. We shall sufficiently discuss the details of the subseries occurring in the Northeastern Alps under the heading "Caloceras," in the chapter on "Descriptions of Genera and Species," and shall find that these in part exist also in Western Europe.

The first subseries in the Northeastern Alps contains the well known *Cal. Johnstoni*. This seems to be the immediate radical of a small series, consisting of *Cal. hadroptychum*, an unnamed form also figured by Wähner, and the giant *Cal. nigromontanum*. The last has a keel, but no channels.

This subseries also includes *Cal. Liasicum*, which is very close to *Cal. Johnstoni*, *Loki*, and *Seebachi*, species having very immature keels, shallow channels, and slightly depressed abdomens connecting *Liasicum* with *Cal. Haueri* of the next subseries.

The second subseries includes forms like *Cal. proaries*, which shows in its development how closely they are all connected with Psiloceras and the forms of the first subseries. This is the representative of *Cal. nodotianum* of Central Europe, and a close ally of this species, though the young are apparently more immature at the same age in the development of the keel and form of whorl. *Cal. gonioptychum* appears to connect this with the extraordinary series of *Cal. cycloides*, *Doetzkirchneri*, *Castagnolai*, and *abnormilobatum*. This is peculiar to the Mediterranean province, and shows that, like Psiloceras in the same region, Caloceras probably had a complete cycle of forms, varying from the discoidal psiloceratitic transitions with more or less elevated abdomens resembling *Cal. Johnstoni* and *tortile* to *Cal. abnormilobatum*. having complicated sutures, more involute, compressed whorls, and a narrowed umbilicus. This series, however, though it evolved an elevated acute keel in the two highest species, did not have deep channels in any species.

This subseries also contains *Cal. laqueum*, var. *scylla*, and *Cal. prespiratissimum*, two forms that approximate to Vermiceras in their characteristics.

The third subseries arose apparently from *Cal. Loki* or *Seebachi*. The young

[1] Summ. Pl. xi. fig. 16.

[2] Summ. Pl. xi. fig. 20, 21.

of its first member, *Cal. Haueri*, appears to indicate such a line of descent, though of course this can only be considered a suggestion derived from Wähner's figures. *Cal. perspiratus* and *supraspiratus* are more or less decidedly channelled, and the last inherits well defined keel and channels at an earlier stage than in *Cal. Coregonense*. *Cal. ophioides* is a very curious species, with an early development of the keel and channels in some varieties, and a very late appearance of these in other varieties, as shown by Wähner. This subseries appears in Central Europe in a few keeled and channelled forms.[1]

The third subseries includes also *Cal. laticarinatum*, a varietal modification of *Cal. proaries* according to Wähner, and this leads into several shells with much depressed and very stout whorls, such as *Cal. salinarium*, *centauroides*, and *Grunowi*. We consider *laticarinatum* as separable from *proaries*, because of the earlier or accelerated development of the keel, and the broad and depressed abdomen.

There is also a subseries including only the curious *Cal. Sebanum* described by Neumayr, which appears to be a form of Caloceras, possibly somewhat similar to the equally remarkable *Cal. laqueoides* of Würtemburg.

This enumeration shows that the species of the Northeastern Alps, if arranged in natural order, would probably form a greater number of subseries in that province than in Central Europe, though for convenience' sake we have here placed them in the same number of subseries.

Vermiceran Series.

The young of *Vermiceras spiratissimum*,[2] before the quadragonal form is fully developed, has a stage in which it approximates both in size and characteristics so closely to some varieties of *Cal. laqueum* that separation is not natural. The comparison of Fig. 17 and 18, Plate I., with Fig. 23, Summary Plate XI., shows the tendency of this species to the production of varieties with channels like those of *Conybeari*. The transition from *spiratissimum* to *Conybeari* has been recognized by many paleontologists; in fact it is not possible to separate these species, though the extreme forms of *Conybeari* have much stouter young, and usually develop the channels and keel at a much earlier age.

Ver. Conybeari has the usual broad varieties, with late development of keel and channels, as in *Schlænbachi* and the like, and also a form which acquires tubercles, the *Bonnardi* form of D'Orbigny, and loses them again either in the adult or during the first stage of senility. From this form the transition to *ophioides*, D'Orb.,[3] which has the adult *Conybeari* form at a very early age, and also faint tubercles, is natural and easy.

The old age metamorphoses of *Ver. spiratissimum* and *Conybeari* are quite distinct from those of Caloceras. The sides showed an increasing tendency to converge, the abdomen became narrower, the pilæ obsolescent, and the geniculæ disappeared. In very large specimens this tendency finally obliterated all traces

[1] Summ. Pl. xi. fig. 14-16.

[2] Pl. i. fig. 17; Summ. Pl. xi. fig. 23.

[3] Pl. i. fig. 21; Summ. Pl. xi. fig. 25.

of the pilæ and of the channels, but often left the keel more prominent. The whorl acquired the true flat-sided trigonal form, but never became rounded, so far as yet observed.

LEVIS STOCK.

Arnioceran Series.

This series begins, when zoölogically considered, with *Arn. miserabile,*[1] a form very commonly in collections named *Amm. planorbis* or *psilonotus,* on account of its close external resemblance to that species.[2] It has, however, distinct sutures, and acquires by growth a subacute abdomen. During the younger stages, while it is still round on the abdomen, or in varieties with broad abdomens, it is, with the exception of its smaller size, a close reproduction of the adult of *Psil. planorbe,* var. *leve.* This grades into *Arn. miserabile,* var. *cuneiforme,*[3] which has a more acute abdomen and curved and more perfect pilæ acquired at an earlier age, and from this without a break the series passes into *Arn. obtusiforme.*[4]

Starting again from variety *acutidorsale* of *miserabile,* we can follow another line of affinities. There are some forms of this variety which acquire in the adult a keel with faint but abruptly terminating folds or pilæ, and these lead into a variety of *Arn. semicostatum.*[5] This species has many varieties, which grade from an immature planorbis-like form[6] to those which are prominently keeled and pilated even at a comparatively early age,[7] and also into varieties which have deep channels on the abdomen.[8] These last are inseparable from *Arn. tardecrescens,*[9] and when they have numerous pilæ they are inseparable from *Arn. ceras.*[10] There are also varieties of *Arn. semicostatum* which fade into *Hartmanni,*[11] and this in turn grades into the still more compressed *Bodleyi.*[12] From *Arn. Hartmanni,* also, we can pass into another compressed form, the true *Amm. falcaries* of Quenstedt.[13]

Returning again to *semicostatum,* we find that one of its varieties is distinguished for remarkably raricostatus-like pilæ and a low keel. This when followed out leads to *Arn. kridioides.*[14] This species in some of its varieties so closely resembles *Cal. raricostatum,* that for a time it was thought to indicate the direct descent of that species from *semicostatum.*

There are also some forms, usually identified as *Amm. kridion* in Germany, which have remarkably broad whorls in the adult, and approximate to the true *kridion.* These, however, never possess the tubercles of the true *kridion,* and also have young which prolong the smooth stage and otherwise resemble the young of the stouter forms of *semicostatum.*

[1] Pl. ii. fig. 4, 5; Summ. Pl. xii. fig. 2.

[2] The apertures are also similar as figured by Quenstedt, Amm. Schwab. Jura, pl. xiii. fig. 27, by Dumortier.

[3] Pl. ii. fig. 7.

[4] Pl. ii. fig. 8, 9; Summ. Pl. xii. fig. 3.

[5] Pl. ii. fig. 10; Summ. Pl. xii. fig. 14.

[6] Pl. ii. fig. 10.

[7] Pl. ii. fig. 11.

[8] Pl. ii. fig. 15.

[9] Pl. ii. fig. 19; Summ. Pl. xii. fig. 6.

[10] Pl. ii. fig. 20, 20 a.

[11] Pl. ii. fig. 17; Summ. Pl. xii. fig. 5.

[12] Pl. ii. fig. 23; Summ. Pl. xii. fig. 7.

[13] Pl. ii. fig. 25 27.

[14] Pl. ii. fig. 28; Summ. Pl. xii. fig. 8.

The only signs of old age observed in any specimens were the disappearance of the geniculæ and pilæ, and increasing flatness and convergence of the sides.

Coroniceran Series.

This series is composed of three subseries.

First Subseries.—The radical form is *Cor. kridion*, and this species shows direct connection in many varieties with *Arn. semicostatum.* The similarities of form and characteristics of the young of some varieties in both species indicate mutual affinities, though the young of other forms of *kridion* have a very different aspect. Three specimens of *Cor. kridion* from Möhringen in the Museum of Stuttgardt, named from their arnioceras-like forms *Amm. Bodleyi*, have the precise characteristics of an immature *kridion*, viz. divergent sides, an elevated abdomen and keel, and tuberculated pilæ.[1] These grade into the typical *Cor. kridion*,[2] having in the extremely young stages whorls with gibbous, divergent sides, smooth at first, but becoming more quickly pilated and tuberculated.

From these forms the transitions are complete to *Cor. coronaries*, which indeed might be very properly considered as a variety of the same species, since it merely exaggerates all the characteristics of *kridion.* From this we can pass into the true *Cor. rotiforme*,[3] in which the adults differ greatly from *kridion.* The young[4] belong to the typical variety, and are broader and flatter on the abdomen than in *kridion*, and also have divergent sides and very heavy coarse tubercles. Senility is shown only in specimens of exceedingly large size by the very gradual obsolescence of the tubercles, pilæ, and channels, though we have not found any specimens, which had become entirely smooth, or in which the channels had entirely disappeared.

The transition from *Cor. rotiforme* to *Cor. lyra*[5] is accomplished through a variety, which is separable from the former only by a single character of no special value. The superior lateral saddle is somewhat pointed and narrow, instead of being cut into on the border by numerous marginal lobes, as in *rotiforme.* The varieties of *lyra*[6] which follow have, at an early age, a form similar to that of the adult *rotiforme* with a more or less elevated abdomen, slightly convergent sides, and tuberculated pilæ. There is also a tendency to increase the abdomino-dorsal diameter of the whorls, the pilæ becoming more closely set and less prominent than in the first described variety.[7] Senility[8] is indicated by obsolescence of the tubercles and the decreasing width of the abdomen. No specimens were observed in which the pilæ had disappeared, though in one specimen they were reduced to broad curved folds, and the channels were almost obsolete, the keel also having been reduced to a low broad ridge. This specimen measured 440 mm., while one at Semur measuring 525 mm. had lost only the tubercles, and the first senile or clinologic stage had but just been entered upon.

[1] If *Arn. kridioides* had been found on the same level with the earliest form of *Cor. kridion*, it would undoubtedly have to be considered a transitional form between *semicostatum* and that species; but since it is not found there, perhaps the safest way is to indicate the descent from *semicostatum* alone.

[2] Pl. iii. fig. 3; Summ. Pl. xii. fig. 9.

[3] Pl. iii. fig. 14-17.

[4] Pl. iii. fig. 4-9 a.

[5] Summ. Pl. xii. fig. 13.

[6] Pl. iv. fig. 9-14.

[7] Pl. iv. fig. 5, 6.

[8] Pl. iv. fig. 15, 16.

From this species we may follow two lines of evolution, one into *Cor. trigonatum*,[1] and one into *Cor. Gmuendense*.[2] The former, *trigonatum*, can be distinguished by its young whorls, which were stouter than is usual in the young of *lyra*, by the increasing amount of the involution, which is no longer confined to the abdominal region, but covers in the geniculæ in some specimens, and by the earlier period at which the pilæ become fold-like and the abdomen subangular.

Cor. Gmuendense is also distinguishable from *lyra* and from *trigonatum* by its extremely flattened whorls in the young and adult, though it may otherwise exactly resemble the young of the typical variety of *lyra*. The involution did not increase by growth, but was confined to the abdominal area, and limited laterally by the geniculæ. The senile changes were very distinct, and occurred at earlier stages than in *lyra;* the abdomen[3] became narrower and the sides convergent before the loss of the tubercles. Thus we can say with certainty, that, in this species, degradational old age changes began to alter the form before the other adult characteristics showed signs of obsolescence.

The Second Subseries of Coroniceras begins again with *Cor. kridion.* The connection is made by a very remarkable form, *Cor. Sauzeanum.* The young in some specimens are like the young of *kridion*, and then in the next older but still immature stages[4] acquire the characteristics of the adults of *kridion.* The typical *Sauzeanum* maintained until a late period of growth, and probably throughout the ephebolic stages in some specimens, the broad abdomen and prominent tuberculated geniculæ of the young, but the sides usually became slightly convergent.[5] Variety *Gaudryi*,[6] for a greater or a less number of whorls repeated the typical form of *Sauzeanum.* The geniculæ in older stages were carried inwards, the abdomen became slightly elevated and proportionately narrower, and the tubercles almost obsolescent. A large whorl, over six centimeters in the abdomino-dorsal diameter, was observed, in which these characteristics were not changed otherwise than by the shallowing of the channels and the depression of the keel.

The transition forms from variety *Gaudryi* to *Cor. bisulcatum*[7] are not perfectly satisfactory. They are, however, nearly allied by the peculiarities of the abdomen and geniculæ in the young of *bisulcatus*, which are similar to those of the young of variety *Gaudryi* until a late stage of growth. Two specimens of large size were observed. One had a diameter of 620 mm., the tubercles and channels were almost obsolescent, the pilæ very thick and fold-like, but the geniculæ were well developed and prominent, as in the adult. Another, 650 mm. in diameter, had the abdomen much narrower proportionately, the tubercles had disappeared, and the channels were almost obsolete, the keel being much reduced in size. The former was 170 mm. in the abdomino-dorsal diameter of the last whorl, but the latter reached the enormous size of 240 mm. in the same part. There was, therefore, a difference of 70 mm. in the diameter of the last whorl, as compared with the difference of only 30 mm. in the diameter of the entire shell.

[1] Pl. vi. fig. 1, 2; Pl. vii. fig. 1; Summ. Pl xii. fig. 15.
[2] Pl. v. fig. 4–9; Summ. Pl. xii. fig. 14.
[3] Pl. v. fig. 6, 8–9.
[4] Pl. vi. fig. 9, 10; Summ. Pl. xii. fig. 10.
[5] Pl vi. fig. 5, 6, 12, 13.
[6] Pl. vi fig. 11.
[7] Pl. vii. fig. 2–8; Summ. Pl. xii fig. 11.

The Third Subseries of Coroniceras begins with *Cor. latum.*[1] This species is remarkable for retaining, until a late stage of growth, the characteristics of the young of *rotiforme*, and for its exceptional form, the sides of the whorl being exceedingly divergent, the pilæ fold-like and heavily tuberculated, the abdomen gibbous and slightly elevated.

There is one variety of *rotiforme* with very stout and gibbous whorls in the young, which cannot be distinguished from one variety of *latum* until a late stage of growth, except by the singleness of the pilæ. Single pilæ occur, however, in many specimens of all varieties of *latum*, so that this is not a distinction of constant value. *Cor. latum* must, therefore, be considered a direct descendant of *rotiforme*. From this species the transition to *Cor. Bucklandi*[2] is accomplished by numerous intermediate forms. These exchanged the form of *latum* in the young for a sinemuriense-like stage, in which the abdomen became contracted in breadth, the sides parallel, and the channels deep. This stage was retained in some specimens for a long time, while in others it quickly gave place to the huge pilæ, parallel but gibbous sides, transversely broad whorls, and flattened abdomen of the adults of the typical *Bucklandi*.

In other forms, with similar young, the pilæ assumed during their adult stage the usual aspect, with either only a trace of tubercles, or none. I have not been able to follow the transitions of this, or the *sinemuriense* variety, into the stout form of *Bucklandi*. There can be but little doubt, however, that the large form found at Lyme Regis differs only in having had a more accelerated development; i. e. in skipping the double pilæ and large tubercles of the *sinemuriense* stage. It evidently acquired, at a very early period in the young, large untuberculated pilæ, and in old age was characterized by a very decided narrowing and rounding off of the abdomen, obsolescence and bending forward of the pilæ, disappearance of the channels, and a broader and less elevated keel.

The evidence of transition from the *sinemuriense* variety to *Cor. orbiculatum* rests upon similar grounds. The singleness and perfection of the pilæ are the only differences which separate the young of *orbiculatum* from the young of such forms as variety No. 5 of *sinemuriense*. In the adults, however, the narrowness of the abdomen, flatness of the sides, and their convergence outwardly, are marked differences in aspect, which were greatly increased by advancing age. The abdomen in some very large specimens became almost obtusely angular, as in Vermiceras, and the pilæ fold-like, much bent forwards, and the channels obsolete.

Agassiceran Series

This series obliges us to return once more to *Psiloceras planorbe*. It has two subseries.

First Subseries. — The young of *Agas. lævigatum*[3] had a close resemblance to the young of the compressed varieties of *Cor. kridion*, and to *Cor. rotiforme* in some varieties, before the latter acquired tuberculated pilæ. But this likeness was

[1] Pl. iii. fig. 19-23; Summ. Pl. xii. fig. 16.
[2] Pl. viii. fig. 9-11; Summ. Pl. xiii. fig. 1.
[3] Pl. iii. fig. 18; Summ. Pl. xii. fig. 17.

due to the stout whorls of the younger stages, and cannot be relied upon as at all conclusive. The stout helmet-shaped whorl is a larval characteristic, derived from the primitive ancestral Goniatitic form, Anarcestes. It is found in all the Ammonitinæ at an early stage of growth, and may be retained in radical forms until a late stage; and in this species it sensibly influenced the shape of adults. The adults of many specimens of *Agas. lævigatum*[1] are closely parallel with *Psil. planorbe.* Dwarfed specimens sometimes have the form and smooth aspect of *planorbe*, and even the apertures are similar, and *Agas. lævigatum*, therefore, must have been a direct descendant of *Psil. planorbe.*[2] In var. *d* of *lævigatum* the depressed helmet-shaped whorl is exchanged in course of growth for the compressed helmet-shaped, just as in *planorbe*. The young,[3] unlike the adult of *planorbe*, have short living chambers,[4] and the septa are quite distinct, and in most specimens there is a raised siphonal ridge along the abdomen, though the keel is not well developed, nor are the channels present. The misnaming of varieties of *lævigatum* as *Amm. planorbe* is also common in European collections.

The same peculiarities are present also in *Agas. striaries.*[5] In some varieties of this species there are perhaps still closer approximations to the general form and aspect of the smooth forms of *Psil. planorbe.*

Agas. Scipionianum[6] has two marked varieties, — one less involute, with spines in the adult,[7] and one more compressed, with smaller spines.[8]

Agas. nodosaries is apparently a compressed form, very similar to *Scipionianum*.

Agas. Scipionis is a distinct species, having smooth and more involute whorls.[9]

The Coroniceran proportions and aspect of the sutures in *Scipionianum* are well marked, and would have led to the association of this species with that genus if there had not also been similar sutures in *Ast. obtusum*, showing that these proportions are progressive characteristics of independent origin in each series. The completeness of the gradations from the adults of *Agas. striaries* to the young of this species also forbids this conclusion.

Asteroceran Series.

This series has two subseries.

First Subseries. — The more advanced varieties of *Agas. lævigatum*[10] have divergent-sided whorls and fold-like pilæ, and a form[11] similar to the tuberculated young of *Ast. obtusum*,[12] and still more like the untuberculated young of this species.[13] In the accelerated development of the tuberculated variety of *obtusum*,[14]

[1] Pl. viii. fig. 9, 12.

[2] Compare the young of the last named, fig. 4, pl. i., with fig. 10, pl. viii.

[3] Pl. viii fig. 13.

[4] Short living chambers are found in the young of *Psil. planorbe*, and therefore this characteristic is really a confirmation of the assumed direct descent of *Agas. lævigatum* from that species. *Agas. lævigatum* is an arrested development of *Psil. planorbe*, in so far as the living chambers and its small size are concerned.

[5] Pl ix. fig. 14, 15; Summ Pl. xiii. fig. 6.

[6] Pl. x. fig. 11–13; Summ. Pl. xiii. fig. 7.

[7] Pl. x. fig. 11, 12.

[8] Pl. x. fig. 13, and pl. vii. fig. 15.

[9] Summ Pl. xiii. fig. 8.

[10] Pl. viii. fig. 11.

[11] Pl. viii. fig. 11.

[12] Pl. viii. fig. 8.

[13] Embryology of Cephalopods, pl. ii. fig. 11.

[14] Pl. viii. fig. 4.

the divergent-sided whorl is noticeable.[1] This is often replaced by a parallel-sided whorl on the fourth volution, and this in its turn is replaced by the convergent sides of the fifth whorl.[2] The divergent-sided whorl, with its tuberculated pilæ, is skipped in the development of some specimens of *obtusum*, and it is replaced on the third whorl by the parallel-sided smooth whorl and pilæ of the later stage, instead of on the fourth whorl, as described above.[3]

The broad abdomen and the correlative divergent-sided larval form of *Ast. obtusum* are retained in the adults of some varieties,[4] but even in these the pilæ are smooth and without geniculæ, and the whorls discoidal. Notwithstanding this fact and the enormous size reached by some normal specimens before manifesting old age, there are specimens in the closely allied *Ast. stellare* and *acceleratum* which exhibit a remarkable tendency to assume retrogressive characteristics, and to inherit them in their younger stages, while still becoming more involute and holding the keel comparatively unchanged. These characters induced me at first to estimate the whole series as geratologous, but this view cannot be maintained. Most specimens lose the tubercles early, or do not have them at all, the pilæ become mere folds, and bend forward, the keel being low and broad and the channels shallow. There is so close a resemblance between these ephebolic characteristics and the old age stages of the common English form of *Bucklandi* at Lyme Regis, especially in the stout varieties of *obtusum*, that collectors frequently call the old of *Bucklandi* by the name of *Amm. obtusus*. Upon one occasion I was myself completely deceived by the exposed portion of a whorl, which, when finally cleared of its surrounding matrix, was readily identified as a senile specimen of typical *Bucklandi*. Nevertheless the characteristics of *Ast. obtusum*, when compared with the radical *Agas. striaries* or *lævigatum*, are not geratologous, but nealogic. They have the same relation to the characteristics of these radical forms that the fold-like pilæ and immature whorls of *Cal. Johnstoni* have to those of its immediate radical, *Psil. planorbe*. Their real value as radical characters is shown also by the fact, that in some full grown specimens of *obtusum* tubercles appear, and in the ephebolic stages of *Ast. Turneri* of the next subseries the typical arietian characters appear, namely, deep channels, well defined keel, and quadragonal form. These therefore occur in the same succession as in other series of the Arietidæ, and during the growth of the individual they appear in similar order.

Ast. acceleratum, the second and last of this subseries, occurs rarely, but is found in several collections. It has young until a late period precisely identical with the young of certain varieties of *obtusum*, and the adults of *stellare*. This stage, which may last until the individuals are from 76 to 89 mm. in diameter, is immediately followed by a stage in which the involution is increased, the sides are flattened, the abdomen narrowed, and the pilæ obsolescent. In fact, during its adult stage a form and characteristics are produced very similar to the stouter varieties of *Brooki*, with which it was at first associated.

[1] Pl. viii. fig. 6. [2] Pl. viii. fig. 8.

[3] Pl. viii. fig. 8, does not show the inner whorls accurately enough, and a comparison of the figures is necessary in order to give an accurate idea of the development.

[4] Summ. Pl. xiii. fig. 2, has parallel sides, but belongs to this gibbous whorled variety.

Second Subseries.—Some specimens of *Amm. stellare*, Sow.,[1] have a young stage during which the sides become more or less flattened and parallel. These are intermediate between true *obtusum* and *Turneri*. The old of the stout varieties of *obtusum*, and specimens of *Turneri* in their first senile stage, have characteristics similar to those of the adults of *stellare*, and occasion confusion in the identification of fragments. The extreme senile metamorphoses of *Turneri*, when the whorl became smooth, the channels shallow, the sides convergent, and the abdomen narrow, occurred, as in other species, at variable ages, sometimes in shells only 102 mm. in diameter.

The differences between the adult of *Turneri* and the adult of the next species, *Ast. Brooki*,[2] are well marked in most specimens, but the stoutest and least involute forms of the latter are very closely allied to the former. The adults of the stouter variety of *Brooki* retained the channels, the keel remained prominent, the sides remarkably flattened, and the pilæ in some specimens prominent and like those of *Turneri*, but the whorls were generally more involute. The young have very close resemblance to the adults of *Turneri*. The young[3] of *Ast. impendens* had no very close resemblances to *Turneri* at any stage. They repeated the adult characteristics of the stouter variety of *Brooki* during the nealogic stages, and in the adults exaggerated the normal tendency to convergence of the sides, depression of the pilæ, and narrowing of the abdomen. The adult of this variety approximated quite closely to the senile stage of *stellare*. The fine series of figures given by Wright in his "Lias Ammonites" shows most completely the transitional forms of *impendens*, and are referred to below in the description of *Brooki*. *Ast. denotatum* is simply a more involute form of *impendens*.

The next species, *Ast. Collenoti*,[4] can be traced directly to the preceding form, and, if my translation of the facts is correct, it is the geratologous offspring of *impendens* or *denotatum*. The young[5] were similar to the young and adults of *impendens*, and also more remotely to the adults of *stellare*, but the next or first ephebolic stage was precisely similar in all respects, except the sutures, to the first senile stages of *impendens*. In the adults of one variety this stage retained distinct pilæ, though in other specimens the sides became smooth. The involution of the adult whorl was more considerable than in *impendens*, and the shell closer in this respect to *denotatum*.

The extreme variety of *Collenoti* had a similar form and development, but was somewhat sharper on the abdomen, and the pilæ were wholly confined to the nealogic stages, the adult stage being similar in form and characteristics, except in the sutures, to the extreme old age of *impendens*. Thus the characteristics of the transient senile stages of *Ast. obtusum* and other normal species were similar to the permanent characters of the ephebolic and even nealogic stages of degenerate or pathological species like *Ast. acceleratum* and *Ast. Collenoti*.

[1] Pl. ix. fig. 2, 3.
[2] Summ. Pl. xiii. fig. 4.
[3] Pl. x. fig. 6–9.
[4] Pl. x. fig. 10; Summ. Pl. xiii. fig. 5.
[5] Pl. ix. fig. 10–11 b.

Oxynoticeran Series.

The apparently wide divergence from the usual structure of the Arietidæ presented by the hollow keel led me at first to classify this group as a distinct family. The close affinities with the Arietidæ shown by the young, however, and the intermediate characters exhibited by the agassiceran series render such a classification unnatural and undesirable.

The loss of the keel and flattening of the abdomen in the old has no parallel in the normal forms of the Arietidæ, so far as known.[1] It must be remembered, however, that this modification, together with its correlative decrease in the lateral diameter of the whorl, is a fulfilment of the series of geratologous transformations.

First Subseries. — There are two subseries; one, the *oxynotum* subseries, with comparatively smooth shells, as in the less involute and stouter varieties of *oxynotum*, and one, the *Greenoughi* subseries, which has highly developed folds. Both of these series progress in the amount of involution. The less involute *Oxyn. oxynotum*, the somewhat more involute *Oxyn. Simpsoni*[2] and the still more involute *Oxyn. Lymense* of the first subseries are parallel with *Oxyn. Greenoughi*, *Guibali*, and *Lotharingum* of the second subseries. According to most authors, we could legitimately consider that the first three were only varieties of one species, though very few would be willing to join the last three under one specific name. The sutures of the adults of the *oxynotum* subseries are very close together, reminding one of the approximate sutures in the oldest stages of the individual in other genera. The pointed lobes and broad saddles, the short abdominal lobe and long finger-like marginal lobes and saddles, remind us also of the senile peculiarities of the sutures of *Cor. trigonatum*. The increase in number of auxiliary lobes and saddles and the general aspect of the sutures are, however, upon the whole additional complications, and therefore progressive characteristics.

Second Subseries. — The gradations are uninterrupted from *Greenoughi*[3] to *Lotharingum*. The descriptions of the species show that the principal differences consist in the increasing involution of successive species, and a correlatively smoother and more compressed form of whorl.

The young of *oxynotum* and *Greenoughi* resemble closely the young of *Agas. striaries*. There are, however, no intermediate forms between the latter and these two species which would enable one to verify this relation of the younger stages. Whether *Oxyn. oxynotum* or *Agas. striaries* gave rise to *Oxyn. Greenoughi* cannot be decided at present, owing to this deficiency in the evidence; but that both these forms came from the same common stock, and that this stock was *Agas. striaries*, seem quite probable.

Oxyn. Guibali, the next species of this subseries, bridges the gap between *Greenoughi* and *Lotharingum*. The nealogic characters of *Oxyn. Lotharingum* also show that this species must have been derived from *Guibali*. *Lotharingum*, like *Ast. Collenoti* and other terminal forms of series which have marked geratologous characters, is the smallest form of its own genetic line.

[1] Pl. x. figs. 24 and 31. [2] Summ. Pl. XIII. fig. 11. [3] Summ. Pl. XIII. fig. 13.

Oxyn. Oppeli[1] is a remarkable form, apparently a direct descendant of *Greenoughi*, which alone survived in the Middle Lias.

NOTE. — I have so far found but few specimens of the Arietidæ which could not be identified or properly placed in some genetic series. Two anomalies are in the Museum at Stuttgardt, and both were found in the Angulatus bed. One is somewhat similar to the larger forms of *Cal. carusense*, and is labelled *Amm. bisulcatus*. It has a very broad abdomen, the sides of the whorl divergent, the pilæ well developed, geniculæ prominent and straight. The keel is low and angular, and two sulcations on either side stretch to the incurved edges of the abdomen and these edges form two ridges as prominent as the keel itself; the sutures are similar to those of Vermiceras. It may be an extreme form of Caloceras, allied to *Cal. Haueri*, but is apparently not allied to *laticostatus*, Quenst.

The other specimen is labelled *Amm. nodosaries*, Quenst. It resembles *Agas. Scipionianum* in the pilæ and tubercles, the absence of channels, prominent keel, and helmet-shaped outline of the whorl in section. The superior lateral saddles are narrow and deep, the superior lateral lobes also very narrow, long, bifid, and deeply divided by a terminal marginal saddle. The inferior lateral saddles are deep, and occupy nearly the entire breadth of the sides of the whorls, and have deep, rounded marginal saddles.

In the Museum of Amherst, Mass., there is also an enormous shell, which had reached the large size of 600 mm. Though undoubtedly very old and much compressed, it had not yet suffered the loss of its keel, which is plainly apparent, nor the pilæ, even on the extreme outer whorl. The three outer whorls alone are preserved, the centre having been destroyed. The pilæ are about 20 mm. apart on the outer whorl, and have depressed folds. They are more prominent and about 10 mm. apart on the second inner whorl, and about 5 mm. apart on the innermost whorl. No geniculæ or tubercles were apparent, but the specimen would require cleaning before this could be decisively stated. The pilæ were slightly bent forward, and fold-like, as in Caloceras. On the umbilicus were two fossil shells, said to be *Plagiostoma gigantea*, and the locality where it was found was Dorsetshire, England. The outer whorl was 110 mm. in the abdomino-dorsal diameter, and the slow increase and evidently large number of whorls in the full grown shell, as well as the rotund form of the sides of the whorls and the slight amount of involution and extremely discoidal aspect, indicated a species of either Caloceras or Vermiceras.

[1] Summ. Pl. xiii. fig. 16.

III.

GENESIS OF CHARACTERISTICS.

ANAGENESIS,[1] OR THE GENESIS OF PROGRESSIVE CHARACTERISTICS.

THE introduction of the peculiar pilæ and single channelled abdomen in Schlotheimia, which occurred in the earlier species, must be regarded as a progressive complication, since it is not only a new characteristic, but it is correlative with constant progress in the amount of involution, and with the advent of species having more compressed, more involute and sub-acute whorls. The wæhneroceran series introduces the observer to Schlotheimia by its intermediate modifications when one begins with the radical stock, Psiloceras.

Undoubtedly the steady increase of involution in successive species of the psiloceran, wæhneroceran, and schlotheimian series is, like the similar phenomena of other series, to be regarded as progressive. This is clearly shown, both by the steady increase of size in individuals throughout each series, and also by the fact that these changes are in accord with the general progression of the whole group.

The younger stages, as we have remarked above, were closer coiled during the Mesozoic than in the Paleozoic, and the adult forms were more involute as a rule in the Trias and Jura, than in the earlier geologic periods. The genesis of this progressive character independently in each series may be seen by examining the different series in the four summary plates, and we need not allude to it again in this chapter. It is also interesting to note, that the most exact parallelisms in this respect are to be found between the series, which are widely separated. Thus the extreme aberrant forms of the family, namely, Schlotheimia, Wæhneroceras, the radical Psiloceras, and the opposite extremes of the group, Asteroceras and Oxynoticeras, all possessed highly involute compressed whorls.

Neither of the first three had any species with quadragonal whorls; the shells are all modifications of the helmet-shaped or secondary radical form. There is an approximation to the subquadragonal in the most discoidal species, *Schlot. catenata* and some others, but this is not very noticeable, and the absence of geniculæ in the pilæ confirm this conclusion. These series, therefore, can be placed in strong contrast with the more normal species of the caloceran series, in which the quadragonal form of whorl and its correlated characters played a prominent part. The acmic species of the progressive series of the Arietidæ were these pilated and tuberculated quadragonal whorls. In the development of the individual, also, the quadragonal form and tubercles are the last characters added by progressive growth, and were primarily of ephebolic origin.

[1] Ἀνά, upwards; Γένεσις, descent by birth.

Cal. Johnstoni was at first smooth, then ribbed, and the ribs had a peculiar fold-like character, and they appeared in this succession in the young of all the remaining series. The keel was added to these in the adult of *Cal. tortile* after the pilæ were developed. The adult of *Cal. laqueum* had the keel, and added also faint channels and in one variety the tubercles.[1] If we are right in referring *Cal. Deffneri*[2] to this series because of its sutures, then the terminal species of Caloceras had a very highly accelerated development, producing the quadragonal form, keel, channels, complete pilæ, and tubercles at nearly the same stage of growth as in *Ver. ophioides*.

In the development of the young of *Ver. Conybeari*, the succession of characters was similar,— first a smooth whorl, then fold-like psiloceran pilæ, then keel, then channels, then true pilæ, which often became tuberculated. In *Ver. ophioides*, a tuberculated species with highly accelerated development, it is difficult to determine whether the keel was developed before or after the channels, since they appeared almost simultaneously.

In the varieties of *Cal. laqueum*, we found the forerunners of all the rounded, quadragonal, keeled, channelled, and tuberculated forms of Vermiceras. The variety which led into *Ver. spiratissimum* had no tubercles, and could be called quadragonal, though it had only a slight keel and no channels, or at most very faint bands of depression on either side of the keel. In *Ver. spiratissimum*, these characteristics are fixed within narrower limits of variation, the keel, channels, and quadragonal form were invariably present in adults, but better defined in some than in others, and no variety with tubercles has yet been discovered. In *Ver. Conybeari* also the characteristics above mentioned were more invariable, but here we found numerous adult individuals with tubercles on the pilæ, and varieties which produced all these advanced characteristics, including the tubercles in some cases, at a very much earlier age than in other species. Lastly, *Ver. ophioides* is always tuberculated, channelled, and keeled in adults, though, as shown by its young, evidently derived from those individuals of the tuberculated variety of *Conybeari* which did not produce these same characteristics at so early an age.

In the arnioceran series, the keel appeared in the young before the channels, and also previous to the development of pilæ. This is the case in *Arn. miserabile*, and in the derivative *Arn. semicostatum*. This is in strict accord with an independent descent from the smooth Psiloceratites, but not with a supposed derivation from any intermediate caloceran or plicated form of Psiloceras. The pilæ appeared in the growth of an individual of Caloceras before the keel,— a condition due to the fact that the young remained, as previously explained, very similar to a plicated keelless Psiloceras during the earlier stages of development. The channels were first apparent in the adults of certain varieties of *Arn. semicostatum*, and in some other species of Arnioceras they became of specific value.

[1] This progression was much fuller in the species of the Mediterranean province (see Summ. Pl. xi. fig. 17–19), showing the correlations of the development of the individual and evolution of forms in the series better than in Central Europe.

[2] Summ. Pl. xi. fig. 21.

There is a similar succession in the evolution of the varietal and specific characteristics of the series. Thus, in Plate II., Fig. 10, 11, and 15 represent the extreme varieties of *Arn. semicostatum*, the former with immature pilæ without channels, the second with well developed pilæ without channels, and the third with well developed pilæ and distinct channels.[1] The young of *Arn. tardecrescens*, Fig. 19, shows that the derivation of this species was probably from the unchannelled forms of *Arn. semicostatum* similar to Fig. 11. The same is true of *Arn. Bodleyi*, with reference to *Hartmanni*, as is shown by comparing the young of the former, Plate II. Fig. 23, with the adult of *Hartmanni*, Fig. 17, which had very slight channels even in the adult, and this is still more apparent in the involute flattened form of Fig. 24, in which the channels were earlier developed. The close connection of all its characters, both of young and full grown, with its immediate ancestor, forbids us imagining an independent descent from a variety of any other species than *Hartmanni*, and the evidence is strong that it had no descendants beyond its own species. The channelless variety of *Arn. falcaries*, Fig. 26, gives similar evidence of its genetic connection with the channelless varieties of *Arn. Hartmanni*, or if this is doubted, a more direct connection with *Arn. semicostatum* may be claimed; but certainly there is no evidence for any connection with the channelled varieties of *semicostatum* or *Hartmanni*.

The pilæ began with psiloceran-like immature folds, after the keel appeared in the arnioceran varieties of *Cor. kridion*, and before the keel in the more accelerated development of other varieties of the same species. In some forms the pilæ were completed and became tuberculated before the channels appeared.[2] This same confusion with regard to the time of the appearance of characteristics with relation to each other is a peculiarity of highly accelerated species, as before noted in *Ver. ophioides*.

Such observations are of importance, since they enable us to understand that characteristics do not necessarily develop with invariable regularity. The usual order of their succession may be in a measure changed, or even reversed, when acceleration takes effect upon one character more than another. So far we have found this occurred only in species where all the principal characters of the series were undergoing exceptional acceleration.

The common form of the younger stages of all the Ammonitinæ during the goniatitinula stage is shown in the plates.[3] The depressed goniatitic helmet shape was succeeded in Psiloceras by a laterally flattened helmet shape. In Caloceras the same form was succeeded for a very prolonged period, in species with flattened abdomens, like *Cal. carusense*,[4] by a stage in which the abdomen became broader and the sides slightly divergent. In *Arn. ceras*, as in *Cal. carusense*,[5] this often occurred at a much earlier period, replacing entirely the psiloceran helmet

[1] By accident these specimens were all of different sizes. Thus they give false impressions. Although fig. 15 is older and larger than the others here figured, my observations were made on specimens of similar size and age.

[2] Pl. iii. fig. 9, 20

[3] Pl. i. fig. 4 a, for *Psil. planorbe*; pl. vi. fig. 7, for *Cor. Sauzeanum*; also in Embryology of Cephalopods.

[4] Pl. ii. fig. 1, 2.

[5] Pl. i. fig. 15.

shape, — a fact accordant with the more specialized structure and more accelerated development of the species in this genus.

In Arnioceras[1] the goniatitic helmet shape was replaced by a purely psiloceran helmet shape on the third whorl; and this was retained throughout life in *Arn. miserabile*,[2] but lasted for a more limited period in *Arn. semicostatum*,[3] and was then followed by a flatter and broader abdomen, the sides becoming slightly divergent, as in *Arn. obtusiforme*;[4] and this condition was often maintained throughout the adult stage.

The broad abdomen and divergent-sided whorl, which came out in only a few species of Vermiceras and Arnioceras, and was not very strongly marked in them, became in Coroniceras characteristic of the young at an early stage.[5] It is a significant fact favoring our theory, that in the arnioceran-like forms of *Cor. kridion* it did not replace the more compressed whorls of the arnioceran ancestor until a late stage of growth. In other species of Coroniceras, however, the broad abdomen and divergent-sided whorl replaced the laterally compressed, helmet-shaped whorl inherited from Arnioceras, as in *Cor. latum*.[6] All the species of Coroniceras did not have this stage. It was in its turn more or less replaced, in some of them, by the acceleration of other characters, as will be shown farther on.

The law of succession in anagenesis, therefore, is, that progressive species in each separate genetic series were the direct descendants of progressive varieties or forms. The facts consequently are in strict accord with the theory of descent with modification, and with the law of heredity, that like tends to reproduce like.

Coroniceras was not derived from *Arn. semicostatum* directly, but indirectly, through the more highly specialized forms of *Arn. kridioides* and *Cor. kridion*. It was not the varieties of *Cor. kridion* with arnioceran characteristics most completely developed which led into *Cor. rotiforme*, but those with divergent-sided and highly specialized pilæ, keel, and channels. So in *Cor. rotiforme* with reference to *Cor. latum*, and also in this last with reference to *Cor. Bucklandi*. These are the purely progressive forms; and their connection with ancestral species occurred through progressive varieties.

Catagenesis,[7] or the Genesis of Retrogressive Characters.

Many large specimens of the species noted in the preceding remarks had narrow abdomens, and the sides converged outwardly. Thus, in what is often mistaken for the full grown adult stage of Caloceras an acute helmet shape appeared, as in some varieties of *Cal. Johnstoni*, *tortile*, *Liasicum*, and *nodotianum*. This was certainly not, as usually stated by paleontologists, due to a retention of the psiloceran form. It took place after the intermediate or progressive stages in which the abdomen had become widened, more or less flattened, and the sides

[1] Embry. Ceph., pl. ii. fig. 8, 9.
[2] Pl. ii. fig. 4–7.
[3] Compare above with *semicostatum*, pl. ii. fig. 10 and 15.
[4] Pl. ii. fig. 8.
[5] Pl. iii. fig. 22 a; pl. iv. fig. 1; pl. vi. fig. 6.
[6] Pl. iii. fig. 20.
[7] Κατά, downwards; Γένεσις, descent by birth.

gibbous;[1] that is, after the quadragonal whorl had appeared in the development of the same individual.

We have also shown that in every series similar changes took place in the geratologous species, and were accompanied by a correlative series of retrogressive pathological changes in the keel, channels, pilæ, tubercles, and sutures. The convergence of the sides is, therefore, a retrogressive character when it occurs after the gibbous or quadragonal whorl has appeared either in the evolution of the series or in the development of the individual. In Psiloceras a slight convergence of the sides of the whorls was present, and was a primitive character of the helmet-shaped whorl, and this occurred also in *Arn. miserabile*, and in the nealogic stages of other forms of the Levis Stock. Such characters in the individuals of radical species occur before the quadragonal whorl is developed, and in connection with primitive radical characteristics and forms which will not be confounded with geratologous characteristics and forms by any close observer, if he have sufficient materials for study.

There is a true senile degeneration in the old age of some forms, which is apparent in the marked convergence of the sides and sub-acute abdomen of the old whorl, even in such discoidal species as the *Psil. pleurolissum*.[2] This, as a degenerative character, was reproduced at an earlier nealogic stage in the involute species, as may be seen by comparing these figures with those of the involute form *Psil. mesogenos*.[3] The same law holds also in Wæhneroceras. In Schlotheimia it becomes apparent when we compare the old age of *Schlot. catenata* having smooth abdomen and convergent smooth sides, with the sides and abdomen of *Schlot. Boucaultiana* which are similar in the nealogic and ephebolic stages. Such characters are therefore retrogressive, and indicate decline in so far as the forms of the whorls, the pilæ, and the channels are concerned, notwithstanding the fact that they are often correlated with the progressive character of greater involution, and appear in the nealogic stages of some (geratologous) species. It will be observed that, in *Caloceras* from the Mediterranean province,[4] the compression of the whorl and other degenerative characteristics occurred without a proportionate increase of involution, and that the same phenomena occurred also in Coroniceras.[5]

The convergence of the sides was evidently a geratologous stage in Caloceras[6] and Vermiceras, but in some species of Arnioceras a slight tendency of the sides to become convergent in the adult stage was noticed. In *Arn. semicostatum*[7] and *tardecrescens*,[8] it occurred in the adult stage of varieties with well developed keels, channels, and pilæ, but not so noticeably in the lower varieties of these species with less accelerated development. In *Arn. Bodleyi*, where it was found in all varieties,[9] it is noticeable at an early stage, and in the still more highly accelerated development of the involute variety[10] it appeared very much earlier than

[1] See also p. 59.

[2] Wahner, Unter. Lias Mojsis. et Neum., Beitr., III, pl. xxvi, fig. 4 a, b.

[3] Wahner, fig. 3, same plate.

[4] Summ. Pl. xi. fig. 17-19.

[5] Summ. Pl. xii. fig. 14, 15.

[6] Wahner, in the work quoted, figures several species of this genus in their senile stages.

[7] Pl. ii. fig. 15.

[8] Pl. ii. fig. 19.

[9] Pl. ii. fig. 23.

[10] Pl. ii. fig. 24.

in any other species of this genus. Thus a high degree of specialization in the development of keel, channels, and pilæ is correlative with decidedly retrogressive changes.

In Coroniceras, the Bucklandi series exhibits very decided changes in both the individuals and the species. The tubercles were first lost during the old age of the individual, the sides became more convergent even in *Bucklandi* itself, the abdomen narrower, the pilæ reduced to folds and bent like those of the adult of *Ast. obtusum*, the channels shallow and finally almost obsolete, and the keel, even though becoming apparently more prominent on account of the convergence of the sides and obsolescence of the channels, was really not so sharp or well defined.

Cor. orbiculatum exaggerates all these old age changes, becoming narrower on the abdomen, with more convergent sides, and this convergency began even in the ephebolic period in some examples. Similar changes occurred very late in the life of individuals in the next subseries. Thus even the convergency of the sides was not found in the adults of *Cor. rotiforme* in many specimens, and is but slightly developed even in the extreme old age of some of this species, and in its predecessor, *Cor. kridion.* This characteristic is, however, observable habitually in the adults of *Cor. lyra.* These lead into *Cor. Gmuendense* of the same series, which had very convergent sides in the adult, and was often also destitute of tubercles. The last were confined to the earlier stages of this species, and in old age the changes were very marked and rapid. The extreme variety of *Cor. trigonatum* inherited convergent sides, smooth and half obsolete pilæ, narrow abdomen, shallow channels, and elevated keel, so early that we may say with confidence they all appeared in the ephebolic period.

The old whorls of *Cor. Gmuendense* and *Cor. trigonatum*[1] have the sides of the whorls convergent and a decidedly trigonal form. This form is correlated with obsolescing pilæ and a marked though late decrease in the sutures. These lose the characteristic prominence of the second lateral saddle, which is a progressive characteristic in this genus. All the lobes and saddles also become broader and decrease in proportionate length, and finally in extreme age the abdominal lobe is decidedly shortened.[2] In the Museum of Comparative Zoölogy there was also a much smaller specimen,[3] in which the same stage of decline had been reached at an earlier age. The law of succession was, therefore, quite different from that which governed the inheritance of progressive forms. The most retrogressive of the bucklandian varieties were those which were most closely connected in every way with *Cor. orbiculatum.* The genetic connections also between *Cor. rotiforme* and *Cor. lyra* were traceable only through those varieties of *rotiforme* which had the most convergent sides and the most retrogressive pilæ, tubercles, etc. This also holds for the connections between this last and *Cor. Gmuendense* and *Cor. trigonatum.*

The law of succession in catagenesis, therefore, is that retrogressive species in each separate genetic series are the direct descendants of retrogressive varieties or forms. The facts consequently are in strict accord with the theory of descent with modification. The law

[1] Pl. v. fig. 8, 9; pl. vi. fig. 3; pl. vii. fig. 1. [2] Pl. vii. fig. 1. [3] Pl. vi. fig. 1, 2.

of heredity, that like tends to reproduce like, cannot be assumed with regard to the transmission of senile characters, since these were probably not directly transmitted from one species to another. Nevertheless, the tendency to degeneration must have been inherited, if we can judge by the appearance of retrogressive characters at earlier stages in successive species.

In the three geratologous series, Asteroceras, Agassiceras, and Oxynoticeras, we find the same laws of anagenesis and catagenesis. The psiloceran-like or progressive species were the immediate progenitors or proximate radicals of progressive varieties, species, and genera in the direct line of descent, but when geratologous forms began to appear, and progression changed into retrogression, there was a corresponding change in the radicals. Then the retrogressive forms arose from varieties which were themselves also proportionately degenerate, and had similar retrogressive and geratologous characters.

The progressive stage with divergent sides and broad abdomen, which appeared in the young of *Ast. obtusum* and was found in some adults, was suppressed, and was replaced by a modified quadragonal form in *Ast. Turneri.* This in turn was replaced by the tendency to accelerate the development of the trigonal convergent-sided whorl and its correlative retrogressive characters, the untuberculated pilæ, low broad keel, and shallow channels, in *Ast. Brooki, impendens,* and *denotatum.* The geratologous trigonal form appeared at an earlier age in each successive species, until at last in *Ast. Collenoti*[1] it took possession of the earliest nealogic stages.

The retrogression of form in the series of species may often be compared with parallel pathological series of individuals, which may be made within a single species. *Ast. stellare*[2] had dwarfed forms, much smaller than most of the healthy adult specimens of its own species. These last, though so much larger, ordinarily showed no signs of old age, while the dwarfs were completely changed by senile metamorphoses. Much smaller but similarly dwarfed specimens occurred in *Ast. acceleratum,* with even more compressed and prematurely aged whorls.[3] A remarkable series of these dwarfs, from which the two figures referred to in the notes were drawn, is to be found in the Museum of Stuttgardt. The smallest of these completely geratologous specimens is not over half the size of the largest, which itself is not of average size, as stated above. The comparison of these dwarfs with the more involute varieties of *Ast. Brooki* and the adult of *Ast. Collenoti* shows that they cannot have been connected by direct inheritance. They were evolved independently of these geratologous forms, and I am not calling upon the imagination to fill any blanks when I speak of them as homoplastic morphological equivalents of *Ast. impendens* and *Ast. Collenoti.* It can hardly be doubted that the geratologous forms, when found as dwarfed varieties within a species, are the products of the unfavorable action of the surroundings, or, in other words, that they are more or less diseased individuals. Their close parallelism in every respect with *Ast. Brooki, impendens,* and *Collenoti* shows that we can attribute with great probability the origin of all such forms to similar pathological causes.

With regard to the agassiceran series, it may be remarked that the quad-

[1] Pl. ix. fig. 10-11 b; pl. x. fig. 10. [2] Pl. x. fig. 1, 2. [3] Pl. x. fig. 3.

ragonal form, or rather an immature representation of it, occasionally occurred in some adult individuals of *Agas. lævigatum*, in which the sides were flatter than usual. In *Agas. striaries* the quadragonal form and the siphonal line or keel were more decidedly expressed, as well as the tendency to elevate the abdomen. In *Agas. Scipionianum* after the earlier nealogic stages were passed which closely resembled the full grown of *striaries*, with the exception of the thicker pilæ and somewhat deeper umbilicus, the adult showed a quadragonal whorl with a keeled abdomen and tuberculated pilæ. The old age had a smooth trigonal whorl. In *Agas. Scipionis*,[1] which is a naturally distinct form, the extreme varieties had more involute whorls, smooth pilæ, and became trigonal and smooth at an early stage.

Thus, at all stages of growth and decline, the correspondence or parallelism between the individual and the morphogeny of the series is complete.

In the second subseries of Oxynoticeras we have found that there was one species, *Oxyn. Lotharingum*, in which the whorl during the last senile stage became completely rounded on the abdomen. The sides became gibbous and narrower, thus showing a slight tendency to revert to the primitive form of the less discoidal *Agas. striaries* and *Psil. planorbe*. These similarities were also greatly increased by the appearance of senile folds similar to the primitive pilations of this species and Psiloceras. The adults of the species of this subseries were also geratologous, in so far as the forms were not only much compressed and trigonal, but also smooth. The degeneration and the total loss of the hollow keel also occurred in this oldest stage. We should not be at all surprised if species should be found, and identified as belonging to this series, in which the hollow keel was either not present at any stage, or was only slightly indicated during the nealogic stages. These adults would then correspond to the geratologous stage of *Oxyn. Lotharingum*, in the same way that *Ast. Collenoti* corresponded to the old of the normal forms of *Ast. obtusum* and *stellare*.

If a tendency to the inheritance of retrogressive characters be granted, and certainly their occurrence at earlier stages in successive species makes this view seem highly probable, then the same law of replacement which produced progression would now act upon successive organisms so as to produce retrogression. The observed phenomena indicate the direct replacement of the characters of progressive ancestors by degenerate characters, which were first observable in the old age of these ancestors themselves. If there had been in most cases simply a mass of degenerate forms, without any definable evidences of successive gradations, as in the famous instance of the Magnon examples of distorted Planorbidæ, it would be possible to say at once that the parallelisms of the geratologous period, with retrogressive characters in what we have called geratologous species of the same series, were purely homoplastic correspondences. On the contrary, the gradations are perfectly well marked, as we have described them above and in the Introduction to this monograph, and the replacement of progressive characters by the geratologous takes place in strict accordance with the law of acceleration in heredity.

[1] Summ Pl. xiii. fig. 8.

We can make our meaning plainer by comparing this cycle to an imaginary cycle in the history of architecture. The buildings of primitive times would necessarily be substantial, plain, and suitable to the limited wants of the people; then, as wealth increased, the architects would respond with showy structures, having more ornamentation, and more complicated interiors. We will suppose that they had begun to place most of their ornamentation in and upon the central parts of the modern buildings, and, out of deference to inherited canons of taste, had always, even in the most florid acme of their progress, adhered to this law, leaving foundations primitive in style and uppermost portions always unadorned. As time progressed, these structures would assume vast proportions, and would be built in ever increasing numbers, until at last the nation, having outgrown its strength, would begin to decline. The vast buildings would have to be abandoned, and smaller habitations would arise, in answer to the requirements of a poorer population. The architects, faithful to their inherited canons, but forced into simplicity, would gradually follow the decline, and record it in the structures of the decadence. They would effect this, we will suppose, by reducing the ornamentation from above downwards, thus gradually doing away with the central band of ornamentation, and also by actually lessening the height and otherwise contracting the bulk of the buildings. Primitive simplicity would thus be restored, but strong traces would still be left in the style and construction of the buildings of their having been adapted, by a process of reduction, from a previously existing period of greater size and complexity in structure. It would be possible to read in the style of the decadence, that all the buildings had come from primitive forms through the medium of a progressive period, during which the central stories had undergone the greatest modifications. This would be traceable in many surviving peculiarities of the modes of laying the courses of stone, the cutting and more elegant shaping of the interiors, etc. It would, however, be equally plain that the architecture of the upper stories had always been more or less degenerate, and also that their degenerate forms had replaced the progressive ornamentation and forms of the central parts of buildings during the decadence of the nation.

This would quite accurately represent the reversion of the forms we have been tracing, so far as the purely retrogressive series were concerned. We can understand their structural degeneration and their positions as the latest evolved forms of each series upon the same grounds, since they would necessarily stand at the termini of the series. Their degenerate characters could not be said, perhaps, to have been inheritable, any more than the architecture of the buildings alluded to above, but a tendency to degeneration caused by the unfavorable surroundings would have to be assumed. Each generation in succession, acted upon by this tendency, like the successive buildings of the decadence, would arrive earlier at a stage when senile characters would replace the progressive characters of the adult period. The geratologous characters are, however, in greater or less degree, reversions due to the loss of the progressive characters of the adult; and this is equally true when the characters of geratologous species are compared with those of the simple, generalized radical species from which the group originated. That these reversions are the remnants of the earliest acquired structures and physiological powers seems perfectly plain, in view of the well known case of the return of childish structural peculiarities and memories in man after his adult peculiarities and powers have been exhausted.

The peculiarities of series which, like Oxynoticeras, presented certain highly progressive or novel characters in combination with retrogressive characters, have been sufficiently described in these pages. It only remains to add, that such types are not uncommon in the different families of the Ammonoids and Nautiloids, and therefore they must not be considered as unique.[1]

Differential Characteristics.

The differential characteristics have already received a considerable share of attention, but it still remains to review them in each series. The diagnosis of each genus is necessarily deceptive, in so far as it gives false views of the invariability of the differentials.

The psiloceran series presented an altogether peculiar helmet-shaped whorl, with more decided congeners in the Trias than in the Lias. The involution increased in successive species, and in correlation with this tendency the complication of the sutures also became greater.

The marked differentials of Wæhneroceras, which are transitional from the plicated forms of Psiloceras to the series of Schlotheimia, the retention of the psiloceran form and sutures, the geniculess pilæ, and the nascent channel on the abdomen are so obvious, that they need only be mentioned and attention again be drawn to the very remarkable fact, that, as in Psiloceras, this series departed from the discoidal radical, and exhibited increase of involution in successive species.

Starting from *Psil. planorbe*, var. *plicatum*, as the radical discoidal progenitor of the remainder of the Plicatus Stock of the Arietidæ, we find that the compressed helmet-shaped whorl was exchanged in *Cal. Johnstoni* for a more gibbous rounded whorl, but the discoidal character of the shell was maintained, and the pilæ did not have geniculæ or tubercles except in the highest species. There was also a tendency in *Cal. Johnstoni* towards a complication of the margins of the sutures through the deepening of the lobes and saddles, which was especially noticeable in *Cal. nodotianum*. This increase of complication took place especially in the marginal lobes, and there is a backward trend of the auxiliary lobes and saddles, which causes a close likeness between the tendency of the progression in this genus and that of the involute forms of Psiloceras. In Caloceras, however, it

[1] We can mention as similar cases the following: Subclymenia with its ventral lobe and ventral siphon, a true Nautiloid of the Trigonoceratidæ; Pteronautilus among the Goniceratidæ with its winged aperture; Centroceras among the Hercoceratidæ with a deep V-shaped ventral lobe. Among Ammonoids there are the genera Pinnacites and Celæceras with remarkable sutures among Nautilinidæ; the Gonioclymenidæ with ventral lobes instead of continuous saddles in the Clymeninæ; Beloceras with its extraordinary sutures, and Medlicottia with its remarkable ventral lobe and first pair of saddles among the Prolecanitidæ; and a host of others.

took place independently of increase in the breadth of the whorl by growth, or of increase in the involution of the successive species.

The radical species of the laqueum subseries showed a completely arietian form of whorl. This appears in *Cal. laqueum* as quadragonal in section, with a keel, faint channels, and straight pilæ, tuberculated in one variety. This form was perpetuated in *Cal. carusense* of the Upper Bucklandi bed; the keel and ribs were, however, somewhat more highly developed in one variety of *Cal. raricostatum*. The deep narrow abdominal lobe, also a peculiar arietian characteristic, appeared in *Cal. carusense*, and was perpetuated in *raricostatum*; it was reproduced at a very early age in the last species, and in *Cal. Deffneri*. The peculiarities of the straight or curved, fold-like, and crowded pilæ are differentials of importance, which correlate with the other immature transitional characteristics of this series. The series described in the chapter on Descriptions of Genera and Species discovered in the Northeastern Alps shows that highly compressed forms with acute abdomens occurred also in this genus. *Cal. Castagnolai* had a tendency towards increase of involution, though this shell, and even the extreme form *abnormilobatum*, must still be classed as discoidal.

In the radical species of Vermiceras, *Ver. spiratissimum*, the whorl became quadragonal with flattened sides and abdomen, channels, and pilæ with arietian geniculæ. These characteristics were maintained throughout the series, becoming more intense in *Ver. Conybeari*, and inherited at a very early nealogic stage in *Ver. ophioides*. The shells remained discoidal, however, as in Caloceras, even in the largest specimens. Looking back, we see that the radical species, *Cal. Johnstoni* and *laqueum*, and *Ver. spiratissimum*, formed a series of proximate radicals, in which there was a regular gradation in the intensity of expression of the different characters after they were once introduced, culminating in the quadragonal form and arietian sutures of *spiratissimum*. We could, therefore, with perfect propriety associate these three forms in a distinct series, and they would then be related by gradations parallel with those occurring in either Caloceras or Vermiceras, though composed solely of radical species. This is possible because of the discoidal forms of the species of the vermiceran branch of the Plicatus Stock, all of which have numerous whorls, and retain the very long living chambers, at least one volution in length, of the Psiloceran Stock.

The differentials of the Levis Stock had a more abrupt beginning, the transitions from *Psil. planorbe* to the first form, *Arn. miserabile*, or the lower varieties of *Arn. semicostatum*, having been less complete, and the forms separated by a certain interval of time. There was also a much quicker transition from the helmet-shaped whorl to the quadragonal. This took place in the first species of the first series, and this radical, whether the one or the other of the two mentioned, is keeled in adults. In *Arn. semicostatum*, also, the pilæ assumed in most varieties the peculiar straight, trenchant aspect, and the prominent and square geniculæ, which are characteristic of this genus. In *Arn. miserabile* and *semicostatum* the keelless, smooth form of *Psil. planorbe*, var. *leve*, was retained so long in the growth of some individuals that it became characteristic of some varieties, and in other species of this series, though less important, it is always found as a marked characteristic of the umbilicus. The sutures are also peculiar in the simplicity of their marginal outlines and proportions, and these peculiarities remain constant.

In the adult and young of some varieties of the radical species of the coroniceran series, *Cor. kridion*, a form appeared having strongly divergent sides, lyre-shaped tuberculated pilæ, sutures with deep abdominal lobes and prominent inferior lateral saddles, while in the young of other varieties there was a nearer approximation to the young of Arnioceras. In all the succeeding species of the series except *Cor. Sauzeanum*, a direct descendant of *kridion*, this divergent-sided, broad-abdomened whorl was found at an early nealogic stage, having the same lyre-shaped pilæ, deep channels, and arietian sutures.

On looking back, we see that *Arn. miserabile, semicostatum, kridioides,* and *Cor. kridion*, may be considered as a series in which *kridion* was a terminal species with an accelerated development in some varieties, and that from this last highly specialized form arose, as we have stated above, the species of the highly progressive coroniceran series, the typical acmic series of the Arietidæ. The arietian differentials, the long abdominal lobe and prominent inferior lateral saddles, and the combination of these with the quadragonal whorl, highly developed keel, channels, and geniculated and tuberculated pilæ, were barely indicated in the caloceran series, and appeared in perfection only in the higher species of Vermiceras. Although they were generated with great rapidity in the arnioceran series, yet they were present in full perfection and were comparatively constant only in the species of the coroniceran series, which, as we have said, were directly derived from *Cor. kridion*, a species in whose adults these characters first appeared in their final arietian shape and proportions.

The remaining series, which can be properly called the geratologous genera of the Levis Stock, form a distinct group composed of a central series and three lateral series, offshoots from the common radicals, *Agas. lævigatum* and *striaries.* The necessary mode of arrangement places Asteroceras on the left, Agassiceras in the centre, and Oxynoticeras[1] on the right. The structural characters also agree with such an arrangement. No progressive linear series can be formed out of the radical species of these series, as in the genera mentioned above the arrangement is necessarily radiatory like the spokes of a fan. The differentials of the adult of the radical species *Agas. lævigatum* were quite constant in the species; we refer to the discoidal smooth whorls and fold-like pilæ, the simple but arietian sutures with their deep abdominal lobe and prominent inferior lateral saddles. The shell also had fewer whorls and shorter living chambers than the adult of *Psiloceras planorbe*. In *Agas. striaries* there is close similarity to *lævigatum*, but very distinct striæ and a larger size. In *Agas. Scipionianum*, the prominent keel, channelless abdomen, pilæ, and tubercles were abruptly introduced, and were the principal differential characteristics which distinguished the series from all others in the Arietidæ. This abrupt introduction indicates the former existence of intermediate forms which remain to be discovered.

It may be that a true hollow keel may have appeared in *Scipionianum*, as is

[1] Summ. Pl. xiii. and xiv.

described by Quenstedt, though we failed in getting positive evidence of anything more than a large solid keel. This, though distinct from the usual arietian structure of this part, had not the black layer above the siphon which distinguishes the typical hollow keel of some species in Oxynoticeras.

In the well known species, *Ast. obtusum*, the radical of the asteroceran series, the keel was broad and low with shallow channels, and the pilæ were fold-like with either small tubercles or none, and the sutures in adults were like those of Coroniceras. The changes in course of growth from the divergent-sided to the convergent-sided whorl were rapid in some varieties, though in others the broad-abdomened and gibbous-sided whorl was retained even in adults.[1] In *Turneri*, keel, deep channels, and quadragonal whorls were correlated with peculiarly flattened and broad sides. These species showed a tendency to specialization parallel with those of Coroniceras; nevertheless, in varieties of *Turneri*, and in the succeeding forms *Brooki* and *Collenoti*, the differentials, with the exception of the keel and sutures, tended to become extinct in consequence of the prepotent influence of heredity in the transmission of geratologous characters.

Parallel phenomena were also observed, as stated above, in individuals of preceding series during old age, when the adult differentials disappeared, and also in the adult stages of certain geratologous species of the progressive Coroniceran series, *Cor. corbiculatum*, *Gmuendense*, and *trigonatum*, in which the quadragonal form, tubercles, etc. were similarly affected.

In *Oxyn. oxynotum*, the differentials which enabled us to separate this from *Ast. impendens* and *Collenoti* were the hollow keel and the sutures. The hollow keel appeared, as has been shown; in *Oxyn. oxynotum*, but it was filled with layers of shell, though in other species it was really hollow, and appeared during the nealogic stages. The increase of involution was correlative with the steadily increasing breadth and flatness of the sides, and an intensified trigonal outline. *Oxyn. Lymense*[2] was more involute, more acute, and smoother even than *oxynotum*. The differentials of the Greenoughi subseries were less important characters. They consisted of a stouter form of whorl, which was more like that of *Agas. Scipionianum*, and fold-like pilæ. These are less pronounced in the higher species, *Oxyn. Guibali* and *Lotharingum*, in consequence of the prepotency of the geratologous tendencies shown in the more compressed, more involute, and smoother whorls.

The genera of the Lævis Stock had, as a rule, shorter living chambers, usually less than one volution in length, and differed in this respect from the genera of the vermiceran branch of the Plicatus Stock.

The important fact should be noted here, *that in all individuals and series the sutures were the last to yield to degeneration, and the characteristics of these are considered by most authors as the pre-eminent differentials of the Arietidæ.*

In estimating certain characters as differentials, we mean only those which can be artificially separated and contrasted in different series of the same family, and which may be therefore peculiar to some one series or genus. When a more specialized series is contrasted with an ancestral radical species or series, then

[1] Summ. Pl. xiii. fig. 2.
[2] Summ. Pl. xiii. fig. 12.

the equivalent or parallel characters are often differentials. Thus, the keel was varietal in the lower species of Caloceras as compared with Psiloceras, and became a differential in the higher forms. The same held good for the quadragonal form of Vermiceras, and its arietian sutures. A very instructive comparison may be made between the cretaceous angulatus-like forms of Hoplites, and their approximately exact morphological equivalents in Schlotheimia, and yet no one well acquainted with their development and genesis would hesitate to use the channelled abdomen, pilæ, and form in both genera as true differentials. These characteristics do not indicate affinity between these cretaceous forms and Schlotheimia.

Vaeck, in his article upon the hollow keel of the Falciferi,[1] makes somewhat similar statements, and gives details showing the presence or absence of this peculiarity in different species of Harpoceras. Though not prepared to agree that these forms really belong to the same genus, it has been evident to us for some time that the hollowness of the keel was a characteristic which was homoplastic in several distinct series, and it is not a mark of genetic affinity with Oxynoticeras, unless accompanied by other characteristics showing that the descent of the species possessing it was probably traceable to Oxynoticeras. Unless the nealogic stages show traces of this ancestry, it is not in itself a differential characteristic sufficient to bind the forms possessing it into the same genus.

The development of the keel, channels, and pilæ in Arnioceras shows that they were new modifications in this series, as they were also in Caloceras. The keel, after its appearance in varieties of *Arn. miserabile*, became of specific value in *semicostatum*, and remained thereafter constant. The straight pilæ and peculiar geniculæ were also first of varietal value in *miserabile*, and then approached specific importance in *semicostatum*, and became constant in other species. The channels were variable in all the species in which they appeared, except one of the most highly specialized, *Arn. ceras*. We have not, however, seen many specimens of this species, and it is not unlikely that this form may, upon further research, prove to be as variable as the more generalized species.

[1] Bemerk. u. d. hohlen Kiel d. Falcif., Jarhb. geol. Reichs., XXXVII., 1888, p. 311.

IV.

GEOLOGICAL AND FAUNAL RELATIONS.

Remarks.

THE point of view in this chapter naturally rests upon the assumed existence of a persistent series of discoidal shells which formed a continuous radical stock for all the Ammonoidea, beginning in the Silurian and having their last representative in Psiloceras of the Planorbis bed. This, as we have said above, was closely allied to Gymnites of the Trias, and enables us to connect all the Ammonitinæ of the Jura directly with the more ancient primary radicals of the central trunk of the genealogical tree. The chronological distribution of this trunk of forms must be actually represented by more or less broken lines, until all the gaps now existing between the different systems or periods in the earth's history have been filled by the progress of discovery.

The surviving genus of the trunk stock, *Psiloceras*, consists of a series of species which we have called the Radical Stock of the Arietidæ, which became in the Lower Lias the generator of new series of peculiar modifications, spreading out from *Psil. caliphyllum* or *planorbe* like the spokes of a fan, each genetic radius being composed of a separate series of modifications or species. We have given this classification above, and shown that the chronological distribution of the species in each series is in accord with their positions in the series; it now remains to apply the same classification to the solution of the problems of chorological distribution.

There are many more or less complete lists and monographs of local faunas in the province of Central Europe, and extensive collections, which afford a solid basis for comparison. The preliminary work of Prof. Jules Marcou,[1] in synchronizing the minuter subdivisions of the Jura in Central Europe, was completed by the more extensive application of the same principles by Oppel,[2] who visited, studied, and synchronized the faunas of the different localities, and identified the same beds in a large part of this province. The illustrated publications of Hauer,[3] Neumayr,[4] Wähner,[5] Geyer,[6] and Herbich,[7] have also thrown a strong light upon the peculiarities of the faunas of the eastern part of Europe, particularly the basin of the Northeastern Alps. All of these researches, and many others not mentioned, have made still further advances in the classification of the chronological relations of the minuter subdivisions or beds practicable.

[1] Roches des Jura, pp 23, 162, 173, *et seq.*

[2] Die Jura-Format. Eng. Frankr. u. d. sudwestl. Deutschl. Wurtt. Jahresb., XII. – XIV., 1856

[3] Die Cephal. a. d. Lias d. nordostl. Alpen, Denksch. Akad. d. Wissensch., Wien, XI

[4] See note 2, page 86

[5] Mojsis. et Neum., Beitr., II – VI

[6] Ceph. heirl. Schich. Abh. k. k. geol. Reichsans., XII.

[7] Das Széklerland, Mitt. Jahrb. d. k. ungar. Anst., V, Pt. II.

The principles of geographic distribution first announced by Marcou[1] have been carried further by Neumayr,[2] who has defined the homozoic bands of life in the faunas of what he has denominated the Mediterranean, Central European, and Russian provinces.

Neumayr, in his article "Ueber climatische Zonen der Jura und Kreidezeit,"[3] describes the boundary between the Mediterranean and the Central European provinces. This line, as far as traced by him, begins at the east between the Donetz and the Crimea, at about 47° north latitude, and runs thence to the easterly end of the Carpathians; thence, north-northwest to the neighborhood of Krakau; thence, southwest towards Vienna, and south of Brünn; thence, westerly to the neighborhood of Lake Constance; thence, west-southwest, and later southwest through southeastern France; thence, across the Gulf of Lyons to Spain, and across that country and Portugal to between 38° and 39° north latitude on the Atlantic. This author regards the Mediterranean province south of this line, and the Central European province north of it, as respectively parts of two homozoic bands, which encircled the earth during the jurassic period.

The Central European province was defined by Neumayr, in a general way, as including the British Islands, France, Germany, Bohemia, Moravia, and Poland, north of the line described above, and perhaps the Dobrudscha region. The Jura north of these countries was included in his Russian province, which contained Central Russia, Petschora Land, Spitzbergen, Greenland, and perhaps Vancouver's Island in North America. Neumayr quotes the works of various authors upon the fossils found in South America, and concludes that the Jura in Bolivia, Chili, the Argentine Republic, Columbia, and in Central America is probably Mediterranean. He thinks also that the few fossils found in the United states indicate the presence of a Central European fauna.

Waagen, in his "Fauna of Kutch," shows that India is a distinct basin, containing forms of the Upper Jura found in the provinces of the Mediterranean and Central Europe, besides numerous peculiar species. Steinmann is of the same opinion with regard to the fauna of the Upper Jura which is found near Caracoles in Bolivia.

We have examined a number of the latter collected by Alexander Agassiz at this locality, also several species collected by him at the pass of Tilibichi in Peru, as well as those mentioned in the chapter "Descriptions of Genera and Species" of this work, and have read Gottsche's "Paleontology of the Argentine Republic." These and other sources of information show, we think, the same history as in India; namely, that this region may be advantageously separated as the South American province on account of the number of peculiar species it contains. There are, over and above these, also a number of forms identical with those of Central Europe and the Mediterranean. We have also seen the fossils of the Upper Jura, found in California, through the kindness of Prof. Joseph

[1] Roches des Jura, pp. 71-91, 230, *et seq*

[2] Ueber Juraprov. Verh. k. k. geol. Reichsans., 1871, p. 54; Ueber unverm. auftret. Cephal., Jahrb. geol. Reichsans., XXVIII., 1878; and Jurastud., Ibid., II, 1871, p. 524.

[3] Denksch Akad Wien, 1883, XLVII., and also Geog. Verbreit d. Jurafor., Ibid., L., 1885.

Leconte, and have collected some forms in California and other localities in the United States. There are also a few species in the collections at San Francisco, but these and the fossils collected at Vancouver's Island, and described by Mr. Whiteaves of the Canadian Survey, which we have also seen at Ottawa, show a mixture of the species of the European province besides a number of peculiar forms. Though not disposed to give any final opinion at present, the facts justify the suggestion that the North American assemblage of species has a distinct facies of its own, and ought to be separated at least provisionally from the South American and all European faunas as the province of North America.

The collections so far made in the Jura show that there is a prevalence of the Arietidæ in the Lower Lias, and of the species of Perisphinctes in the Upper Jura of the South American province, whereas these are less abundant in North America. Whiteaves also shows a mixture of the species of the Cretaceous with those of the Jura at Vancouver's Island, which, together with the peculiar species found there, suggests a distinct basin for that locality as compared with the Jura farther to the south and east in the United States. The fossils so far found in the district of Atacamas, and at localities in the Argentine Republic, show that a provisional separation should be made between this region and that of northern Peru, and that two basins at least, if not more, exist in the Jura of the South American province.

Both the physical features of the distribution of the deposits and the faunas appear, therefore, to make it doubtful whether the terms Mediterranean, Central Europe, and Russia can be assumed as appropriate names for the homozoic bands of the jurassic period in America. It would be preferable to adopt for these bands the nomenclature of Marcou. Thus, the Bande[1] Homozoique Centrale of Marcou would become the Tropical Homozoic Band; the Bande Homozoique Neutrale du Nord of Marcou would become the Temperate Homozoic Band; and the Bande Homozoique Polaire du Nord of Marcou would become the Polar Homozoic Band. These bands could then be subdivided into provinces and basins according to the faunas, and the real facts of the distribution of forms more clearly shown than by using the names of European regions for that purpose.

Waagen, in his article "Ueber die Zone des Amm. Sowerbyi," has traced in a general way, following out simply the physical features of the distribution of the Jura, the following basins: I. South German Basin, consisting of Suabia, Franconia in Bohemia, and southeastern Baden "und des Randen." II. Helvetic Basin, including Switzerland, departments of Doubs, Jura, and Ain, also Rhone, Saone et Loire, Côte d'Or, Haute Saône, Haut Rhin, and Bas Rhin, and the neighboring deposits in the south of Baden. III. Mediterranean Basin, including the departments of Lozère, Aveyron, Hérault, Gard, Ardèche, Drôme, Basses Alpes, Var, and Bouches du Rhone, and suggests an Italian basin for the Southern Alps. IV. Pyrenean Basin, including the departments of Lot, Charente, Charente Inférieure, and perhaps Deux Sèvres. V. Parisian Basin, including the depart-

[1] The use of the word *zone* instead of *band* is likely to lead to confusion, on account of its employment in geology for the synchronous faunas of the same beds, and we think it ought to be avoided.

ments to the north, to which Waagen adds Dorsetshire and Wiltshire in southern England. VI. North English Basin, from Gloucestershire to Yorkshire inclusive. VII. North German Basin, including Hanover, Brunswick, and the neighborhood of Magdeburg.

We have not needed to use these divisions precisely as laid down by Waagen, but it is interesting to remark that they accord more or less completely with the observations on the faunas here recorded. Our principal interest has been, of course, in the central portion of each basin, and not in the more deficient records of outlying localities. The South German basin is as it has been given by Waagen. His Helvetic basin appears to be a natural division, with the exception of the departments of Saone et Loire, the Côte d'Or, and the Rhone. The Côte d'Or has appeared to us to be the centre of a different basin, which extended indefinitely through the departments to the westward, and also to the south until it met the fauna in the valley of the Rhone described by Dumortier. Whether such closely contiguous faunas as that of this valley and the Côte d'Or ought to be designated by distinct names we cannot pretend to decide, but that they differ materially from the point of view of the evolution of their faunas seems to us highly probable.

The faunas of northeastern France and Luxemburg, though perhaps in a distinct basin from those of Westphalia, Hanover, etc., which are properly included in the North German Basin, are all similar in so far as they contain similar residual faunas. The basin of the Rhone includes the departments mentioned as in the Mediterranean basin by Waagen, with the exclusion of the southeastern part of the department of Var, which, as shown by Dieulefait, belongs to the Italian basin. We have not been able to study any collections from Wiltshire, but the Dorsetshire fossils of the Lower Lias, though certainly presenting a very distinct facies and association of forms from those of Waagen's North English basin, have not seemed to require separation into a different basin. The fossils do not resemble those of any other fauna so closely as they do that of the rocks in the rest of England to the northeast, and, though it may be natural to make this separation, we have not required it for the immediate purposes of this memoir, and have consequently spoken of the entire region as the English basin.

The Lias in territories to the north, like Scotland and Sweden, is deficient in Ammonitinæ, and Judd[1] remarks upon the estuarine character of the deposits. At Dompau and Döshult in northwestern Sweden a few poorly preserved fossils show the presence of the bucklandian fauna. It is possible that these deposits may have a yet undiscovered fauna of Ammonitinæ distinct from more southern localities; but so far as one can see, the forms of the Swedish basin are not distinct from those of the faunas of North Germany.

Neumayr has already traced in a general way the origin of the fauna of Central Europe to the Mediterranean province, and we think a still further advance has been made practicable by the methods of constructing genetic series as advocated in this monograph, and the discovery of definable cycles in the genesis of forms. Though our conclusions have been reached under the dis-

[1] Quart. Journ. Geol. Soc. London, 1873, XXIX. p. 98.

advantages attending residence at a distance from the fields of research, the results have appeared to be sufficiently novel and suggestive to warrant publication. The results reached have been just what one might have anticipated from *a priori* reasoning upon the basis of the theory of evolution and monogenesis, but nevertheless have not been admitted without much hesitation, because of the author's natural feeling that so great exactitude in statement with regard to the relative age of faunas on the same horizon should be distrusted.

If our data have led us correctly, there are some basins in the Lower Lias which were capable of evolving new forms. These we have called Aldainic[1] Basins, because they were centres of origin for new series, and their faunas were what we have called Autochthonous Faunas. Other basins were apparently incapable of giving origin to new forms, or at any rate received all, or almost all, the forms which occupied their territory by migration from the aldainic basins. These we have called Analdainic or Residual Basins, and their faunas Residual or Analdainic Faunas. The beginning of the Arietidæ was in the Northeastern Alps, and this, being the first autochthonous fauna, was older than all others. Thence South Germany or Suabia was peopled by chorological migration, and then the basin of the Côte d'Or. Thus a Zone of Autochthones, or an aldainic band of basins, was formed running to the westward. North and south of this zone all faunas seem to have been residual faunas.

The fauna of the Lower Lias in the basin of the Northeastern Alps was, however, not in the zone of autochthones after the deposition of the Angulatus bed. This zone, just before the deposition of the Lower Bucklandi bed, had become narrowed in its easterly extension, and confined to the faunas of South Germany and the Côte d'Or.

Psiloceras and Caloceras.

The discovery by Gümbel[2] of *Psil. planorboides* in the triassic strata of the Bavarian Alps having been confirmed by Winkler[3] and the shell and sutures figured, there can be no doubt that it is a true Psiloceras. As a result of our researches upon cycles of form, we can, however, unhesitatingly assume that this shell is too involute to be considered a radical of the Arietidæ. It indicates, if estimated according to the usual history of these cycles, that undiscovered species of discoidal Psiloceratites must have existed in the Trias, as necessary antecedent or ancestral forms. Two forms have also been cited by Neumayr, in his "Unterster Lias,"[4] as *Ægoc. planorboides* and *Ægoc. form. nov.* from the Kössener shales. These are from Wallegg, and appear to be the same as those previously cited by Stur[5] as *Amm. cf. longipontinus* and later described by Wähner.[6] Wähner considers them both to be specimens of his *Psil. Rahana*, and writes that

[1] 'Αλδαίνω, to make to grow.

[2] Ober. Abth. d. Keupers, p. 110.

[3] Zeits. deutsch. geol. Gesellsch., 1861, XIII, p. 189, pl. ix. fig. 3. Neumayr also, Unterster Lias, Abhand. geol. Reichsans., VII, figures this species in the Planorbis bed.

[4] Abh. geol. Reichsans., Wien, VII. p. 44.

[5] Fuhrer z. d. Excursion. d. deutsch. geol. Gesellsch., Wien, 1877, p. 148.

[6] Verhand. geol. Reichsans., 1886, p. 175.

they were probably taken from loose rock not in place, and may have come from a dark gray limestone in the horizon of *Psil. caliphyllum* or *megastoma.* They cannot, therefore, be considered forerunners of the psiloceran forms of the Planorbis bed.

Neumayr's and Wähner's researches, quoted below in Table VI. and in the chapter on "Descriptions of Species," show that a wonderfully rich fauna of Psiloceratites and Caloceratites existed in the region of the Northeastern Alps; but, so far as we know, there is nowhere any statement of the appearance in time of the discoidal radical *Psil. caliphyllum* or *planorbe* before Caloceras in that province, as there is in South Germany. The aspect of the fauna is older than that of South Germany; but though composed of an assemblage of radical forms of Psiloceras, they occur side by side with *Cal. Johnstoni* and *Schlot. catenata* (*subangulare* of Wähner), and are equivalent to the fauna of the Caloceras bed of South Germany, but not to the lowest Planorbis bed. Suess and Mojsisovics, in their table of strata in the mountains of the Osterhornes,[1] Northeastern Alps, describe a very thick Planorbis horizon, and in the uppermost bed they enumerate *Psil. planorbe,* supposed to be the English form; also *Psil. Hagenowi* and *Cal. Johnstoni,* no fossils having been found in lower beds. Here again it is probably the Caloceras bed, and not the lowest Planorbis bed, which contained the fossils described.

In South Germany *Psiloceras planorbe,* the radical species of the Arietidæ, is prevalent, as may be seen in collections, and in the works of all the geological writers on this region, especially Quenstedt. Quenstedt notes what he calls the Laqueum layer, and speaks of caloceran forms as having made their first appearance somewhat later in the Planorbis horizon than *Planorbis* itself, and in the "Ammoniten der Schwabischen Jura" describes and figures a specimen, *Planorbis,* var. *leve,* from the Bone-bed, which is placed by most writers in the Rhætic.

In the neighborhood of Salin and Besançon, Prof. Jules Marcou has shown that there is a deficiency in the Planorbis horizon, and lately Louis Rollier,[2] following in his footsteps, has confirmed these observations. Professor Marcou, however, at Boisset, near Salins, found a true Planorbis bed containing the typical species. W. A. Ooster, in the "Catalogue des Cephalopodes des Alpes Suisses,"[3] enumerates many species; but unluckily the beds are not defined. It is, however, evident that the collections in Switzerland which he examined, and the authors he quotes, did not give any data contradictory to Waagen's conclusions, which we give below.

Waagen, in his "Der Jura Franken, Schwaben und der Schweiz," says that outside of Suabia, whether going northeast or southwest, one finds nowhere the typical development of the Lower Lias as it exists in Suabia; and it is especially the lowest bed which is apt to be nearly everywhere starved out. This remark and the table given by Waagen are very important, and coincide with the results reached in this chapter.

[1] Gebirgesg. d. Osterh., Jahrb. geol. Reichsan., XVIII., 1868, p. 195.

[2] Form. Jurass. Soc. d'Emulat. Porrentruy, 1883, p. 105.

[3] Denksch. schw. Gesellsch. Naturwissen., XVIII., 1861.

M. Collenot[1] mentions *Amm. Johnstoni, tortilis, laqueum,* and *Burgundiæ* as occurring in the Planorbis horizon. The collections at Semur show that *Planorbis* was small, and evidently already losing ground, whereas the fine suites of caloceran fossils indicate at least that this series had suffered no loss by migration when compared with the fauna of South Germany. This collection is also arranged to show a bed similar to the Laqueum layer of Quenstedt, called by Collenot the "zone of *Amm. Liasicus,*" which contains only caloceran forms, and also *Psil. longipontinum.* *Cal. laqueum* is smaller, and more like the German form when found in company with *Liasicus.*[2] A few dwarfed forms of *Psil. planorbe,* var. *leve,* have been found together at Saulieu, and at Beauregard there is a bed with large forms of *Cal. Johnstoni* and *tortile,* accompanied by a larger form of *Cal. laqueum* than is usual in South Germany, and a small *Psil. planorbe,* var. *leve.* The latter is in Boucault's collection, Museum of Comparative Zoölogy, but not represented at the time of my visit in the collections at the Museum of Semur. The researches of M. F. Cuvier[3] are important in this connection. He states that a separable Planorbis bed was found by him on the section of the railway between Arcy-sur-Cure and Guillon, and immediately above this a bed characterized by the presence of *Cal. Liasicum.* Again, on page 177, he speaks of finding at Gravelles, near Saulieu, a bed containing *Psil. planorbe* and *Cal. laqueum* or *Burgundiæ,* and this agrees with Collenot's observations.

Dumortier[4] states that *Psil planorbe* occurs everywhere in the Planorbis bed of the basin of the Rhone in company with *Cal. Johnstoni,* though not an abundant fossil, and from a fragment in his possession infers that the former may in some cases have reached the great diameter of 220 mm. Quenstedt describes and figures a specimen of *Psil. planorbe,* var. *leve,* from Provence,[5] which he names *Amm. psilonotus provincialis.* Martin[6] designates the Planorbis bed in the region of the Côte d'Or as the "zone of *Amm. Burgundiæ*" (our *Cal. laqueum*). He considers that the beds of "lumachelle," the Planorbis horizon, show evidences of having been deposited during a period of violent currents, etc. This is an important fact, since it indicates the littoral character of the deposits.

Terquem,[7] in the department of Moselle, writes that Ammonites are generally rarer and more often broken than Nautili in the Lower Lias, and enumerates only six species. Chapuis and Dewalque state[8] that in Luxemburg the Planorbis zone is not fossiliferous.[9]

[1] Description Géologique de l'Auxois, p. 209.

[2] The remarks of M. Collenot on page 161 are very instructive, and confirm the impressions received from the collections at Semur.

[3] Notice Géologique, etc., Bull. Soc. de Semur, ser. 2, No. 3, 1886, pp. 170, 176.

[4] Étude Paléontologique du Bassin du Rhone, p. 28, pl. i.

[5] Amm. Schwab. Jura, pl. i. fig. 19.

[6] Pal. Strat. de l'Infra-Lias de la Côte d'Or, Mém. Soc. Géol. de France, VII.

[7] Infra-Lias Luxem., etc., Dept. Moselle, Mém. Soc. Géol. France, V. See also, for similar opinions, Collenot, Descr. Géol. de l'Aux., p. 162, and Dumortier, Études Pal. Bass. du Rhone, I. p. 20, II. p. 97.

[8] Descr. Foss. Terr. Secon. de Luxembourg.

[9] The late researches of Schumacher, Steinmann, and Van Werveke, Erlaut. z. Geol. Uebersichtsk. d. Westl. Deutsch-Lothringen, show that the Planorbis bed containing *Psil. planorbe,* var. *plicatus,* is found in the region explored by them, though it is absent in the French part of Lothringen, as stated by Bleicher, Bull. Soc. Géol. de France, ser. 3, XII., 1884, p. 145. In Deutsch-Lothringen it is one meter in thickness.

In North Germany, according to Schlönbach,[1] the Planorbis horizon is present; but *Psil. planorbe* is largely, if not entirely, replaced by *Cal. Johnstoni*, and he designates this layer as the "zone of *Amm. Johnstoni*." Braun[2] gives similar results for his work in the localities of northwestern Germany; and Emerson, in his essay "Die Liasmulde von Markoldendorf," did not find Psiloceras in that basin, though *Johnstoni* was abundant, and of large size. Römer,[3] the first observer in North Germany, states that the Lower Lias is less developed in that region than in South Germany, and enumerates only a few species. Schlüter, in his "Schichten des Teutoburger Waldes bei Altenkirchen," shows that a thick Planorbis bed occurs in this locality, and *Psil. planorbe* is abundant, while *Cal. Johnstoni*, which he considers to be identical with *planorbis*, var. *plicata*, and *Amm. laqueolus*, is much less frequent.[4] He also gives *Amm. angulatus* as appearing in the upper part of the same bed. There is unfortunately no record of the exact beds in which the fossils occurred, and it is not certain, therefore, whether we are here dealing with the Caloceras bed or a true Planorbis bed. Quenstedt also describes and figures a specimen of *Psil. planorbe*, var. *leve*, from Quedlinburg.[5]

The paleozoölogical and geological data, therefore, appear to sustain the conclusion, that Psiloceras and Caloceras, as a rule, arrived later in North Germany and Luxemburg, the Côte d'Or, and the Basin of the Rhone, than in South Germany.

In England the aspect of the fauna has greater similarity with the Côte d'Or and South Germany, than with the North German and Luxemburg basins. The Planorbis zone is well developed, and in the Bristol Museum the South German varieties of *Psil. planorbe* and the English forms from Cotham[6] are found side by side. This was also the richest collection in caloceran species which we saw in England, though it was still far behind that at Semur. Rev. J. E. Cross, in his "Geology of Northwestern Lincolnshire," claims that no true Planorbis bed occurs, but in place of this a bed containing *Amm. angulatus* and *Johnstoni*, which is probably the Caloceras bed. Wright's section at Uphill railroad cutting shows the bed containing "*angulatus* and fragments of *Liasicus*," called by him the "Angulatus bed," and at Binton, Warwickshire, there is a transition bed containing only *Liasicus*, included by him in the Planorbis zone.[7] In his sections of the Planorbis horizon *Psil. planorbe* occurs earlier than any species of Caloceras at the Uphill railroad cutting; at Binton, Warwickshire; Street, Somerset; and at Brockeridge and Defford Commons. No mention, however, of Psiloceras in any earlier bed occurs, and its appearance must therefore have been later, as a rule,

[1] Ueber Eisen. d. Mittl. Lias, etc., Zeits. d. geol. Gesell., 1863, p. 498; Paleontogr , XIII.; and Die Hannoverische Jura, p. 17.

[2] Der untere Jura in nordwestliche Deutschland, 1871.

[3] Verstein. norddeutsch. ool. Geb.

[4] Zeits. deutsch. geol. Gesellsch., 1866, XVIII. p. 40.

[5] Amm. Schwab. Jura, pl. i. fig. 17.

[6] Stoddart, in his "Notes on the Lower Lias of Bristol," Geol. Mag., V., 1868, p. 139, shows that *Amm. Johnstoni* occurs in the section he described earlier than true *planorbis*, if one can judge from the names he gave to the beds, since no lists of fossils were added. The section given certainly indicates the existence of a Caloceras, rather than a true Planorbis bed.

[7] Wright, Lias Amm., pp. 11, 20.

than in South Germany. Tate and Blake[1] discuss the conditions of the deposition, and arrive at the conclusion, that "it seems probable that no portion of the liassic beds was formed in very deep water, but that even the shales partook of the nature of submerged mud flats."

Psil. Hagenowi occurs in the Northeastern Alps, North Germany, Bohemia, and Switzerland; and in all these places the true *Psil. planorbe*, var. *leve*, is scarce. This form is a degraded modification of *planorbe* which may have arisen independently in each locality, and it indicates that this species probably lived under unfavorable conditions in these regions. Caloceras was, however, strongly represented in the same basins. It formed an unbroken procession, so far as *Cal. Johnstoni* was concerned, from the Northeastern Alps to England.

The facts, with certain exceptions, of which we shall take note farther on, appear to indicate that Psiloceras was autochthonous in the Northeastern Alps. It probably appeared as a radical or chronologic migrant from the Trias, and gave rise to Caloceras in the Lias. Thence both series may have spread by chorological migration into the basins of South Germany, the Côte d'Or, Switzerland, North Germany, and England During these migrations they met with favorable conditions in some localities, and unfavorable conditions in others; hence the inequalities of representation. In both series, however, it is obvious that it was the discoidal species which settled in the new territories to the west of the Mediterranean province. It thus becomes evident that the more highly specialized and more involute species were probably not the progenitors of any of the derivative series that subsequently arose, — an inference agreeing exactly with all our conclusions with regard to the radical nature of discoidal, as compared with involute forms.

Wæhneroceras and Schlotheimia.

The exceptionally rich fauna of the Angulatus (Megastoma) bed given by Wähner[2] contains, besides the distinctive Wæhneroceran series, *Schlot. angulata*, and other forms of the same series, as well as many of the involute Psiloceratites and keeled Caloceratites, mentioned above. This assemblage shows undoubtedly that a region so richly populated must have been exceptionally favorable for the evolution of Wæhneroceras, and possibly also the autochthonous home of Schlotheimia. The announcement by Neumayr[3] of Waagen's discovery of a true *Schlot. angulata* in the Rhætic beds near Parthenkirchen in the Mediterranean province, should be mentioned in this connection. Suess and Mojsisovics show that the Angulatus zone is very slightly developed in the Osterhornes mountains, but it contains *Psil. longipontinum*, *Cal. laqueum*, *Schlot. angulata* and *Moreana*, besides a possible *Cor. kridion*, identified as similar to that figured by Dumortier in France. This assemblage, therefore, contains the most important of the species found in other regions in the Caloceras bed, as well as in the true Angulatus bed above.

[1] Yorkshire Lias, p. 215. [2] Unter Lias, *loc. cit.* IV., 1886, p. 199.
[3] Jahrb. geol. Reichsans., 1878, XXVIII p. 64, and Abh. geol. Reichsans., VII p. 44.

The radical form *Schlot. catenata* appeared in the Planorbis horizon, according to the collection at Semur, and in this fauna the successive forms of the schlotheimian series succeed one another without a break in their gradations. Quenstedt's work on "Die Ammoniten des Schwabischen Jura" shows that in South Germany the series may be complete in numbers of forms, and even more remarkable in the size of specimens, and the whole series except *Boucaultianus* appeared before the termination of the Angulatus fauna. There is also a specimen referred doubtfully even to the "gelbe Sandstein" of the Rhætic beds near Tübingen, thus carrying the possible origin as far back as in the Northeastern Alps. If, as we have supposed, *Wæhn. subangulare* is found in South Germany, the evidence becomes still stronger that this was the probable centre for the chorological distribution of the group in Central Europe.

Schlot. angulata and *catenata* are very numerous in North Germany; but there is a notable tendency to the production of smaller specimens in the collections we have seen. Schlüter, in his "Schichten des Teutoburger Waldes bei Altenbecken,"[1] states that *Amm. angulatus, Moreanus,* and *Charmassei* occur there, but that the latter is never so large as in South Germany.

Terquem, in his "Province de Luxembourg et de Hettange,"[2] mentions *Amm. angulatus* as occurring in abundance, and of good size, but no species like *Charmassei* or *Leigneletii*. Chapuis and Dewalque give figures of *Schlot. angulata*,[3] which show that the species is similar to *catenatus* in having discoidal whorls and the pilæ crossing the abdomen. This species is evidently similar to that from Markoldendorf, described by Emerson. Seebach, in his "Hannoverische Jura," declares that in North Germany there has so far been found only the *Amm. angulatus* (equal to *depressus, catenatus,* and *Moreanus*), and denies the existence of *Charmassei*. Brauns, in his "Untere Jura im nordwestlichen Deutschlands," cites both *angulatus* and *Charmassei*.

The whole series, including radical, discoidal, and involute species, appear to have come into the Northeastern Alps basin first, and to have reached in this locality their highest development in discoidal forms. Thence they seem to have spread somewhat later in time into the Angulatus horizon of the South German basin, and migrated still later to the Côte d'Or and England. In the first two basins they reached their highest development in involute forms,—a fact which strengthens the impression that the series must have originated in the Mediterranean province, since the involute forms are the descendants of the discoidal forms. That they arrived in the Côte d'Or later than in South Germany is shown by Tables I. and II., in which we find *Charmassei* appearing in the Lower Bucklandi zone instead of the Angulatus zone, and by the presence of two new and more highly modified species, *D'Orbigniana* and *Boucaultiana*, which have not been found in South Germany by any collector up to the present day. These views are further sustained by the fact that the English fauna possesses only a slender representation of the group, all the species being rare, and occurring at about the same time as in the Côte d'Or, except *Boucaultiana*, which is

[1] Page 42.
[2] Mém. de la Société Géol. de France, V.
[3] Descrip. Foss. Terr. Secon. de Luxembourg.

found somewhat earlier in the Upper Bucklandi bed. Neither *Schlot. D'Orbignyiana*, nor any of the similar modifications so well exhibited in the collections at Semur and in the Boucault collection of the Museum of Comparative Zoölogy, are represented in this fauna.

VERMICERAS.

Vermiceras is represented in the Northeastern Alps by *Ver. Conybeari*, figured by Hauer, and *Ver. Hierlatzicum*, Geyer, a dwarfed species. *Amm. spiratissimum*, Hauer, occurs in company with *Conybeari* in the Lower Bucklandi bed at Enzesfeld; but this is probably a species of Caloceras, similar to *Cal. caruscnse*, of the large variety which occurs in the Bucklandi horizon in South Germany.

Suess and Mojsisovics do not give any species of this genus as occurring in the Osterhornes mountains, and this is also the case in several other localities where the formations are sufficiently well developed to lead one to expect that the genus would be represented if at all common in this province. *Cal. prespiratissimum*, in the Angulatus bed of the Kammerkahr Alps and Adneth, as given by Wähner,[1] is the only example of a transitional form. Nevertheless the great development of caloceran species in the Mediterranean fauna shows that a complete series of transitional forms probably occurred in that province.

Gümbel does not mention Vermiceras, in his "Geognostische Beschreibung der Bayerischen Alpen," as having been found in the Kammerkahr Alps, unless indeed his *Amm. spiratissimum* is a true vermiceran form, or similar to Wähner's species of *prespiratissimum*, nor did he find any species of this series in the gray limestones at Gastätter Grabens. Herbich, in his "Széklerland,"[2] gives figures and descriptions of *Ariet. multicostatus*, with both young and adult similar to and probably the same as his *Ariet. Conybeari*, all having been found near Also Rakos in the Besanyer mountains. The radical species *Ver. spiratissimum* made its appearance in South Germany earlier than elsewhere, if we can regard, as seems to us correct in every way, transitional forms like that on Summ. Pl. XI. Fig. 22, though named as belonging to *Cal. laqueum*, as really closer to Vermiceras than to Caloceras. The principal transitions must have taken place in the Caloceras bed of this basin, instead of in the Angulatus bed, as in the Mediterranean province.

The basins of South Germany and the Côte d'Or are about equivalent in the number of transitional forms, and it is as easy to trace the gradations from Caloceras to *Ver. spiratissimum* in one locality as in the other. The extraordinary evolution of the series in the Côte d'Or indicates that it must have met with its most favorable home on the bucklandian horizon in this basin. Even on the Tuberculatus horizon several new varieties were evolved, some of which, however, like *debilitatus*, Rey., must be considered as degradational, and consequently indicate the decadence of the genus in this later fauna.

According to Dumortier's figures and descriptions, this genus is represented

[1] Mojsis. et Neum., Beitr., V. p. 53.

[2] Mittheil. Jahrb. d. k. ungar. Geol. Anstalt., V., Part II

by very few forms in the basin of the Rhone, and *Ver. spiratissimum* appeared first in the Lower Bucklandi bed.

In England the number of varieties or forms is not equal to either of the three faunas above mentioned, but the transitional forms are present. Wright, in his "Lias Ammonites," gives a section at Red Car, and *Amm. Conybeari* is cited as occurring in the lowest stratum of the Bucklandi zone. With regard to the English fauna, one can see, in spite of the large size and the multitude of specimens, that the small number of distinct species and the entire want of autochthonous species, or varieties, indicate a purely residual fauna composed of unmodified forms. This basin is north of the zone in which autochthones arose during the Lower Lias, and the basin of the Rhone lies south of this zone, and both are residual faunas. *Ver. Conybeari* is mentioned by several authors as occurring in North Germany and in Luxemburg, but, so far as we have seen, other forms of this genus have not been cited, and Vermiceras appears to have had but slight development in these basins

The facts, so far as now known, are opposed to the inference that this series originated in the Northeastern Alps. On the contrary, it seems more likely that it began in the Caloceras bed of South Germany with a variety of *Cal. laqueum*, and subsequently appeared as *Ver. prespiratissimum* in the fauna of the Angulatus zone in the Mediterranean province. The series, however, did not, either at this time or on any subsequent horizon in this province, meet with very favorable conditions for the evolution of new forms. It must be remarked, also, that the variety of *Conybeari* figured by Hauer and by Herbich has a whorl quite distinct from that which occurs most commonly in Central Europe. It is more like the degenerate variety of *Conybeari*, which is usually called *Bonnardi*, though apparently of smaller size.

ARNIOCERAS.

There are quite a number of forms described by various authors as having been found in the Mediterranean province, but they have all been found in horizons above the Lower Bucklandi bed. This may be seen by our Table VI., and also in the fact that Suess and Mojsisovics found no species of this genus in the Osterhornes mountains, the beds above the Bucklandi zone being unfossiliferous, and Paul states, in his article "Die Nördliche Arva,"[1] that only one species of this series was found in the Lias, and this occurred in the beds above the Bucklandi zone.

My notes on the collections at Stuttgardt and Tübingen do not show so rich a fauna as in the Côte d'Or, nor do Quenstedt's publications indicate so full a development of the series as in that basin. Thus, though the series began in the Angulatus zone, as shown in Fraas's collection, it did not reach its acme of development in the South German basin. The evolution of Arnioceras in the fauna of the Côte d'Or is exhibited in the Semur collection, and in Boucault's collection of the Museum of Comparative Zöology. The large number of forms in

[1] Jahrb. geol. Reichsans., XVIII., 1868, p. 233.

the bucklandian horizon, and their early appearance in the Angulatus zone of Côte d'Or, show that this was their most favorable home. We have identified the earliest occurring Semur specimen with *Arn. falcaries*, but it had some transitional characters allying it with *Arn. miserabile* and also with *Arn. semicostatum*. Arnioceras did not appear at all in the Angulatus zone, but in the Bucklandi zone of the Rhone basin, if Dumortier's work can be considered as authoritative upon this question. This fauna also possesses specimens of much larger size than any found elsewhere, and the series is quite as fully, though perhaps not so richly, represented as in the basin of the Côte d'Or.

In England there are certainly fewer species and forms than in South Germany or the Côte d'Or, and they appear to have been wholly migrants, not possessing the numerous varieties observable in South Germany and at Semur.

Only one, or at most two, species of Arnioceras, called either *obliquecostatus* of Zeiten, or *geometricus* after Oppel, appear to have been found in North Germany. Making all due allowances for negative evidence, this appears to indicate a very slight representation of the genus. Schlüter gives, however, a lengthy description and figures of *Amm. obliquecostatus* as occurring in a bed between the Angulatus and the Bucklandi zone in the Teutoburger Wald, and his description and figure show that this species may be in reality divisible into several, — one similar to *Arn. obtusiforme*, one to *miserabile* or *semicostatum*, and perhaps another with more marked keel and channels. The forms are confined wholly to this stratum, which may belong either to the Angulatus or the Bucklandi bed. The Luxemburg fauna was equally poor.

This genus, therefore, certainly does not have the aspect, as far as is now known, of having originated in or near the basin of the Northeastern Alps. The evidence is rather in favor of its having arisen from small planorbis-like forms, occurring first either in the Côte d'Or or in the South German basins. At present the evidence is not determinative, though somewhat in favor of the former basin. The series subsequently migrated to the Mediterranean province, making its first appearance there in the Upper Bucklandi zone.

Coroniceras.

In company with the first arnioceran species at Semur is a doubtful form of *Cor. kridion*, and later in the Scipionis bed a true *Cor. kridion* is found together with a representative of *Cor. rotiforme*. *Cor. latum* also occurs in company with these, but is the radical of another subseries of this genus. *Cor. kridion* is cited by Suess and Mojsisovics from the Osterhornes mountains as occurring in the Angulatus zone, and this is not a difficult species to identify. The Coroniceran forms as cited by the same authors in the Bucklandi zone are represented only by *Cor. bisulcatum*. Hauer's work,[1] however, shows that this is probably only a local peculiarity, though the fauna is not so rich as that of either South Germany, France, or England.

Dumortier, in his "Études Paléontologiques du Basin du Rhone," gives *Cor.*

[1] Nordostlichen Alpen, Denk. Akad. Wien, XI.

kridion as occurring in the Angulatus beds, and figures a specimen.[1] According to Fraas's collection, *Cor. kridion* certainly appeared in South Germany in the Angulatus bed at Möhringen, and Quenstedt declares it to be a rare form in the Bucklandi zone. Coroniceran forms are so numerous in the Bucklandi zone of South Germany and France, that it becomes difficult to determine whether they were more fully evolved in the one or the other of these basins.

Wright's tables and lists show that the English fauna was by no means so rich in numbers of species and varieties as either the French or South German; and this result, notwithstanding the great size and multitude of specimens found in the various localities of that basin, confirms our experience in the study of collections while in England.

The works of North German paleontologists show less thinning out of the forms of this series in that direction than in any of the preceding genera. The names *bisulcatus*, *multicostatus*, and the like, occur frequently. This suggests that in bucklandian times the species of the Arietidæ had become hardier and more able to survive in the unfavorable localities to the northward, or else the surroundings themselves had changed and become more favorable. There is one fact, however, favoring the former as the most probable conclusion. The specimens are neither very abundant, nor are they so large, nor so generally distributed in North Germany as in South Germany.

The radical of the third subseries of Corniceras, *Cor. Sauzeanum*, did not appear earlier than the Upper Bucklandi bed in any fauna, not excepting that of the Mediterranean province.[2] Chapuis and Dewalque show that *Cor. Sauzeanum* persisted in the Luxemburg region, and that *Cor. bisulcatum* and *multicostatum* were also present; but the number of forms found there are certainly very limited. Schlönbach mentions the usual fauna of the Bucklandi zone in Brunswick, but the species are not so numerous as in South Germany, and no note is made of their abundance. The absence of the Tuberculatus bed, or its unfossiliferous character when present, is noted by Schlönbach, and this indicates a decrease in number of forms as compared with other regions. Brauns in "Hannoverische Jura," and Emerson in "Liasmulde von Markoldendorf," show that the coroniceran series is represented, but is not remarkable for the number of species, and in most localities, so far as we can learn, the species of this series are not abundant. Shlüter cites *Cor. rotiforme* and *Cor. Gmuendense* as occurring in the Bucklandi zone of the Teutoburger Wald, and his descriptions support these results. He alludes to other forms than these species, but does not enumerate them.

The poverty of the later beds of the Lower Lias in North Germany, and the constant recurrence of unfossiliferous strata, are characteristics similar to those of the basin of the Northeastern Alps, and these facts indicate that similar unfavorable conditions obtained there.

Dumortier's work enables us to see, also, that in the Rhone basin on the southern side of the Côte d'Or the fauna thinned out. Thus, though *Cor. kridion*

[1] Pl. xviii. fig. 3, 4.

[2] See Mojsisovics's mention of the zone of *Amm. Sauzei*, Gebirgsgr. d. Osterhornes, p. 199.

appeared in the Angulatus zone, the number of species on the bucklandian horizon was evidently more limited than in South Germany, Semur, or England.

The coroniceran series, therefore, seems to have arisen on the same level in the Mediterranean province, in the South German basin, and probably in the Côte d'Or. The radicals of the subseries, so far as known, do not follow the same law. *Cor. latum* has not yet been mentioned or described as occurring in any other basin than the Côte d'Or. *Cor. Sauzeanum* occurs, however, in northwestern Germany, according to Braun, and in the South German, Côte d'Or, and English basins in the Upper Bucklandian bed, though in the basin of the Rhone and Mediterranean province it is not recorded with certainty from any level earlier than the Tuberculatus beds.

It is possible that *Cor. kridion* may have originated in the Northeastern Alps, but Neumayr and Wähner have not yet found this species in their researches among the fossils of the Angulatus zone, and no good figure has been published. The early occurrence and large number of varieties and species in the collections at Stuttgardt and Semur, and the numerous transitional varieties, also show that *Cor. kridion* found its most favorable home either in the South German or the Côte d'Or basin. The earlier occurrence of the radical of the third subseries, *Cor. latum*, at Semur, indicates the Côte d'Or to have been the centre of distribution for the Bucklandi subseries. The occurrence of *Cor. Sauzeanum* on the same level in South Germany, Côte d'Or, and England shows, together with the number and variety of the forms subsequently evolved, that the centre of distribution of the Bisulcatus subseries lay in one or the other of these basins.

This conclusion accords with the origin and distribution of the parent series, Arnioceras, and derives additional support from this fact. It is evident also, from these facts, that the Mediterranean province must be regarded as having been peopled with migrants from the province of Central Europe, so far as relates to the subseries of this genus, and this makes it more likely that the radical species of the whole series, *Cor. kridion*, also arose in this province. So far as known its appearance in the Angulatus horizon of the Northeastern Alps is not supported by the presence of transitional forms, nor by the presence of Arnioceras in the same horizon. The species, if a real *kridion*, certainly must be provisionally regarded as a chorologic migrant from the west.

Agassiceras.

Agas. lævigatum appeared in the Angulatus zone of the Semur collection, and was represented by numerous specimens in this fauna. It is also attributed to this horizon in the basin of the Rhone by Dumortier, and is well figured by him.[1] In South Germany *Agas. lævigatum* did not appear until the Upper Bucklandi bed. In England and North Germany it appeared associated with *planicosta* above the Bucklandi horizon. This radical species, therefore, according to our present knowledge, was a migrant in all of these basins, derived probably from the Côte d'Or or the Rhone basin.

[1] Etudes Pal., pl. xviii. fig. 5, 6.

Neumayr[1] includes what we consider the young of the radical species of Agassiceras in his genus Cymbites, and states that he has not found them in the basin of the Northeastern Alps. Geyer, in his "Cephalopoden Hierlatz-Schichten bei Hallstadt," figures and describes under the name of Cymbites a characteristic young form of *Agas. lævigatum.* Hauer's drawings of *Amm. abnormis,* in his "Unsymmetrische Ammoniten der Hierlatz-Schichten," illustrate typical shells belonging to the compressed variety of the same species, one of them exhibiting the peculiar aperture, and another the gibbous young in the interior. The radical species of the series, therefore, appeared in the Northeastern Alps not earlier than the Upper Bucklandi beds, as in other faunas more or less remote from the Côte d'Or.

In the next subseries we find that *Agas. Scipionianus* and *Scipionis* are characteristic fossils of the Lower Bucklandi bed in the Côte d'Or and Rhone basins, but in South Germany and England they appeared later, together with *Agas. striaries* in the Upper Bucklandi bed, and in North Germany on the same horizon. So far as known, no species of this subseries has been found in the Northeastern Alps.

This series, therefore, has the aspect of having first appeared and met with a favorable home in the Côte d'Or or the basin of the Rhone, where its immediate radicals are found.

ASTEROCERAS.

The asteroceran series is represented in the Northeastern Alps, though apparently not by many forms. Hauer figures an *Ast. obtusum,* var. *stellare,* and we have seen several specimens from this region, but the fauna evidently was not a rich one as compared with those to the westward. According to Suess and Mojsisovics, this species does not occur earlier than the Obtusus bed[2] in the strata of the Osterhornes mountains, the Adnether-Schichten in which it appears being placed by them above the Tuberculatus bed. According to our classification, however, this curiously mixed fauna may have begun to receive migrants from the west during the time of the lower bucklandian horizon.[3]

The first recorded appearance of *Ast. obtusum* occurred in the Upper Bucklandi bed of South Germany, and in the similar formation of Luxemburg.

M. Collenot, in his table of the forms in the Côte d'Or, quotes only the usual three names, *Amm. obtusus, stellaris,* and *Brooki.* Boucault's collection in the Museum of Comparative Zoölogy shows, however, that probably all the principal forms were present in the basin of the Côte d'Or, and the type of *Ast. Collenoti* was certainly found there. Dumortier shows in his work, that this species was also present in the Rhone basin, but the series of forms in the genus was not otherwise so complete as in the Côte d'Or. The finest series exists in the collection at the Museum of Stuttgardt. This does not have *Collenoti,* though it

[1] Ueber unvermit. auftret. Cephalopodentypen, pp. 63–65.

[2] *Op. cit.*, p. 198.

[3] The form cited by Wähner, *Ariet. stellaeformis,* an ally of *Ast. obtusum,* var. *quadragonatum,* is cited as having been found in the Megasoma or upper part of the Angulatus beds in the Kammerkahr Alps. This is a doubtful matter, since only one specimen exists, and we have therefore allowed the text to stand as written (Wähner, Mojsis. et Neum., Beitr., VI., pl. xxvi, 1888). See also description of this variety, Chapter V.

does possess *Ast. acceleratum*, a form found nowhere else except in the Côte d'Or. Quenstedt's collection at Tübingen is very fine, and his descriptions and figures indicate a full representation of species, though *Collenoti* is not present.

Chapuis and Dewalque show that the Luxemburg rocks contain several different forms of the genus, though they are not so numerous as in South Germany or England. Schlönbach shows that there is an *obtusus* horizon in North Germany containing the usual forms, but only fossiliferous in certain localities, and Brauns publishes similar results in his work. This horizon according to Schlüter does not appear to have been represented in the Teutoburger Wald, unless his Gmuendense bed and the broken beds mentioned on page 48 of his work be considered the equivalent of all the beds between the Angulatus and Raricostatus horizons.

The English fauna, according to Wright's "Lias Ammonites" and the collections examined by me, has all the principal forms, and often very large shells, and there are also, as in the Côte d'Or and Rhone basins, representatives of the extreme modification of this genus, *Ast. Collenoti.*

This series had, therefore, a more general development in all the basins we have considered than any of the preceding series, but in spite of this there seems to be a preponderance of forms in favor of England and France. The unusual case of an early appearance of the radical species *Ast. obtusum* in the Luxemburg region should have its due weight, but the evidence of an equally early occurrence in the South German basin shows that *Ast. obtusum* probably made its appearance as an autochthone upon the level of the Upper Bucklandi bed in the South German basin, and was thence distributed. It is probable that the series subsequently met with more favorable conditions in the Côte d'Or and in England than in any other basin.

Oxynoticeras.

Oxynoticeras oxynotum, the radical species of its peculiar series, appeared in such profusion and with such excessively compressed and involute whorls in the Northeastern Alps, South Germany, the Côte d'Or, and England, that one seems to be dealing with contemporary migrants from some unknown fauna. With regard to this conclusion, however, it may be well to be cautious. The morphological gap is not so great as appears between an adult of a species like *Oxyn. oxynotum*, and *Agas. striaries* or *laevigatum*. This is indicated clearly by the development of the individual in *Ast. obtusum*, *oxynotum*, and *Agas. Scipionianum*, as we have tried to show in the previous pages and in the descriptions of the genera and species.[1] *Oxyn. oxynotum* was a species with a highly accelerated development, and in such forms the departure from allied forms took place suddenly. In consequence of this abbreviated mode of evolution gaps were left in the series which it is difficult to fill. The evidence with regard to the connection of *Ast. Collenoti* with *Ast. obtusum* and the young forms of *Oxyn. oxynotum*,

[1] See young of *Oxyn. oxynotum*, pl. x fig. 4, 5, and 14 17, and Summ Pl xiii fig 9, 10, and compare with *Agas. laevigatum*, pl. viii fig 9, 10, and *striaries*, pl ix fig 14, 15.

which convinced me of the derivation of that species from Agassiceras, was found in 1873 in the Stuttgardt collection. The specimens of the last named species had been selected by Professor Fraas out of several barrels of specimens of the same species gathered in the same locality. I looked very carefully in all other collections, handling hundreds of specimens, without finding any duplicates of these forms.

Hauer has given, in his "Nordöstlichen Alpen,"[1] an involute form, apparently the same as *Oxyn. Lymense*, and figures of the young, which are, however, in part distinct.[2] His *Amm. Greenoughii* is evidently a member of the same subseries, and identical with the more involute forms of *Amm. Guibalianus* of Reynés. This subseries is only sparsely represented in the Northeastern Alps, and its date of appearance is not yet settled.

The collection at Semur has this species in the Birchii or Tuberculatus bed. M. Collenot states that this bed in the Côte d'Or basin contains the same species and is equivalent to the Tuberculatus, Obtusus, Oxynotus, and Raricostatus beds of South Germany and England, and that it is not possible to separate the faunas, as has been done elsewhere. The appearance of the usual forms of *Oxyn. oxynotum* in great abundance in Southeastern France according to Dumortier, and also of *Oxyn. Simpsoni* and *Lymense*, shows that the last named forms may have made their first appearance in France. This is further substantiated by the fact that *Oxyn. Lymense*, according to Wright, is found more abundantly in the South of England than in the midland counties. The appearance of *Oxyn. oxynotum* and *Lymense* in the basin of the Northeastern Alps can be accounted for by chorological migration, in the same way that we have accounted for the presence of Asteroceras and others in that basin. The radical species, *oxynotum*, is cited by Schlönbach[3] from only one locality in North Germany, and is not mentioned at all by Dr. Brauns in his "Unterer Jura nördwestlichen Deutschland," or by Emerson.

The second subseries of this genus is completely represented in the fauna of France. Three species only are found in England, none in South Germany, and two in the Northeastern Alps. Apparently none have been found in North Germany[4] or Luxemburg. The collections at Semur contain a nearly complete series of forms, and Dumortier has added others occurring in the Rhone basin. The home of the series, therefore, appears to have been in the Côte d'Or or Rhone basin.

This is the only series of the Arietidæ which overstepped the boundaries of the Lower Lias. Other species have been reported by various authors as occurring in the Middle Lias, especially the Jamesoni bed; but these were found asso-

[1] Denkschrift. Acad. Wien, XI., pl. xiii. fig. 6, 7.

[2] Fig. 6, 7, appear to us to belong to some species of the second or Greenoughi subseries.

[3] Eisenst, etc., Zeitsch. deutsch. geolog. Gesellsch., XV., 1863, p 502. *Amm. affinis*, however, described in Paleontogr., XIII p. 170, pl. xxviii. III. fig 1, by the same author, is from Middle Lias, Greene, Brunswick, which is very similar to if not identical with *Oxyn. oxynotum*. We have not cited it in the table, however, since it may prove to be more nearly connected with *Oxyn. Oppeli* than with *oxynotum*.

[4] Schluter describes *Oxyn. Oppeli* of the Middle Lias as occurring at Altenkirchen and Borlinghausen in the Teutoburger Wald, and Schlonbach describes and figures the same from Amberg.

ciated with *Cal. raricostatum*, and therefore, according to our classification, are in the Lower Lias. *Oxyn. Oppeli* and *numismale* survived in the Middle Lias of Germany, *Oxyn. Oppeli* alone in the basin of the Rhone, and *Oxyn. numismale* alone in England.

Fauna of South Germany. — Table I.

The notable facts brought out by this table are the following. The abundance and concentration of schlotheimian forms in the Angulatus zone, and their early appearance in the Rhaetic. The completeness of the Caloceran series in the lower horizons, and the poverty of the faunas existing between the Geometricus or Upper Bucklandi beds and the Raricostatus bed in respect to these series, and also in the vermiceran, arnioceran, and coroniceran series. The asteroceran series reached a high stage of development as regards the number of forms, but is not represented by the extreme modifications noticeable in the basin of the Rhone. The oxynoticeran series is also present, and even passes into the Middle Lias, but has not a full representation of species.

Fauna of the Côte d'Or. — Table II.

The Ammonites at Semur were named by M. Reynès, and these names have come into circulation through publication by M. Collenot in his "Description Géologique de l'Auxois," and have also been quoted by Zittel and several other authors. Reynés considers many well-marked varieties to be distinct species. This is our principal disagreement with this author, and the following notes, together with the descriptions of species and table, sufficiently explain other differences of opinion.

Terquem's figures of *Hettangensis*[1] show a keeled, broad caloceran form with pilæ in the young, which belongs somewhere between *Cal. laqueum* and *raricostatum*. The specimens in the Museum at Semur, identified as *Hettangensis* by Reynés, do not agree with these figures. The specimens identified as *Delmasi* belong to several species, and one of these is so exactly like *Pirondi*, as figured by Reynés in his unpublished plates, that I have quoted this name as a synonym for *Johnstoni* in the table.

With regard to the vermiceran series, we traced the relations as follows. Beginning with *spiralissimum*, the forms appear to grade into *Schlumbachi*, which represents *Conybeari* in the Scipionis bed, then into *rotator*, which is a close ally, if not identical with *Amm. caprotinus*, D'Orb., and also with the spinous varieties of *Conybeari* found in Germany. The simpler ribbed forms grade into *conybearoides*, Rey., which is not very far removed from *spiralissimum*, thence into true *Conybeari*, and thence into *Broomi*, which last is a stouter and more robust form. *Broomi*, Rey., exactly agrees with typical *Conybeari*, and also with German forms of the same name, whereas *Conybeari*, Rey., is equal to our *Bonnardi*. *Bechardi*, Rey., has the form and characters of *Conybeari* during its earlier and adolescent stages, but

[1] Pal. Lias de Luxem., etc., Mém. Géol. Soc. France, V, pl. xiii, fig. 1, a, b.

has no tubercles. The specimens are large shells, and afford fine examples of the senile stages. *Debilitatus*, Rey., is similar to our lowest transitional forms of *Conybeari*. It may be a direct descendant of this from earlier times, or, more likely, a degenerate form. This grades into *Landrioti*, Rey. (D'Orb.), which is simply a more compressed form.

The occurrence of a form like *Arn. falcaries* in the Angulatus bed at Semur shows that we may anticipate in the future the finding of the radical arnioceran forms at this level or earlier. It is also very interesting to note that *Arn. Hartmanni*, of the Birchii or Tuberculatus bed, is a morphological equivalent of *raricostatum*, being, with the exception of the young, very similar to that species.

The more interesting facts shown by this table are as follows. The succession of the forms in the schlotheimian series has remarkable regularity, according very closely with their genetic relations. The caloceran series, though very complete in the lower beds, is not so fully represented as in South Germany. Higher up in the Birchii or Tuberculatus bed of Collenot, and probably upon the highest level at about the time the Raricostatus bed of other basins was being deposited, the series had an unusual number of forms. The vermiceran series has a most extraordinary display of varieties, but apparently not quite so full a representation in the lowest beds as in South Germany. Arnioceras is more fully represented in the Bucklandi beds than in any other fauna, and has also many species in the higher beds. The coroniceran series has a similar history, but is not more fully represented than in South Germany. The agassiceran and asteroceran series are also very fully represented, and have the most highly modified species; the absence of *Brooki* will therefore probably be supplied at no distant day. The oxynoticeran series has also a complete history, and probably is nearer perfection than is shown in the table, but it nevertheless seems to have had no Middle Lias forms.

Fauna of the Rhone Basin.—Table III.

The basin of the Rhone is equally important with that of Semur, and we give below a list of Dumortier's species and their synonyms in the different horizons. Dumortier mentions only *Burgundiæ*, and fragments of *Johnstoni* and *planorbis*, in what he calls the Planorbis bed. This indicates the possible absence of the lower beds of this horizon, since this is evidently the fauna of the Caloceras bed.

The Angulatus horizon has a fauna less rich in species than that of the Côte d'Or, especially when one considers the large number of localities from which the author's collections were gathered. The list includes, besides the species given in the table, *Amm. bisulcatus*, a very doubtful form. It may be a form of *Conybeari*, or similar to the peculiar sulcated form described in the note above on page 70, but it is probably not a true *Cor. bisulcatum*.

There are no transitional beds mentioned between this and the bucklandian horizon, and the beds are evidently not so fully presented, either geologically or paleontologically, as in the basin of the Côte d'Or. The list is very meagre as compared with that in the corresponding beds at Semur, but the presence of

Scipionianus indicates that the bucklandian horizon of this basin represents the Lower Bucklandi beds of other basins.

Dumortier divided his zone of *Amm. oxynotus* into four beds, distinguished by their faunas.

The "Davidsoni bed" should have been called Striaries bed, since his *Amm. Davidsoni*[1] is identical with *Agas. striaries.* The list of species does not enable one to synchronize these beds with the Tuberculatus beds of Semur or other basins, nor do they show that it is equivalent to any bed above the Upper Bucklandi beds.

The Stellaris bed of Dumortier contains, besides the species mentioned in the table, *Amm. Locardi*, a species of Deroceras, and *Amm. Birchi*, a form of Microderoceras; both of these, therefore, belong to a family distinct from the Arietidæ. The presence of *Birchi*, *Boucaultiana*, and *obtusum* show that this, and not the so called Davidsoni bed, is the equivalent of the bed immediately above the Upper Bucklandi beds at Semur. This result confirms our opinion that the Davidsoni bed of Dumortier should be called the Upper Bucklandi bed.

Dumortier's Planicosta bed contains *Cluniacensis*,[2] which is identical with *Ast. Collenoti;* and this seems to settle the geological position of this important species. *Amm. jejunus*[3] seems to be an abnormal or diseased *Arn. miserabile; Pellati* is a young form of *Cal. raricostatum ;* and *armentalis*,[4] if one can trust the aspect of the inner umbilical pilæ, is a diseased form of *Cal. raricostatum.* It appears from the figure to be similar to the deformed *Amm. longidomus æger* of Quenstedt,[5] and other similar pathological forms, in which the keel and channels have been superseded during growth by pilæ crossing the abdomen.

Viticola (Plate XXXI. Fig. 9–13) is the same as the Johnstonian variety of *Cal. raricostatum ; Edmundi* (Plate XXXIX.) is the equivalent of the young of *Cal. nodotianum ; tardecrescens* (Plate XXXI. Fig. 3, 4) may be related to *Arn. falcaries.* The umbilicus, sutures, and general aspect of the last indicate that it is a form of Arnioceras. *Oosteri* (Plate XXX. Fig. 2–4) is a keeled and channelled form of Arnioceras, with distorted pilæ.

Amm. planicosta, subplanicosta, and *Pauli* are all varieties of our *Der. planicosta,* and belong to a family distinct from the Arietidæ.

The three upper beds of Dumortier are apparently the equivalents of the Birchii or Tuberculatus beds in the table of the Côte d'Or basin.

The notable facts brought out by this table are as follows. There is a regularity in the distribution of the schlotheimian series similar to that in the Côte d'Or basin. Caloceras is not so fully represented in the lower beds, and is equally deficient in the Bucklandi zone. It is represented by a full list of species in the highest beds, with the exception of *nodotianum*, which is absent. *Cal. carusense*, however, is more fully represented, and *Cal. raricostatum* has a greater number of varieties than in any other fauna. The arnioceran series is not so fully represented in the Bucklandi zone, but it is notably richer in forms in the highest beds than in any other fauna. Coroniceras is well represented in the

[1] Pl. xxi. fig. 1–4. [2] Pl. xxv. fig. 8–10. [3] Pl. xxxi. fig. 6–8.
[4] Pl. xxix. fig. 1, 2. [5] Die Amm. d. Schwab. Jura, pl. vi. fig. 3.

lowest beds and in the Bucklandi zone, but is deficient above. Asteroceras is probably more fully represented than is shown in the table, since the extremes of the series have been found, and, the fauna being near to that of the Côte d'Or, there are grounds for anticipating the discovery of intermediate forms. Agassiceras is complete in its lower forms, but *Scipionis* has not yet been found. The oxynoticeran series is not only quite complete, but has also a middle lias representative. As regards Schlotheimia, Caloceras, Vermiceras, Arnioceras, and Asteroceras, this fauna impresses one as containing the most highly modified derivatives, and as being possibly a residual fauna representing an acme of chorological migration and varietal modification so far as these genera are concerned. Possibly Oxynoticeras will also have to be included in this category, and then the parallel with the English fauna north of what we have called the zone of the autochthones would be complete.

Fauna of England. — Table IV.

In this table the same regularity of succession is found in the schlotheimian series as in the Côte d'Or and Rhone basins. Caloceras is again deficient in the Bucklandi zone, as in the Rhone basin, but is quite fully represented and has an extraordinary new form in the Raricostatus bed, *Cal. aplanatum.* There is also a curious parallelism with the Rhone fauna in the arnioceran series, which, as in that basin, has the extraordinary form of *Arn. Macdonelli* of the Raricostatus bed. Besides the general absence of radical species, except of course the generally distributed psiloceran and caloceran radicals, there is in this fauna a very important fact to be noted, similar to that observed in the fauna of the Rhone. The extreme modifications in the highest formations are very generally present, — more so than in any other fauna. Thus, besides *Cal. aplanatum* and *Arn. Macdonelli* there are doubtful forms of *Cor. bisulcatum* in the Oxynotus zone. *Ast. Collenoti*, *Ast. denotatum*, and the extraordinary series of var. *sagittarius* of *Ast. obtusum*, are also present. The Oxynotum subseries is complete, and the second or Guibalianus subseries alone is imperfectly represented.

The English fauna is therefore a residual fauna, not only because of the absence of radicals, but because it presents a chronological and biological acme in the evolution of the most highly modified and most recent forms of the different series, thus clearly indicating chronologically and biologically its more recent derivation by chorological migration from the older, though apparently contemporaneous, faunas of the autochthonous zone.

Fauna of the Province of Central Europe. — Table V.

This table has already been amply explained, with the exception of certain general facts. The independent origin of the schlotheimian and psiloceran series is in strong contrast with the Northeastern Alps fauna, which as tabulated in Table VI. shows that Psiloceras and Schlotheimia are connected by means of intermediate wæhneroceran forms. Schlotheimia and Caloceras are characteristic of the Planorbis zone; they were immediately succeeded in the Angulatus zone by a full presentation of schlotheimian, caloceran, and vermiceran species, that is, of the entire Plicatus Stock. This stock then entered upon a period of decadence, slight in the Lower Bucklandi, but more marked in the Upper Bucklandi bed. Arnioceras attained its greatest development in the Upper Bucklandi zone and was more persistent in the higher beds than Coroniceras. This last attained its fullest expansion earlier in the Lower Bucklandi beds, and declined rapidly in the Upper Bucklandi, and disappeared altogether in the Obtusus bed. This decline is shown by the geratologous characteristics of the species in the Upper Bucklandi beds, rather than by a less number of forms. Thus *Cor. orbiculatum, Gmuendense, trigonatum*, and the *multicostatus* variety of *bisulcatum*, are all degenerate species as compared with the forms of the Lower Bucklandi bed. They have more convergent-sided whorls, and these are usually developed at an earlier age.

Agassiceras also reached its acme in the Lower Bucklandi bed, but is more persistent, and has some forms in the higher formations. Asteroceras is the only series which attained its acme in the Obtusus zone, and then declined in the Oxynotus zone. The oxynoticeran series reached its maximum in the Oxynotus zone, and, though surviving the changes which attended migration into middle liassic habitats, became extinct in that formation.

The schlotheimian series is a highly modified series, composed of involute derivatives, and ceased to exist in the Obtusus bed, but there are a few dwarfed forms in the Oxynotus bed. Caloceras persisted in the highest beds, whereas its highly modified derivative series, Vermiceras, is shorter lived, and less fully represented in the highest beds. Arnioceras is parallel with Caloceras, and is the radical series from which the more highly modified and shorter lived Coroniceras originated. Agassiceras, the radical of the remaining series, persisted from the Angulatus to the Oxynotus bed, whereas the derivative Asteroceras and Oxynoticeras were both shorter lived. These series, even when thus minutely followed out, accord with the law of persistence in radical stocks, as expressed above, on page 26.[1] Psiloceras itself is not persistent, and is an apparent exception. It is the last of a long line of paleozoic secondary radicals which survived in the Lower Lias. It can be compared with the upper part of a stem which has reached the point of growth at which it splits into many branches. Psiloceras was in like manner resolved into derivative forms, the arietian radicals Caloceras, Arnioceras, and Agassiceras.

We have already noted and discussed the rise and progress of each series: first, the radical stage, or epacme; second, the acme; third, the final decline, or paracme, caused by the prevalence of geratologous forms. The result of such a serial history, when the series are considered together as one family found within certain specified beds, is shown in this table. There is a precise parallelism between the history of the whole and of any one series. The Planorbis and

[1] If, as we have inferred above, on page 24, the channelled and keeled species of Caloceras are transitional to *Hildoceras Walcoti* and other radical forms of the Carinifera, this opinion acquires additional strength, since Caloceras would then become the tertiary radical for the whole of the Carinifera of the Jura.

Angulatus zones contain principally radical species and their immediate derivatives. The Bucklandi zone is characterized, with some exceptions occurring only in the Upper Bucklandi bed, by the presence of truly progressive forms. The highest beds, the Obtusus and Oxynotus zones, are almost exclusively the homes of more or less degenerate and geratologous forms.

Extraordinary and unforeseen correlations, such as these, between chronological distribution and a biological classification founded upon the life history of the individual, cannot be accidental. We have already shown, in preceding chapters, that our classification of series is natural, and capable of verification by means of the cycles which are found to be present in the history of the individual and of the group. The process of verification does not, however, end with this, since approximately exact agreements may be found between the paleozoölogical and geological records wherever both classes of facts exist and have been minutely studied.

There is even some evidence that cycles may be traced in the so-called contemporaneous faunas of the same horizon. Thus, what we have said about the analdainic faunas of England and the basin of the Rhone indicates this possibility. These faunas show an extraordinary evolution of the geratologous forms of the geratologous series; the aldainic basins show, on the contrary, in so far as the Côte d'Or and South Germany are concerned, an extraordinary assemblage of the progressive forms of the Arietidæ, whereas the originating or aldainic centre of the family in the Northeastern Alps has a fauna in which the radical series are enormously developed. *This would seem almost evidence enough that there are cycles in the chorological migration, as well as in the chronological evolution of forms.* The whole might be represented as a complex of vortices, in which the result is apt to be a cycle, whether the spiral lines of evolution form small vortices upon the same or nearly the same horizons, or whether the picture is the blending of all these into one great spiral, or a series of more or less parallel and blended spirals ascending through geologic time.

Fauna of the Province of the Mediterranean. — Table VI.

It was intended to omit this table, as well as those of the North German basin, Italy, Corsica, Spain, etc., the species of which have not yet been fully described and illustrated, since it is not practicable in such researches to accomplish much unless aided by very full information. Lists of names from which these faunas might have been made up are rarely of much use, since authors differ essentially in the identification of species, and therefore we have not considered it safe to venture upon tabulating them. The publication of Wähner's and Neumayr's researches, however, induced the author to attempt to give a tabular view of the Mediterranean province. It has not been found practicable to carry out the system of connecting the forms by lines representing genetic bonds, except in so far as they have been published by the authors named above, and the usual connecting lines have therefore been omitted in series occurring above the Lower Bucklandi bed, and in all the genera of the Levis Stock.

The mixed faunas of the Adneth and Hierlatz beds, and of the gray lias limestones and Fleckenmergel, have been described by Gümbel,[1] by Dionys Stur,[2] and by Geyer,[3] with very interesting remarks upon the similar faunas elsewhere. The first author regards the faunas of the Adneth and Hierlatz limestones as having species representing not only the various faunas of the Lower Lias, but also the faunas of the Middle and even Upper Lias. Oppel considered the Hierlatz beds as the equivalent of the Obtusus, Oxynotus, and Raricostatus beds.[4] Geyer, who has examined this locality in detail, thinks, if it is compared with any single fauna, that we should have to select that of the Oxynotus bed. He however calls attention to the occurrence of *Ast. obtusum* and *Cal. raricostatum* in the same horizon, thus demonstrating the mixed character of the fauna. Stur regards it as possible that the different beds of the Lower Lias may, by further investigation, be defined in the Adneth and Hierlatz beds. This conclusion, however, rests upon theoretical considerations, and not upon actual observations, and this author observes, "dass in den Alpen einzelne arten der Lias fauna höher oder tiefer hinauf und herabreichen als in den ausseralpinischen Schichten beobachtet wurde, . . . und . . . während der Liaszeit innerhalb der Alpengebiets eine weniger streng geschiedene und minder mannichfaltige Gliederung wirklich vorhanden ist."[5]

Both Stur and Gümbel distinguish only three faunas in the Lower Lias of the Kammerkahr Alps: 1. A yellowish limestone with a species similar to *Johnstoni*. 2. An intensely red limestone with *Amm. spiratissimus* of Hauer, *Liasicus* of Hauer, *Haueri, Kridion, Ceras, Bodleyi, Hierlatzicus, Grunowi, bisulcatus, oxynotus, euceras, Charmassei, acutiangulatus, Doetzkirchneri, Hermanni, Kammerkahrensis, Partschi, cylindricus, Lipoldi, Foetterli, Petersi*, but in which, however, a true Bucklandi bed was not distinguishable according to Gümbel. 3. Above this, thinner layers with *Amm. raricostatus, zithus, densinodus*, and a form similar to *stellaris*. Gümbel states that the Adneth or dark red limestones, the Hierlatz, and the gray limestones of Gastatter Grabens are equivalent to one another, and that each contains a mixture of species from Lower, Middle, and Upper Lias.

Suess and Mojsisovics[6] distinguish a Planorbis, an Angulatus, a Bucklandi, a Tuberculatus, and an Obtusus bed in the Osterhornes mountains, but consider the Angulatus bed as the equivalent of the Enzesfeld limestones, and the Obtusus bed as the equivalent of the Adneth limestones. The fauna found by them did not, however, so far as published, appear to justify this conclusion.

Wähner[7] gives a clear statement of the facts in his "Heteropischen Differenzirung des alpinen Lias." He quotes Stur[8] as having distinguished two beds at Enzesfeld, the yellow limestones of the Angulatus zone underlying the true red limestones of the Adneth or Rotiformis horizon. The various localities of the

[1] Geogn. Beschreib. d. bayer. Alpen, pp. 428-432.
[2] Geol. d. Steirmark.
[3] Ceph. Hierlatz-Schichten.
[4] Neues Jahrb. 1862, p. 60.
[5] Geol. d. Steirmark, p. 433.
[6] Op. cit., p. 195.
[7] Verhandl. k. k. geol. Reichsans., p. 168.
[8] See Stur, Lias Hirt. u. Enzesf. Jahrb. geol. Reichs., 1851, pt. 3, pp. 19, 24.

Mediterranean province are summarized by Wähner in this very satisfactory paper, and one sees that the lowest beds are apt to be well defined, but that after passing through the Angulatus zone definition becomes more difficult, so that even this author, for whom as an acute discriminator of species we have a great respect, seems not to have been able to define the separate beds in either the Adneth or the Hierlatz limestones.

Herbich makes a valuable contribution to this problem in his Széklerland, in which he describes several species of the Arietidæ, including an Asteroceras like *stellaris* of Hauer, equivalent to our *obtusum*, var. *stellare*, and *Ægoc. Althii*, which appears to be a true Microceras allied to *Micr. planicosta*, together with a number of species of the Lytoceratidæ, all occurring in a bed not over three meters thick, and he denies that any distinct beds can be defined.[1] Geyer, in the work above quoted, gives a detailed argument for the probable admixture of faunas, and comes to the conclusion that Oppel's scheme of zones is not applicable to the Northeastern Alps so completely as it is to the formations of Central Europe. Favre, in his "Terrains Liassiques et Keuperiens de la Savoie," gives a list of localities in which mixtures of different faunas have been announced by various authors, and Geyer adds several other localities.

Favre considers that the species in such localities, among which he includes the Northeastern Alps, must have been protected from the geological changes which produced new forms and modifications in other localities, and adds that we must seek the causes of admixture in the continuation of sediments of the same nature, and in the configuration of the surface. His idea was, that the persistent species continued to exist in closed basins, where they were secure from the action of the causes that destroyed the faunas to which they originally belonged in other localities. This explanation has a reasonable sound, but it appears to us inadequate. We regard the species quoted as migrants from previously existing faunas, which, having found favorable homes in these localities, became the radicals of new series upon new horizons; or else they were survivors of the geratologous forms of faunas upon the same horizon, which, having found favorable conditions in these new localities, persisted perhaps somewhat longer than the parent series. We have not found adequate evidence of closed areas, except perhaps between the western extension of the Mediterranean province as a whole, and that of Central Europe. The basins of the Lower Lias were evidently not, as a rule, so completely closed as to keep out migrants from other basins and provinces, since all the evidence tends to prove the constancy and uninterrupted migration of species throughout the faunas of Central Europe and the Mediterranean province.

Whatever hypothesis is maintained, there seems to be no possible way of accounting for the finding of a species in a truly anachronic position; that is to say, in a bed which belongs to an earlier horizon than that in which it has been proved to have originated. A specimen of *Coroniceras Bucklandi* in the Planorbis bed, or even in the lower part of the Angulatus bed, would introduce great

[1] Page 103.

confusion into any stratigraphical or genetic classification. We have not yet been able to find any such case.[1]

Examples of mixed faunas such as have been quoted above are not so extensively mixed as has been claimed. The Hierlatz and Adneth limestones are, for example, mixtures only of the faunas of the beds above the Angulatus bed; the examples given of so-called psiloceran forms as occurring in them are due to mistakes in identification, since these forms are species or young of species of Arnioceras or Agassiceras, and the species cited as belonging to the Middle and Upper Lias are either radical forms or else morphological equivalents, like all the so-called anachronic forms which we have yet studied. A paper by W. B. Clarke[2] is very instructive in this connection, since he found in the Rhætic a true Arcestes, showing conclusively how favorable this region must have been for the preservation of ancient forms. He also was able to make out and describe the Planorbis and Angulatus horizons, with a full list of species already described by Wähner and others, and, above this, the Hierlatz horizon.

The facts appear also to accord perfectly with the theory of autochthonous faunas. If the Northeastern Alps were the seat of origin for the major portion of the radical forms of Arietidæ, we should naturally expect to find in this province the geological and zoölogical relations which are shown in Table VI.; namely, a clear definition of the lower formations and faunas throughout the Planorbis and Angulatus horizons, and an extraordinary number of radical species and their immediate allies, these also having in the sutures a more ancient or triassic aspect than in Central Europe. An analdainic fauna made up of modified forms arising by migration from other faunas would necessarily be shown either in the admixture of forms above these horizons in case the sediments were similar and continuous, or else in the non-appearance of new radical or progressive forms if the sediments were more varied and more distinctly separable, as in England and in the basin of the Rhone.

While the Mediterranean province was an analdainic fauna so far as the Arietidæ were concerned during the deposition of the upper beds of the Lower Lias, subsequent to the deposition of the Angulatus beds, this was by no means the case with other groups, such as the Lytoceratidæ. On the contrary, as has been already announced by Neumayr, this province was the autochthonous home of this family, and Neumayr's opinion is strongly sustained by the remarkable series of species described from the Northeastern Alps by Geyer, Hauer, and others, and an especially fine series by Herbich from Siebenburgen. The Lytoceratidæ are by no means absent from the faunas of the Lower Lias in Central Europe, though generally quoted as being found in the Middle and Upper Lias. Thus *Amm. Driani*, Dumortier, and *Amm. Salisburgense* and *Amm. altus* of the same author, are apparently members of this family, found in the Oxynotus bed of the basin of the

[1] Barrande, with all his knowledge and close study of the fossil Cephalopoda, has not been able to prove a single example. Those he has given are readily explained as morphological equivalents, and we have found by the investigation of Bohemian specimens that the Nautili of the present time are entirely different from paleozoic forms. As soon as the nepionic and nealogic stages are studied and compared, they are found to be distinct. This is also true of his *Gon.* (our *Ceratites*) *primaturum*.

[2] Geol. Verhalt. d. Geg. nordw. v. Achen-See.

Rhone. The last two are closely comparable in aspect with species figured by Hauer from the Adneth limestones.[1] In the same way, we should be disposed to regard the Mediterranean province as the autochthonous home of some genera of the Middle Lias, which appear here in association with the Arietidæ.

The Arietidæ afford an excellent standard, since their genera and species have been found, with rare exceptions, only in the Lower Lias; and, so far as our knowledge now goes, the series of forms and cycles have a very complete and satisfactory aspect, indicating a history of progress and decline within the limits of that group of strata in the faunas of Central Europe.

In the Mediterranean faunas, however, so far as known, only the rise of the group is recorded in the sediments and fossil remains, and its acme and decline are not clearly indicated. We have been accustomed to look upon the fauna of the Hierlatz beds as composed for the most part of degraded dwarfs, whose peculiarities or modifications were due to the unfavorable action of the surroundings upon migrants from other contemporaneous faunas of the Lower Lias. This seems to be the only theory which can account for the prevalent smaller size and more or less degraded aspect of many of the shells, when compared with their nearest allies in other locations.

Summary.

The facts cited above, though far from complete, show that the series of the Radical and Plicatus Stocks, with the exception of the vermiceran series, were probably evolved in the Mediterranean province. The series of the Levis Stock had however a different history, since they probably arose in the basins of Central Europe. We therefore venture to differ in part from the eminent geologist and paleontologist Neumayr, who regards, if we properly understand his views, the Northeastern Alps as the aldainic home of the whole of the Arietidæ.

The sutures of all the Mediterranean forms of Psiloceras and Caloceras are, as figured by Wähner, more complicated, or, as we should say, more triassic than those commonly found in Central Europe; but we occasionally find a variety of *Psil. planorbe*, like that figured by Quenstedt[2] and by Wright,[3] in which there is a close approximation to the outlines common in the Mediterranean province. After having written the above, we were extremely gratified to find precisely the same results with regard to the relation of *caliphyllum* and *planorbe*, but more fully and exactly stated by Neumayr, in his "Unterster Lias" (p. 25). His conclusion, that *planorbe* is consequently a derivative of *Psil. caliphyllum*, and is characteristic of Central Europe, while the latter species is equally characteristic of the Mediterranean province, is sustained by the fact that the sutures of *caliphyl-*

[1] The peculiarities of the senile whorls are similar to those of *Oxynoticeras Lotharingum*, and will lead to much confusion until the sutures and the young are fully known. It is quite possible that our own conclusion may be wrong in this respect, but the sutures of *Salisburgensis* and *altus*, Hauer, are Lytoceran, and the aspect of these compressed shells is very similar to that of those found in France, whose sutures are however unknown. The young are known only in *Driani*, which resembles some of the forms described by Herbich.

[2] Amm. d. Schwab. Jura, pl. i. fig. 10.

[3] Lias Amm., pl. xiv. fig. 1

lum become simpler with advancing age, and more like those of *planorbe*, and by the scarcity of the latter, which, though found by Wähner,[1] is declared to be rare. One of Wähner's specimens was transitional to *Hagenowi* in its sutures, and this indicates that the province of the Northeastern Alps was the autochthonous home of *caliphyllum*, *planorbe*, and *Hagenowi*, and adds greatly to the probabilities in favor of Neumayr's hypothesis. In *Cal. Liasicum*, *Johnstoni*, and *nodotianum* it is common to find varieties varying in the sutures between the Mediterranean and Central European extremes of modification, the latter being of course the most numerous in their own province and rare in the Northeastern Alps. The sutures of *Liasicum*,[2] *tortilis*,[3] and *nodotianus*,[4] when contrasted with Quenstedt's, Wright's, and our own figures, give a good idea of the extent of variation, which is quite as great as in *Psil. planorbe*, if not greater.

Undoubtedly these facts, and the nearer approximation in aspect and sutures of the Mediterranean forms of Psiloceras to Gymnites of the Trias, the genus we have always regarded as the probable ancestor of the former, are strongly in favor of Neumayr's opinion that the forms of the European province arose by chorological migration from the apparently more ancient fauna of the Mediterranean province. The richer evolution of triassic forms in the Mediterranean province, as described and illustrated by Mojsisovics, can also be brought forward in favor of this view. Nevertheless, it is not right to yield entirely to the fascinations of this opinion until there is positive proof that *Psil. planorbe* or *caliphyllum* occurred earlier in this province than in Central Europe.

With regard to the origin of Caloceras from this province, the facts are still stronger in favor of Neumayr's view, but Vermiceras appears to have arisen in South Germany.

With regard to the origin of Wæhneroceras and Schlotheimia, it seems probable from the zoölogical evidence that they also arose in the Mediterranean province. The evidence is, however, geologically incomplete, since it is probable that *Schlot. catenata* occurred quite as early in South Germany. Wæhneroceras, the series of connecting forms uniting Schlotheimia and Psiloceras in this same province, is not yet proved to be of as ancient origin as Schlotheimia itself, and this introduces an anachronism which requires additional facts for its explanation.

Mösch[5] has decided that the Lias to the west of the head-waters of the Rhine contains species peculiar to the Central European province. W. A. Ooster's descriptions and figures of species confirm this conclusion, since he does not mention any novel species, though he describes twenty-one forms, representing more or less all the genera of the Arietidæ.[6]

Zittel[7] remarks that there is great resemblance between the Upper Lias in Provence and Lombardy. Mojsisovics,[8] in quoting these observations, says that

[1] Verh. k. k. geol. Reichsans., 1886, p. 169.

[2] D'Orb., Terr. Jurass., I. pl. xlviii. [3] Ibid., pl. xlix. [4] Ibid., pl. xlvii.

[5] D. Jura Alpen d. Ost-Schweiz, 1872, p. 1.

[6] Cat. des Ceph. des Alpes Suisses, Denk. schweiz. Gesellsch. Naturwis., XVIII., 1861; see also Studer, Geol. d. Schweiz, II. p. 231, for similar views.

[7] Central-Appenn., Geogn. pal. Beitr., Benecke, II. p. 171.

[8] Dolomit Riffe Sud-Tyr. und Venet., p. 26.

they raise the question whether the Mediterranean forms of the Swiss Alpine Jura may not have come by the way of southern France into the western Alpine region.

The very interesting and instructive essay of M. Dieulefait on the "Zone à Avicula contorta et l'Infra Lias dans le Sud-est de la France"[1] shows that in Provence a southern and northern basin may be clearly separated. The southern or Mediterranean basin comprises a range of deposits reaching from the neighborhood of Toulon and Brignolles to Draguignan, Grasse, and Nice. The basin of the north and northwest, or of the Durance, encloses the valley of that river and the neighborhood of Castellane and Digne in the department of Basses Alpes. The basin of the Mediterranean possesses a series of beds identified as belonging to the zone of *Avicula contorta*, but there are no Ammonitinæ, and all the beds above these in the Lower Lias are absent. In the basin of the Durance, however, a very complete series of lower lias beds, including a Planorbis and Angulatus bed, has been described. M. Dieulefait has here traced the limits of the Mediterranean province at a very important, and for our theory an essential locality. He has shown that the sharp division between the Mediterranean faunas and those of Central Europe, which, according to our conclusions, ought to exist along the boundaries between the basin of Italy and of the Rhone, can be actually traced in the field.

Dumortier's extensive observations in the valley of the Rhone and Collenot's at Semur show the sudden spreading out by migration of forms of Psiloceras and Schlotheimia from South Germany into the Côte d'Or at about the same time, and a somewhat later appearance of these radicals in the Rhone and North German basins, and possibly still later in England. It seems more likely also, from the two tables given above, that the species of Schlotheimia, Psiloceras, Caloceras, and perhaps Vermiceras, were migrants from the Côte d'Or basin to the Rhone, than that the reverse should have taken place. Coroniceras also thins out in this direction, whereas the genera having their acme in the upper horizons of the Lower Lias, viz. Asteroceras, Agassiceras, and Oxynoticeras, are more abundantly represented, perhaps, than in the Côte d'Or. All the information obtainable with regard to the faunas of the Lower Lias in Switzerland indicates a general thinning out in numbers of species and varieties in that basin which, like the basin of the Rhone, lies to the south of the autochthonous zone.

Emerson's collection from Markoldendorf now at Amherst, Mass., and others we have seen, show that the fauna of North Germany was probably derived from South Germany, and this accords with Seebach's conclusion, that a connection existed between the Hanoverian and South German faunas during the time of the deposition of the Lower Jura.[2] There is considerable doubt whether the English species of Psiloceras and Caloceras came by the way of the Côte d'Or, or found this locality by independent migration. The former opinion is supported by the general fact that the English fauna does not contain an autochthonous series, nor does any radical species appear earlier in this basin than in those of the continent; it is therefore probably a residual fauna, peopled by chorological migration.

[1] Ann. des Sci. Géol., I. 1869, p. 173, pl. v.

[2] Hannoverische Jura, p. 70.

The prevalence of the geratologous forms of the different series in the highest beds of the Lower Lias indicates that this fauna, like those of the Swiss and Rhone basins, is also a residual fauna, but lying north instead of south of the zone of the autochthones. The only definite information with regard to the Lias faunas of the higher northern latitudes, which I have been able to lay hands on, is the "I Sueriges Aldre Mesozoische Bildungen," by B. Lundgren.[1] *Cor. Bucklandi* and *bisulcatum* are mentioned, and *Cor. Sauzeanum*,[2] *Agas. Scipionianum*,[3] *Agas. striaries*,[4] and *Arn. falcaries* are figured.[5] These indicate the presence of the Bucklandi beds in northwestern Sweden, but the fossils were in bad condition and not abundant in the number of species. Lundgren mentions, also, that these beds are underlaid by an unfossiliferous bed, which he thinks is probably the equivalent of the Planorbis and Angulatus beds of Central Europe. M. Hebert has, in his interesting paper, "L'Age des Grès à Combustible d'Helsinborg et d'Hoganas,"[6] given proofs of the presence of the existence of the Planorbis and Angulatus beds in southern Sweden, but they contain no specimens of Ammonitinæ.

It is well known that the Lias does not exist in Central Russia, and A. Pavlow, in his article on "Russie, Esquisse Géologique,"[7] gives an account of the deposits of the Jurassic, but mentions the Lias as occurring only in the Crimea and perhaps the Caucasus, and refers these to the fauna of the Mediterranean province, and not to Central Europe. Savi E. G. Meneghini, "Geologia della Toscana," gives several lists of fossils from many distinct localities, among which are a number of the Arietidæ. Von Rath[8] quotes a list of fossils from Meneghini containing many Arietidæ, and he states that there are a number of new forms; but lists of names and descriptions of species are unfortunately not usually of value in such work as we are striving to do. Taramelli, in his monograph, "Del Lias nelle Provincie Venete,"[9] describes and figures several species of Ammonitinæ. His *Amm. Guibalianus* is a true *Oxyn. Guibali* of considerable size, 300 mm. in diameter, and too involute for a specimen of *Greenoughi*. *Arietites rotiformis* is a young form of *Cor. Gmuendense*, or some such compressed shell; it is assuredly not *rotiformis* if his figure is correct. *Ar. obtusus* is a true *obtusum*. *Ar. stellaris* is the adolescent form of *Ast. stellare*. All of these have the facies of the Northeastern Alps, except perhaps *Guibali*, which is new to us as occurring in the Mediterranean province.

Sacco states, in his "Lias della Valle Sturio di Cuneo,"[10] that all the beds of the Lower Lias are present, and gives lists of fossils, including a supposed *Psil. planorbe*, several species of Schlotheimia, *Ver. Conybeari*, and a doubtful *Cor. kridion*, and *Cor. Bucklandi* and *bisulcatum* are said to be of good size and abundant near Pouriac. In "Lias Inferiore ad Arieti," by C. de Stefani, it is distinctly stated, according to Geyer, that the Lower Lias of Italy is divisible into only two parts; one which is similar to the Angulatus horizon, and yet contains the fauna of

[1] Sueriges Geologiska Undersokning, ch. xlvii., Mollusk.
[2] Pl. ii. fig. 5-7.
[3] Pl. iii.
[4] Pl. ii. fig. 9.
[5] Pl. ii. fig. 8.
[6] Ann. Sci. Géol., I., 1869.
[7] Annu. Géol. Universel, II., 1886, p. 302.
[8] "Geogn.-mineralo. Fragm. a. Italien," Zeitsch. deutsch. geol. Gesellsch., XX., 1868, p. 320.
[9] Atti dell' Instituto Veneto, ser. 5, V., 1880, Appendix.
[10] Boll. del R. Comitato Geol. d' Italia, XVII., 1886, p. 15.

Spezia, and another higher horizon, which is supposed to be the equivalent of the Bucklandi horizon. This last is said to contain Cephalopods representing all the later faunas of the Lower Lias, and some species are quoted as being referable to the Middle Lias.

Canavari, in his "Fauna der unteren Lias von Spezia," so frequently quoted above, states that the fossils occur in a single zone, which does not admit of subdivision, though it was carefully investigated, layer by layer, by Cocchi. He states also, that it is unquestionably the lowest of the lower lias sediments in Italy, and comprises all the horizons except those of Planorbis and Oxynotus. He considers that the fossils have closer affinities with those of the Mediterranean province than with those of Central Europe, a fact which seems to be established. The species of the Lytoceratidæ and of Amaltheus, etc., which are supposed to be anachronic and to indicate a fauna derived from the Middle and Upper Lias, appear to us to be found in their appropriate positions, like those of the Northeastern Alps. They may be either the radicals of the similar forms which occur in the Middle and Upper Lias of the Central European faunas, or morphological equivalents, or pathological specimens.[1] This is also Canavari's opinion with relation to some forms, since he expressly states that the ægoceran species, as he calls them, are the immediate forerunners of Microderoceras. The fauna of the Rhone basin is almost exclusively composed of species having a Central European aspect. There are, it is true, some slight indications, in the presence of three species of Lytoceratidæ in this basin, that the migrants may have come this way on their march into Central Europe, but there are no supporting facts with which we are acquainted. The absence of the Planorbis horizon, or at any rate its sporadic appearance in Italy, and the absence of Ammonitinæ in this horizon of southern Provence, are very serious difficulties in the path of a supposed southern track of migration.

The evidence, so far as known, seems therefore strongly in favor of the view, that during the time of Planorbis and Caloceras, and perhaps earlier in the Angulatus horizons, the stream of migration flowed south and westerly from the Northeastern Alps into Italy, while another from the same basin directed itself westerly along the then existing coast lines into the basins of South Germany and the Côte d'Or, and the species were distributed thence into the basins to the north and south of these two, in the province of Central Europe. In South Germany and the Côte d'Or the conditions became favorable during the time of the Angulatus horizon for the evolution of Vermiceras among the descendants of the Plicatus Stock, and for the origin of Coroniceras, Arnioceras, and Agassiceras of the Levis Stock. Asteroceras arose later in these same faunas in the Upper Bucklandi beds, and Oxynoticeras probably even still later, though here the series is evidently older than the date of its first appearance. The migrations of these genera spread the forms to the east into the faunas of the Northeastern

[1] The figures of Amaltheus given by Canavari in his last work, "Fauna del Lias inf. della Spezia, R. Comit. Geol. d' Italia," III., Pt. II. pl. vi., are certainly startlingly similar to Amaltheus, but such resemblances in forms of widely distinct series are not uncommon. See the pathological case figured on Plate X. Fig. 19 of this memoir, and others quoted in the descriptions of the species.

Alps, and thence they passed southerly into the Italian basin. Migrants also passed in all other directions into the residual basins to the north and south of the basins of the Côte d'Or and South Germany, in the province of Central Europe.

While these faunas in the Northeastern Alps and Italy became analdainic faunas so far as the Arietidæ were concerned, they were aldainic faunas for some other groups, like the Lytoceratidæ, and also very likely for the Liparoceratidæ, Deroceratidæ, and possibly other families. These mixed faunas, which have been deemed such sources of confusion, are in reality the most instructive, and will enable us to trace both chronological and chorological migrations with greater security, if the views here advanced are correct.

Table V. shows that there are but two examples of what Neumayr calls cryptogenous types in Central Europe, species appearing suddenly without apparent ancestors, *Schlot. catenata* and *Psil. planorbe*, var. *leve*. *Schlot. catenata*, however, cannot be called an unquestionable cryptogenous form in the Northeastern Alps. It is in that basin connected by intermediate forms, as stated above, with Psiloceras, and it is therefore probable that in course of time the geological evidences which are now confusing will be brought into accord with the paleozoölogy. *Psil. planorbe* is a radical derived from *Psil. caliphyllum*, or else from pre-existing triassic ancestors, and the absence of a complete series connecting it or *Psil. caliphyllum* with Gymnites of the Trias is evidently due to the absence of an equally complete series of formations. That the intermediate species might have been deep-sea forms, and therefore not represented in the rocky strata now exposed, as supposed by Neumayr, is an admissible explanation. Newberry's hypothesis[1] of the retirement of the sea is, however, equally supposable, and has the additional recommendation of explaining the absence both of intermediate forms and of the sediments. Newberry thinks that the presence of intermediate links in paleozoölogic history, and their absence from localities so far explored, are explicable on the supposition that the chain of the rocky deposits is incomplete in those localities, and that the sea had retired from them carrying with it the threads of life. The missing links of the record were then evolved in other places, but not brought back by the return of the ocean to its former shores. This seems to us more in accord with what is already known of the merely fragmentary aspect of the geologic record in any one region, the occasional discovery of the absent leaves of the record in other places, and the want of absolute synchronism between the strata of Europe and those of America.

That *Psil. planorbe* was a littoral form, as well as its congeners, can hardly be doubtful, since, besides the facts quoted above, they are found associated in the same series of layers with bones of saurians and even remains of insects in England. The remarks of Martin and other authors, quoted above, upon the characteristics of the lumachelle in the Côte d'Or, and the broken aspect of the shells of Ammonoids compared with those of swimmers like the Nautiloids, as stated by Terquem, in the department of Moselle, the opinions of Tate and Blake, and

[1] Circles of Deposition in American Sedementary Rocks, Proc. Am. Ass. Adv. Sci., XXII., 1873, pp. 185, 189.

the great abundance in which Ammonoids occur as contrasted with Nautiloids, are all in favor of the conclusion that they were structurally rostrated, creeping animals, which necessarily followed the shore lines in their migrations. Fraas takes the view that the Suabian Lower Lias was as a whole, when compared with the synchronous strata to the west and north, a deep-sea formation, and cites the absence of sandstones and coarse deposits, the small Lamellibranchs, and Brachiopoda. It is very evident, however, that whatever the bathymetrical differences of the South German basin, and however far removed from the ancient shores now represented by the Black Forest and the Vosges, the surroundings were not sufficiently distinct to make any marked differences in the Arietidæ of this basin.

We have noted above the occurrence in Peru of *Cal. Ortoni*, a form having close resemblance to a species of the Northeastern Alps, and the apparent identity of other species with those of Central Europe, the forms found at Vancouver's Island and in California, etc., show that on this continent the faunas possessed a mixed character. The paucity of the development both geologically and paleontologically of the Lower Lias is in accord with the similar deficiency of this stage in the analdainic basins of northern Europe, India, and Italy. There is another fact in this connection, which strikes us as very remarkable, — the absence of any absolutely new types of Ammonitinæ. So far as explorations have gone, not a single species indicates the evolution of any widely distinct family or genus from those found in Europe. Thus, although not able to produce any satisfactory evidence that all the faunas throughout the world during the lower lias age were more or less analdainic faunas derived from the zone of the autochthones of the Arietidæ in Europe, the evidence is sufficient to make such an opinion worthy of the attention of students of geology and paleontology.

The view expressed by Neumayr, that the Cephalopoda are exceptional in respect to the rapidity with which their modifications probably took place, seems to us erroneous. There is no greater aspect of pliability in this than in other types, when accurately classified. When, however, we assemble within the same family species of the Lytoceratinæ and Ammonitinæ, or in the same genus forms of entirely distinct stocks without sufficient reference to their genetic history, then of course a belief in the polygenesis of the progressive series,[1] and in an exceptional tendency to modification, becomes essential in order to explain the heterogeneous aspect of the groups. We think, however, that even the most variable families of Cephalopoda are not, as a rule, any more variable than the Unionidæ, Ostreadæ, or Hippuritidæ, among Lamellibranchs, or the Planorbidæ, Vermetidæ, etc., among Gasteropoda, and many other groups that might be mentioned.

The expansion of the whole series of forms of Psiloceras, Schlotheimia, and Wæhneroceras in the Northeastern Alps, and the apparent rapidity of chorological migrations and changes and introduction of new series, the equally sudden

[1] We desire to call attention here to the fact that we have admitted the polygenetic derivation of retrogressive types like Baculites, etc.; but this in no manner commits us to the doctrine of polygenesis for any of the progressive types. So far as we know, these are monogenetic in mode of origin.

expansion of the Arietidæ in the Bucklandi zone of Central Europe, the rapidity with which the forms of the still later beds must have come into being in order to be presented in a body, as in the Tuberculatus beds of the Côte d'Or, and the limited thickness of the beds, are all against the supposition that it required vast periods of time for a species to become modified and give rise to series of distinct forms. Either the species of the Arietidæ had time enough during the deposition of the Planorbis, Angulatus, and Bucklandi beds of the Lower Lias to spread themselves over the entire area of modern Europe, and generate from one form all the series described above, or else the same species and genera had invariably distinct centres of origin in the different basins. One might support the latter view and favor polygenesis even in this extreme sense with considerable show of reason, if there were not such a mass of evidence in favor of migration, some of which we have given above. If there were space, we could add examples from the researches of various well known zoölogists upon the migrations and modification of species in modern times, both along the coasts and over the land. The more striking examples are, however, quite well known, and hardly need to be dwelt upon.

V.

DESCRIPTIONS OF GENERA AND SPECIES OF ARIETIDÆ.[1]

RADICAL STOCK.

FIRST, OR PSILOCERAN BRANCH.

PSILOCERAS.

SHELL smooth, plicated or with fold-like pilæ in some subseries. The abdomen is rounded, or with smooth median zone, never channelled or keeled. Whorl in section is compressed, helmet-shaped. The sutures are similar in proportions and outlines to those of Caloceras. This is shown in the broad abdominal lobe and large siphonal saddle, the equality in length and size of the abdominal and lateral lobes and saddles, their leaf-shaped marginal digitations, and the number and inclination posteriorly of the auxiliary lobes and saddles.

The living chamber is one, or more than one, volution in length, and is shorter in the young than in the adult stages.[2] Senility is indicated by increasing convergence of the sides, and the loss of plications,[3] but a subacute abdomen, such as appears in the old whorl of Wæhneroceras, is never present. The completeness and accuracy of Wähner's illustrations and descriptions, which enable one to study all the stages of growth in some species, has tempted us to suggest the existence of three subseries in this genus. (1.) The first contains smooth shells, typical helmet-shaped whorl, and an old age in which a subacute whorl is not yet recorded in any species. (2.) The second contains plicated shells exactly similar in form, but the folds numerous and regular, and in some species figured by Wähner these cross the abdomen with a forward bend. They are, however, not true pilæ, and, so far as we know, they do not become depressed along the median zone as in Wæhneroceras. (3.) The third contains shells having psiloceran forms but flattened sides, and often plicated as in the second subseries, though the *Psil. Hagenowii* is smooth. We regard this subseries as of doubtful utility, but do not know how to dispose at present of the forms it contains.

[1] Throughout this chapter there is no attempt to give a complete synonymy of any one species. The references given under each name are only those which were considered essential to settle the application of the specific name and the range of the forms to which it was applied in this memoir. The localities given are those of specimens in the collections of the Museum of Comparative Zoölogy.

[2] Quenstedt, Amm. Schwab. Jura, pl. i. fig. 6, shows a nealogic stage in which this chamber is not quite half a volution in length. Wahner takes note of this. (Unter. Lias d. nordöst. Alpen, Mojsis. et Neum., Beitr., IV., 1886, p 135.) and states that in one example of *Psil. planorbe* from Würtemburg observed by him the living chamber was only two thirds of a volution in length, and suggests the same opinion with regard to the shorter living chambers of the young.

[3] Quenstedt figures what may be a fragment of an old specimen of *Psil. planorbe*, Amm. Schwab. Jura, pl. iii. fig. 1, and Wahner has figured several old specimens in Unter. Lias, Mojsis. et Neum., Beitr.

First and Second Subseries.

Psiloceras planorbe, Hyatt.

Var. **leve.**

Plate I. Fig. 1-4. Summ. Pl. XI. Fig. 1; Pl. XII. Fig. 1.

Amm. planorbis, Sow., Min. Conch., V. p. 69, pl. cccclxviii.
Ægoc. planorbis, Wright, Lias Amm., p. 308, pl. xiv fig. 1-4.
Amm. psilonotus levis, Quenst., Die Ceph., p. 73, pl. iii. fig. 13; Amm. Schwab. Jura, pl. i. fig. 1-7.
Amm. Sampsoni, Portl., Rep. Geol. Londonderry, etc., p. 138, pl. xxix. A. fig. 13.
Psil. planorbe, Hyatt, Bull. Mus. Comp. Zool., I. No. 5, p. 73.

Localities. — Whitby, Watchet, Montloy, Semur, Rudern, Nellingen, Balingen, Neuffen.[1]

This remarkable form is a somewhat flattened discoidal and perfectly smooth shell in its typical adult form. The young are often plicated.

Var. **plicatum.**

Plate I. Fig. 5, 6. Summ. Pl. XI. Fig. 2.

Amm. psilonotus plicatus, Quenst., Amm. Schwab. Jura, pl. i. fig. 1-11 (not fig. 8, 13).

This shell differs from variety *leve* merely in having immature pilæ or folds in the neologic and ephebolic stages. There is therefore the most gradual and hardly perceptible gradation from the preceding variety to this form. The septa of both are exceedingly variable. The marginal digitations may be either very shallow, as in the Arietidæ generally, or they may be foliaceous and complicated, as in the radical series. The lobes and saddles may also vary exceedingly in size and proportions; some species have deep and narrow saddles with long broad lobes, as in the radical series, while others, more like the typical Arietidæ, have shallower, broader saddles, and shorter, more pointed lobes. In the collection at Semur there are forms from Saulieu identical with the South German, which when compared with *raricostatum* and *Johnstoni*, show closer approximations than any specimens seen elsewhere.

The Bristol collection contains undistorted specimens of this species from Cotham, and in Dr. Wright's collection from Whitby the *plicatus* variety is labelled *Amm. erugatus*, Bean. The connection with the flattened Watchet specimens of *planorbis*, Sow., can be clearly made out by the large tablet in the British Museum, containing about one hundred and fifty specimens. Of these, perhaps ninety exhibit folds like those of *plicatus* and *erugatus*. The largest on this slab is from 60 to 80.5 mm. in diameter. These large specimens are not equivalent to *Cal. Johnstoni*, as Oppel supposed, but to *plicatus*. *Erugatus* seems to be a dwarfed form with the folds often developed very strongly in the young,[2] and the shell has fine striæ of growth, as in *Agas. striaries*, Plate IX. Fig. 14, 15. In the Museum of Comparative Zoölogy the series is complete from *leve* to var. *plicatum*, as figured by Quenstedt in "Der Jura," and in another direction to the var. of *planorbe* from Semur.[3] This is a slightly plicated form, having the sides of the whorls broader

[1] These localities also include var. *plicatum*.
[3] See Pl. I. fig. 5, 6.
[2] *Amm. erugatus* Bean has only the young plicated, resembling in this respect var. *leve*. It is however always a small form or dwarf.

than usual, and the involution slightly increased, a modification which is also sometimes present, though less marked, in *erugatus*.

Wähner found what he claims to be *Psil. planorbe* at Pfonsjoch in the Planorbis bed. These were small specimens, measuring 15–40 mm. in diameter, and one of them is said to be similar to Hagenowi.[1] In the same work he figures the following discoidal shells of the smooth subseries: *Psil. polycyclum* and *caliphyllum*, Plate XV., and *Psil. pleurolissum*.[2] Neumayr, in the Unterster Lias,[3] gives *Psil. planorboides*, a more involute, smooth species of this series. *Planorboides* appears to lead into two much more involute and compressed species figured by Wähner in the same work, *Psil. Atanatense* and *mesogenos*.[4] Both of these are devoid of true pilæ, and possess only senile fold-like pilations.[5]

Second Subseries.

Psiloceras longipontinum, Wähner.

Amm. longipontinus, Opp., Pal. Mittheil., p. 129, pl. xli.
Psil. longipontinus, Wähner, Unt. Lias, Mojsis. et. Neum., Beitr., IV. p. 196.
Ægoc. Clausi, Neum., Unterst. Lias, Abh. k. k. geol. Reichsans., VII. pl. iii.

The original of this species in the Museum of Stuttgardt has considerable likeness to *Psil. planorbe*, var. *plicatum*. Oppel seems to have considered it one of the schlotheimian series.[6] The open umbilicus, straight folds in place of true pilæ, keelless abdomen, and helmet-shaped form of whorl, show it to be a member of the psiloceran series. The sutures,[7] as figured by Oppel, exhibit the strong psiloceran affinities of the species. In his specimen the last whorl has become smooth on one side, and the pilæ nearly obsolete on the other, thus indicating the approach of senility, though the shell is but 95 mm. in diameter. The pilæ begin to obsolesce posterior to the last septum. The living chamber is nearly one volution in length, though still incomplete. An empty cast in the Semur Museum from Ruffy undoubtedly belongs to this species; it is 155 mm. in diameter, and the last whorl is smooth, showing its great age. There are specimens in the collection at Munich labelled *Amm. Roberti*, Hauer, locality Filder, and *Amm. Oeduensis*,

[1] Unter. Lias, Mojsis. et Neum., Beitr., IV. p. 136.
[2] Ibid., III. pl. xxvi.
[3] Abhandl. geol. Reichsans., VII. pl. iv.
[4] *Op. cit.*, III. pl. xxvi.
[5] We have figured only the most involute of this smooth series on Summ. Pl. xi. fig. 13.
[6] The closeness of the parallellism between some of the forms of Psiloceras and some species of the Lytoceratidæ is such as will be likely to cause considerable confusion unless great care is taken in studying the species. Comparison of such forms as *Amm. Petersi*, Hauer, Ceph. nordöst. Alpen, pl. xxi. fig. 1–3, *Lyt. Petersi*, Herb., Széklerland, pl. xx., *Lyt.? Driani*, sp. Dumort., Études Pal. du Basin du Rhone, and *Lytoc.* (*Amm.*) *Roberti*, Hauer, Capric. oesterr. Alpen, pl. iii., will show that without close study of the sutures and young no separation can be made with certainty. In fact, in identifying *Driani* in the absence of figures of the sutures as a form of Lytoceras, we have been led by the geological position and size, which accord better with Lytoceras than with a species of Psiloceras. It is possible that in doing this we are illustrating these remarks in a forcible manner.

See also in this connection the forms of Rhacophyllites and Phylloceras figured by Canavari in his "Fauna des unteren Lias von Spezia," pl. ii.
[7] The sutures figured by Portlock, as well as the form of the section (b) of his *Amm. Sampsoni* (fig. 13 c, not fig. 13 a), suggest *longipontinus*, and may indicate the presence of this form, or transitional varieties, in the English basin.

Despl. d. Champ., locality Blumenstein am Thuner See. One of the specimens from Filder shows the exact aspect and markings of *Psil. planorbe*, but has the form of *longipontinum*. Though it is somewhat difficult to judge from a figure, nevertheless, *Æg. Clausi*, Neumayr, very closely resembles *Psil. longipontinum*, and we have considered it to be a variety of this species with somewhat stouter whorls than the normal form. It is also a large aged specimen, and according to Neumayr came from Würtemburg.

Quenstedt referred this species, in his "Ammoniten des Schwäbischen Jura," to *Cal. laqueum*. His comparisons were evidently made with the old whorl of *laqueum*, and, as this has no keel, and is smooth or with obsolescent pilæ, it is of course very like the adult stages of *Psil. longipontinum*. Nevertheless, both the young and adult stages of *laqueum* are easily distinguished from the same stages of *longipontinum*. Quenstedt's figure shows the length of the living chamber to have exceeded one volution.

Tate and Blake's citation of this species from the Angulatus bed[1] is likely to mislead. Their species is, as figured, a diseased Caloceras, or poorly drawn species of Schlotheimia with pilæ crossing the abdomen, but certainly not, as named by them, *longipontinus*.

Species of the second subseries figured by Neumayr in the work quoted above are as follows. *Psil. cryptogonium*, Plate VI., is discoidal. *Psil. majus* and *Gernense*, Plate V., are slightly more involute shells. Wähner, in Volume IV. of the work above quoted, figures *Psil. sublaqueum*, Plates XV., XVI., *Psil. crebricinctum*, Plates XVI., XVIII., *Psil. pachydiscus* and *polyphyllum*, Plate XVII., all discoidal shells. This subseries and the preceding agree closely with the western European forms except in the involute species. Wähner also figures, in Volume III. of the same work, *Psil. Berchta* and *aphanoptychum*, Plate XXIII., which are discoidal, and *Psil. pleuronotum*, Plate XXV., *calcimontanum*, Plate XXIV., and *Kammerkarense*, Plates XXIV., XXV., which are more involute and compressed.[2]

Third Subseries.

Psiloceras Hagenowi, Wähner.

Amm. Hagenowi, Dunk., Paleontogr., I. pl. xiii. fig. 22, pl. xvii. fig. 2.
Amm. Hagenowi Terq. et Piet., Lias Inf. de l'Est de la France, Mem. Soc. Geol., VIII. pl. i. fig. 3, 4.
Amm. Hagenowi, Quenst., Amm. Schwab. Jura, pl. i. fig. 18.
Psil. Hagenowi, Wähner, Unt. Lias, Mojsis. et Neum., Beitr., IV. p. 196

The form of this shell approximates to that of *Psil. planorbe*, var. *læve*, but the sutures are more widely distinct, and degenerate in outline. In Terquem and Piette's figure they resemble quite closely the sutures of *Popanoceras Kingianum* and *antiquum*, Goniatitinæ of the Dyas. The lobes of that figured by Quenstedt are not so coarsely dentate, and approximate more closely to the sutures of *Psil.*

[1] Yorkshire Lias, p. 273, pl. v. fig. 4.

[2] On Summary Pl. xi., outline figures have been given of the principal forms, *aphanoptychum*, fig. 11, and *Kammerkarense*, fig. 12.

planorbe. The saddles sometimes have entire margins, as in some Ceratitinæ of the Trias. Neumayr's *Hagenowi*, in his "Unterster Lias Nördalpen,"[1] is not a true *Hagenowi*, if the sutures are correctly drawn. Such facts and the remark of Wähner quoted above (page 113) show that *Hagenowi* is probably a dwarfed deformation of *Psil. planorbe*, which is likely to occur in any locality, and has an independent existence as a race or species only in certain basins where it is abundant. It seems to indicate, wherever it appears, that *Psil. planorbe* has there been subject to unfavorable conditions.

Neumayr in the work above quoted, Plate IV. Fig. 1, gives a *Psil.* (*Ægoc.*) *Naumanni*, a good-sized species with numerous folds, compressed slightly convergent sides, and a rounded smooth abdomen, exactly the form and characters of his *Hagenowi*, except that it is more decidedly plicated. The smaller *Psil.* (*Ægoc.*) *crebrispirale*, Ibid., Plate V. Fig. 4, is probably the young of this shell. The sutures have complicated margins, as in other shells of this province, and are not similar to those of *Hagenowi*. We place it here until its exact affinities can be settled by the study of a series, or of the young.

Ægoceras Struckmanni,[2] Ibid., Plate VI. Fig. 5, as remarked by this distinguished authority, is a unique survival of triassic forms. It resembles the flat-sided whorls in Tirolites, and even certain earlier forms, like Popanoceras. It may be provisionally associated with this series until the sutures are known, since the shell is smooth, and similar to that of *Psil. planorbe*. This series should be carefully studied with ample materials. It may be that confusion exists between some forms now supposed to be true *Psil. Hagenowi* and some triassic forms still surviving in the Lias. Canavari, in his "Fauna del Lias Inferiore di Spezia," 1888, Plate VII., has figured a series of what appear to be true Tropites. These are very close congeneric forms of this triassic genus, and in our opinion should be referred to Tropites itself.[3] This gives greater force to the suggestion made above.

Canavari, in his "Fauna des unteren Lias von Spezia," gives some interesting forms of this genus. *Psil.* (*Ægoc.*), Plate XIX. Fig. 2, 4, 5, is a plicated form similar to *pleuronotum*. *Psil. pleuronotum*, Plate XIX. Fig. 3, may possibly be the same as *Psil. calcimontanum*, as stated by Wähner, but it is a dwarf, like most of the species from this locality. *Psil.* (*Ægoc.*) *Portisi*, Plate XIX. Fig. 6, appears to bear a similar relation to *Psil. mesogenos*. Wähner, however, considers it identical with the young of his *Psil. Kammerkarense*.[4]

[1] Abhandl. geol. Reichsans. Wien, VII. pl. ii

[2] Wähner's *Psil. Struckmanni*, Unt. Lias, Mojsis. et Neum., Beitr., IV. p. 196.

[3] The survival of characteristic triassic forms in the Jura shows that the connections between these two systems are closer than has been supposed, and gives support to opinions advocated in the chapter on Geological and Faunal Relations, and adds another group to the three already noted, Psiloceras, Lytoceras, and Phylloceras. These facts demonstrate that no insuperable barrier arrested the migration of forms and the continuity of the faunas in time. See remarks on Tropites in note to page 154.

[4] Paleontogr., XXIX., and also Mem. del. Car. Geol. d' Italia, III., 1888.

TMÆGOCERAS.[1]

Tmaegoceras latesulcatum, Hyatt.

Amm. latesulcatus, Hauer, Ceph. d. Lias. d. Nordostl. Alpen, pl. ix. fig. 1–3.

This extraordinary form, found in the red limestones of Adneth, has a combination of characteristics altogether distinct from that of any other species. The form of the whorl, its smooth shell, and the discoidal mode of growth, are purely psiloceran. The sutures are, however, arietian, and more like those of Caloceras than typical Psiloceras or those of any other genus. We are not aware of its having been found elsewhere than in the Mediterranean province. Hauer appears to think that its affinities may lie with the Arietidæ, and that is also our opinion, but until the young have been studied it cannot be classified.

Tmaegoceras levis, Hyatt.

Ariet. Levis, Geyer, Ceph. v. Hierlatz b. Hallstadt, pl. iii. fig. 10.

This is a smooth, keeled, and channelled discoidal form like the preceding, but dwarfish, like other species of this locality.

PLICATUS STOCK.

SECOND, OR SCHLOTHEIMIAN BRANCH.

The living chamber is of uncertain length, though Quenstedt gives it in his "Ammoniten des Schwäbischen Jura" as possibly a volution in length in Schlotheimia. The shell is involute in some forms. The whorl is flattened laterally, and in old age became subacute. A smooth median zone or channel was formed on the abdomen by the suppression of the pilæ, which were continuous across the abdomen in the preceding nealogic or ephebolic stages. There are no geniculæ, though the pilæ are very completely developed. The forward bend is necessarily gradual, the whorl never having a sufficiently quadragonal form for the formation of abrupt bends or geniculæ on the edges of the abdomen. The sutures resemble those of Psiloceras and Caloceras.

WÆHNEROCERAS.[2]

The adult has a smooth median zone along the abdomen. The pilæ, so far as the young are known, cross the abdomen during the earlier nealogic stages, and this character is retained throughout the adult stages in some species. The smooth zone is really an incipient channel, formed subsequently by the resorption of the pilæ. This process may take place either in the later nealogic, ephebolic, or senile stage, according to the species. In old age the pilæ tend to degenerate into folds, and

[1] Τμῆγος, a furrow.

[2] Dedicated to Dr. Frantz Wahner, as a token of respect for his remarkably accurate and instructive researches upon the Arietidæ.

become wider apart, the abdomen narrower, and the whorl consequently much compressed and subacute. No proper quadragonal whorl is formed during the growth, and therefore the senile outline of a section of the whorl is not trigonal, as in the senile stages of shells of other branches having a flattened abdomen and a keel in the ephebolic stages. All the species have true pilæ, though these are not prominent, and the earlier nealogic stages resemble adult specimens of the second subseries of Psiloceras, in which the folds are well developed and cross the abdomen. We cannot distinguish either this genus or Schlotheimia, or Caloceras, from Psiloceras by means of the sutures. *Psil. sublaqueum*, Wäh., and other species of Psiloceras having plications which cross the abdomen until a late stage of growth, are not distinguishable until they are nearly full grown from some discoidal forms of this series.

Waehneroceras subangulare, Hyatt.

Amm. subangulare, Oppel, Paleontolog. Mittheill., p. 130.

We have referred the species to this genus entirely upon the information derived from notes made before Wæhneroceras was separated. It will be seen, however, that no species of Schlotheimia has young which remain similar to Psiloceras for such a prolonged stage as in Wæhneroceras.

One of the types of *Amm. subangularis*, Oppel, from Kalthenthal, in the collection at Munich, has a form similar to that of *Psil. planorbe*, and pilations which cross the abdomen. The young is also a pure *planorbe* until over 14 mm. in diameter. Another specimen from Filder, which we have referred also to this species, has curved and close-set pilæ, and the form and smooth abdomen of *planorbe* (not channelled at all) until over 26 mm. in diameter; then the pilæ begin to cross the abdomen. This last specimen was named *Amm. planorbis* by Oppel. There are also specimens from Hammerkhar, formerly referred by us to *subangulare*, which may be distinct. They certainly possess characters which were noted by us as intermediate between this form and true *angulata*, and one of them has a very peculiar old whorl, and may be a caloceran form.[1]

Waehneroceras tenerum, Hyatt.

Ægoc. tenerum, Neum., Unterst. Lias, Abh. k. k. geol. Reichsans., VII. pl. iii. fig. 4, 5.
Psil. tenerum, Wäh., Unt. Lias, Mojsis. et Neum., Beitr., IV. p. 198.

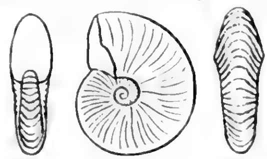
This form, described by Neumayr as occurring in the Northeastern Alps and also in Central Europe, at first seemed to us identical with *Wæh. subangulare*. Neumayr remarks that, though the young are so similar, the adults are separable, and we have upon his authority held it to be distinct. He also looks upon this species as very closely allied to *Psiloceras*, and to be a transition form from the latter to *Schlot. angulata*.

Species of this series have been figured by Wähner in Volume III. of his "Unteren Lias" as follows: *Wæh. Pallar*, Plate XXI., and *Rahana*, Plate XXIII.;

[1] Proc. Bost. Soc. Nat. Hist., XVII., 1874, p. 18.

and in Volume II. he figures *Wäh. extracostatum*, Plates XIV., XVI., and *Panzneri*, Plates XV., XXI. The figure of *extracostatum* shows an old whorl which is acute, but not involute. Among discoidal shells, *Wäh. circacostatum*, Plates XV., XVI., *curviornatum*, Plate XVI., and *haploptychum*, Plate XVII., show that the whorls of their earlier nealogic and adult stages are without channels. *Wäh. anisophyllum*, Plate XIX. Fig. 1 a, shows a very old stage with subacute trigonal whorl, and pilæ replaced by folds. *Wäh. megastoma*, Plate XVIII. Fig. 2, 3, shows earlier nealogic stages with pilæ continuous across the abdomen in the adult and senile stages. *Wäh. euptychum*, Plates XVIII., XX., *stenoptychum*, Plate XX., *latimontanum*, Plate XX., and *diploptychum*, Plate XXI., also belong to this genus. The last two are senile specimens, with subacute outer whorls, and all the above are discoidal shells exhibiting transitions from Psiloceras to Schlotheimia.

There are, however, involute forms in this series also figured by Wähner in the same work, but in Volume IV. These are *Wäh. Guidoni*, Plate XXVI. Fig. 3 a, b (not Fig. 7), and *Wäh. Emmrichi*, Plate XXVI.[1] We doubt whether either of these involute forms can be regarded as transitional to Schlotheimia, as supposed by Wähner.



20 21 22

FIG. 20-22. — Views from in front, side, and abdomen, of the young of *Wäh. Emmrichi*, after Wähner, showing the involution of this species. The characteristic pilæ and channelless abdomen of this genus are also noticeable in these figures.[2]

The results of our work upon the nealogic stages and their meaning in *Schlot. catenata*, and all other species, show that series arose only from discoidal shells, and probably never originated from the compressed and involute forms. These are themselves invariably discoidal and less compressed in their own young, showing them in every case to have been derived from shells having depressed abdomens and discoidal whorls.

Canavari, in his "Unteren Lias von Spezia,"[3] describes and figures dwarfs or the young of *Wäh.* (*Ægoc.*) *Emmrichi* under the name of *Guidoni*. Wähner thinks that Canavari's forms (Plate XVIII. Fig. 14, 15) are referable to his *Guidoni*, and Fig. 16 to be identical with his *Emmrichi*. The last is to us a very remarkable form, since it possesses continuous lateral and abdominal constrictions.

SCHLOTHEIMIA.

The form varies in this genus from discoidal to involute, but the umbilici are never entirely covered in. The whorls are usually flattened more or less on the sides, and the abdomen depressed. In the nealogic stages this form is common,

[1] We have given outline figures of *Wäh. curviornatum*, Summ. Pl. xi. fig. 7, *haploptychum*, fig. 8, *tortophorum*, fig. 9, and *Emmrichi*, fig. 10.

[2] This figure, according to Wähner, is poorly drawn, the last volution too narrow, the umbilicus too open. It, however, exhibits the general aspect of involute forms in this series, and we have retained it with that purpose in view.

[3] Palæontogr., XXIX., and Mem. del. Carta Geol. d' Italia, III., 1888.

but in the adults of involute species the whorl is necessarily more compressed. The compressed stage occurs very early in the most involute species, the flattening of the sides and the depressed abdomen being omitted. A distinct median channel is formed on the abdomen in all species except some varieties of *Schlot. catenata*. The pilæ cross the abdomen in the earlier nealogic stages, but this peculiarity is rarely retained in adults except in *catenata*. The channel is formed by the suppression of the pilæ along the median zone of the abdomen, and is sometimes, especially in the young, supplemented by the bending inwards of the shell. This channel is converted into a smooth zone in old age by the degeneration and disappearance of the geniculæ, and the tendency of the abdomen to become narrower elevates this zone and makes the whorl subacute. Involution so far as known does not decrease in old age, and while it is easy to separate the senile stages of involute species from the senile stages of any species of Wæhneroceras, it is not practicable to distinguish those of the discoidal species until the ephebolic stages are studied. The specimens figured by Quenstedt[1] show that, in extremely aged specimens, the abdomen becomes in some cases rounded, and it is instructive to compare Fig. 10 m, Plate III., with the aged Psiloceras, Fig. 1 m, in order to see how complete the reversion occasioned by senility may sometimes become.

The sutures are not distinguishable from those of Wæhneroceras. They are perhaps less like those of Caloceras than those of that genus. The superior lateral lobes also are usually not so long and narrow, nor the superior lateral saddles so large and deep, nor the auxiliaries so much inclined posteriorly. The sutures are similar, both during the nealogic and senile stages, to those of Wæhneroceras, and the differences, if any can be detected, occur only in the adult stages.

Wähner's plates[2] are so complete, that one can study the history of the development of each form, and the relations of the species in their nealogic stages. The young of the more involute species, like *Schlot. ventricosa* and *marmorea*, are similar to the later nealogic stages of less modified and more discoidal forms, like *Schlot. donar*, and are also similar to the adult stages of still more modified species, like *Schlot. angulata*. These facts confirm the opinions we have advanced in the description above, and in other parts of this memoir.[3]

[1] Amm. d. Schwab. Jura, pl. iii. and iv.

[2] Mojsis. et Neum., Beitr., IV., 1886.

[3] We have several times referred in this memoir to extraordinary parallelisms. But we know of none more remarkable than those figured by Canavari in his "Fauna der Unteren Lias von Spezia." We refer to the genus *Ectocentrites* of Wähner, in which the young as described by Canavari are similar to Lytoceras, while the later nealogic and adult stages have the pilæ and abdominal channel of Schlotheimia.

First Subseries.

Schlotheimia catenata, Wähner.

Summ. Pl. XI. Fig. 3.

Amm. catenatus, Sow., De la Beche, Traité de Géol., p. 407, fig. 67.
Amm. catenatus, D'Orb., Terr. Jurass. Ceph., p. 301, pl. xciv.
Ægoc. catenatus, Wright, Lias Amm., p. 320, pl. xix. fig. 5-7; pl. xvii fig. 3-6.
Schlot. catenata, Wäh., Unt. Lias, Mojsis. et Neum., Beitr., IV., 1886, p. 196.
Ægoc. subangulare, Wäh., Unt. Lias, Mojsis. et Neum., Beitr., IV., 1886, p. 162.
Amm. angulatus thalassicus, Quenst., Amm. Schwab. Jura, pl. ii. fig. 9 (not fig. 4, 5).
Amm. angulatus psilonotus, Quenst., Ibid., pl. ii fig. 10, 11.
Amm. angulatus hircinus, Quenst., Ibid., pl. ii. fig. 12.
Amm. angulatus oblongus, Quenst., Ibid., pl. ii. fig. 6.
Ægoc. angulatus, Neum., Unterst. Lias, Abhandl. geol. Reichsans., VII. p. 33, pl. ii. fig. 5.
Ægoc. subangulare, Neum., Ibid., p. 33.

Localities. — Chevigny near Semur, Balingen, Diebrook near Ravensburg, Mühlhausen, Coppenbrügge in Westphalia, Hildesheim, Markoldendorf.

In the collection of the Museum of Stuttgardt from the Planorbis bed there is a specimen of this species, which is more discoidal than *Schlot. angulata*, and more like Wæhneroceras in its aspect than any other members of this series, and the same facts are observable in Quenstedt's collection. In the collection at Semur there are three specimens from the Planorbis bed correctly named *catenatus*. They are not large, and one specimen at the diameter of 52 mm. shows signs of old age in its obsolescing pilæ and smooth abdomen. We have also examined D'Orbigny's types and confirmed these comparisons. Neumayr compares his specimen from the Planorbis bed of Pfonsjoch with the North German species of *angulatus*, which is a true *catenatus*, and in Professor Emerson's collection from Markoldendorf, now at Amherst, Mass., all specimens of this species agree very closely with *catenatus* as figured by Quenstedt. The pilæ cross the abdomen with a forward bend, but in one precisely the peculiarities of Quenstedt's Fig. 12 are exhibited, the pilæ being straight as they cross the abdomen. *Amm. ang. oblongus*, Quenst., may be a large variety; the whorl as figured resembles that of *catenata*.

Schlotheimia striatissima, Hyatt.

Amm. angulatus striatissimus, Quenst., Amm. Schwab. Jura, pl. iii. fig. 2.
Amm. angulatus striatus, Quenst., Ibid., pl. iii. fig. 3-5.

Locality. — Semur.

Two specimens of this species in the Museum of Comparative Zoölogy and Quenstedt's descriptions and figures show that it is a discoidal shell like *catenata*, but the abdomen is narrower, the whorl more compressed, and the pilæ more numerous and finer than in that species. They remind one in this respect of the second subseries, but unfortunately there are no transitional modifications by which to follow out the connection, if it existed, with these dwarfed forms of the Oxynotus bed. The mould of the young specimen supposed by Quenstedt to have probably come from the "gelbesandstein" of the Trias, near Tübingen, belongs to this species, and it contains also other discoidal varieties, as well as the extraordinary compressed but still discoidal form of *striatissimus*, Quenst.

Schlotheimia colubrata, Hyatt.

Amm. colubratus, Ziet., Verst. Würt., pl. iii. fig. 1.
Amm. Moreanus, D'Orb., Terr. Jurass. Ceph., pl. xciii.
Amm. Moreanus, Hauer, Ceph. Nordöstl. Alpen, pl. xv. fig. 1, 2 (not fig. 3, 4).
Ægoc. Moreanus, Wright, Lias Amm., p. 322, pl. xvii. fig. 1, 2.
Amm. angulatus Thalassicus, Quenst., Amm. Schwab. Jura, pl. ii. fig. 4, 5 (not fig. 9).

Localities. — Deyrolay, Hanover.

In the Semur collection there is a specimen named *Moreanus* from the lower part of the same zone with *Liasicus*, and it may be said to agree with D'Orbigny's figure.[1] This is a variety identical with *colubratus*, Ziet., growing to a larger size than *catenata*. At the diameter of 168 mm. in this specimen, the pilæ crossed the abdomen, showing that old age had set in. That this is sometimes a nealogic feature retained throughout life is shown by another specimen, which at the diameter of 21 mm. has the pilæ continued across the abdomen.

Schlotheimia angulata, Zittel.

Summ. Pl. XI. Fig. 4.

Amm. angulatus, Schlot., Die Petrefactenkunde, p. 70.
Amm. angulatus depressus, Quenst., Amm. Schwab. Jura, pl. ii. fig. 1, pl. iii. fig. 9.
Amm. angulatus costatus, Quenst., Ibid., pl. ii. fig. 8.
Ægoc. angulatus, Wright, Lias Amm., pl. xiv. fig. 5, 6.
Schlot. angulata, Zittel, Handb. d. Paleont., I. p. 456, fig. 637.
Schlot. angulata, Wähner, Unter Lias, Mojsis. et Neum., Beitr., IV., 1886, p. 163, pl. xix fig. 1–3, pl. xx. fig. 1–6

Localities. — Muhlhausen, Hildesheim, Lyme Regis.

The young *appear* to be smooth for about one and a half whorls, then lateral tubercles appear. These spread upon the sides into folds, which on the early part of the fourth or last of the third whorl rapidly become true depressed pilæ, and then begin to be continued across the abdomen with a very decided forward bend at the geniculæ, and form an acute angle on the abdomen. The depression which obliterates the angle of intersection of the pilæ on the abdomen and forms the smooth zone begins on the last half of the fourth whorl.

On the early part of the fourth whorl the abdominal lobe is somewhat deeper than the superior laterals, and these again very much deeper than the inferior laterals. The saddles are broad and shallow, the superior laterals being a trifle shallower than the inferior laterals. On the first quarter of the fifth volution the bases of the superior and inferior lateral saddles and the tops of the superior lateral lobes have become trifid, or unequally divided, whilst those of the inferior lateral lobes and auxiliary saddles are equally divided. The abdominal lobes are shorter than the superior laterals, though the saddles maintain

[1] The original at the Jardin des Plantes is a fragment, and D'Orbigny's figure is in large part a restoration especially with regard to the internal whorls.

their old proportions. In the full adult condition the characteristics of the sutures differ considerably from those of the typical Arietidæ, and approximate to those of Psiloceras.

The seventh whorl increases in size with great rapidity, the abdomen becoming narrower, the channel shallower, the pilæ more depressed, losing their prominent somewhat abrupt genicular bend, and on the abdomen becoming depressed to a level with the siphonal line. The involution of this whorl is about two fifths, and that of the ninth a trifle over one half. The peculiar flattening of the sides and form of the adult whorl, and the amount of involution, are close approximations to the adult characteristics of *Amm. Charmassei*, but the septa are different and the young more robust; the pilæ are developed earlier and more rapidly, and the abdominal channel also. In some specimens, however, these last are not noticeable until quite a late period, the pilæ being continuous across the abdomen, as in *Der. planicostum*, even on the sixth volution.

In the collections at the Stuttgardt Museum are several very fine specimens of the old age of this species, and it is easy to distinguish it from *Charmassei* by the narrowness of the whorls and its more open umbilicus and discoidal aspect. One of the largest of these measures 495 mm., the last whorl 17 mm.; another measures 515 mm., and the last whorl 18.5 mm.

In the Museum at Stuttgardt, in the centre of a crushed specimen of the true *angulata* from Kirchheim, the young was very clearly exposed. This had very smooth and round, though rather stout whorls. The pilæ appeared on the sides as faint folds, which are straight at first, then curve, reach the abdomen, and finally cross it with a forward inflection. These become very prominent and decided before the channel is formed, which finally cuts through the pilæ. This variation, however, is considerable, since in the adult of this specimen the channel is only partially developed, the pilæ being only about half cut through, though the specimen is about two and one fourth inches in diameter. There is here a close likeness to some of the trias forms, but not to the true *planorbe*, which the young does not resemble closely. They resemble Waehneroceras very closely. The same relations were observed in young specimens in Professor Quenstedt's collection, and in the Museum of Comparative Zoölogy.

It often occurs, also, that after the channel is developed, and the shell is quite large, the pilæ again cross the abdomen, but this is not so frequent as has been supposed. They oftener remain separate until old age.

The original of *Amm. angulatus*, Sow., which we saw in the British Museum, is only a malformed *communis*.[1]

[1] See also Wright, Lias Amm., p. 173.

Schlotheimia Charmassei, Wähner.

Summ. Pl. XI. Fig. 5.

Amm. Charmassei, D'Orb., Terr. Jurass. Ceph., p. 296, pl. xci. (not pl. xcii.).
Amm. angulatus compressus, Quenst., Amm. Schwab. Jura, pl. ii. fig 2.
Amm. angulatus compressus gigas, Quenst., Ibid., pl. iv. fig. 2.
Schlot. Charmassei, Wäh., Unt. Lias, Mojsis. et Neum., Beitr., IV. p. 196.
Ægoc. Charmassei, Wright, Lias Amm., p. 323, pl. xx. fig. 1–3.

Localities. — Semur, Lyme Regis, Tübingen.

Besides the characteristics mentioned in the description of *angulata* the following may be added. On the sixth volution, the extremely gibbous form of the young begins to change. The whorl increases more rapidly, the abdomen is narrower, and the pilæ as in preceding species, with this exception. On this volution, or perhaps on the fifth, they become bifurcated, or else have intermediate short pilæ interspersed between the longer ones. The sutures have remarkably large abdominal lobes, shallower than the superior laterals, but with much more ragged outlines. The siphonal saddle is extraordinary in this respect. It is very large, and marked with several lateral minor lobes and saddles. The remaining lobes and saddles are more complicated than in *angulata*.

On the sixth volution, the form of the whorl changes more than in *angulata*. The involution of this whorl equals one half of the side of the sixth, whereas in *angulata* the envelopment does not equal this until it reaches the ninth volution. The involution at the same age in this species, i. e. on the ninth whorl, covers full two thirds of the side of the eighth whorl. There is a form in Professor Fraas's collection from Möhringen answering to the young of *Charmassei*, as figured by D'Orbigny, Plate XCI., and another from Filder, which is precisely intermediate in its characteristics between this and the smoother, flatter variety figured on Plate XCII. The oldest specimens in the possession of the Museum of Stuttgardt measured 53 mm., and the last whorl 23 mm. *Schlot. angulata* parts with its pilæ and grows smooth much earlier apparently than *Charmassei*. Possibly this occurs at about the same age, but the superior size of *Charmassei* makes it seem older when the senile characteristics begin to appear.

Schlotheimia Leigneletii, Wähner.

Amm. Leigneletii, D'Orb., Terr. Jurass. Ceph., p. 298, pl. xcii.
Schlot. Leigneletii, Wäh., Unt. Lias, Mojsis. et Neum., Beitr., IV. p. 197.
Amm. compressus (pars), Quenst.

Localities. — St. Thibault, Semur, Vaihingen, Stuttgardt, Behla.

The same class of facts divides this species from *Charmassei* that we used above to show the differences between the latter and *angulata*; namely, that the young differ as well as the old in some specimens.

The differences are very great between the fifth whorl of *Leigneletii*, and the same age in *Charmassei*. The tubercles are more prominent on the edge of the abdomen, the pilæ more depressed on the sides, and their terminations tubercular on the edge of the abdomen, which, instead of being a broad, rounded space, is a flattened zone. The reduction of the abdomen of course occurs in all species of this group, but in other species, except *Boucaultiana*, it is found only during the senile stage.

Amm. angulatus compressus of Quenstedt may also in part belong to *Charmassei*, since two specimens from the Stuttgardt Museum of this name apparently belong to this species only. The envelopment in one of these specimens covers about two thirds of the sides of the eighth whorl, and about the same age the pilæ again cross the narrow abdomen, obliterating the median depression or smooth zone, and introducing a series of crenulations instead. This is a return to the young condition, and indicates the first degradational or clinologic stage. It is not intended by this to deny that there are no young which closely approximate to the young of *Charmassei*. On the contrary, some specimens are apparently identical in all respects, except the greater flatness of the whorls and the earlier period at which involution appears, and the two species are connected by numerous transitional forms.

Schlotheimia Boucaultiana, WÄHNER.

Summ. Pl. XI. Fig. 6.

Amm. Boucaultianus, D'ORB., Terr. Jurass. Ceph., p. 294, pl. xc.
Schlot. Boucaultiana, WÄH., Unt. Lias, Mojsis. et Neum., Beitr., IV. p. 196.
Ægoc. Boucaultiana, WRIGHT, Lias Amm., p. 327, pl. xviii. fig. 1-4.

Locality. — Semur.

This remarkable species differs from *Leigneletii* in about the same manner that the latter differs from *Charmassei*, in other words, it is more involute than *Leigneletii* at the same age; i. e. on about the seventh or eighth whorl at least three fourths of the sides are hidden. The pilæ are not so coarse as in that species, and the abdominal channel is obliterated at an earlier age and is succeeded by crenulations caused by the pilæ. The sutures differ considerably. The specimen examined was one of D'Orbigny's types. The same transitional forms which lead into *Leigneletii* also lead into other more compressed and more involute forms which are transitional to the true *Boucaultiana*. They differ from *Leigneletii* only in the suppression of the tuberculated pilæ, and a general tendency toward obsolescence of the pilæ on the sides.

Schlotheimia D'Orbignyana, HYATT.

Amm. Charmassei (pars), D'ORB., Terr. Jurass. Ceph., pl. xcii. (not pl. xci.)

Locality. — Semur.

This species has depressed pilæ and resembles closely *Boucaultiana*, but is not so involute. It is in fact, as described by D'Orbigny, an extreme modification of *Charmassei*, with excessively compressed whorls, and acquiring in the clinologic stage a subacute abdomen. It resembles more closely *Schlot. ventricosa* of Wähner than it does any other species, but it is even more compressed and more like *Charmassei* in the adult stage than that species. D'Orbigny's figure is that of an old shell; the adults are less acute and more like *Charmassei* or *Leigneletii*.

The forms figured by Wähner in his "Unteren Lias"[1] may be divided into three subseries. It was not practicable to determine whether these series were artificial or natural, though many figures of the young were given by Wähner.

The first series can be distinguished by the finer pilæ and somewhat compressed whorls. They are as follows. *Schlot. catenata*, Wäh., and *angulata*, in the Planorbis bed. The following, though still discoidal, are slightly more involute forms, if one can say this after comparison with Neumayr's figure of *angulatum* from Pfonsjoch.[2] They are *Schlot. montana*, Wäh., Plates XIX., XX., *Donar*, Plates XIX., XXI., *extranodosa*, Plate XX., *pachygaster*, Plate XXI., and *marmorea*, Plate XXII., and all occur in the Megastoma and Marmorea beds.

The second or coarsely pilated series have more gibbous forms in the young and much deeper channels, or, in other words, the pilæ have more prominent terminations on the abdomen. The discoidal forms are as follows. *Schlot. ind.*, Plate XVIII. Fig. 4, which has in an exaggerated condition the characteristics of the subseries, and may be a pathological specimen, *taurina*, Plate XIX. Fig. 5, *angulata*, var. *ind.*, Plate XX. Fig. 5. All three of these were found in the Megastoma and Marmorea beds, but were followed by two young forms occurring, according to Wähner, in the Rotiformis beds. These are *Schlot. scolioptycha* and *posttaurina*, Plate XXIII., and appear to have been the young of species, which may have been more involute in the adults.

The third subseries has young with even stouter whorls than in the second subseries, though not otherwise separable. *Schlot. trapezoidale*, the first species, occurred, according to Wähner, in the Marmorea bed, and was succeeded by *ventricosa*, Plate XXIII., and an undetermined form, Plate XXIII. Fig. 12, both in the Rotiformis bed.

Canavari in "Unteren Lias von Spezia" describes dwarfs or young of *Schlot.* (*Ægoc.*) *trapezoidale*, Plate XVIII. Fig. 8, 9, and *ventricosum*, Plate XVIII. Fig. 10, which seem to be identical with forms described by Wähner; also *Schlot.* (*Ægoc.*) *catenatum*, Fig. 1, *comptum*, Fig. 3–5, *Collegnoi*, Fig. 6, all of which are very closely allied, and may be either young or dwarfs of *Schlot. Charmassei*, or the more involute varieties of *Schlot. angulata*.

Second Subseries.

The abdominal channel is narrower and deeper proportionally than in the first subseries, and is a true furrow, in place of being a smooth zone or mere depression formed between the interrupted pilæ, as in Wæhneroceras and in the first subseries of Schlotheimia. The shells known are finely pilated, and the furrow is similar to what it is in the young of some species of the first subseries.[3] The species have been found only above the Bucklandi zone, and are all, so far as known, dwarfs.

[1] Mojsis. et Neum., Beitr., IV., 1886.
[2] Abh. k. k. geol. Reichsans., VII., pl. ii. fig. 5.
[3] See *Schlot. trapezoidale*, Wäh., Mojsis. et Neum., Beitr., IV. pl. xxiii. fig. 2 c, and others on the same plate.

Schlotheimia rotunda, Hyatt.

Amm. lacunatus rotundus, Quenst., Amm. Schwab. Jura, p. 167, pl. xxii. fig. 5, 6.

This shell is more discoidal than any others described below. The whorls are also stouter as a rule. The pilæ on the umbilical shoulders are coarser and are tuberculated according to Quenstedt's figures and descriptions. *Amm. lacunoides*, Quenst.,[1] may be the young of this or an allied species. It occurs so far as now known only in South Germany.

Schlotheimia lacunata, Hyatt.

Amm. lacunatus, Buckman, Murch. Geol. Cheltenh., 2d ed., p. 105, pl. ii. fig. 4, 5.
Amm. lacunatus, Quenst., Amm. Schwab. Jura, p. 167, pl. xxii. fig. 1–4.
Amm. lacunatus, Dum., Étud. Pal. d. Bas. d. Rhone, p. 120, pl. xxi. fig. 18–20.
Amm. lacunatus, Wright, Lias Amm., p. 330, pl. lvi. fig. 16–18.
Amm. deletum, Canavari, Lias v. Spezia, Paleontogr., XXIX. pl. xviii. fig. 13.
Amm. sp. ind. cfr. lacunata, Canavari, Fauna del Lias, Mem. del. Carta Geol. d' Italia, III., 1888.

Localities. — St. Thibault, Semur.

The pilæ are not coarse or tuberculated at the umbilical shoulders. The whorl is also more compressed and the involution greater than in *Schlot. rotunda*, covering about two thirds of the side. The young according to the figures given are also not smooth to so late a stage as in that species. The description of the originals in the Geology of Cheltenham in a measure makes up for the figures. The latter belong to a discoidal species, the former gives the usual combination of an involute shell, narrow abdomen, flattened sides, and half-concealed whorls. An important statement is also added, that the "ribs" cross the abdomen in the young. The latter indicates the possibility of a direct derivation of the second subseries from *Schlot. catenata*, and also serves to confirm the identification of Wright's species with this, since Wright mentions the same characteristics.

Schlotheimia Geyeri, Hyatt.

Schlot. lacunatus, Geyer, Liasis. Cephal. v. Hierlatz b. Hallstadt, p. 259, pl. iii. fig. 22, 23.

This species has fine but sparsely distributed pilæ at the umbilical shoulders which speedily divide into two or more finer pilæ. The abruptness of the division gives the umbilical pilæ a resemblance to those of *Schlot. Quenstedti* in Geyer's figures, but there are no tubercles, and the involution covers about four fifths of the side, and the whorls are considerably compressed.

Schlotheimia angustisulcata, Geyer.

Schlot. angustisulcata, Geyer, Liasis. Ceph. Hierlatz b. Hallstadt, p. 256, pl. iii. fig. 24, 25.

The pilæ are finer, the whorls more compressed, the involution quite as extensive as in the preceding. The sutures which are figured in this species, if they can be correctly given in so small a figure, are quite distinct from those of the similar involute forms of Schlotheimia.

[1] Amm. Schwab., p. 162, pl. xxi. fig. 24, 25.

Schlotheimia Speziana, Canavari.

Ægoc. Spezianum, Canav., Unt. Lias v. Spezia, p. 166, pl. xviii. fig. 12.
Schlot. Spezianum, Canav., Fauna del Lias, Mem. del. Carta Geol. d' Italia, III., 1888.

This form is more compressed, has different pilations, and a remarkably narrow channel. It is also as involute as any other species of this subseries, and appears in the drawing to exceed all other forms in this respect.

THIRD, OR VERMICERAN BRANCH.

The living chamber is in most species attenuated, cylindrical, at least a volution in length, and sometimes over one and a half volutions. The shell in the majority of forms is discoidal, and the area of envelopment almost invariably limited to the abdomen. During the senile stages, the whorl tends to acquire smooth, rounded, and convergent sides, and frequently loses the keel and channels, thus completely reverting to the smooth cylindrical form of the young. The sutures in each separate series tend to increase in the depth and breadth of the second lateral saddles in the higher species, and there is a backward trend of the auxiliary lobes and saddles which is strongly marked in some forms. In Vermiceras the sutures become more decidedly arietian, the abdominal lobe is deeper and narrower, the lateral lobes are broader and less dendritic, and the auxiliary lobes and saddles are not as a rule inclined posteriorly.

CALOCERAS.

The shells are extremely discoidal, with numerous almost cylindrical whorls which often retain the nealogic form throughout life. The pilæ are curved, and they usually have an immature fold-like character, in keeping with the arrested development of the form in the adult whorls. They also do not have well defined geniculæ, and in some species they may be straight, and even tuberculated. The sutures usually have longer and narrower lobes, deeper saddles, and more complicated margins than in Psiloceras. They are, however, hardly distinguishable generically from those of some species of that genus, which occur in the Northeastern Alps, and in some species also they approximate to those of Vermiceras. The range of form and characteristics is very great, as might be imagined, in a group which is transitional from Psiloceras to the true Arietidæ.

First Subseries.

The whorls are rounded and gibbous, the keel when present not prominent; the channels absent or appearing merely as smooth, inflected zones; the pilæ fold-like, and without geniculæ or tubercules. The sutures are very variable, some having more complicated margins, as in the Psiloceratites of the Northeastern Alps, and others approximating more nearly to the simplicity of *Psil. planorbe* of Central Europe. The abdominal lobe, however, as in Psiloceras, is not usually deeper than the superior laterals.

Caloceras Johnstoni, Hyatt.

Amm. Johnstoni, Sow., Min. Conch., p. 461, pl. ccccxlix.
Amm. torus, D'Orb., Pal. Française Ceph., p. 212, pl. liii.
Amm. psilonotus plicatus, Quenst., Amm. Schwab. Jura, pl. i. fig. 12, 13.
Amm. Johnstoni, Quenst., Ibid., pl. i. fig. 20.
Ægoc. Johnstoni, Wright, Lias Amm., pl. xix. fig. 3, 4.
Ægoc. Belcheri, Wright, Ibid., pl. xix. fig. 1, 2 (not pl. xv. fig. 7-9).
Ægoc. Johnstoni, Neum., Unterst. Lias, Abhandl. geol. Reichsans. Wien, VII. pl. iii. fig. 2.
Ægoc. torus, Neum., Ibid., pl. iii. fig. 3.
Ægoc. Johnstoni, Wäh., Unt. Lias, Mojsis. et Neum., Beitr., IV. pl. xvi. fig. 6-9.
Localities. — Wiesloch near Heidelberg, Bristol, Cheltenham.

This form differs from *planorbe* in the outline of the whorl, which is much narrower, more rotund and gibbous laterally, and in the greater prominence of the pilæ.

A specimen in the Museum of Stuttgardt measuring 120 mm., labelled *tortilis*, Nürtingen, has a living chamber still incomplete, though nearly one volution in length. Abdomen is slightly more elevated than in typical adult torus and the sides more inclined, as is usual in old age of this species. Otherwise the form and pilæ, especially in the umbilicus, are the same.

Sutures of adult are similar, as far as seen, to those of Psiloceras, and in old age the lobes and saddles decrease in size, becoming simpler in outline. Quenstedt's specimen, figured in "Ammoniten des Schwäbischen Jura," Plate I. Fig. 20, is 110 mm. in diameter and shows the effects of senility in the compressed whorl. His Figure 13 shows the living chamber to have been at least one volution in length. The typical forms of this series are found in the Northeastern Alps, but the distribution is general, as has been already noted by Neumayr.

In the collection of the Sorbonne at Paris there is one specimen from Beauregard precisely similar to that figured by D'Orbigny, except that the whorls are much larger and stouter. In the collection at Munich there are specimens from Pfonsjoch, Kander in Bresgau, and Lyme Regis, exhibiting the typical form of *Johnstoni* until they reach the diameter of 145 mm.

Var. Beauregardiense.

Amm. Beauregardiensis, Collenot.

This form from Beauregard in the collection at Semur is 185 mm. in diameter, and has whorls increasing more rapidly in size than in the typical *Johnstoni*, but otherwise does not differ from that species.

Caloceras tortile, Hyatt.

Plate I. Fig. 12-14. Summ. Pl. XI. Fig. 14.

Amm. tortilis, D'Orb., Terr. Jurass. Ceph., p. 201, pl. xlix.
Amm. raricostatus, Dunk., Paleontogr., I. pl. xiii. fig. 17.
Ægoceras intermedium, Wright, Lias Amm., pl. xv. fig. 5, 6 (not fig. 3, 4).
Amm. laqueus (pars), Quenst., Amm. Schwab. Jura, p. 19, pl. i. fig. 15, 16 (not fig. 14, nor p. 18, fig. 4).
Localities. — Semur, Rinteln, Quedlinburg.

This species is very generally misinterpreted by German and English paleontologists. The young have exactly the same broad, gibbous whorl as the young of the keelless *Johnstoni*, but gradually become elevated a little on the abdomen, and at the same time acquire a faint keel. Subsequently the abdomen becomes more elevated, and slight channel-like inflections appear on either side. At the diameter of 98 mm. this occurred in one specimen from Beauregard in the collection at Semur. At the diameter of 195 mm. in other specimens from Beauregard, the faint channels had disappeared, the pilæ were nearly obsolete, and the keel not so distinct. The marginal digitations of the lobes and saddles were also deeper and much changed. At the diameter of 270 mm. senile changes were far advanced in the only specimen of this size yet studied. The abdomen had become rounded and keelless, and the pilæ so nearly obsolescent as to be barely distinguishable.

A specimen from Beauregard in the collection of the Sorbonne, under the name of *Amm. laqueolus*, Schlönbach, must have been when complete about 200 mm. in diameter. The outer whorl of this shell resembles a typical *tortile*, with depressed abdomen and keel. The abdomen at earlier stages in the same specimen is rounded. *Laqueolus*, Schlönbach, is not of this species, but belongs to *Cal. Liasicum*.

In some specimens the abdomen changes from rounded and rather flattened in the young to a more angular outline in older stages, but does not acquire a keel. This occurs in D'Orbigny's original at the École des Mines, and in specimens labelled *tortilis* from Chalandry, in the collection of the Sorbonne, at sizes varying from 22 to 55 mm. It is probable that a well defined keel never made its appearance even in the adults in some of these specimens.

Var. **raricostatoides**.

There are two specimens in Quenstedt's collection from Quedlinburg, three in the Museum of Comparative Zoölogy, and others at Semur, all found in association with *Planorbis*. These seem to be identical with the forms described by Dunker in the "Paleontographica" as *Amm. raricostatus*.

A part of the specimens identified by Oppel as *Johnstoni* in the Munich collection appear to belong to *Cal. tortile*. One specimen especially is a rather compressed form, from Waldenburg, with a slight keel developed at a late stage of growth, and at the same time there is a change of form in the whorl, which approximates to the parallel-sided, flattened-abdomened, carusense-like varieties of *Cal. Nodotianum*; the pilæ also begin to wear a more advanced aspect.

The torus-like variety is finely represented in the Bristol Museum by specimens from Cotham, and a form which appeared to be the same was reported as coming from the Bucklandi bed at Ashley Down. This has somewhat stouter whorls than the earlier forms at the same age, and shows the same tendency to become stouter and larger manifested in the later occurring species of other progressive series. The young have the usual development of *tortile*, in some instances producing a decided keel, and in others merely a slightly more compressed form in the adult or old, the abdomen remaining keelless. They have straight pilæ, and look remotely like *raricostatus* in form, but the young have the usual stout smooth whorl of the young of *Johnstoni*. Quenstedt places them with *laqueus*, but this, we think, is a mistake, arising from not giving proper weight to the characteristics of the nealogic stages.

The presence of this form in the North German basin is worthy of remark, since it is a degraded variety. The transitional keelless varieties uniting this species and *Johnstoni* would have been considered distinct under the name *tortile*, while the keeled forms would have been separated and designated as a distinct species, but for the fact that similar variations are also represented within two other species, *Cal. Liasicum* and *Nodotianum*. It is evident from this, that the keel in Caloceras has not become an hereditary character, but is a morphological equivalent in varieties of different species.

Caloceras Liasicum.

Amm. Liasicus, D'ORB., Pal. Fran. Ceph., I. pl. xlviii.
Amm. Liasicus, HAUER, Ceph. Lias Nordostl. Alpen, pl. iii. fig. 1-3.
Amm. sironotus, QUENST., Handb. Pet., p. 432, pl. xxxvii. fig. 1; and Die Amm. Schwab. Jura, p. 23, pl. i. fig. 21.
Amm. laqueolus, SCHLÖN., Paleontogr., XIII. pl. xxvi. fig. 1.
Ægoc. laqueolus, WRIGHT, Lias Amm., p. 315.
Ægoc. Liasicum, WRIGHT, Ibid., pl. xv. fig. 1, 2; pl. xvi. fig. 1, 2.
Ægoc. tortile, WRIGHT, Ibid., pl. xv. fig. 10, 12.
Ariet. Liasicus, WÄH., Unt. Lias, Mojsis. et Neum., Beitr., VI., 1887, pl. xx. fig. 1-5.

Localities. — Semur, Bristol.

A large specimen in the Tübingen collection, about 100 mm. in diameter, shows by comparison with D'Orbigny's figure that *sironotus*, Quenst., is probably identical. One specimen at Semur retained very gibbous sides and broad abdomen to a diameter of 175 mm., and then formed an elevated abdomen without acquiring a true keel as figured by D'Orbigny. Another shell had reached the diameter of 260 mm., but no true keel was formed, though old age began to show its approach in the obsolescence of the pilæ. In D'Orbigny's collection these very broad forms stand side by side with the narrow one figured by him, which is identical with *sironotus*, Quenst. D'Orbigny's original has the keel as well developed at a diameter of 100 mm. as the broad variety at a diameter of 250 mm. A comparison of the young with the young of *tortile* showed that they are closely allied by their development. No constant distinction exists, except that *Liasicum* is usually a stouter shell, and has about the same relation to *tortile* that the stouter forms of *carusense* in the Upper Bucklandi bed have to those of the same name in lower beds. Wähner's work upon this species gives figures of the young, and exhibits a close alliance with *Cal. Johnstoni*. The keel appears in his Figure 3 b, in a small but probably full-grown specimen, but no channels are noted in his figures or description.

The extraordinary series of forms discovered by Neumayr and Wähner in the Northeastern Alps enable us to give the following list of species, arranged in subseries.

Cal. (*Ægoc.*) *Johnstoni*, as figured by Wähner, Mojsis. et Neum., Beitr., IV., Plate XVI. Fig. 6–9, and Neumayr, Unterster Lias, Plate III., show that the typical coarsely pilated form of the Central European province exists also in the Northeastern Alps, but has probably a more limited number of descendants in that fauna. A not infrequent but very interesting variation in this species is the *torus* variety, also present in the Northeastern Alps, Neum., Ibid., Plate III., and Wähner, *op. cit.*, Plate XVI. Fig. 6. It is distinguished by a marked tendency to sudden increase in the size of the whorl by growth at a late nealogic stage. The next gradation in the subseries, as exhibited in the Northeastern Alps, is a species having a still quicker increase in bulk, as described by Wähner, *Cal.* (*Ægoc.*) *hadroptychum*, Ibid., Plate XVIII. Fig. 1–3. The increase in the whorl takes place quite early, and the coarse fold-like pilæ and rather broad whorls indicate the next step in gradation to be, as pointed out by Wähner, the unnamed form figured on his Plate XVII., which leads, as also pointed out by the keen eyes of this author, into the remarkable *Cal.* (*Ægoc.*) *nigromontanum* given on Plate XXIV. The affinity is better shown by the young figured on Plate XXV. Fig. 2, which is very similar to the adult of the preceding species. This species has a distinct but broad keel in the adult, and slightly compressed whorls similar to those of *Cal. proaries*, and is a good example of morphological equivalence. *Cal. Liasicum*, as described and figured by Wähner,[1] evidently has compressed whorls, and is more closely allied to *Cal. Johnstoni* in all varieties than the same species in Central Europe.

Cal. (*Ariet.*) *Loki*[2] has close relations to *Liasicus* of the Northeastern Alps, as pointed out by Wähner, and *Cal.* (*Ariet.*) *Seebachi*[3] is also an allied species.

Second Subseries.

The whorl is subquadragonal in the adult. An obtuse keel is always present. Very shallow channels are developed, and the pilæ are prominent, straight, and in some species have slight geniculæ like those of Vermiceras.

The sutures, with the exception of *Cal. laqueum*,[4] have an abdominal lobe deeper than the superior laterals, but the superior and inferior lateral lobes are of nearly equal size and length, the superior lateral saddles broader, but of about the same depth as the inferior laterals, and the marginal lobes and saddles similar to those of *Psil. planorbe*.

The young are similar to *Cal. Johnstoni*. The clinologic period has a subacute abdomen, but this becomes rounded in the last part of the senile stage. The lobes in this stage return to their younger or psiloceran proportions, the abdominal lobe becoming shallower and broader, the lateral lobes narrower and shorter, and the lateral saddles broader and shallower in proportion.

[1] Mojsis. et Neum., Beitr., VI. pl. xx. [2] Ibid., V. pl. xvii. [3] Ibid., V. pl. xx.

[4] *Cal. laqueum* seems to have an abdominal lobe shorter than the inferior lateral lobes, and in some specimens the sutures are similar to those of the first subseries. In other specimens they resemble more closely those of *Psil. planorbe*, and in still others they become similar to the sutures of Vermiceras.

Caloceras laqueum, Hyatt.

Summ. Pl. XI. Fig. 22.

Amm. laqueus, Quenst., Amm. Schwab. Jura, pl. xviii. fig. 4; pl. i. fig. 14 (not fig. 15, 16).
Amm. intermedium, Portl., Geol. Londonderry, p. 136, fig. 17.
Ægoceras intermedium, Wright, Lias Amm., p. 314, pl. xv. fig. 3, 4 (not fig. 5, 6).
Ægoceras Belcheri, Wright, Ibid., p. 313, pl. xv. fig. 7–9 (not pl. xix. fig. 1, 2).
Ariet. Scylla, Wäh., Unt. Lias, Mojsis. et Neum., Beitr., VI. 1887, pl. xxv. fig. 7, 8.
Amm. Scylla (pars), Reynès, plates.

The youngest specimen I have yet seen of this species was 26 mm. in diameter. The abdomen, however, was smooth, with no indications of the immature keel of the adult, the sides exceedingly gibbous. The pilæ evidently began early, and were closely crowded and slightly curved forwards.

In one specimen the pilæ were very slightly developed in the adult; in another, at a corresponding size, they were already disappearing, and upon the next or senile whorl they were almost obsolete. The keel probably becomes very slight at this time, and the likeness to its own young must then have been remarkably close.[1] This specimen was 53 mm. in diameter.

The similarity of the adult of this species to the young of *Ver. spiratissimum* is unmistakable. A specimen from Bebenhausen, in Quenstedt's collection, shows that the sutures are intermediate between those of *Cal. Johnstoni* and those of *Ver. spiratissimum.* The young of a specimen from Oestringen in Fraas's collection, Stuttgardt Museum, when about 26 mm. in diameter, has the exact form and characters of Quenstedt's figure, but no signs of a keel, though this appears soon afterwards. A fine series in the Semur Museum shows that the keel may not yet have arisen in a specimen at the diameter of 45 mm. The whorl also at the time of the appearance of the keel may have either a broad, depressed abdomen, as in the varieties which approximate to the young of *Ver. spiratissimum* and *carusense*, or this part may be elevated, as in *Cal. tortile.*

The young, however, are like the young of *Cal. Johnstoni.* The sutures also vary in the same way, some specimens having sutures like those of *Johnstoni*, and others approximate to those of *carusense* and *spiratissimum.* Old age in all these was marked by narrowing of the abdomen, loss of the keel, etc., which probably precedes a rounding off of the same region, though this extreme effect of senility was not observed. The pilæ often cross the abdomen in the young, but not in the adult. In one specimen, however, which had the senile angularity of the abdomen well marked at the diameter of 73 mm., the pilæ again crossed the abdomen, and then faded out almost entirely. Another specimen, even at the extreme diameter of 105 mm., retained a keel, as in the adult.

Ægoc. Belcheri, Wright, from the Angulatus bed, may be an example of this species. It exhibits the squared or quadragonal form of this series, and is not, as figured, at all similar to any species of the first subseries. *Ægoc. intermedium*, Wright, from the lower part of the Angulatus bed, probably also belongs to

[1] Quenstedt figures and describes, in his Amm. Schwab. Jura, one old specimen a trifle larger than that described above, which confirms this supposition as to the senile degradation of the keel, and it has no pilæ on the last whorl. The living chamber is still incomplete, though as long as the last volution.

this species. The abdominal view is not similar, not being flat enough on the abdomen, but the lateral view has the straight perfect pilæ of this subseries.

The *Amm. Burgundiæ*, Martin, as identified at Semur, is identical with this species. It is, however, smaller than those from Saulieu, which are associated with *Psil. planorbe*, and is placed in the same bed as *Liasicum*. Wähner's figures and description of *Ariet. Scylla*,[1] Reynés, seem to agree closely with the descriptions and figures of this species. The aspect of the umbilical or young whorls in Wähner's figures shows that *Scylla*, Wäh., is certainly not identical with the *Johnstoni*-like variety of *Cal. raricostatum*, though it very closely resembles that form.

Caloceras carusense.

Plate I. Fig. 15, 16. Plate II. 1-3 a. Summ. Pl. XI. Fig. 15.

Amm. carusensis, D'Orb., Terr. Jurass. Ceph., pl. lxxxiv. fig. 3–6.
Amm. Arietis, Ziet., Verst. Würt., p. 3, pl. ii. fig. 4 (not fig. 2, 3).
Amm. spiratissimum, Hauer, Ceph. Lias Nordöstl. Alpen, pl. iii. fig. 1–3.[2]
Amm. latisulcatus longicella, Quenst., Amm. Schwab. Jura, pl. xii. fig. 5 (not fig. 1–4, 6).
Amm. laqueus (pars), Quenst.
Amm. Scylla (pars), Reynés, plates.

Localities. — Lyme Regis, Semur, St. Thibault, Balingen, Willershausen in Hanover, Luxemburg.

The characteristic of this species as given by D'Orbigny, the crossing of the abdomen by the pilæ, is not an important peculiarity, since it is common in the young of caloceran forms. The young of the normal variety is, however, identical with D'Orbigny's figure. It acquires the keel when the shell is about 25 mm. in diameter, and is at this stage very similar to one variety of *Cal. laqueum*. The sides in the later stage and adults become more flattened, and the abdomino-dorsal diameter of the whorl increases proportionally. One variety in the Museum of Comparative Zoölogy has much stouter more quadragonal whorls than this, with flattened sides and abdomen, though the pilæ are never very prominent or perfectly geniculated.

The abdominal lobe is long, and much deeper than the superior laterals. This is owing largely to the non-development of the superior laterals, which remain short and broad. The superior lateral lobes are shallow and broad, the inferior laterals narrow, and not usually long in proportion. The most characteristic parts of the sutures are the first auxiliary saddles; these are remarkably large, and often tongue-shaped. The auxiliaries do not, therefore, incline backwards, at least in adults. The marginal lobes and saddles, and the margins of the superior and inferior lateral saddles and lobes, are simple, and like those of *Psil. planorbe*.

This variety retains the keel until a very late age, even after the shell becomes perfectly smooth. The form at this time is precisely similar to that of the old of the stouter variety of *Cal. Nodotianum* or *tortile;* subsequently, however, the whorl becomes round, as in Plate II. Fig. 1–3 a. This stout variety

[1] Mojsis. et Neum., Beitr., VI. pl. xxv.
[2] The specimen in Oppel's collection enabled me to quote this as a synonym.

is sometimes identified with *Amm. Liasicus* in Germany, but that species has a form more like *Johnstoni*, a larger keel, and entirely distinct sutures.

A specimen from Aldingen, in the Museum of Stuttgardt, shows an entirely smooth senile whorl, precisely similar in form to that described above in the collection of the Museum of Comparative Zoölogy, though it is not half the size, the diameter being 103 mm. Another from Vaihingen had a living chamber still incomplete, though nearly one and a half volutions in length. On the latter part of the eighth volution in this specimen the sides began to become flatter and convergent, and on the ninth and tenth volutions the form was subtrigonal, the channels absent, the pilæ still prominent though obsolescing, and the keel reduced to a raised line; diameter, 163 mm. Another, of nearly the same size as Hauer's figure of *Amm. spiratissimum*, agreed closely, the sutures also being identical. The form of the whorl is, however, slightly more flattened laterally. It belongs to the large variety of *caruseuse*, and is found, according to Hauer, with *Conybeari*, *rotiformis*, and *bisulcatus*, in the "gelben kossener Schichten of Enzesfeld." A specimen from Elwangen, labelled *Amm. torus*, in the Geometricus zone, exhibits all the characteristics of the large specimen described above. It has larger and stouter whorls and pilæ than the specimens described from the Lower Bucklandi beds, though the sutures and other characteristics are similar. A specimen of this variety from Aalen also occurs in Professor Quenstedt's collection at Tübingen, with larger and more prominent pilæ than usual.

The young and old stages of this species at Semur and elsewhere are usually identified either as *torus*, or *tortilis*, or *Johnstoni*, because of the resemblances of the stages of development and senility in the different species of this series.

Caloceras longidomum, Hyatt.

Amm. longidomus, Quenst., Amm. Schwab. Jura, p. 50, pl. vi. fig. 1, 2.
Amm. longidomus æger, Quenst., Ibid., pl. vi. fig. 3.

This species, as described and figured by Quenstedt, cannot be classified with certainty. Not having seen specimens unquestionably referable to the species, we cannot positively decide as to its true affinity. It is, according to Quenstedt's description, a more immature or primitive form than *spiratissimum*, since he alludes emphatically to the resemblances between the young and Psiloceras. He also states that the young are closely allied to the young of *spiratissimum*. This evidence seems to conflict, but the sutures, their backward inclination, and the fact that the abdominal lobe, though longer than the superior laterals, is only slightly longer, the not very prominent and curved pilæ of Quenstedt's figure, the broad keel and slight channels, and the somewhat compressed form of the older whorls, are all characteristics similar to those of *caruseuse*. It may be a variety of *caruseuse* larger than the French, and becoming senile more slowly. The curved pilæ are not like *laqueum*, and the cylindrical whorl and tendency of the pilæ to cross the abdomen in the young also suggest connection with *caruseuse*.

Caloceras Nodotianum, Hyatt.

Plate I. Fig. 7-11 a. Summ. Pl. XI. Fig. 16.

Amm. Nodotianus, D'Orb., Terr. Jurass. Ceph., p. 198, pl. xlvii.

Locality. — Semur.

I have never seen the original, but the species as identified in D'Orbigny's collection and at the Museum of Semur, and also in Boucault's collection named after D'Orbigny's types, has not a close resemblance to Oppel's type of *Nodotianum*. This last is probably its morphological equivalent in the genus Arnioceras, since it has smooth young, and is otherwise similar to Arnioceras. A specimen in the Museum of Comparative Zoölogy, said to be from Semur, has a stouter form and straighter pilæ than any specimen I have seen elsewhere. It has in these characters and in general aspect resemblances with forms like *Cal. proaries*, var. *latecarinatum*, but the abdomen differs in not being so much flattened.

The fine suite of specimens in the Museum at Semur shows that this species has several varieties. One resembles the variety of *Cal. tortile* from Waldenburg. Another, at 128 mm. diameter, has the sides inclined and the abdomen narrow, but not yet entirely acute. Another, even at the small diameter of 57 mm., has an abdomen acute, as is represented in D'Orbigny's figure. The septal digitations of this species are not so complicated as in *Liasicum* or the *torus* variety of *Johnstoni*. The examination of the specimens in the Museum at Semur shows them to have been derived from *Cal. carusense*. The shells found in the Tuberculatus bed resemble the adults of this species until a late stage of growth. Plate I. Fig. 11, represents the full-grown adult, and Fig. 11 a section of the last whorl with its broad abdomen; Fig. 7, a larger specimen; Fig. 9, 10, the approach of old age in a fragment of a still larger specimen. In the section the abdomen is shown growing narrower on the last whorl.

Caloceras raricostatum, Hyatt.

Var. **A.**

Plate VI. Fig. 15.

Amm. raricostatus, D'Orb., Terr. Jurass. Ceph., p. 212, pl. liv. fig. 1, 2 (fig. 3, var. B).
Amm. raricostatus, Quenst., Amm. Schwab. Jura, pl. xxiii. fig. 22, 23; pl. xxiv. fig. 4-10 (other figs., var. B).
Ariet. raricostatus, Wright, Lias Amm., pl. vii. fig. 2 6 (pl. xxvi. fig. 5-14, var. B).
Ophioceras Johnstoni, Hyatt, Bull. Mus. Comp. Zool., I., No. 5, p. 75.

Localities. — Lyme Regis, Somerset, St. Thibault, Semur, Salins, Balingen, Boll, Willershausen in Hanover.

The pilæ apparently begin abruptly, but they are really preceded by depressed folds hardly perceptible to the naked eye. The pilæ are very closely set at first, but begin to be more widely separated on the fifth or sixth whorl. On the third or fourth whorl there are over forty, while on the eighth whorl there are not over thirty. No other changes take place in them or in the form of the whorl until about the sixth whorl. During this volution the abdominal region is raised to a slightly greater prominence, and the siphonal ridge appears.

A large specimen from Semur shows pilæ, which are obtuse, but prominent and bent forward. These characteristics belong to the adult stage, and are preserved without change throughout the tenth whorl. On the ninth and tenth volutions the pilæ are very numerous, being respectively forty-one and thirty-eight in number, and the young of this shell must have had a larger number of pilæ than any specimens described above. On the second and third quarters of the eleventh volution the pilæ became more and more depressed and finally disappeared. The twelfth whorl was rounded and smooth, like that of the young, and therefore a good illustration of the nostologic stage.

There is not usually much variation in the sutures of this species. The abdominal lobe is considerably longer than the superior lateral lobes, and the inferior laterals may be of about the same length, or not more than half as long. The superior lateral lobes are broad at the summits and serrated, the inferior lateral lobes are very small in some specimens, owing to the small size of the first auxiliary saddles. The two larger saddles may be of equal depth, or the inferior laterals somewhat the deeper; the superior laterals are, however, very broad in proportion to their depth, and the inferior laterals much narrower, occasionally even club-shaped. These proportions are apparent at an early age, and were observed upon the latter part of the third whorl before the development of the marginal lobes.

Var. B.

Plate I. Fig. 24, 25 a.

Amm. raricostatus, Ziet., Verst. Wurt., p. 18, pl. xiii. fig. 4.
Amm. raricostatus, Quenst., Amm. Schwab. Jura, pl. xxiii. fig. 8–21, 24–31; pl. xxiv. fig. 1–3 (other figs., var. A).
Amm. raricostatus, Hauer, Ceph. Lias Nordostl. Alpen, pl. xvi. fig. 10–12.
Ariet. raricostatus, Wright, Lias Amm., pl. xxvi. fig. 5–11 (pl. vii. fig. 2–6, var. A).
Ophioc. raricostatus, Hyatt, Bull. Mus. Comp. Zool., I., No. 5, p. 75.

The true pilæ begin upon the third whorl. There are about forty on the third and fourth whorls, decreasing to about twenty-five on the fifth whorl, and on the seventh whorl there are only about twenty pilæ, the last of which already begin to exhibit symptoms of senile degradation. On the eighth whorl the pilæ are degraded to mere blunt folds. The remainder of this whorl could not be observed, but a fragment of the first quarter of the ninth shows that these blunted folds are still more depressed, being merely lateral ridges. The whorl at this time has an elevated abdomen, and the keel has disappeared. The form is similar to the old age of the stout variety of *Cal. tortile*.

The distinctions between this and the preceding variety are to be sought in the sutures, the development of the pilæ, and the size of the adult shell. The young are precisely like the young of *Cal. carusense*, *Amm. arietis*, Ziet., but on the fifth volution the whorl spreads out more laterally, and the pilæ become more prominent as well as more widely separated and fewer in number than on the fifth whorl of this species or of *Cal. Johnstoni*.[1]

The large form of *Cal. carusense* exhibits no sign of senility on the beginning of the ninth whorl, thus attaining a much larger size in its adult condition than the typical *raricostatus*, which often exhibits signs of senile decay upon the latter part of the seventh whorl.

The abdominal lobe is somewhat longer than the superior laterals, and the inferior laterals shorter than, or about equal to, the superior laterals. The superior lateral saddles are very broad in proportion to their depth, as are also the inferior laterals, the latter being either equal to or rather deeper than the former. The first auxiliary saddles are, as usual, very variable in size and form, but when compared with the inferior laterals they are very much more prominent than in the adult of *Cal. carusense*. This seems to be the only marked difference between the sutures of these two species, and it is probably not very important.

The true *raricostatus* from the Raricostatus bed, is rarely misnamed in collections, but there are other forms of distinct species occurring earlier which are frequently misnamed *raricostatum*. The peculiar variety of *tortile* from Quedlinburg is one of these, but it has smooth and gibbous young whorls like the young of *Johnstoni*. *Cal. sulcatum*, with coarse but sparse pilæ, from Semur, is another example. Some varieties of *carusense* afford other examples, but *raricostatus* is frequently almost inseparable from the young of *carusense* until the specimens are over 51 mm. in diameter.

The adult of variety A of true *raricostatum* is almost precisely like *carusense* in those varieties which have very closely set pilæ in the young, as in Plate I. Fig. 16. *Cal. raricostatum*, var. A, therefore, seems to have arisen through an arrested development of *carusense*, and then subsequently to have given rise to the peculiar flattened typical whorls of variety B.

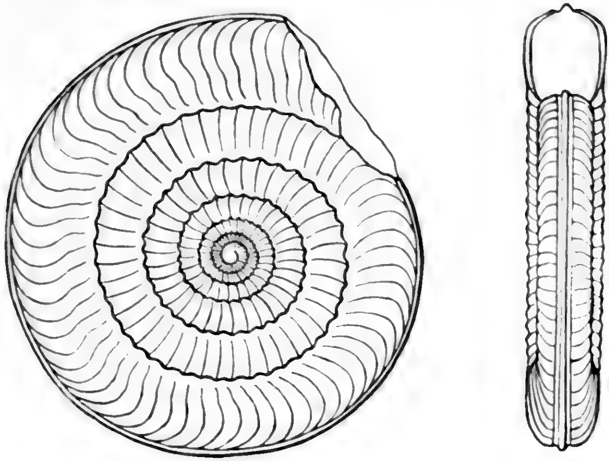
Caloceras aplanatum, Hyatt.

Ariet. tardecrescens, Blake, Yorkshire Lias, p. 285, pl. v. fig. 5 a, b.

Locality. — Whitby.

This species is represented by a specimen which we were at a loss to dispose of until we read Blake's description, and saw the figure. The latter is poor, but with the description it suffices, if one has a specimen in hand. The whorl in the young has a completely caloceran form and pilæ, which are similar to the young of *Cal. raricostatum*. It is in fact a much compressed, keeled, channelled form of *caloceras* similar to *Nodotianum*. It occurs in Blake's Jamesoni bed of the Middle Lias, but is doubtless to be accounted for in the Raricostatus bed of Wright, which is included in Blake's Jamesoni bed. It is discoidal, and the pilæ on the outer whorl have become depressed and curved. Specimens in the British Museum from Robin Hood's Bay have been named *Conybeari* by

[1] Plate I. Fig. 25 a represents an abdominal view of the adult.



23 24

FIG. 23, 24. Views from the side and abdomen of *Cal. aplanatum.*

Bean, and were said to have been found in the Lower Lias. Their young, seen from the side and only in the umbilicus, have the peculiar pilæ and general aspect of *raricostatus*, with similar rotund sides and fine closely set pilæ.

Cal. (*Ariet.*) *præspiratissimum*, Wäh.,[1] has distinctly caloceran sutures and pilæ without geniculæ. It develops a keel at an early stage, and has a subquadragonal whorl in the adult with slight channels. It is a close morphological equivalent of the Vermiceran-like variety of *Cal. laqueum* of Central Europe, if not identical with it, and is certainly, as stated by Wähner, transitional to *Ver. spiratissimum.*

Wähner's figures prove that *Cal. proaries* is a form with late development of a keel, the exact equivalent of *Cal. Nodotianum* in the Central European province. Wähner's full series of young and adults,[2] and Neumayr's senile specimen figured in Unterster Lias,[3] show that the young of *Cal. proaries* (Plate XXX. Fig. 7) resemble very closely the adult stages of *Psil. sublaqueum*, Wäh. (Plate XXX. Fig. 4), *Cal. Johnstoni* (Plate XVI.), and *Cal.* (*Psil.*) *orthoptychum*, Wäh. (Plate XXVII. Fig. 2), and the unnamed form figured on Plate XXVII. Fig. 3. *Cal.* (*Psil.*) *gonioptychum*, Wäh.,[4] has the same compressed whorls as in the more advanced stages of *proaries*, and appears to be intermediate between that species and *Cal. cycloides*. The sutures agree with those of *proaries*. We venture to differ from Wähner, who associates this species more closely with *Cal. Sebanum* of the Planorbis bed. The apparently intermediate aspect and characteristics seem to have been inherited at an earlier stage than in *proaries*, but not quite so early as in *cycloides*, if one can use figures for arriving at such conclusions. *Cal.* (*Ariet.*)

[1] Mojsis. et Neum., Beitr., V. pl. xxi.
[2] Ibid., IV. pl. xxviii.–xxx.
[3] Abhandl. geol. Reichsans., VII. pl. xxviii.
[4] Mojsis. et Neum., Beitr., IV. pl. xxvii.

cycloides, Wäh.,[1] is a slightly more compressed form, which may be transitional between the last and the next species, *Cal.* (*Ariet.*) *Doetzkirchneri*. This last is figured by Neumayr.[2] Wähner's figures of the young of this species show the rounded sides, slight keel, and pilæ similar to those which *proaries* has at later stages in some specimens, and even in adult stages in others. *Cal.* (*Ariet.*) *Castagnolai*, figured by Wähner,[3] shows in its very compressed whorls, narrower umbilici, and sharp prominent keel, which are well developed at an early stage, when the shell is about 15 mm. in diameter, that the cycle of normal modifications is approaching completion. *Cal.* (*Ariet.*) *abnormilobatum*[4] gives us the final gradation. This is a shell having still more compressed whorls, narrower umbilici, due to the more involute whorls, and a more attenuated keel.

This keel and that of *Castagnolai* leads to the suspicion that it may be hollow, but Wähner is too keen an observer, as shown in his complete descriptions, to have let such an obvious peculiarity pass unnoticed. His remarks also show that he knows how to distinguish between the morphological equivalence of this species with Oxynoticeras and its true genetic affinities, as demonstrated by the nealogic stages and their similarities to the later stages and adults of *Castagnolai* and *cycloides*. Wähner's descriptions, which we did not consult until we had written the above, are sustained by our experience so far as the serial relations and affinities of *Doetzkirchneri*, *cycloides*, *Castagnolai*, and *abnormilobatum* are concerned.[5]

Third Subseries.

This subseries contains species which have better defined channels and more prominent keels in the adults than is common in the second series, and during the clinologic stage these are still retained. The whorl in other words becomes rounded only in the nostologic stages, and probably very rarely attains this extreme of modification. The clinologic stage has also slightly flattened and inclined sides.

Caloceras sulcatum, Hyatt.

Plate I. Fig. 19, 20. Summ. Pl. XI. Fig. 20.

Amm. Conybeari, Ziet., Verst. Würt., pp. 3, 35, pl. ii. fig. 4?
Amm. Nodotianus, Hauer, Ceph. Lias Nordöstl. Alpen, pl. vi. fig. 4?
Amm. kridion, Quenst., Amm. Schwab. Jura, pl. ii. fig. 7 (not fig. 5, 6).

Locality. — Semur.

This species is precisely similar to Hauer's figure, except that the sutures are more distinctly caloceran, having the line of auxiliaries inclined backwards. Our specimens are also somewhat stouter, the abdomen broader, the channels deeper, the geniculæ more prominent, but the pilæ and general aspect of the shell are exactly similar.

[1] Mojsis. et Neum., Beitr., V. pl. xxii., xxiii.
[2] Abhandl. geol Reichsans., VII. pl. v. fig. 1.
[3] Mojsis. et Neum., Beitr., V. pl. xxii., xxiii.
[4] Ibid., pl. xxviii. fig. 4–7.
[5] We have given outline figures on Summ. Pl. xi. of *Cal. cycloides*, fig. 17, *Castagnolai*, fig. 18, and *abnormilobatum*, fig. 19.

One specimen in the Museum of Comparative Zoölogy has somewhat deeper channels than is usual in this species, but is otherwise quite similar to the raricostatus-like variety (Plate I. Fig. 19, 20). Quenstedt identifies this variety with *Arn. kridioides* (*kridion*) in his "Ammoniten der Schwabischen Jura," but from this species it differs essentially, if we are right in our selection of the form to which the name *Amm. kridion*, Oppel, has been applied. Undoubtedly there is a close resemblance between this species and *raricostatum*, on the one hand, and *Arn. kridioides* on the other. The young and the channels separate it from the former, and the great breadth of the whorls, channels, caloceran pilæ, and sutures, from the latter. The raricostatus-like form of the whorl and pilæ, and absence of tubercles, distinguish it from what we consider to be the true *kridion*. Zieten's figure of a specimen from Kalthenthal, near Stuttgardt, has exactly the aspect of this species, and though the abdomen looks somewhat broader in Zieten's section the pilæ have no tubercles. It is more like this species than any form of *kridion* or *kridioides*, if the figure is accurate.

Caloceras laqueoides, Hyatt.

Amm. sinemuriense, Fraas.

In this specimen, now in the collection of the Museum at Stuttgardt, found, according to Fraas, in the Angulatus bed, there is a most singular mingling of the characteristics of *laqueum* with the peculiar pilæ of *Coroniceras Bucklandi*, var. *sinemuriense*.

The young and adult whorls are smaller and more numerous than those of *sinemuriense*, and like those of *laqueum*. The abdomen, however, has narrow channels, and many of the pilæ in the adult have large tubercles somewhat thrown back, which give them the aspect of the undivided pilæ of *sinemuriense*. Between these there are usually two or more of the linear pilæ of one variety of *laqueum*, and the tubercles when covered by the shell do not extend into spines, but remain mere tubercles.

In old age or on the last whorl of this specimen, which may perhaps be prematurely old, the intermediate pilæ alone are found, the stout tuberculated simuriense-like pilæ having become obsolescent. At this time the form and characteristics of the whorl are precisely as in *laqueum*, except the channels; these still remain very much shallower. Upon the whole, therefore, it is probable that this may be a distinct species. Together with others, it shows that Caloceras may have forms which are the morphological equivalents of the tuberculated, keeled, and channelled progressive forms of Vermiceras, Coroniceras, and Asteroceras.

Caloceras ? Deffneri.

Summ. Pl. XI. Fig. 21.

Amm. Deffneri, Opp., Mittheilungen, II. p. 131, pl. xl.

Locality. — Stuttgardt.

This species has whorls at first sight apparently identical in form with those of the typical *Conybeari*.

The young have prominent pilæ and geniculæ on what seems to be the first quarter of the fourth whorl, and the geniculæ become tuberculated in the adult, without, however, exhibiting the angular forward bend of *Conybeari*.

The abdominal lobe is extremely broad, its lateral branches at first extending over the channel ridges on either side, and then diminishing to two pointed minor lobes. The siphonal saddle is very large. The superior lateral lobes are very narrow, profusely branching, a trifle longer than the abdominal lobe, and very much longer than the inferior laterals. These and the auxiliary lobes are often inclined posteriorly, as in Caloceras. The inferior lateral saddles are about as deep as the superior laterals, and have deeply cut margins, as in that genus. The first auxiliary, however, is often of considerable size, and then the inclined aspect of the inner margin is destroyed. The superior lateral saddles are penetrated by a very peculiar and remarkable marginal lobe, which divides them into two portions, the inner shorter than the outer half. The proportions of the lobes and saddles, and this last peculiarity, show, besides the form, a closer repetition of the characteristics of *Conybeari* than could have been anticipated from the general aspect of the shells.

The channels are shallow, but have lateral ridges, and the keel is well formed and prominent, as in *Conybeari*. The series of this species in the Museum at Stuttgardt illustrates the different ages at which senile characteristics may begin to appear. The last specimen described above was only 175 mm. in diameter. Another specimen, however, reached the size of 380 mm., and yet only the last volution and a half exhibited senile degradation. The first senile half-volution had obsolescing pilæ and tubercles, while the last half-volution was entirely smooth. The channels and keel remained almost unchanged, as in the adult. Not even a fragment of a living chamber was present. Oppel's original is in the Museum at Stuttgardt. The eighth and ninth whorls of this specimen are senile, the tubercles have disappeared, the sides are more convergent, and the abdomen more elevated than in the adult; the keel and channels, however, were retained even after the pilæ disappeared, though they had become shallower.

The sutures indicate affinity with the Caloceran series, but our knowledge of the early stages is incomplete, and this opinion is consequently uncertain.

Neumayr in his "Unterster Lias" figures a large specimen of *Cal.* (*Ariet.*) *Haueri*, and gives a section. These show that the nealogic stages of this species are first similar to *Johnstoni*, then as the keel appears resemble *Cal. Loki* and the like, and finally take on the narrow channels of the adult. The closely set, bent, immature-looking pilæ are also characteristic and persistent in this subseries. The sutures are distinctly caloceran. Our own notes made in the Museum at Munich give the same results as regards this important species. Neumayr clearly points them out as transitional, while calling the species an Arietites. It is evident that we differ mostly in the limits which are ascribed to genera. *Cal.* (*Ariet.*) *Loki*, Wäh.,[1] and *Cal.* (*Ariet.*) *Seebachi*, figured on Plate XX., indicate, when compared with *Cal.* (*Ariet.*) *Haueri*, Wäh., that *Haueri* must have been connected with *Johnstoni* through some such flat-sided shells as the former. The *Cal.* (*Ariet.*) *Haueri* of Wähner, as figured on Plate XIX. and especially on Plate XVII., shows acceleration in the earlier development of the keel and channels. The specimen on Plate XVI. Fig. 3, though about the size of the specimen figured on Plate XVII., has very shallow channels, and an immature keel, which contrast markedly with the deep channels and perfect keel of the former. *Cal.* (*Ariet.*) *coregonense*, Wäh.,[2] is figured so fully that, as in *Cal. Haueri*, one can see that the keel and channels were developed at different stages of growth, in some much earlier than in others, and that old age began also in some cases much earlier than in others. *Cal.* (*Ariet.*) *ophioides*,[3] Wäh. (not D'Orbigny's species, which is a true Vermiceran species with constant channels, tuberculated pilæ, etc.), has also varieties in which channels are very late in appearing, and others in which they appear early. *Cal.* (*Ariet.*) *perspiratus*, Wäh.,[4] a stout form of whorl, but the age at which channels appear is not given. *Cal.* (*Ariet.*) *supraspiratus*, Wäh.,[5] has the channels developed at an early age as compared with other species.

Caloceras Newberryi,[6] Hyatt.

Locality. — Peru.

Two very interesting specimens of this species have been placed in my hands for identification and description through the kindness of Prof. J. S. Newberry. They are reported as having been collected near, but not at, the Cerro de Parco mines in Peru. The largest is 128 mm. in diameter; abdomino-dorsal breadth of last whorl, 24 mm.; transverse diameter, 20 mm.; next inner whorl, 20 by 16.5 mm. It resembles the form of *Cal. Nodotianum* in the aspect of the section when restored, and in the number, close proximity, and linear appearance of the pilations. They are also similar in being slightly and evenly curved. The keel is low and broad, the channels shallow and more distinct than in the figure, but the abdomen similar to that of the section, Fig. 9, Plate I. The outer whorl of the older stages and all the inner whorls are compressed, as in the typical forms of *Nodotianum*. The distinct keel and shallow channels appear late in the life of the shell, as is usual in that species. The living chamber is incomplete, but over one volution in length. The species more closely resembles *Cal. proaries*, Neum., than any other form of the fauna of the Northeastern Alps, but differs in having flatter sides in all the whorls, an earlier

[1] Mojsis. et Neum., Beitr., V pl. xvii. [2] Ibid., VI pl. xxi.-xxvi.
[3] Ibid., pl. xxv. fig. 1-6. [4] Ibid., pl. xx. [5] Ibid., pl. xx. fig. 6-9.
[6] This species has been referred to previously in these pages as if identical with *Cal. Nodotianum*.

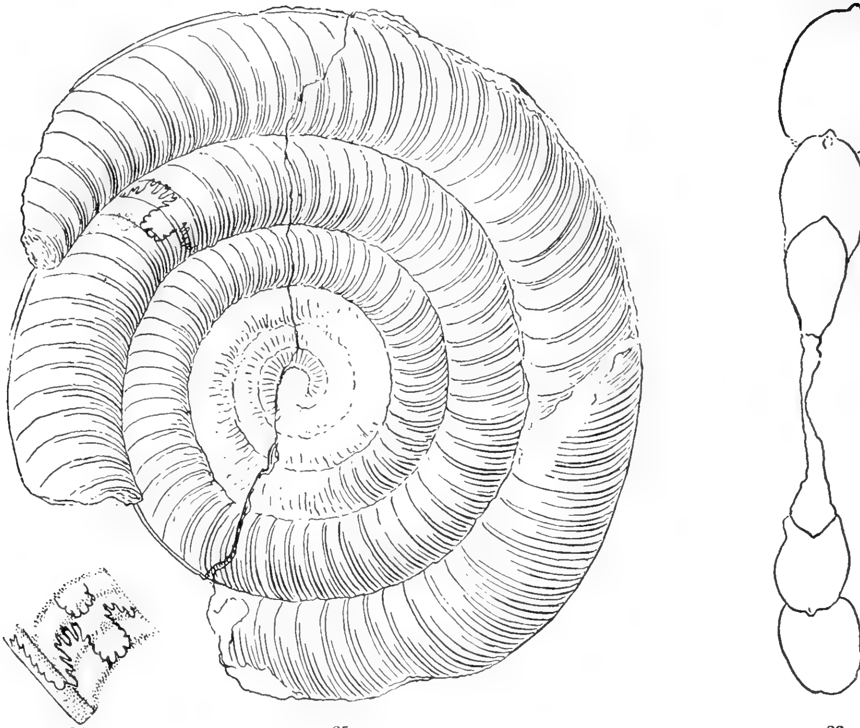


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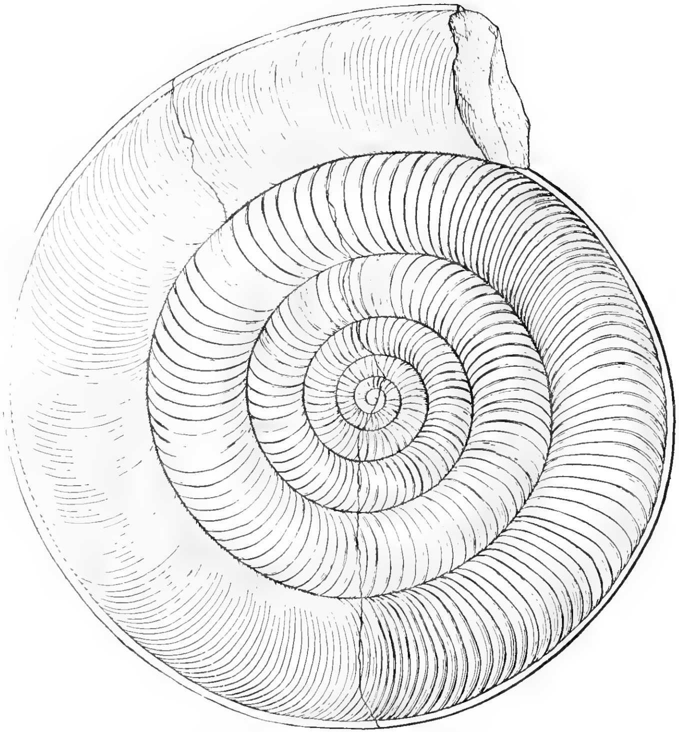
Fig. 25, 26. Views from the side and in section of *Cal. Newberryi* showing incomplete living chamber and outlines of whorls.

Fig. 27. View of suture made up from the last suture in Fig. 23 and the study of others. The abdomen is projected, to show depth and narrowness of abdominal lobe.

development of keel and channels, narrower abdomen in the whorls of the adult, and in being, like the species of Central Europe, considerably smaller. The largest specimen had just begun to pass into the first senile stage. The internal or young whorls have pilæ similar to those of the young of *Cal. varicostatum* and *Cal. carusense*. The sutures are similar to those of the normal species of Central Europe, having broader lobes and saddles than is customary in the basin of the Northeastern Alps. This agrees with other characteristics, which are essentially similar to species from the European province. The second and smaller specimen, which is 80.5 mm. in diameter, has similar but straighter pilæ. The abdomen is broader and more depressed, and the channels better defined, but how much of this is due to pressure cannot be stated. Both specimens have been distorted by pressure. The first has been affected in such a way that it is easy to restore the normal form, whereas in the second case it is not easy to separate the results of pressure from the true characters.



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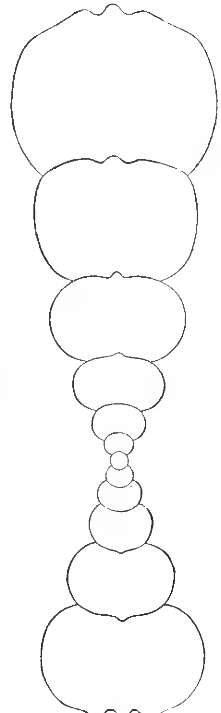

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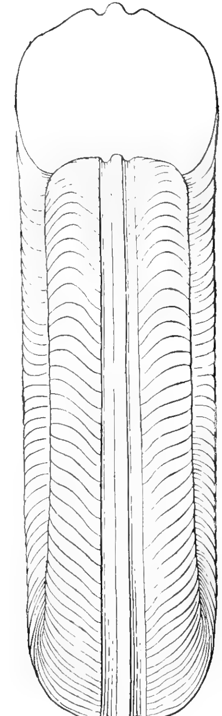

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FIG. 28, 29. Views from the side and in front of *Cal. Ortoni*, showing geratologous changes of the pilæ in the clinologic stage and the slight constrictions in the umbilicus due to the greater or less permanence of apertures, or imperfect resorption of these apertures —FIG. 30. Section taken along the broken line marked in Fig. 28.

Caloceras Ortoni, Hyatt.

Caloceras Ortoni, Hyatt, Proc. Bost. Soc. Nat. Hist., XVII., p. 367

Locality. — Tingo, near Chacapoyas, Northern Peru.

The shell is fully preserved in the only specimen found. This form resembles *Cal. salinarium* of the Northeastern Alps more than any other species. There are the same closely crowded fold-like bent pilæ without geniculæ, similar narrow channels with depressed lateral ridges and sunken keel, and similar gibbous form of whorl, flattened abdomen, and discoidal aspect. The young were studied in section. The earlier stages are excessively broad and smooth for three whorls. Coarse tubercular folds appear on the latter part of the third or first quarter of the fourth volution, near the abdomen. These gradually lengthen, but remain very broad folds separated by wide depressions during the entire fourth whorl. There are about twenty pilæ on this whorl including the tubercles, thirty-five on the fifth, and perhaps fifty-eight on the sixth.

Occasionally a pilation is wanting, indicating the former presence of a more or less constricted aperture, but these, though numerous, are not at regular intervals. Occasionally pilations are doubled, but these are not shown in the figure.

On the seventh whorl there are about eighty pilæ, and on the latter part of this volution they begin to lose their prominence, and on the latter part of the eighth they suddenly degenerate into coarse crowded striations. These changes are accompanied by a very slight elevation of the abdomen, broadening and shallowing of the channels, while the keel appears to be more prominent.

The young whorls are similar to those of *Cal. Liasicum*. The keel appears as a low, broad ridge on the first quarter of the sixth volution, but the channels were not present, in the section examined, until first quarter of seventh volution. They are at this time very shallow and narrow, and the keel is also depressed and not very broad, but on the eighth volution both these parts become more fully developed. Effort was made by removing the shell to see the sutures, but not with success. The auxiliary portions of the sutures are inclined posteriorly, but otherwise nothing was satisfactorily ascertained.

Cal. (*Ariet. proaries* var.) *laticarinatum*, Wähner,[1] is the geographical equivalent of the broad, depressed-whorled varieties of *Cal. Liasicum* of the Middle European province. Wähner considers that *Loki* may be the nearest affine to *Cal. Liasicum*, taking as his guide Reynès's figure of the latter. This means only the compressed varieties of this species, which we have noted in the first subseries. The extreme depressed whorls of *laticarinatum* are closely similar to the next form of the subseries *Cal.* (*Ariet.*) *salinarium*, figured on Plate XVIII., and this is very likely, as supposed by Wähner, an old specimen of *salinarius*, though described by Gümbel as *Amm. euceras*. *Cal.* (*Ariet.*) *centauroides*, Wäh.,[2] exhibits very stout whorls in the young, and acquires the deep channels and well developed keel at a late stage of growth, and these continue to be better

[1] Mojsis. et Neum., Beitr., V. pl. xvi. [2] Ibid., VI. pl. xxiv.

defined, though the first old age stage is shown to have begun by the flatness and inclination of the sides in the section given by Wähner on Plate XXIV. Fig. 7 e. *Cal.* (*Ariet.*) *Grunowi* (Hauer), Wäh.,[1] resembles closely *centauroides*, but is evidently even less advanced, since the development of the keel is less marked, and it is doubtful if it ever have channels. The two species mentioned above, *centauroides* and *Grunowi*, as described by Wähner in their younger stages, have sutures which differ from the similar forms described by Canavari in his Fauna of the Lias, so often quoted above. The sutures are unquestionably arietian, having deep narrow abdominal lobes and lateral sutures like those common in Caloceras. The sutures, form, and characteristics of *Aegoc. centauroides*, Canavari, figured on Plate V., ally it closely with the species figured on Plate VII. as *Aegoc. Listeri.*[2]

The extraordinary species figured by Neumayr, *Cal.* (*Ægoc.*) *Sebanum*, Pich.,[3] is supposed by him to be a species with young, like those of the schlotheimian series. It is apparently, if the figures are accurate, a keeled caloceran form, with prominent angular geniculæ in the young, and we entirely agree with Wähner that it cannot be allied to *Schlotheimia*. Such a shell might be traced either to *Cal. tortile*, or almost any species of Caloceras having an immature keel and well defined pilæ. The characteristics suggest a subseries of which the tuberculated *Cal. laqueoides* of the Angulatus bed of Würtemburg would be also a member.

Geyer, in his "Lias. Ceph. d. Hierlatz b. Hallstadt," gives three species of small size, *Cal.* (*Arietites*) *sp. indet. aff. Nodotianus*, D'Orb., Plate III. Fig. 16; *Cal.* (*Ariet.*) *doricus*, Plate III. Fig. 3; and *Cal.* (*Ariet.*) *raricostatus*. This is a fauna mostly composed of dwarfed forms of species, which there lived under unfavorable conditions, as did those of Spezia in the south.

Canavari, in his Unteren Lias v. Spezia, gives *Cal.* (*Ariet.*) *Corregonense*, Fig. 12–15, which seems to be the young of a stout variety of *Johnstoni*; *Cal.* (*Ariet.*) *retroversicostatus*, which may be young of *Cal. salinarium* described by Wähner from the Northeastern Alps; *Cal.* (*Ægoc.*) *helicoideum*, Plate V. Fig. 7, *tortuosus*, Fig. 8, and *carusense*, Fig. 10, all belonging apparently to the same species, most likely young or dwarfs of the last named;[4] and *Cal.* (*Ariet.*) *raricostatum*, Fig. 9, is probably the young of some Caloceran species, since the drawing does not have the aspect of *raricostatum*.

VERMICERAS.

In this genus we find several characteristics which were merely specific or varietal in Caloceras, becoming established as an integral part of the growth, and furnishing good generic characteristics.

[1] Mojsis. et Neum., Beitr., VI. pl. xxv. fig. 2. 3.

[2] The species accompanying this one, figured on the same plate as *Tropites ultratriasicus*, *Arietites Campigl'iensis*, *ligusticus*, and *discretus*, are all apparently true Tropites with tuberculated and coronate whorls in the earlier nealogic stage, and acquiring a keel and pilæ while still retaining the coronate depressed form of their triassic radical, *Tropites subbullatus*. The sutures as figured are similar to those of the adult of *Tropites Jokelyi*, as given by Hauer, Ceph. d. Hälst. Schich., Denks. Akad. Wien, IX., 1855, pl. iv.

[3] Unterst. Lias, Abhandl. geol. Reichsans., VII. pl. iv. fig. 2–4.

[4] Referred by Canavari to the young of *proaries* in Mem. della Carta Geol. d' Italia.

The young whorls for a very limited stage are smooth, then the rounded abdomen and immature pilæ of Caloceras appear. The keel is introduced after this stage, and we have for a stage of greater or less duration, according to the species, a resemblance to some varieties of *Caloceras laqueum*.

The adults are characterized by quadragonal forms and flattened, keeled, and channelled abdomens. The pilæ are straight, with distinct geniculæ bending forwards. In one variety of *Verm. Conybeari* the geniculæ are tuberculated, in other examples they are smooth.

The sutures have arietian proportions in the adults, though they retain the immature proportions of the young until a late period of growth, and often even in the adult stage. The abdominal lobe is longer than the superior laterals, and the superior lateral saddles shallower than the inferior laterals; the auxiliary saddles and lobes may occasionally have a backward trend in the young, but this is not found in adults.

The old stage retains the keel, and has smooth, somewhat flattened and convergent sides. This is very distinct from the similar stages of Caloceras, in which the keel is lost and the whorl becomes rounded. The extreme form assumed in old age, when contrasted with the adult whorl, can be best described as trigonal. It is, however, still similar to the senile stages of Caloceras before the keel is lost, and the sides are more gibbous than in the trigonal senile whorls of the more highly developed species of Coroniceras. The sutures degenerate, the abdominal lobe becomes shorter. Our observations on the geratologous period in this genus were not so satisfactory as in some others, senile specimens being of rarer occurrence. Quenstedt, in his "Amm. Schwab. Jura," Plate VII., figures under the names of *brevidorsalis* and *brevidorsalis macer* several fragments of large shells, which are probably examples of senile metamorphoses belonging to this genus, but we are not able to designate the probable species. Although the last whorls are represented as perfectly smooth in these figures and the sides convergent, and the abdomen considerably narrowed, the keel and channels are still persistent. The whorl in the oldest specimen had become so excessively altered by senile degradation that it was smooth and helmet-shaped, as in Psiloceras, and the channels obsolescent, though a low broad keel still remained.

There is also in the British Museum a fossil, 1010 mm. in diameter, labelled, "Zone of *A. planorbis* and *Pent. tuberculatus*, Newbold Quarries, Rugby, Warwickshire." This has the outer whorls compressed and smooth, as in *Psil. planorbe*, but with a keel and obsolescent channels preserved on part of the last volution. We identified this as an aged specimen of *Verm. Conybeari*, but eminent paleontologists in England have expressed their opinion that it might be a specimen of *planorbe*. We are much indebted to Mr. Henry Woodward, of the British Museum, for a large drawing of this fossil, but unfortunately this is not sufficient to settle the questions involved. We have had no opportunity for re-examination, and should have considered our former opinion as probably erroneous but for other evidence. According to Wright, *Pentacrinus tuberculatus* is not found below the Angulatus bed in England. We have also seen in the rock at Lyme Regis sections of old whorls of *Conybeari* closely resembling this, and also a still more advanced stage, in which the channels were entirely obsolete, the keel being almost completely merged in the surface, or represented only by a raised sub-angular line on the sub-acute abdomen.

These specimens are among the few rare examples of species in this family which have entered upon what we have called the nostologic stage on account of the resemblances to ancestral forms which make their appearance in consequence of senile degeneration of the differential characters of the preceding adult stages. It is to be anticipated that in very exceptional cases of extreme senility, the reversion to the form and characteristics of *Psil. planorbe* may have been completed by the entire loss of the keel at the termination of the nostologic stage, but we have not yet seen such a case in Vermiceras, or any other keeled and channelled genus of the normal Arietidæ.

Vermiceras spiratissimum, Hyatt.

Plate I. Fig. 17, 18. Summ. Pl. XI. Fig. 23.

Amm. spiratissimus, Quenst., Handb. d. Petrefact., p. 355, pl. xxvii. fig. 9; Amm. Schwab. Jura, pl. xii. fig. 7–10; pl. xiii. fig. 1, 2, 6.
Discoceras spiratissimus, Hyatt, Bull. Mus. Comp. Zoöl., I, No. 5, p. 77.
Amm. arietis, Ziet., Verst. Würt., p. 3, pl. ii. fig. 2, 3 (not fig. 4[1]).
Amm. Conybeari, Ziet., Ibid., p. 35, pl. xxvi. fig. 2.
Amm. latisulcatus, Quenst., Amm. Schwab. Jura, pl. xii. fig. 1–4 (not fig. 5, 6).

Localities.—Whitby, Semur, Filder, Stuttgardt, Balingen, Vaihingen, Nellingen, Metzingen, Hohenheim.

Var. A. The pilæ begin early upon the third whorl, the shell during the first two whorls being smooth. The pilæ are about twenty in number on the third or fourth whorl, and increase to from thirty-two to thirty-four on the sixth whorl, and forty-five to fifty on the eighth. The aspect of the shell, until the keel becomes well defined, is precisely like that of the adult of *Cal. laqueum*. At earlier periods the development is the same as in that species; the keel, however, is always developed earlier. The whorls assume the flattened sides and abdomen on the fourth whorl, and this continues in some specimens throughout the fifth. The channels become deeper upon the last quarter of the fifth whorl or the first quarter of the sixth; but while these remain without well defined lateral ridges, the shell continues immature. When, however, the ridges appear, the abdomen and the pilæ gradually acquire their adult characteristics.

The variety figured on Plate I. Fig. 18, might be called the dwarfed or *raricostatus* variety of this species. The pilæ are between fifteen and nineteen in number on the third whorl, and only about twenty-two on the fourth, increasing again to twenty-six on the fifth. The young, however, are like those of typical *spiratissimum*.

Senile characters made their appearance in one specimen upon the ninth whorl. A fragment of the fourth quarter of this whorl, in one specimen, exhibited unmistakable signs of advanced senility. The pilæ are only ridges, destitute of geniculæ and slightly bent forwards. The whorl is broader near the dorsum, and the sides converge. The keel and channels remain apparently unchanged.

[1] This seems to be identical with *carusense*, judging from the type in Oppel's collection.

The sutures have reverted to larval outlines. On the eighth whorl the lobes are all of equal length; the superior lateral saddles, however, are deeper than the inferior laterals, and the first auxiliary saddles not more than half as deep as the inferior laterals.

The abdominal lobe and the larger saddles are much shallower in proportion to their breadth in this species than in *Conybeari*. The rate of increase in the bulk of the whorl by growth is also less than in *Conybeari*, and the umbilicus shallower. The longest living chamber was observed in a specimen in the Museum of Stuttgardt from Vaihingen; it was full one and a half volutions in length, and not complete. Quenstedt[1] figures a senile specimen with a living chamber, the aperture preserved, which is a trifle over one and a half volutions in length. The aperture is remarkable for having no lateral sulcations, and no abdominal rostrum. It would be instructive to compare this with the aperture of an adult or young specimen, since it suggests degeneration in the rostrum, and, if this be true, is another characteristic occurring through senile metamorphosis which is analogous to the younger stages.

The Museum of Comparative Zoölogy received in exchange from the Museum of Stuttgardt a young specimen of this species labelled "*Amm. laqueus*, Quenst., Lias, and found with *Amm. psilonotus* at Nellingen."[2] The geniculæ had already begun to be developed, and the presence of a subquadragonal form of whorl, as well as the keel and immature channels, at such an early age, shows that this must have been a vermiceran and not a caloceran species.[3]

A specimen from the Arietenkalk in the Museum of Tübingen, and belonging either to this or to *Cal. longidomus*, has a rupture in the shell at an early age, and is distorted. The distortion of the spiral is slight, but the pilæ cross the abdomen, which has no keel. On the first part of the exposed whorl they are more or less alternate, but subsequently quite regular, and on the latter part of this whorl a keel-like ridge appears below, though not high enough to interrupt the pilæ. The diameter of this specimen is about 39 mm.

Vermiceras Conybeari, Hyatt.

Summ. Pl. XI. Fig. 24.

Amm. Conybeari, Sow., Min. Conch., I. p. 70, pl. cxxxi.
" " D'Orb., Terr. Jurass. Ceph., p. 202, pl. l.
" " Quenst., Amm. Schwab. Jura, pl. xv. fig. 1.
" " Hauer, Ceph. d. Nordostl. Alpen, p. 16, pl. ii. fig. 1–6.
Discoc. Conybeari, L. Agassiz, Bull. Mus. Comp. Zool., I. No. 5, p. 77.
Ariet. Conybeari, Wright, Lias Amm., pl. ii. fig. 1–3.
Amm. obliquecostatus, Ziet., Verst. Wurt., p. 20, pl. xv. fig. 1.
Amm. Bonnardi, D'Orb., Terr. Jurass. Ceph., p. 196, pl. lxiv.
Ariet. Bonnardi, Wright, Lias Amm., p. 196, pl. xi. fig. 1–3.
Ariet. Conybeari, Herbich, Széklerland, Mitth. Jahrb. ungar. geol. Anst., V. pt. 2, pl. xx. b.
Ariet. multicostatus, Herbich, Széklerland, Ibid., pl. xx. a. xx. b.

Localities. — Lyme Regis, Semur, Salins, Mohringen, Vaihingen, Balingen, Waltzing in Luxemburg, Adnet.

The young of this species is smooth throughout the first volution. On the second whorl scattered folds appear, which develop into true pilæ on the third whorl.

[1] Amm. Schwab. Jura, pl. xiii. fig. 6.

[2] See Plate I. Fig. 17.

[3] A similar form is figured by Quenst., Amm. Schwab. Jura, pl. vi. fig. 3, as [illegible]

These at first have the depressed aspect of the adult pilæ in Caloceras, and the rotundity of the abdomen increases the resemblance to this genus. On the first quarter of the fourth whorl the abdomen grows broader, flatter, and the pilæ acquire immature geniculæ. The channels make their appearance upon the second quarter of the fourth whorl, and the bent geniculæ of the adult become apparent also, though very obscure. When the lateral ridges of the sulcations are developed on the fifth whorl, the shell becomes similar to *Ver. spiratissimum;* and finally, as the sulcations deepen and broaden, and the geniculæ become more salient and bend more forward, the adult characteristics of the species are fully brought out.

The young as compared with the young of *spiratissimum* present considerable differences. They are broader in proportion and increase faster in bulk. Thus they form an umbilicus deeper and with fewer volutions within a given diameter than in *spiratissimum*. Five volutions of *spiratissimum* have about the same diameter as four or four and a half of *Conybeari*. There are about twenty-five pilæ on the third whorl, thirty-six on the fifth or sixth whorl, and forty on the seventh whorl.

The channels are deeper and broader, the lateral ridges and keel sharper and narrower, the sides more deeply furrowed, the pilæ more salient, and the whorl narrower from side to side in proportion to the breadth of the channel area, and narrower also in proportion to the dorso-abdominal diameter than in *spiratissimum.*

The sutures also differ considerably. The abdominal lobe in some specimens is one half deeper than the superior laterals; the inferior lateral saddles are deeper than the superior laterals, and the inferior lateral lobes shorter than the superior laterals; the auxiliary lobes and saddles continue the inclined line formed by the apices of the lobes. This anterior inclination is subject to variations in the adults of varieties. In the young the lobes and saddles are nearer to the same level, and approximate to the outlines of the sutures in *spiratissimum*. In Professor Fraas's collection there are two specimens, one in which the superior and inferior lateral lobes are about equal, and one in which the inferior laterals are a little the longer; these are both full grown.

A specimen in the Museum of Stuttgardt has a living chamber nearly one and a half volutions in length, and still incomplete.

One specimen in the Museum of Comparative Zoölogy completes nine and one half whorls without exhibiting any senile characteristics. The largest specimen yet recorded is now in the collection of the British Museum; this measured, according to Wright, about 460 mm. in diameter. The one figured by Wright, in "Lias Amm.," was 340 mm. in diameter, and old age had begun to show its effect slightly upon the last whorl. A specimen from Lyme Regis, in the collection of the Museum of Comparative Zoölogy, is associated upon the same slab with *Birchii*. The largest specimen in the Stuttgardt Museum was 365 mm. in diameter, and had not yet begun to exhibit very decided senile characteristics.

In the collection at Tübingen is a specimen, perhaps the same figured by Quenstedt, Plate XV. Fig. 1, with undoubted spines on the casts of the geniculæ. The original of Sowerby's figure is 455 mm. in diameter, and had begun to lose the pilæ, but the specimen shows distinctly that the form of the adult is more compressed than in *spiratissimum*, with more convergent sides, and it has tubercules. It is precisely similar to the original of D'Orbigny's *Bonnardi* in the Ecole des Mines. *Ver. Bonnardi* is figured by Wright as occurring in the Turneri bed, and a much more discoidal form is regarded by him as the true *Conybeari* and figured as such. The great flatness of the whorls and aspect of the whole shell in this figure are probably the effect of age. The sutures figured have senile proportions, the abdominal lobe being of about the same length as the superior laterals. The specimens figured by Hauer from the Northeastern Alps, and by Herbich from Siebenburgen, have more convergent sides and less angular geniculæ than is common in Central Europe. The variety from Luxemburg is very like the more discoidal varieties in England.

Var. planaries.

Amm. planaries, Fraas, MS.
Amm. Bonnardi, Oppel, not D'Orbigny.

Locality. — Semur.

The specimen in the Museum of Comparative Zoölogy on the ninth whorl had an abdominal lobe one half longer than the superior lateral lobes, and inferior lateral saddles one half deeper than the superior laterals. The inferior lateral lobes, however, are somewhat longer than the superior laterals, and the first and second auxiliaries, which show plainly on the sides, are still longer than these. Thus the sutures appear to incline rapidly towards the umbilicus, as in Caloceras, but this is a delusion due to the peculiar proportions of the auxiliary saddles. The outlines of the superior lateral saddles are covered by the involution of the whorl, instead of being in part exposed, as in *Conybeari*, in which last, also, these saddles are apparently broader. The superior lateral saddles are divided by a single marginal lobe.

The pilæ begin to show senile characteristics on the first quarter of the tenth whorl, and on the second quarter of the same whorl the abdomen has suffered a diminution in breadth. Throughout the remainder of the volution there is no change in the abdomen, but the pilæ become obsolescent near its termination. The external aspect of the adult is similar to *Conybeari*.

Only one specimen of this variety occurred in Professor Fraas's collection; it is placed with *Bucklandi*, but its position with relation to that species was considered uncertain. Professor Fraas considers it a new species under the name of *Amm. planaries*, and the sutures differ greatly from those of the specimen described above, though in the form it is more like it than either of them is like *Conybeari*. On the last volution of this specimen the pilæ are almost obsolete, the keel more prominent, the channels considerably shallower than in the adult. The form of the whorl changes somewhat and the sides tend to converge, and the abdomen is narrower, but these changes are very slight, and due entirely to the obsolescence of the pilæ.

This form was at first identified with *Bonnardi*, D'Orb., but the examination of the original at the École des Mines showed the young of the true *Bonnardi* to be tuberculated, which is not the case with the young of *planaries*. This fact was apparently not observed by Oppel, who considered *planaries* to be identical with the typical *Bonnardi*. It is possible that *Conybeari*, as figured by Hauer, may belong to this variety.

Vermiceras ophioides, Hyatt.

Plate I. Fig. 21-23. Summ. Pl. XI. Fig. 25.

Discoceras ophioides, Hyatt, Bull. Mus. Comp. Zoöl., I., No. 5, p. 76.
Amm. ophioides, D'Orb., Terr. Jurassique, p. 241, pl. lxiv.

Locality. — Semur.

The young is smooth for one volution and a half. On the third quarter of the second, scattered folds begin, developing into true pilæ on the first quarter of the third whorl. During the first half of this whorl, after the keel is developed, the rounded sides of the shell show that the form of the whorl, as well as the immature pilæ, resemble *Cal. laqueum*.

The abdominal sulcations are well defined on the last quarter of the third whorl, and from their well marked character on the early part of this quarter it may be inferred that they begin on the third quarter, where, however, they were not directly observed. For the same reasons, also, I should infer that there are well defined lateral ridges to the sulcations almost immediately after their first appearance on this same third quarter. The very rapid appearance of these characteristics probably prevents a repetition, or only permits a very partial one, of the adult characteristics of any of the species intermediate between *Caloceras Johnstoni* and *Ver. Conybeari*. In the course of the growth through the second quarter, the sides of the whorls remain rounded and the pilæ more or less immature, as in the adults of *laqueum* and *Johnstoni*. On the third quarter of this whorl, and simultaneously with the channels, the peculiar geniculæ and squared or quadragonal whorl appear, and we find also distinct lateral ridges to the channels, a well defined keel, and what seem to be minute tubercles, but are really only very angular geniculæ.

From this period these characteristics, which render a fragment of the adult whorl identical in its aspect with the adult of *Conybeari*, are increased and strengthened, but not otherwise changed by growth.

The sutures, however, though observed in only one specimen, differ somewhat. The lobes and saddles are more pointed and have smoother outlines than in *Ver. Conybeari*. It is a species which illustrates admirably the law of acceleration in heredity.

Canavari, in his work on the Lias of Spezia, figures under the name of *Ver. (Ariet.) spiratissimum*, Plate XX. Fig. 2, a very interesting dwarf, with exceedingly narrow channels and linear sunken keel. This is probably distinct, and the name *supraspiratus* subsequently given by this author, in his republication of this paper in the third volume of the "Memorie della Carta Geologica d' Italia," to the same species does not appear to indicate the exact affinities. *Ver.* (*Ariet.*) *Conybeari*, Plate XX. Fig. 6, *Ver.* (*Ariet.*) *doriens*, Figs 8–10, and *abjectus*, Fig. 11, all seem to be the young of some species of Vermiceras, in which keel and pilæ are developed early, possibly some form of *Conybeari*.

LEVIS STOCK.

The living chambers may be cylindrical, or they may be broadened out and considerably modified by the growth of the whorl, but the length is invariably under one volution, and often does not exceed one half of a volution. There seems to be no necessary correlation between the shape of the chamber and its length; the most attenuated and cylindrical whorls have not invariably the longest living chambers, nor the broadest whorls invariably the shortest living chambers. It is however true, in a very general way, that the longest living chambers, as a rule, occur in the Plicatus Stock among the species which have the most attenuated or cylindrical whorls.

None of the shells of the Levis Stock are directly or indirectly traceable to any known form of *Psil. planorbe*, var. *plicatum*. Their gradations and radical forms, nevertheless, do indicate derivation from *planorbe*, var. *leve*, and we must therefore consider the keels, channels, pilæ, and sutures which are similar in the two stocks as having originated independently in each stock, or, in other words, as homoplastic, and not homogenous characters.

The higher species of each series tend to become involute, and to elongate the abdomino-dorsal diameter of the whorl.

The sutures are almost purely arietian in proportions and outlines, the auxiliaries are rarely or never inclined posteriorly, the marginal digitations are less complicated, and the saddles broader and less dendritic than in the Plicatus Stock.

FOURTH, OR CORONICERAN BRANCH.

The shells are discoidal, and involution is limited to the area of the abdomen. During senile degeneration the shell is apt to acquire flattened smooth sides and a narrow abdomen, but never loses the keel, nor becomes rounded on the abdomen, nor decreases in the amount of involution. Flattened sides and narrow abdomens may also appear in the adults of species with accelerated development of progressive characters.

ARNIOCERAS.

The members of this genus may be recognized by the smoothness and thin, discoidal psiloceran form of the first three or four whorls. The keel appears as an angular ridge, which develops later into a true keel. There are lateral folds in the young, which develop later into pilæ. The true pilæ appear after the keel, and then in some specimens well defined channels arise.

The form in adults is discoidal, but the whorl is quadragonal. The adult shell is discoidal; no involute forms have been found. The pilæ are prominent, thin, sharp, straight, and smooth;[1] the geniculæ very abrupt, and on a level with the abdomen.

The sutures have immature margins, but an arietian aspect. The siphonal saddles are large and pointed; the abdominal lobe may be either equal to or much shorter than the superior lateral lobes. The latter are remarkably large and long, and the inferior lateral lobes short. This gives an elevated aspect to this portion of the suture. The superior lateral saddles are more distinctly bifid in this genus than in any other, owing to the absence, as a usual thing, of the accompanying marginal lobes of large size. The sutural margins are generally smooth or simply serrated, instead of more or less foliaceous.

The living chambers may be from one half to one volution in length.

Aged specimens are very rare, though the species are well represented by individuals. Indications of the approach of senility have been seen in some specimens, and the geratologous metamorphoses were probably similar to those of Vermiceras. Such a giant, however, as *Amm. Arnouldi*, Dum., figured in the "Études Pal. Bassin du Rhone," Plate VI., which was 274 mm. in diameter, is not described or figured as affected by senile metamorphoses, and the huge *Amm. geometricus*, Dum., Plate XXX., which was 162 mm. in diameter, had a similar history.[2]

First Subseries.

Arnioceras miserabile, Hyatt.

Plate II. Fig. 4-7. Summ. Pl. XII. Fig. 2.

Var. acutidorsale.

Plate II. Fig. 4-6.

Psil. acutidorsale, Hyatt, Bull. Mus. Comp. Zoöl., I., No. 5, p. 73.
Amm. miserabile, Quenst., Amm. Schwab. Jura, pl. xiii. fig. 27–30.
Ariet. nodotianus, Wright, Lias Amm., pl. xxxvii. fig. 4, p. 300.
Amm. Macdonelli, Portl., Geol. Rep. Londonderry, p. 134, pl. xxix. a, fig. 12.

Locality. — Semur.

The lobes and saddles of one specimen in the Museum collection from Semur are shallow and broad; the inferior lateral saddles, however, taper to a blunt point. The superior lateral saddles are divided by marginal lobes more deeply than the inferior laterals, which are only serrated. The auxiliary lobes are smooth, the superior laterals deeply serrated.

The shell is smooth for the first four and three quarters volutions. Very obscure folds then begin to appear near the umbilical shoulders, and on the second quarter of the fifth whorl reach half-way across the side. These still remain, however, more prominent near the umbilicus, and are less prominent near the abdomen, which, with the exception of the keel, is perfectly smooth.

[1] The American species *Arn. Nevadanum* has tubercles, but it is not yet unquestionably settled that this is an arnioceran form.

[2] See *Arn. Macdonelli*, page 164.

In other young specimens, the acuteness of the abdomen begins upon the latter part of the third or first part of the fourth whorl, and the striæ of growth are regular and well marked. Previous to this the abdomen is rounded, as in *Psil. planorbe.*

The smoothness of the sides of the whorls, the immature folds, and the flat discoidal aspect of the young, make the shell very like *planorbe*, var. *læve*, and in the next stage the folds give an aspect somewhat similar to the *plicatus* variety of *planorbe.* The prolonged smooth stage of the young, before it takes on the folds, has no correspondence with any form of Caloceras, and indicates direct derivation from *planorbe*, var. *læve.* In the typical specimens of *Arn. miserabile*, var. *acutidorsale*, the folds are sometimes not apparent upon the cast, even upon the fifth whorl, but in one specimen a careful examination showed that the original shell must have had faintly marked folds, which stretched entirely across the side and had the usual abrupt terminations. Quenstedt[1] figures this variety. The aperture is shown in his Fig. 27 to have been similar to that of *planorbe*, having a well marked rostrum, broad lateral sinuses, and a constriction. It is by no means certain, as Quenstedt states in the same work on page 104, that Wright's figure of the young of *semicostatum*, Plate I. Fig. 7 of his "Lias Ammonites," is a specimen of this species; it is quite as likely that Wright was correct. Professor Quenstedt's specimens at Tübingen are for the most part young from the Oelschiefer, but a large one[2] was nearly, if not quite, full grown. The keel in this appeared as a sharp ridge at an early age, and maintained the same character in adults.

The abdomen does not broaden out as in adult of *acutidorsale*, but persists in maintaining its angular character throughout life. The pilæ began quite early, but never appeared to get beyond the fold-like stage. Sometimes, however, they bend forwards and may cross the abdomen, and then the abdominal ridge forming the keel is crenulated.[3] The variety occurs in South Germany, especially in the Oelschiefer of Quenstedt.

A form doubtfully referred to this variety was collected by Professor Orton at Ipishguanüna in Northern Peru.[4]

Var. cuneiforme.

Plate II. Fig. 7.

Arnioceras cuneiforme, Hyatt, Bull. Mus. Comp. Zool., I., No. 5, p. 73

Abdomen acute, as in variety *acutidorsale*; sides regularly convex; pilæ depressed, most prominent in the centre, and sloping gradually to either side.

The abdominal lobe is somewhat longer than the two lateral lobes, which are of about equal length. Superior lateral lobes and saddles are pointed, the inferior lateral lobes and saddles mere serrations.

[1] Amm. Schwab. Jura, pl. xiii. fig. 27–30.

[2] No. 7742 of his collection, locality unknown.

[3] This does not indicate any affinity with other genera; it is a sporadic and purely pathological modification, as it is also in the young of *Oxyn. Oxynotum*, and many other forms in which the young shells are often affected by similar abdominal crenulations.

[4] Proc. Bost. Soc. Nat. Hist., XVII., 1875, p. 367.

The superior lateral lobes are slightly serrated, and the superior lateral saddles have the generic division; but otherwise the lobes and saddles are apt to be entire. These characteristics were observed in one specimen on the fifth whorl.

The general aspect of the shell is like that of the young of *Psil. planorbe;* the pilæ, however, are not merely broad prominent folds as in that species, but distinct immature pilæ, similar to those of other species of Arnioceras, and the form is quite distinct, besides being obscurely keeled. Some shells have straight pilæ and gibbous whorls, and others have bent pilæ and flatter whorls.

Arnioceras Macdonelli, Hyatt.

Amm. Macdonelli, Portlock, Geol. Rep. Londonderry, p. 134, pl. xxix. a, fig. 12.
Ariet. Macdonelli, Tate and Blake, Yorkshire Lias, p. 290, pl. v. fig. 8 a–b.
Ariet. nodotianus, Wright, Lias Amm., p. 300, pl. xxxvii. fig. 4.

Wright's reproduction of Portlock's figure and Portlock's own figures show that this is a most remarkable modification of *miserabile,* occurring in the Raricostatus bed, or what he first called the base of the Jamesoni bed. It is evidently an aged specimen, a very rare occurrence in this genus, and is consequently smooth. The young, however, have pilæ, and these and the section given by Portlock, the absence of channels, and compressed whorls, show it to be closely allied to *miserabile,* var. *acutidorsale.*

Arnioceras obtusiforme, Hyatt.

Plate II. Fig. 8-9 a. Summ. Pl. XII. Fig. 3.

Amm. obliquecostatus, Brauns, Der Untere Jura, pl. i. fig. 3–5.
Asteroceras obtusum (pars), Hyatt, Bull. Mus. Comp. Zoöl., I., No. 5, p. 79.

Locality. — Semur.

This species has the pilæ so closely resembling the curved depressed pilæ of *Ast. obtusum,* that it was formerly referred to that species. The young, however, are precisely similar to the young of Arnioceras, much too flat laterally for *obtusum,* and the pilæ never begin with tubercles or heavy folds, as in that species. The keel is depressed, and the channels are very shallow or absent.

Var. A.

The pilæ are developed abruptly on the last quarter of the third whorl. The curved pilæ resemble those of the typical form of *miserabile,* var. *cuneiforme.*

Var. B.

The pilæ are developed gradually, beginning with minute, regular folds on the first quarter of the third whorl, and they continue in the adult to resemble those of *miserabile,* var. *cuneiforme,* although the geniculæ become more prominent and make a nearer approach to those of *Arn. semicostatum.* The abdomen is narrow, the keel well defined, and in two specimens channels were faintly shown. The whorls of varieties A and B are both more compressed than in variety C.

VAR. **C.**

The whorls are stouter than in variety B, and acquire on the first quarter of the fourth whorl, or later, a close resemblance to those of *semicostatum*. The inferior lateral saddles are considerably deeper than the superior laterals, the inferior lateral lobes considerably shorter than the superior laterals, and pointed. The sutures were observed upon the latter part of the fifth whorl.

SECOND SUBSERIES.

Arnioceras semicostatum, HYATT.

Plate II. Fig. 10-16. Summ. Pl. XII. Fig. 4.

Amm. semicostatus, SIMPSON, Amm. of Yorkshire Lias, p. 51.[1]
Ariet. semicostatus, WRIGHT, Lias Amm., pl. i. fig. 7 (not fig. 4, 5, 8).
Arn. semicostatum, HYATT, Bull. Mus. Comp. Zool., I., No. 5, p. 74.

Localities. — Whitby, Semur, Basle, Spezia.

VAR. **A.**

Plate II. Fig. 10, 16.

During the first four and three quarters or five volutions, the shell closely resembles *Arn. miserabile*, var. *acutidorsale*. After this the pilæ appear. They are at first broad and depressed, but possess the sharp definition of true pilæ, and terminate abruptly on the edge of the abdomen. The abdomen is rounded, and the keel a distinct though depressed ridge. Its time of appearance could not be determined, but it was plainly apparent on the second or third quarter of the fifth whorl, and previous to this the aspect of the abdomen was precisely that of *miserabile*, var. *acutidorsale*.

VAR. **B.**

Plate II. Fig. 11-14.

In this variety the young resemble very closely the adults of *Arn. miserabile*, var. *acutidorsale*. The pilæ make their appearance earlier than in variety A, but, while becoming more numerous, often retain their fold-like aspect, and terminate abruptly near the abdomen. The keel appears about the same time as the pilæ, and may be either with or without slight channels. In some specimens the whorls become stouter than usual in the adult, and the geniculæ prominent. In one specimen they are inclined posteriorly.

In the Museum of Stuttgardt there are three specimens of this variety, one from Behla and one from Muhlfingen (No. 4688), both in the Geometricus or Upper Bucklandi bed. Another from Filder was found in the Angulatus bed.

[1] This name does not appear in the first edition of Morris's Catalogue, 1843, but is found in the second edition, 1854, as *Amm. semicostatum* Y. & B., Geol. Yorkshire, p. 257. This is an erroneous reference, since no such species was described in that work. In the Museum of Yorkshire is a specimen with this name, and it was described by Simpson in his Monograph of the Ammonites of the Yorkshire Lias, which was not cited in Mr. Morris's first edition, though published in 1843.

Var. C.

The adults are remarkable for their prominent straight keels. The channels when present are very shallow. The young remain smooth for a longer time than in other varieties. The pilæ appear between the first quarter of the fourth and first quarter of the fifth whorl.

While smooth throughout the first three or four whorls, it is identical with the adults of *miserabile*, var. *acutidorsale*, but the sutures are more immature. The pilæ develop quickly, and are similar to those of variety B. In fact, the young can be distinguished only by the larger size, quicker growth, and smaller number of the pilæ. Associated with these are specimens with compressed whorls, perhaps males.

Var. D.

Plate II. Fig. 15, 15 a.

This has a narrow abdomen, and the pilæ are more prominent near the dorsum. They appear on the fourth quarter of the third, or on the first half of the fourth whorl, earlier than in some specimens of variety B, and are more slowly developed. Some of the young are very like the adult of *Arn. miserabile*, var. *cuneiforme*. The pilæ bend forward when they first appear, or soon after, as in this variety, although subsequently becoming straight, like those of the adults of variety A. The abdomen is sharp, as in *miserabile*, var. *acutidorsale;* the keel does not appear until the pilæ begin to acquire their prominent, straight adult characteristics. The sutures have serrated outlines.

The abdominal lobe (Plate II. Fig. 15 a) may be equal to the superior lateral lobes, or one fourth shorter, and the siphonal saddle is remarkably large. The superior lateral saddles are divided symmetrically, and are equal in depth to the inferior laterals. The superior lateral lobes are very broad, and about one half longer than the inferior laterals. These characteristics were observed on the third quarter of the fifth volution of a specimen from Semur. In specimens from Whitby, on the second quarter of the same volution the sutures are similar in all respects, but the superior lateral lobes are at first equal to the abdominal lobe in successive sutures, and then slightly longer. At still earlier stages, when the marginal lobes first appear, the abdominal lobe is usually of the same depth as the superior laterals, or shallower (Plate II. Fig. 15 a). One specimen from Semur had sutures maintaining these immature proportions even on the latter part of the fifth whorl.

There are several specimens from Spezia in Bronn's collection, Museum of Comparative Zoölogy, labelled by Capelini *Amm. subarietinus*, Menegh. These seem to belong to this species, but are so compressed that it is difficult to make sure of the identification. The young are smooth until a very late stage, as is usual in *semicostatum*, and the pilæ and form are also similar. They are in the yellow clayey shale, and described as from Coregna near Spezia.

Arnioceras Hartmanni, Hyatt.

Plate II. Fig. 17, 18. Plate III. Fig. 1, 1 a. Summ. Pl. XII. Fig. 5.

Amm. Hartmanni, Oppel, Der Jura, p. 79; Wurt. Jahresh., XII. p. 139.
Amm. geometricus, Oppel (pars), Ibid.
Arn. kridiforme, Hyatt, Bull. Mus. Comp. Zool., I., No. 5, p. 74
Amm. kridion, D'Orb., Terr. Jurass. Ceph., p. 205, pl. li
Amm. falcaries (pars), Quenst., Amm. Schwab. Jura, pl. xiii. fig. 21.
Amm. robustus (pars), Quenst., Ibid., fig. 22.

Localities. — Whitby, Lyme Regis, Semur, Bonnert, Suabia, Gmund, Adnet.

This species has more compressed adult whorls than any variety of *Arn. semicostatum*, and, although the pilæ are similar, they begin to appear at an earlier age and are developed more gradually. The abdomen is also in many specimens, though not in all, distinctly channelled, and the keel prominent.

In one specimen the superior lateral lobes are nearly as long as the abdominal lobe on the sixth whorl, and on the same whorl in another they were two fifths shorter. The inferior lateral saddles are deeper than the superior laterals, and the inferior lateral lobes very short.

A specimen in the Museum of Stuttgardt, collected by Prof. Fraas, is from Arietenkalk, Hechingen (No. 5026 of that collection); another, from Gmünd, was found in the Geometricus bed, and is labelled *Amm. Nodotianus*, D'Orb. Two others, from Behla, are labelled *Amm. falcaries*, Quenst.; these belong to his sparsely ribbed variety, which is just intermediate between *Arn. Hartmanni*, and some varieties of *Arn. semicostatum*.

A specimen of *falcaries*, Quenstedt, figured by him,[1] is described as partly unrolled. Examination of the broken end, however, shows that a calcareous worm tube has occasioned the distortion by having been built upon the abdomen of the growing shell. This is a common occurrence, and was observed in several specimens at Semur. There are others, however, in which this distortion, as in other species of Ammonitinæ, takes place without the presence of any foreign body between the whorls. Such examples have been named *Crioceras Eryon* and *Mandubuis* by Reynés. These and other cases show the kind of error likely to occur from the use of such names as Crioceras, Gyroceras, etc.

The flattened sides and general aspect of Quenstedt's figure of *falcaries robustus*[2] agrees apparently more nearly with this species than any other known to me. This species is the one commonly named *Amm. geometricus*, Oppel, in the collections in Germany, and seems to have been in part confused with that species by Oppel.

[1] Der Jura, pl. viii. fig. 6.

[2] Amm. Schwab. Jura.

Arnioceras tardecrescens, Hyatt.

Plate II. Fig. 19, 21-22. Summ. Pl. XII. Fig. 6.

Amm. tardecrescens, Hyatt, Bull. Mus. Comp. Zoöl., I., No. 5, p. 74.
Amm. tardecrescens, Hauer, Ceph. Lias Nordöstl. Alpen, p. 20, pl. iii.
Amm. falcaries (pars), Quenst., Der Jura, pl. vii. fig. 7 (not fig. 6).
Amm. falcaries densicosta, Quenst., Amm. Schwab. Jura, pl. xiii. fig. 7.

Localities. — Yorkshire, Semur, Durrenburg.

The pilæ appear on the fourth whorl at variable times. There are fewer whorls, and they are wider from the abdomen to the dorsum and have generally rounder sides, than in *Arn. Hartmanni.*

The abdominal lobe is equal to or somewhat longer than the superior laterals; the inferior lateral saddles are shallower than the superior laterals, and the inferior lateral lobes are much shorter, sometimes a third less, than the superior laterals on the last quarter of the sixth volution. On the third quarter of the same whorl in the same specimen from Semur, the abdominal lobe was one half shorter than the superior laterals. The siphonal saddle was very large, and the superior lateral lobes very long and broad, with straight sides, the inferior lateral lobes two fifths shorter than the superior laterals. The first auxiliary saddles are visible on the sides. The marginal lobes are still hardly more than mere serrations, except along the bases of the saddles. The superior lateral lobes have very broad and minutely serrated summits.

A specimen in the Museum of Stuttgardt had curious characteristics. The sutures are undoubtedly arnioceran, the keel very prominent, and the channels shallow. The form of the whorls and the pilæ, however, are similar to those of *Conybeari.* Another specimen from Boihingen is precisely similar, but the pilæ terminate abruptly at the geniculæ somewhat below the edges of the channels, instead of being continued upwards and forwards, as in the former and in *Conybeari.* Neither of these shows the young whorls well enough to enable one to identify them accurately either with *Arn. Hartmanni* or *Arn. tardecrescens*, but they are undoubtedly arnioceran forms. Both are referred to the Geometricus zone.

The original of Quenstedt's figure in Der Jura, from Pforen, Baden, named *Amm. falcaries*, has the narrow sulcated keeled abdomen, rounded sides, and pilæ of this species. There is also from Achdorf in Baden a specimen about 26 mm. in diameter, which just begins to show the pilæ.[1] The figure by Quenstedt[2] shows a form in which the young is smooth for a considerable number of whorls.

[1] This may be the specimen figured in Amm. Schwab. Jura, pl. xiii. fig. 18, as *Amm. falcaries levissimus*.

[2] Amm. Schwab. Jura, pl. xiii. fig. 7.

Arnioceras ceras, L. Agassiz.

Plate II. Fig. 20, 20 a.

Arnioceras ceras, L. Agassiz, Bull. Mus. Comp. Zoöl., I., No. 5, p. 74.
Amm. ceratitoides, Quenst., Amm. Schwab. Jura, pl. xiii. fig. 10 (not fig. 8, 9, 11).
Amm. Turneri, Quenst., Ibid., pl. xix. fig. 6-8 (not fig. 5-9).
Amm. ceras, Hauer, Ceph. Lias Nordostl. Alpen, p. 25, pl. vi. fig. 4-6.

Localities. — Semur, Whitby, Lyme Regis.

This species approximates to the aspect of Coroniceras, and also imitates closely the general form and characteristics of some varieties of *Ast. Turneri*. Both in England and Germany, when the interior of the umbilicus or the smooth compressed younger whorls are not preserved, even the most acute observers are apt to consider the adult whorl as belonging to *Turneri*. Some of Quenstedt's figures, especially Fig. 8, Plate XIII., may be either *ceras* or some allied species of *Arnioceras*. The keel is prominent, the channels are broader and deeper than usual, the geniculæ are prominent and slightly bent forward, the sides, however, flat and slightly convergent, and the pilæ straight and smooth, as usual in this genus. The pilæ begin upon the third quarter of the fourth whorl.

The superior lateral lobes are somewhat longer than the abdominal lobe. The inferior lateral saddles are one fourth deeper than the superior laterals, the inferior lateral lobes one half shorter than the superior laterals on the latter half of the sixth volution.

A specimen in the Museum of Stuttgardt, locality uncertain, is referred to the Geometricus zone. Two young specimens from the Bucklandi zone, labelled *Bucklandi* (No. 2756), in Quenstedt's collection, also probably belong to this species. The young are smooth, and the form differs from that of typical *ceras* only in being a trifle stouter. The channels, perhaps, also appear at quite an early period, but this sometimes occurs in specimens of the typical form. There is also a large specimen from Jettenburg.

What appeared to be very close allies of this species were collected by Professor Orton at Ipishguaniina, in Northern Peru.[1]

Arnioceras Bodleyi, Hyatt.

Plate II. Fig. 23-24 a. Summ. Pl. XII. Fig. 7.

Amm. Bodleyi, Buck., Murch. Geol. Cheltenh., pl. ii. fig. 7.
Amm. ceratitoides, Quenst., Die Ceph., pl. xix. fig. 13; Amm. Schwab. Jura, pl. xiii. fig. 8, 9, 11.
Amm. geometricus, Oppel (pars), Der Jura, Wurt. Jahreshf., XII. p. 199.
Ariet. semicostatum, Wright, Lias Amm., pl. i. fig. 4, 5, 8 (not fig. 7).
Arn. falcaries, Hyatt, Bull. Mus. Comp. Zoöl., I., No. 5, p. 74.
Ariet. difformis, Blake, Yorkshire Lias, p. 289, pl. vi. fig. 3 a, b.

Localities. — Whitby, Bonnert, Semur, Raidwangen, Basle, Salins.

There are three varieties in this species; one, variety A, figured on Plate II. Fig. 23, has stout, thick whorls; the second, variety B, has flattened whorls; and the third, variety C, figured on Plate II. Fig. 24, has flattened whorls like those of the second variety, but they are somewhat wider on the sides.

[1] Proc. Bost. Soc. Nat. Hist., 1875, XVII. p. 366.

Varieties B and C, from Semur, showed tubercular-like folds on the latter part of the first, and part of the second whorl, which were continued on the umbilical border of the succeeding whorls, gradually developing into true pilæ on the third whorl.

For a short interval in the specimen of variety A the shell is smooth again, and in that of variety C the folds still remain apparent, but so depressed that they were made out with difficulty. On the first quarter of the third whorl in one specimen of variety B, and the third quarter of a specimen of variety C, the folds reappear on the umbilical border, but develop so gradually that lateral pilæ are not produced until the latter part of the first quarter of the fourth whorl. Several other specimens of these same varieties, however, from the same locality, did not show the psiloceran folds in the young, or differ from those of variety A.

A fragment from Ramert in the Museum of Stuttgardt is the true *ceratitoides* of Quenstedt, which differs from *ceras* in having a more prominent, narrower abdomen and shallower channels.

A specimen of the stout variety from Cheltenham, named *Bodleyi*, Bruck., has well preserved young which show this species to be closely allied to *ceras*. The thinner variety described above has the young much compressed, and similar to the adult of the Cheltenham specimen. On the other hand, the young of the Cheltenham specimen is precisely like the adult of *Arn. Hartmanni*. Oppel's description shows that he identified the compressed variety as the *Bodleyi* of Bruck., and the stout varieties as *Amm. geometricus*.

Arnioceras falcaries, Hyatt.

Plate II. Fig. 25-27.

Amm. falcaries, Quenst., Der Jura, p. 70, pl. vii. fig. 6 (not fig. 7).
Amm. falcaries, Quenst., Amm. Schwab. Jura, pl. xiii. fig. 12–14.
Arnioceras incipiens, Hyatt, Bull. Mus. Comp. Zool. I., No. 5, p. 74.
Amm. acuticarinatus, Simps., Museum at Whitby?[1]
Amm. Youngi, Simps., Mon. Amm., p. 46?

Localities. — Semur, Robin Hood's Bay, Balingen.

The sides are convex, the whorls compressed, and the abdomen obtusely angular, keel prominent. The pilæ begin with a line of tubercles, which appear on the first half of the fourth whorl, preceding the true pilæ by about one fourth of a whorl. The pilæ are not strongly developed upon the umbilical shoulders of the whorls, which in many specimens are almost smooth.

Variety A, figured on Plate II. Fig. 25, 26, has prominent geniculæ and keel without channels, but some specimens leading to the next variety have less prominent geniculæ.

Variety B has less prominent pilæ and keel. The channels, though mere linear depressions, begin to appear in some specimens.

Variety C, figured on Plate II. Fig. 27, has even less prominent pilæ, but a keel with distinct narrow channels, and in some specimens the pilæ were developed abruptly, not being preceded by the usual line of tubercles.

[1] The ? in these cases is due to the fact that I was not permitted to examine the originals in the Museum at Whitby.

The shell of variety A is smooth for three or three and a half volutions; the tubercles begin to spread entirely across the sides on the first quarter of the fifth whorl, and about this time the geniculæ have become prominent. The channels are not present in any of these specimens, but more or less faintly marked narrow depressed zones may be observed on either side of the keel. This variety leads directly into the next, in which the depressed zones become channels. The geniculæ differ in aspect from those of variety A because they abut against the well defined lateral ridges of the channels.

Variety B has the pilæ developed at about the same period as in variety A, but the channels appear in the young, and on the second quarter of the fifth volution they are quite distinct.

There is one specimen of variety A in which the pilæ are slightly inclined posteriorly, and the geniculæ more prominent than in any other specimen. A very slight sinking of the abdomen in this specimen would produce a form of variety C, which is found at Robin Hood's Bay in England, and which has a keeled, channelled, and flattened abdomen. The single suture which was exposed in this specimen possessed remarkably pointed and serrated superior and inferior lateral saddles, and very broad, rounded, but serrated superior lateral lobes. The auxiliary saddles and lobes were pointed and serrated. There was a very large siphonal saddle, and all of the larger lobes and saddles appeared of about the same depth and length.

One specimen of this species from Balingen was received in exchange from the Museum of Stuttgardt, under the name of *Nodotianus*. Two specimens in Quenstedt's collection belonged undoubtedly to this species, variety A. One from Lias, *α*, Pforen, named *Amm. falcaries* (No. 4428), and one from Göppingen (No. 11182), were in the Arietenkalk. The last was 63 mm. in diameter and a typical form of variety A; the pilæ are, however, inclined posteriorly, while in the other they are pointed forwards. In the specimen from Pforen the pilæ begin abruptly near the abdominal side unpreceded by tubercles. Other specimens, especially the original of his figure, Plate VII. Fig. 6, also from Pforen, show that *Hartmanni* and this species have intermediate varieties.

Several forms are found in the Semur collection under the name of *Hettangensis*, Rey., one of which has smooth young, with fine pilations and an adult whorl having close resemblances to this species and also to *Arn. miserabile*, var. *acutidorsale*.

Third Subseries.

Arnioceras kridioides, Hyatt.

Plate II. Fig. 28. Summ. Pl. XII. Fig. 8.

Ophioceras kridioides, Hyatt, Bull. Mus. Comp. Zool., I., No. 5, p. 75.
Amm. kridion, Quenst., Der Jura, pl. vii. fig. 8. Amm. Schwab. Jura, pl. xi. fig. 5, 6 (not fig. 7).
Amm. Bucklandi carinaries, Quenst., Amm. Schwab. Jura, pl. xi. fig. 3.

Localities. Basle, Semur.

This species approximates in aspect to *Cal. raricostatum*, and was on this account at first erroneously referred to that species. The shell is, however, smooth, as in Arnioceras, on the first three whorls, the pilæ being acquired only on the last quarter of the third or first quarter of the fourth volution. They are only about twenty-five in number on the fourth whorl, and gradually decrease in number on subsequent whorls.

The sutures on the second quarter of the sixth whorl show close affinity for *Arn. semicostatum.* This resemblance ceases in a great measure after the beginning of the fifth volution, when the pilæ assume an aspect similar to those of *Cal. raricostatum.* The resemblance is due to the fact that the pilæ remain undeveloped; if they become more prominent, the shell would be more like *semicostatum.* The keel is also not so well developed as in *semicostatum,* and on this account resembles that of a species of Caloceras. The abdominal lobe at this time is slightly longer than the superior laterals, and these are about one half longer than the inferior laterals. The superior lateral saddles are broad, shallow, and deeply divided by only one marginal lobe. The inferior lateral saddles are tongue-shaped, and slightly deeper than the superior laterals. The lobes and saddles are serrated, and the first auxiliary saddle is very small. There are four specimens in the Museum of Stuttgardt which entirely confirm these observations. They are from Behla, and labelled *Amm. kridion,* Quenst. One is more compressed than the other, and closely approximates to *Arn. semicostatum;* in fact, the young shell is quite as smooth as the gibbous variety of that species, and with the exception of the abdomen, keel, and sutures it is identical with it.

The original of Quenstedt's description from Bebenhausen, the type in Suabia, bears out these remarks in every particular; but in his "Ammoniten des Schwäbischen Jura," Figure 7 has channels and a form not identical with others of this species, all of which are similar to the young of *Cor. kridion* during the adult stage.

Arnioceras? Nevadanum,[1] Hyatt.

Amm. Nevadanus, Gabb, Am. Journ. Conch. Philad., V., 1869, p. 6, pl. iii. fig. 1; IV. pl. xvi.

This interesting form was found near Volcano, in Nevada, and probably belongs to the Lower Lias. The young as figured by Gabb is smooth, and the late stage at which the pilæ were introduced, their linear, straight aspect, and crowded arrangement throughout the young whorls, are unquestionably arnioceran. The sutures also, as figured in Volume IV. Plate XVI., have the characteristic outlines of this genus. Nevertheless, the older whorls have the form and proportions of *Ver. Conybeari,* and are also tuberculated, the abdomen being keeled and channelled. The abdomen has, however, much broader channels than any specimens of Vermiceras yet observed. The character of this part is evidently not unlike that of the specimen in the Stuttgardt Museum described in note to page 70 as occurring in the Angulatus bed and yet having channels

[1] The species associated with this by Gabb, under the name of *Amm. Colfaxi* (Am. Journ. Conch., 1869, V. p. 7, pl. iv. fig. 2, IV. pl. xvi.), and reported as found in the Lias on the western slope of the Sierra Nevada near Colfax, was in poor condition, and was consequently so badly represented in the figure as to be indeterminable.

with entire lateral ridges, which occupy nearly the whole breadth of the abdomen. Gabb's figures are a little at variance with his description on this point, and may have been taken from different whorls; one in Volume V. has narrow channels, while the section in Volume IV. Plate XVI. has broad channels. The section, description, and sutures show lateral distortion. If it were not for this and the possible errors of the figures, we should be positive that it was a tuberculated arnioceran form.

Arnioceras Humboldti, Hyatt.

Locality. — Humboldt County, Nevada.

This species is closely allied to *Arn. tardecrescens*, from which, however, it differs in the sutures and proportions of the whorls, those of the latter being broader in proportion to their breadth. This species also probably reached a larger average size and had a thicker shell. It differs from *Arn. Bodleyi* in the same characters, and the sides are less divergent outwardly than in that species, and not so flat. The great thickness of the shell reminds one of *Arn. Hartmanni*, but the whorls increase faster by growth in the abdomino-dorsal diameter, and it has a smaller number of whorls at the same age. The figures are close to the natural size, and give accurately the proportions of the fossil. The actual diameter of the fragment represented in Figure 31 is 48.5 mm., and the keel is a trifle more prominent than it appears in the drawing. The pilæ were much abraded and are truthfully portrayed in this figure, but when entire they possessed the usual sharpness of the genus Arnioceras.

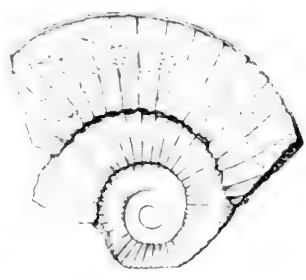

Fig. 31

Fig. 32

Fig. 32

The transverse section represented in Figure 32 is in part a restoration, and has been slightly reduced in the cut. The extreme breadth of the side and keel is 19.5 mm. The sutures are given with sufficient accuracy in Fig. 33, but the median lobe which divides the superior lateral saddles has been overlooked, and the abdominal lobe has not been indicated. The latter has the usual arnioceran proportions, being somewhat shorter than the superior laterals. The marginal lobe dividing the superior lateral saddles is unusually broad, and in fact the broad massive aspect of the two lateral saddles is a marked characteristic of these sutures.

In the collection of the Mining Bureau at San Francisco is a specimen of Arnioceras, which, judging from a hasty sketch, resembles this species. It was labelled as coming from Inyo County, California, but we were not able to verify the locality. It is, however, quite certain that species of the Lower Lias have been found in the West in the regions occupied by the exposures of the Jura.

Geyer, in his "Ceph. Hierlatz b. Hallstadt," gives figures and descriptions of the following species of this genus. *Arn.* (*Psil.*) *abnorme* and *Suessi*;[1] *Arn.* (*Ariet.*) *semilevis*, Plate III. Fig. 7, a channelled form like *Arn. ceras*; *Arn.* (*Ariet.*) *ambiguus*, and (*Ariet.*) of Quenstedt, Plate III. Fig. 14; the last is probably the same as *Arn. cuneiforme*, and probably the same as his undetermined species of Amphiceras figured on Plate II. Fig. 30. Hauer, in his "Ceph. Lias Nordöstl. Alpen," gives figures and descriptions of *Arn.* (*Amm.*) *difformis*, which may be the same as *semilevis*, Geyer, though channels and keel are both figured as preceding the pilæ in his Plate VII. Fig. 12. His young specimen, Plate VII. Fig. 9, named *Amm. multicostatus*, is probably also a species of Arnioceras; but the larger specimen, Plate VII. Fig. 7, 8, is a coroniceran form. All of these were from Hierlatz.

CORONICERAS.

The young are stouter than in Caloceras or Arnioceras, and smooth for a shorter period, and the stage following this usually has tuberculated pilæ and a whorl with more or less divergent sides. The abdomen in the adult is keeled and channelled, the sides parallel or slightly convergent, the pilæ being prominent and heavily tuberculated. In the old, the tubercles are lost, the channels obsolete, the keel very prominent, the abdomen very narrow, and the outline of the whorl in section trigonal.

The abdominal lobe in adults is deep and narrow, the superior lateral saddles are generally shallower than the inferior laterals, and the first auxiliary lobes and saddles are of comparatively small size. The great length of the abdominal lobe, the shallowness of the superior lateral saddles, the small size of the first auxiliary saddles, and the shortness and comparatively small size of their corresponding superior and inferior lateral lobes, give great prominence to the inferior lateral saddles. The outlines of the sutures are also much complicated, the marginal lobes being broader and longer than is usual in this family. In old age the abdominal lobe becomes shorter, often only slightly exceeding the superior laterals in length. Degeneration also takes place in other lobes and saddles, especially on the margins. The oldest sutures are, therefore, simpler than those of the adult.

The first subseries has heavily tuberculated pilæ, and the whorl is very gibbous near the umbilical shoulder.

The second subseries has the tubercular and inner portions of the pilæ more nearly equal in prominence, the whorls are not usually so stout or numerous, and the abdomen has a flatter outline.

The third subseries is apt to have young with broader abdomens than in the first two, and the pilæ are frequently divided in the nealogic stages. Massive whorls and pilæ are characteristic of the first senile stage in the larger shells.

[1] *Amm. Suessi*, Hauer, Unsym. Amm. Hierlatz-Schichter, Sitz. Akad. Wien, 1854, XIII. pl. i. fig. 1–6. and the figures of Geyer, show that this species has not, as supposed by Rolle, Sitz. Akad. Wien, 1857, XXVI., and by Stur, Geol. d. Steirmark, any close affinity with *Hagenowi* from the Bone bed of the Waldhäuser Höhe near Tübingen.

First Subseries.

Coroniceras kridion, Hyatt.

Plate III. Fig. 2, 3. Summ. Pl. XII. Fig. 9.

Amm. kridion, Ziet., Verst. Würt., pl. iii. fig. 2.
Amm. kridion, Hauer, Ceph. Nordostl. Alpen, pl. iii. fig. 1-6.

Localities. — Semur, Stuttgardt, Balingen.

The pilæ were already visible on the first part of the third whorl, but when they began could not be ascertained. On the first quarter of the third whorl the flattened abdomen of the younger volutions became more elevated, and the keel was introduced. The keel continued to increase in prominence thereafter, but the channels, which are faintly visible on the fourth whorl, only broaden out, and do not sensibly increase in depth, after they reach the last part of the fifth volution.

The form acquired on the third or fourth whorl is carried throughout life, the sides curving evenly from the dorsum to the abdomen; the abdomen is elevated, the pilæ are either overhanging or slightly tuberculated on the latter part of the third whorl, but very soon the curvature becomes equal and the tuberculations disappear, though the geniculæ sometimes remain very prominent even on casts. There are three specimens of this species in the Museum of Stuttgardt, the exact position of which, with relation to *Bucklandi*, is considered uncertain by Professor Fraas. The young in all these specimens are smooth, and precisely similar to the young of the specimens from the Angulatus bed, from which the adults, however, differ slightly. The tubercular processes on the casts, as in all other specimens of this species, are blunt, and covered smoothly by the shell, not protruding into spines. The specimens in the Bucklandi bed have longer, stouter whorls, with different sutures, but these differences are not sufficient to separate them; they are probably closely allied direct descendants.

Oppel claimed to have had the original of Zieten's description, and, according to him, it is a species like *Conybeari*, which is found with and under *Bucklandi*. The above is the only species answering to this description and agreeing with Zieten's figure in having tuberculated pilæ, slightly divergent sides, a raised abdomen, and prominent keel. There are no channels in Zieten's figure, but his specimen was young, and even in the full-grown *kridion* they are very shallow. Two adults and three young specimens from Möhringen, labelled *Boblayi* (No. 3977), are in the Museum of Stuttgardt, from the Angulatus zone. The casts appear to be identical with *Amm. Caprotinus* D'Orb., but the apparent tubercles were merely covered smoothly by the shell, and not continued out into points. Besides these specimens there is a fossil from Filder (No. 3978), which is precisely like Zieten's figure,[1] and confirms these identifications.

Though there is close approximation in the characteristics of the young in most forms, there are sometimes differences. The young of the normal forms

[1] Zieten's original I was not able to see, it could not be found in the Museum at Munich during my visit.

often have broad and gibbous whorls, like the young of *sinemuriense,* and the pilæ and sutures are also sometimes quite similar to those of that species.

A specimen of this species occurs in the Scipionis bed of the collection at Semur, in company with the *Amm. Hehli* of Reynés, from some representatives of which it cannot be distinguished.

Coroniceras coronaries, Hyatt.

Amm. coronaries, Quenst., Der Jura, p. 68, pl. vii. fig. 5; Amm. Schwab. Jura, pl. xvi.

Quenstedt's original is a very large cast, 470 mm. in diameter, and has about thirteen whorls, with the young showing in the centre. It differs from variety A of *rotiforme* in persistently maintaining throughout life the breadth and elevation of the abdomen, together with the keel, channels, and ridges.

The adult, though much larger, is similar to *kridion* in its heavy overhanging pilæ, divergent sides, and broad, elevated abdomen. The young with its large pilæ and prominent geniculæ is similar to the young of some varieties of *rotiforme.* There is a broad space on either side of the abdomen, which even in Quenstedt's large specimen is not covered by the succeeding whorl, a character also present, though not invariable, in the adults of *rotiforme* and *kridion.* Quenstedt's figure shows the undiminished dorso-abdominal diameter of the last whorl, and the effects of senile degeneration in the pilæ; these last, having lost the geniculæ, thus become reduced to massive bent folds. The form has been changed somewhat, but nevertheless the keel, channels, and even the lateral ridges, are persistent.

The sutures, though evidently senile, still have an abdominal lobe longer than the superior laterals,[1] but the marginal lobes and saddles have degenerated more markedly.

Coroniceras rotiforme, Hyatt.

Plate III. Fig. 4-17 b.

Amm. rotiforme, Sow., Min. Conch., V. p. 76, pl. ccccliii.
Amm. rotiforme, Ziet., Verst. Würt., p. 35, pl. xxvi. fig. 1.
Amm. rotiforme, D'Orb., Terr. Jurass. Céph., p. 293, pl. lxxxix. fig. 1-3.
Amm. rotiforme, Hauer, Ceph. Nordöstl. Alpen, pl. i. fig. 1, 2; pl. ii. fig. 7-9.
Amm. rotiforme, Quenst., Amm. Schwab. Jura, pl. xv.
Ariet. rotiforme, Wright, Lias Amm., p. 278, pl. v. fig. 1-4; pl. vii. fig. 1 (not pl. ix. fig. 1-3).

Localities. — Semur, Stuttgardt, Vaihingen, Balingen.

Var. A.

Plate III. Fig. 4, 10, 14-16.

This has smooth young during one or more, but rarely throughout two volutions. Large, coarse approximated tubercles then appeared, and rapidly developed into folds, which became more widely separated on the first quarter of the third whorl, and acquired the aspect of the adult pilæ of *Cor. kridion.* The keel appeared on the third quarter of the third whorl, but remained a mere ridge, until the advent of the channels about one volution later, when it became

[1] In the adult stage the abdominal lobe was undoubtedly much longer in proportion.

more prominent. Upon either the latter part of the fourth, or first quarter of the fifth volution, the whorl attained its adult characteristics.

During the first volution the increase laterally had been very great, forming a deep umbilicus; subsequently the tubercles and folds were added to the width of the abdomen of the earlier whorls, giving a general resemblance to *Cor. latum.* The young whorls of specimens in which the tubercles appeared later on the third whorl were usually rounder, and exhibited, when seen from the side, only a very remote resemblance to *Cor. latum.* These passed suddenly, so fast did the tubercles grow to be folds and then true pilæ, into the stage in which they resembled *Cor. kridion.* After this stage, the preponderance of the abdominal region is not so marked, though it may be maintained throughout the fourth volution. Quenstedt's young specimen, with a living chamber one volution in length,[1] exhibited a broad abdomen on the fourth whorl.

The geniculæ are at first not tuberculated, but sharp and angular, as in some varieties of *Cor. kridion.* The abdomen, however, does not usually become sufficiently prominent in the earlier stages of growth to bear comparison with that region in *kridion.* After this period the umbilical shoulders are developed more proportionally, and finally on the fifth volution the whorl becomes broader dorsally than near the abdomen. The dorsal curves of the pilæ become more prominent, and sink or are contracted to form the tubercular geniculæ. These subsequently bend forward in some specimens, ascending the abdomen. This last character may occur earlier, on the third whorl, or, on the other hand, be omitted altogether, even in adults.

This description of the stages of development may be curiously altered by a malformation of the abdomen. The pilæ, Plate III. Fig. 7, 11,[2] are continued across, cutting up the abdomen into a series of waves entirely obliterating the keel and channels.

This variety has young which differ considerably from one another in the relative breadth of the abdomen, some being excessively broad and flat during the young whorls, and others, especially the microceran forms, have much narrower whorls. The number of the pilæ also differs, these parts being more widely separated in the broad, flat young than in others.

In the majority of adult specimens, the superior lateral saddles are deeply divided by two marginal lobes, and spread out laterally beyond, or on the geniculæ. One specimen, however, from Semur, though not differing in other respects, has superior lateral saddles so long and narrow that the superior lateral lobes occupy the genicular line. The abdominal lobe extends beyond the superior laterals by about one third, and the superior lateral saddles are of about the same depth as the inferior laterals, though much broader.

Var. B.

This variety is founded on two specimens, which maintained a broad abdomen and the immature, thick, unshapely pilæ of the young until a late

[1] Figured in Amm. Schwab. Jura, pl. xv. fig. 9.

[2] Fig. 7 represents the abdomen erroneously, the forward projections of the pilæ where they meet on the abdomen being flattened out in the specimen.

stage of growth. The lobes and saddles also remained immature, and the pilæ were in some instances divided. They resemble *Cor. latum* in the rounded outline of the superior and inferior lateral saddles, but are unquestionably rotiformian in the equal height of the saddles, and in the prolonged and slender marginal lobes.

VAR. C.

Plate III. Fig. 17.

This is not the *Amm. caprotinus* of D'Orbigny, as I supposed in my first review of this species, but a local variety of *Cor. rotiforme* found at Semur. The tubercles are very distinct and prominent, and the pilæ are thicker and more decidedly depressed as they approach the tubercles than in variety B. Wright's figure of Sowerby's original,[1] and his other figures, show affinity with this variety; but it is not practicable to identify them with other varieties as they are here described.

During the first senile stage, on the second quarter of the tenth whorl, the keel and channels may be even more elevated than in the adult, but smooth zones appear on either side of the channel ridges. The geniculæ, whose tuberculated bends are also lower on the sides than in the adult, do not terminate, as in that stage, close to the channel ridges, but on the outer edges of the smooth intervening zones.

The abdominal lobe at this period is only one fourth longer than the superior laterals, and the inferior laterals are about one tenth shorter than these last. There is evidently a tendency, as in other cases of senility, to return to the immature proportions of the young.

In the next senile stage the pilæ began to lose their prominence and their tubercles, and on the last quarter of the tenth whorl the latter had entirely disappeared. The abdomen also became more prominent on account of these changes, and marked alteration in the outline of the whorl occurred still later in the more advanced stages of degeneration. The flattening and convergence of the sides, however, really began with the advent of the smooth zones, and this was the beginning of the metamorphoses which in later stages materially altered the outline of the whorl. The keel became more prominent on account of the greater shallowness of the channels, though these still retained their lateral ridges. A slight increase in the breadth of the sides at this stage would have produced a whorl in all respects like *Cor. orbiculatum*.

Several collections were closely examined for this purpose, but they did not contain many young specimens. We found it difficult to trace the likeness of the young *rotiforme* to the adult of *kridion*, on account of the much greater gibbosity of the whorls in the ordinary forms of that species.

A sufficient number of specimens of *rotiforme*, however, always show all the intermediate stages between the extremely thick *latum*-like young (Plate III. Fig. 15) of one variety and a variety in which the young are difficult to separate from the adult of *kridion* by their forms and external characteristics. The

[1] Lias Amm., pl. v. fig. 1-3.

sutures of the nearly adult *kridion* are, however, often quite distinct from those of a *rotiforme* of the same size, but whether this difference is invariable or not, I am unable to say.

The largest specimen in the Museum of Stuttgardt is 470 mm. in diameter. On the latter part of the whorl the pilæ are nearly obsolescent, with no geniculæ, thus reverting exactly to the condition of those of *Cal. Johnstoni*, var. *torus*. The sides were rounded, channels very shallow, but the keel still prominent. There is also a fragment of a very old specimen figured by Quenstedt.[1]

His Fig. 5, together with his Fig. 9, quoted above, show that the living chambers of the nealogic stages probably exceeded one volution in length, but we have not been able to ascertain what they were in adults.

Coroniceras lyra, Hyatt.

Plate IV. Fig. 1 17. Plate V. Fig. 1-3 a Summ. Pl. XII. Fig. 13

Coroniceras lyra, Hyatt, Bull. Mus. Comp. Zool., I., No. 5, p. 78.
Amm. multicostatus brevidorsalis, Quenst., Amm. Schwäb. Jura, pl. vi. fig. 1-6; pl. vii fig. 1-6.
Amm. multicostatus, Hauer, Ceph. Lias d. Nordostl. Alpen, pl. vii. fig. 7, 8 (not fig. 9, 10).
Arietites bisulcatus, Wright, Lias Amm., pl. iii., iv.

Localities. — Semur, Aalen, Filder, Gmund, Boll, Tubingen.

Var. A.

Plate IV. Fig. 1, 8, 12-14

This is similar to *Cor. rotiforme*. The bases of the superior lateral saddles are very narrow on the sixth or seventh whorl. The bases of the superior lateral lobes are proportionally broad, and on the same line with the geniculæ, instead of on the side, as in other varieties. The superior lateral saddles are pointed, but on the eighth whorl they become broader, and are subdivided by three marginal lobes. The abdominal lobe is longer than the superior laterals by about one third, and the inferior lateral saddles exceed in depth the superior laterals by about one fourth.

Var. B.

Plate IV. Fig 2 5.

This has young with the same rapid lateral increase and deep pit-like umbilicus during the first whorl which was previously observed in *Cor. rotiforme*. The lateral increase is, however, less marked on the second whorl, and the abdomen begins to become more prominent and rounder. The pilæ began as folds, probably on the second or third quarter of this volution, and the angular ridge, which is to become the keel, appeared on the last quarter of this or the first quarter of the third volution. The pilæ never overhang, nor does the abdomen acquire greater breadth than the dorsum, as in the young of *Cor. kridion* and *Cor. rotiforme*. This stage is skipped entirely, and it is replaced by a stage having the same proportions and pilæ as in the more advanced stages of *Cor. rotiforme*. The abdomen on the third whorl becomes flatter, the keel plainer, and

[1] Amm. Schwab. Jura, pl. xv. fig. 2

the channels are indicated by faint depressions. Upon the third quarter of this whorl continuous channel ridges appeared, flanked by tuberculated geniculæ bending forwards upon the abdomen. The flatness of the abdomen is due to the rise of the geniculæ upon the sides, which occurred previous to the appearance of the tubercles. The tuberculated geniculæ began to fall below the level of the abdomen upon the last quarter of the fourth whorl, and the abdomen became in consequence more elevated. The whorl acquired rapidly the flattened sides and peculiar aspect of the adult, and the transformation was completed on the third quarter of the fifth volution. Thus in the earlier stages there is a smooth elevated abdomen, which becomes flattened in the next stage, and then elevated again, but in the last stage it is furnished with keel, channels, and geniculæ.

The sutures on the last part of the third whorl have an abdominal lobe one third longer than the superior laterals, but the superior and inferior lateral saddles are of equal depth. These proportions are still unchanged on the first half of the fifth whorl in some specimens, whereas in others, on the last half of the same whorl, the difference between the lobes and saddles is about one fifth, and on the second quarter of the sixth volution the proportion becomes one third. Before the close of the fourth volution the lobes become more complicated and broader at the top, and the marginal saddles more numerous and leaf-like, as in the adult of their own species; the inferior lateral saddles are also deeply cut by two marginal lobes into three marginal saddles. The similar tripartite division of the superior lateral saddles and superior lateral lobes becomes at the same time very marked. The saddles also broaden out at their bases, and upon the sixth volution spread over the geniculæ. This broadening of the bases of the saddles, and the position occupied by the bases of the superior lateral lobes in consequence of this, are characteristics of some value in the species. They also show that the external characteristics of the shell develop contemporaneously with the sutures, and arrive together at their adult development upon the latter part of the fifth whorl. The abdominal lobe extends beyond the superior laterals by about one third of its own length, and the inferior lateral saddles are deeper than the superior laterals in the same proportion. The abdominal lobe of the last suture of the third volution is one third longer than the superior lateral lobes, but the two larger saddles are of equal depth. Quenstedt describes and figures all specimens from Suabia as having an abdominal lobe shorter than the superior laterals, and the superior lateral lobes pointed. This character was found in the nealogic and adult stages. The figures of the very aged forms which he calls *Amm. brevidorsalis*, Plate VII., would have had comparatively short abdominal lobes, to whatever species they might have belonged.[1] Quenstedt complains of Wright for not paying attention to his distinctions, but we think Wright's figures of *multicostatus* show that he was right. The English specimens had long abdominal lobes, and, like French and German shells described above, are undoubtedly identical with those figured by Quenstedt in every other

[1] For example, the huge *Cor. Bucklandi*, Amm. Schwäb. Jura, pl. ix. fig. 1, and *coronaries*, pl. xvi., of Quenstedt. Compare also the gradual decline in length of the abdominal lobe of an aged *Cor. trigonatum*, Plate VII. of this monograph.

respect. A subsequent re-examination and remeasurement of all specimens in the Museum of Comparative Zoölogy has shown that the average length of the abdominal lobe for nealogic and adult shells is considerably over one third longer than the superior laterals. The sutures also vary from the comparatively simple margins, with solid looking and very slightly indented saddles, to the extreme forms figured in our plates and by Quenstedt.

Var. C.

Plate IV. Fig. 9-11, 15, 16.

In this variety the channels are slower in reaching their full development, and the pilæ are not so prominent, but are more numerous and conform more closely to the shape of the whorl. The whorl is altogether flatter, and increases somewhat faster by growth than in variety B. The channels are hardly perceptible on the fourth volution, and in consequence of the smaller size and want of prominence in the geniculæ, the abdomen has at the same time more prominence than in variety B. These characteristics are more or less variable. Thus individual specimens may resemble variety A in some characters, or variety B in others. In a specimen of variety C, Plate IV. Fig. 15, 16, senile characters begin to be apparent upon the second quarter of the ninth whorl. The pilæ are still slightly tuberculated, the abdomen though much narrowed is still comparatively broad. In a specimen of variety B, at same time the abdomen had become narrow, the pilæ had lost not only the tubercles, but also the geniculæ, being in their second stage of obsolescence. A specimen in the Museum of Stuttgardt, from Göppingen, measuring 440 mm. in diameter, showed more pronounced senility. The sides were exceedingly convergent, the pilæ obsolescing, the abdomen elevated, though the channels and keel were not much changed. In another of the same diameter the channels were obsolete, the keel a low broad ridge, the pilæ reduced to broad lateral folds, and the sides very convergent. In the large specimens figured by Quenstedt,[1] if the figures are accurate, the keel, channels, and lateral ridges are persistent.

In the Museum at Semur is a fine suite of specimens named *Vercingetorix*, Reynès. These specimens did not show senile decline as early as is usual in this species. One at the diameter of 525 mm. still retained the pilæ and the channels, though the abdomen had become much elevated. This specimen was distorted by lateral pressure, so that the transverse dorsal diameter was shorter than the abdominal.

Wright's figure[2] seems to be identical with this species, and the more compressed specimen figured on Plate IV. seems to be intermediate between my *Cor. lyra* and *Cor. Gmuendense*. I do not remember having seen any such forms myself, nor are any English specimens mentioned in my notes.

[1] Amm. Schwab. Jura, pl. vii.

[2] Lias Amm., pl. iii.

Coroniceras trigonatum, Hyatt.

Plate VI. Fig. 3. Plate VII. Fig. 1. Summ. Pl. XII. Fig. 15.

Aster. trigonatum, Hyatt, Bull. Mus. Comp. Zoöl., I., No. 5, p. 79.
Amm. Brooki, Ziet., Verst. Würt., p. 26, pl. xxvii. fig. 2.
Amm. Brooki (Riesenbrooki), Quenst., Der Jura, p. 68.
Amm. Crossi, Quenst., Amm. Schwäb. Jura, pl. xiv. fig. 6.
Amm. nudaries, Quenst., Ibid., fig. 5 ?

Locality. — Aalen.

Great size is a characteristic of this species. One specimen was 380 mm. in diameter, and another measured 503 mm. Quenstedt describes one from Endingen 700 mm. in diameter.

The young were seen only from the side, but the following characters could be made out, even from this point of view. The form of the whorl in transverse section at an early stage is evidently quadragonal, since during the first four or five whorls the sides are flat and the pilæ tuberculated, as in *Cor. lyra.* After this the dorsum increases more rapidly, and the whorl gradually assumes the trigonal form. The tubercles and geniculæ become atrophied, the pilæ are merely lateral folds, and the channels very shallow by the time the shell reaches the second quarter of the sixth or seventh volution. On the eighth volution the channels are represented only by smooth inflected zones on either side of the keel.

The sutures on the latter part of the sixth or seventh whorl have abdominal lobes, which are one half longer than the superior laterals, the inferior lateral saddles one half deeper than the superior laterals. The lobes and saddles are all exceedingly broad, and the outlines very complicated. After this period the sutures degenerate, the abdominal lobe decreases in length, and the lobes and saddles, though they retain their complicated marginal inflections, become proportionally broader.

A fine suite of specimens in the Museum of Stuttgardt, from the Geometricus bed, show that the species is very similar to *Cor. lyra* (*multicostatus* of German authors). The whorl, however, has a broader dorsum, and is larger, and the volutions are less numerous. There are also fewer and stouter pilæ at the same age than in *Cor. lyra.* There are two varieties included under this name. One is a smaller form, with premature development of senile whorls, etc., and has broader whorls; the other is the normal form, having slower development of the adult and senile characters, and this alone has been figured.

The more involute shells of this species are the *Amm. Riesenbrooki* of Quenstedt, and the less involute are the normal *Amm. Brooki* of most German authors.

Wright[1] describes the Stuttgardt and Tübingen specimens, but considers them identical with *Cor. Gmuendense* and his *Arietites Crossi*, — a mistake arising from not having observed the differences in the umbilicus due to the number and shape of the whorls, which are less numerous and stouter than in *Gmuendense.* Quenstedt appears to have been led into a similar error, possibly through

[1] Lias Amm., p. 284.

Wright's visit to his collection. Quenstedt's huge specimen, 700 mm. in diameter, noted above, is described[1] as having the pilæ obsolescent near the termination of the last volution, and the keel as showing but little above the almost obsolete channels. This, therefore, is an extreme example of senile degeneration in the clinologic stage, but it has not yet reached the nostologic stage.

Coroniceras Gmuendense, Hyatt.

Plate V. Fig. 4-9. Plate VI. Fig. 1, 2. Summ. Pl. XII. Fig. 14.

Amm. Gmuendense, Oppel, Der Jurafor., Wurt. Jahreshf., XII. p. 200.
Amm. Brooki, Ziet., Verst. Wurt., pl. xxvii. fig. 2.
Aster. tenue, Hyatt, Bull. Mus. Comp. Zool., I. No. 5, p. 79.
Ariet. Crossi, Wright, Lias Amm., p. 283, pl. x. fig. 1, 2.

Localities. — Semur, Gmund, Goppingen, Aalen, Aargau.

The adults of this species are readily distinguishable from *Cor. lyra* by the smaller size of the whorls, the characteristics of the sutures, the extreme narrowness of the abdomen as compared with the dorsum, and the broad, shallow channels. The keel is more prominent also than in *Cor. lyra*, and the pilæ end very abruptly with geniculæ or pseudo tubercles. This peculiarity is observable on the latter part of the sixth whorl, and the bending forward of the geniculæ, as they rise on the narrow abdomen, is hardly observable on the cast until after the completion of the seventh whorl. On the eighth volution the geniculæ become less prominent on the cast, and the depressed geniculæ and pilæ form a single arch slightly interrupted by the tubercular aspect of the former. These characteristics are not altered when the shell is present, but have about the same expression as upon the cast. The geniculæ on the seventh whorl, in one specimen examined, are prominent, and their forward bend plainly observable, though without tubercles.

The abdominal lobe is broad and deep (Plate V. Fig. 5). The superior lateral saddles and lobes are nearly obsolete, the inferior lateral lobes and the first auxiliary saddles are but slightly developed. On this account the inferior lateral saddles, which are of about the usual size, acquire remarkable prominence. We have already noticed, in variety C of *Cor. rotiforme*, a tendency towards the suppression of the superior lateral saddles, and here it is actually carried out. The marginal lobes and saddles of the superior laterals, however, remain on one specimen from Aargau, but on one from Semur only the inner of the three saddles is of noticeable size. These characteristics are present in the adults of this species, and consequently are not due to old age.

On the latter part of the eighth whorl the pilæ lose their tubercles, (Plate V. Fig. 5.) and the geniculæ become almost obsolete, being reduced to curved continuations of the depressed arched pilæ, which are most prominent at the umbilical shoulders. The channels continue to be very well defined, though much shallower, (Plate V. Figs. 8, 9.) and channel ridges are preserved until the first quarter of the tenth whorl. On the second quarter of this whorl the pilæ are

[1] Amm. Schwab. Jura, p. 115.

straight, prominent dorsally, but obsolete on the edge of the abdomen. The channel ridges have also disappeared, and the channels are only indicated on either side of the keel. The keel, however, is persistent.

The abdominal lobe on the latter part of the ninth volution is somewhat more than one half longer than the superior laterals, and the inferior laterals one half longer than the superior lateral lobes. This is a senile tendency to return to larval proportions, since the proportional adult difference in length of the abdominal lobe is at least three fifths.

A specimen in the Geometricus bed, from Nurtingen, labelled *nodosaries*, in the Museum of Stuttgardt, exhibits the characteristics of this species. Quenstedt's original of *nodosaries* shows that the identification of such specimens with his *nodosaries* is not correct. It is very often regarded as the young of *Cor. trigonatum*, but is far too much compressed, and whorls too small, though otherwise quite similar.

Wright's figure of an old specimen of this species under the name of *Ariet. Crossi* leaves little room for doubt that it occurs in England with the same peculiar form as in Germany. Wright does not mention that there are any varieties.

Second Subseries.

Coroniceras Sauzeanum, Hyatt.

Plate VI. Fig. 4-14. Plate VIII. Fig. 1-3. Summ. Pl. XII. Fig. 10.

Amm. Sauzeanus, D'Orb., Terr. Jurass. Ceph., p. 304, pl. xcv. fig. 4, 5.
Amm. spinaries, Quenst., Der Jura, pl. vii. fig. 4; Amm. Schwäb. Jura, pl. ii. fig. 8-14 (fig. 15-17?).

Localities. — Whitby, Leicestershire, Semur, Salins, Gmünd.

D'Orbigny's original specimen, (Plate VI. Fig. 12, 13,) with which this identification was made, is smooth probably throughout the first four whorls. The centre was obscured, and the exact number of whorls was estimated. The abdomen is flat, with a very obscure siphonal ridge on the fifth whorl. The pilæ are terminated by a tubercle, which is elevated so that it stands on a level with or above the abdominal continuation of the pilæ. These nearly meet, and in some specimens actually do cross the siphonal ridge, giving the shell a microceran aspect.

The further development of these peculiarities would lead to a form in which the keel would become more distinct, but would be guarded by very shallow channels, and in which also the pilæ, gracefully curving as in this specimen, would terminate in a tubercle standing out prominently on the edge of a flattened abdomen. Such a form, of which the young is shown in Fig. 10, 11, occurs in the same locality, and it is evidently an older individual of this species.

The sutures of this specimen are visible on the third quarter of the sixth whorl. The abdominal lobe is shallower and broader than in variety *Gaudryi*, and the inferior lateral saddles also broader proportionately. The sutures are more like those of the young of variety A, *Cor. bisulcatum*. The edges of the lobes and saddles are, however, serrated, not deeply divided by the marginal lobes, as in the last named species. The abdominal lobe is one half longer than the superior laterals, and the inferior lateral saddles exceed the superior laterals in the same proportion.

A fine suite of these specimens exists in the Museum of Stuttgardt, showing the variations described above. Some are very decidedly planicostan in aspect, but not more so than other specimens of *Coroniceras*, in which the keel becomes entirely suppressed, and the abdomen is crossed by the pilæ. Young specimens from Behla pass through stages which repeat exactly the characteristics of *Cor. kridion* when considerably older and perhaps full grown. One of these is labelled *capraries*, Fraas, planicostan variety; another lot of three specimens is named *Danubicus*, on account of their thick whorls and pilæ. A large specimen from Gmünd, on the last part of the last whorl, has all the characteristics of the stout English specimens of var. *Gaudryi*, Reynés. There is also a fragment of a much older shell, the dorso-abdominal diameter of the whorl being 60 mm., which has similar characters. The channels are, however, very broad and shallow, and the keel also low and broad.

Since the above and the description of var. *Gaudryi* were written, I have found in the collection of the Museum of Comparative Zoölogy English specimens of this species exhibiting the young. In these, for one or two volutions, the whorls are smooth, then obscure tubercles or swellings begin to appear upon the sides, which elongate into folds on the third whorl, and become distinct pilæ on the latter part of this whorl or the first quarter of the fourth. The external resemblance to the young of *Cal. Johnstoni* is complete in the pilæ, the compressed or embryonic form of the whorl, and the absence of a keel; the sutures, however, do not appear to be similar. Even on the early portions of the third whorl the abdominal lobe is quite long, the superior and inferior lateral lobes exceedingly short, and the corresponding saddles of equal depth. From this time the complication consists in the crenulation, or rather serration, of the margins, and the slow increase of depth in the superior lateral saddles; the other saddles and lobes remain about what they were at first with regard to their proportions. The keel is perceptible as a slightly raised siphonal line on the first quarter of the fifth whorl or last of the fourth. In the first of this stage, the abdomen, pilæ, and form of the whorls are similar to those of the adult of *Cor. kridion*. On the fifth volution, however, the abdomen becomes flatter, the genicular band of the pilæ more abrupt, and finally tuberculated, and the hitherto divergent or gibbous sides flatter and slightly convergent.

The young figured by Quenstedt[1] are questionable. They are more completely pilated than is usual in the species, and the form of the whorl is quite different. We doubt the correctness of the identification.

[1] Amm. Schwab. Jura, pl. xi. fig. 15-17

Var. Gaudryi.

Plate VI. Fig. 14. Plate VIII. Figs. 1-3.

Cor. multicostatum, Hyatt, Bull. Mus. Comp. Zoöl., I., No. 5, p. 78.
Amm. Gaudryi, Reynès, Plates.
Ariet. Sauzeanus, Wright, Lias Amm., Pal. Soc., pl. viii. fig. 1–6.

On the sixth volution this shell has slightly convergent sides, a thick, low keel with shallow broad channels. The pilæ are tuberculated, and the geniculæ bending forward break up the channel ridges into a series of waves. They also pass over the umbilical shoulder on the dorsal side, but are not so prominent there. The very rapid increase in size of the whorl renders the umbilicus about half an inch deep at the end of the sixth volution. On third quarter of the fifth whorl the channels are very faint, the geniculæ where they ascend upon the abdomen are less prominent, and tubercles much higher up on the edge of the abdomen. If the pilæ were less prominent and devoid of abdominal extensions, this stage would precisely represent the usual form of var. *Sauzeanum*.

On the fifth and sixth whorls the abdominal lobe is about two fifths longer than the superior laterals, and the inferior lateral saddles exceed the superior laterals in the same proportion.

The German specimens are precisely like the English. One in Quenstedt's collection from Betzenrieth bei Göppingen is identical with the English specimen of the same age. Wright's figures all belong to var. *Gaudryi*, and exhibit a well defined keel and convergent sides at an early age.

Coroniceras bisulcatum, Hyatt.

Plate VII. Fig. 2-10. Summ. Pl. XII. Fig. 11.

Amm. bisulcatus, Brug., Encycl. Méth., I. p. 39, pl. xiii.
Amm. bisulcatus, D'Orb., Terr. Jurass. Ceph., p. 187, pl. xliii.
Cor. bisulcatum, Hyatt, Bull. Mus. Comp. Zoöl., I., No. 5, p. 77.
Ariet. rotiformis, Wright, Lias Amm., p. 278, pl. ix. (not pl. v., vii.).
Amm. multicostatus, Sow., V p. 76, pl. ccccliv.
Amm. multicostatus, Hauer, Ceph. Nordöstl. Alpen, pl. i. fig. 3, 4.
Ariet. subnodosus, Wright, Lias Amm., p. 288, pl. vi. fig. 2, 3.
Amm. resurgens? Dum., Études Pal. Bassin du Rhone, pt. 2, pl. xxiii. fig. 3–6.
Amm. multicostatus, Ziet., Verst. Würt., pl. xxvi. fig. 3.

Localities. — Lyme Regis, Semur, Hechingen, Balingen.

There are four specimens of this species, two from Semur, one from Hechingen, and one from Balingen, which differ in a significant manner. Both of those from Semur have a somewhat closer resemblance to the full grown *Cor. Sauzeanum* than the German specimens; they differ, however, in some respects. On one, the pilæ are visible on the last quarter of the sixth whorl, and show on the cast distinct traces of tubercles, and the geniculæ terminate before they reach the channel ridges, which are continuous and entire. In the other specimen, the pilæ are visible on the first quarter of the seventh whorl, do not show on the cast distinct traces of tubercles, and the geniculæ pass over the channel ridges as in *Sauzeanum*. In both German specimens the channel ridges have a crenulated outline, and the pilæ are similar. As a whole these four specimens differ from *Cor. Sauzeanum*, var. *Gaudryi*, in having a shallower umbilicus and a somewhat greater number of whorls in proportion to the size of the shell. One specimen from Semur is intermediate in characters between the German specimens, and the true *Sauzeanum*, var. *Gaudryi*. The Semur specimens also differ in the depth and groove-like aspect of the channels, and the almost sunken aspect of the keel on the casts. The prominence of the geniculæ reminds one of the fifth whorl of *Sauzeanum*, var. *Gaudryi*.

Both specimens from Semur have similar sutures. The ventral lobe is deep, the superior lateral saddles and lobes very shallow and broad, the inferior lateral saddles very prominent, and the inferior lateral lobes obtuse. The marginal lobes are more evenly distributed than in the German variety. The sutures on the seventh whorl have an abdominal lobe from one half to two fifths longer than the superior lateral lobes, and the inferior lateral saddles exceed the superior laterals in the same proportion. Both in fact approximate to *Cor. Sauzeanum*, var. *Gaudryi*, by their sutures. In the German specimens the lobes and saddles show about the same general proportions, though the inferior lateral saddles are much broader, and the inferior lateral lobes deeper, and acute instead of obtuse. There is a large specimen in Professor Quenstedt's collection from Bodelshausen (No. 10673), which is similar to these, but unfortunately the name of this was not noted.

The keel is quite prominent at the earliest period observed on the first quarter of the fourth whorl, but the channels are hardly discernible. At this period the channel ridges are not developed, and the tuberculated geniculæ are high upon the sides. When the channel ridges are distinguishable on the fifth volution, they are continuous. The keel loses its prominence after the channels deepen upon the latter part of the fifth, and the early part of the sixth whorl. The pilæ in the young are more numerous than in the adult.

The largest specimen from Semur measured 348 mm. in diameter, and had about eight and a half volutions. The pilæ retained all their adult peculiarities and original sharpness, and the quadragonal form of the whorl was also unchanged. The channels were, however, broader and shallower than in the adult. The approximation of this form in aspect and characteristics to its morphological equivalent, *Cor. lyra*, is so close, that only the most careful study can show them to have been distinct. The young of these two species are quite different at all stages, and can generally be readily separated.

This species has always the broad abdomen of *Sauzeanum* and its spinous tubercles, and the young are not so stout as in *Cor. lyra*. In the succeeding stages the young of *lyra* rapidly changes from divergent to parallel sided, and then to a convergent sided whorl, whereas in this species the development is much slower. The later stages (Plate VII. Fig. 8) are similar in form to *lyra* when quite small (Plate IV. Fig. 9). The geniculæ usually cut up the channel ridges into waves, and, though not invariable in the species, this occurs so generally as to be a useful distinction, and is evidently of genetic importance in the series. The resemblances of the young to the adult of *kridion* and the young of *rotiforme* may be observed by comparing the figures on Plates VII. and III., but from these it may be distinguished by the flatness of the abdomen, the elevated geniculæ, and the much earlier development of the channels.

At Semur there are several varieties of this species. One was 620 mm. in diameter, the last whorl about 170 mm. in diameter from abdomen to dorsum. The abdomen was quite narrow on the last whorl, but the tubercles were still traceable, or rather the geniculæ were very thick and prominent, resembling tuberculations. Another specimen 650 mm. in diameter, has a last whorl 240 mm. in diameter, and the abdomen much narrower, about 110 mm. in breadth, the dorsum being fully 160 mm. in breadth. The keel in this more advanced senile stage is considerably reduced in size, and the channels are almost obsolete; the tubercles are nearly obsolescent, but the geniculæ still rise above the edge of the abdomen. This peculiarity of the pilæ shows that the *Sauzeanus* form is persistent, and it enables the observer to distinguish the differences between a member of this series and all others.

Wright's figure [1] of a specimen from Semur, named by him *Arietites rotiformis*, looks like the full grown adults of the more discoidal variety of this species, but his reference of it to the Lower Bucklandi bed is probably incorrect. Dumortier [2] declares that a species identical with *bisulcatus*, D'Orb., but with channels not so deep, is found in several localities in the Angulatus bed in the basin of the Rhone. Unfortunately, no figures accompany his description, and figures of young and adult would be necessary to support this opinion. *Cor. kridion* and *Verm. Conybeari* are very like *bisulcatum* in the adults, but are quite distinct at earlier stages.

We think perhaps the more involute and broad whorled variety of this species should be recognized as distinct. It is the *Amm. resurgens* of Dumortier, and the *subnodosus* of Wright.[3] Wright was mistaken in placing his specimen with Amaltheus, it being an undeniable Arietian, probably occurring not later than the Obtusus bed, and perhaps as early as the Upper Bucklandi bed. In the Museum of Comparative Zoölogy there is also a magnificent specimen from Lyme Regis, measuring 375 mm. This is a perfect cast of one side, showing the same characters as in the small specimens figured by Dumortier, and the one figured by Zieten as *multicostatus*. These characters persist even at that advanced stage, without any signs of senility, and the pilæ, tubercles, geniculæ, and form of whorl remain unchanged.

The examination of Sowerby's original has induced us to join Oppel in suppressing the name of *multicostatus*. Sowerby's fossil is precisely similar to the adults of the common French variety of this species.

[1] Lias Amm., pl. ix.
[2] Études Pal. du Bassin du Rhone, pt. 1, p. 115, and pt. 2, p. 115.
[3] Lias Amm., pl. vi. fig. 2, 3.

Coroniceras Hungaricum, Hyatt.

Amm. Hungaricus, Hauer, Ceph. Lias Nordostl Alpen, pl. iv.

The figure of this species possesses the exact form and characteristic of the *bisulcatus* series. It has similar unshapely geniculæ thrown out beyond the edges of the abdomen, giving the whorl a peculiar angular and squared aspect; the geniculæ also interrupt the channel ridges, and the keel, though well developed, is almost counter-sunken in the deep channels. The pilæ are very straight in *Hungaricum*, and have no tubercles; the form is also somewhat more compressed than in *bisulcatus*. The sides also are perfectly flat and parallel, and the depressed abdomen and nearly equally flattened dorsum are of the same breadth, the whorl in section being a parallelogram with the sides about one fifth longer than the transverse diameter. The specimen figured by Hauer was 135 mm. in diameter, and consequently the complete shell must have reached a much larger size, since his specimens exhibit no signs of the approach of senility.

Third Subseries.

Coroniceras latum, Hyatt.

Plate III. Fig. 19-23 a. Summ. Pl. XII. Fig. 16.

Coroniceras latum, Hyatt, Bull. Mus. Comp. Zool., I., No. 5, p. 77.
Amm. Bucklandi pinguis, Quenst., Amm. Schwab. Jura, pl. ix. fig. 3?

Locality. — Semur.

Many of the young of this species, Plate III. Fig. 22, 23, have large tubercles early on the second whorl, and on the third these become elongated into tubercular folds. On the fourth, or on the latter part of the third volution, the intervals between them increase, and they become true pilæ. In other specimens, Plate III. Fig. 19, the pilæ are acquired as in *rotiforme*, Plate III. Fig. 5, and there is also in many specimens, Plate III. Fig. 22, a close resemblance to the adult of *Cor. kridion*, Plate III. Fig. 3. The keel appears on the first quarter of the fourth whorl, but at the latest stage observed on the second quarter of the fifth volution of a cast the keel was still very thin, sharp, and but slightly elevated. The channels, however, though very shallow and broad, had acquired lateral ridges. On the second whorl the breadth of the abdomen is very much increased by the development of tubercles, the sides becoming exceedingly divergent in some specimens, and the abdomen gibbous. On the fourth whorl the central area begins to become depressed, Plate III. Fig. 23, but the abdomen on either side retains its remarkable gibbosity. In correlation with this and with the narrow dorsum, the abdomen is never entirely covered by the succeeding whorls, but has an exposed border on both sides. On one specimen, Plate III. Fig. 22, 23, both the pilæ and geniculæ are double; in others, the pilæ are single and the geniculæ are double; on another, the duplication of the geniculæ ceases on the third quarter of the fourth whorl, with the exception of one single genicula on the last quarter, which is double. One cast of the second variety was very much broader than any other observed, and the geniculæ were hardly yet perceptible on the second quarter of the fourth volution. Another cast, though nearly as broad as the last, is somewhat flattened on either side of the keel; it has prominent and immature tubercles, though the pilæ and geniculæ are still imperceptible, and the channels still undeveloped on the latter part of the fourth volution. These two specimens show the retention of nealogic form and characters. When specimens develop more rapidly, the great breadth of the abdomen begins to decrease, and true pilæ replace the tubercular folds on the fourth whorl.

The sutures in this species are peculiar in respect to the great breadth of the lobes and saddles in comparison with their length or depth, the regularity and small size of the marginal lobes, and the rotundity of the marginal saddles even in the oldest stage examined, on the second quarter of the fifth whorl. At this time the superior lateral saddles are not so deep as the inferior laterals, but in the latter part of the fourth whorl they are about even (Plate III. Fig. 23 a). The abdominal lobe exceeds the superior laterals by less than one third, and the inferior lateral lobes exceed the superior laterals in the same proportion. At the earliest period examined, the first quarter of the fourth whorl, the abdominal lobe is only about one fourth longer than the superior laterals, and the inferior lateral saddles, instead of being deeper, are about one third shallower than the superior laterals.

A splendid series of this species from the Bucklandi bed at Semur gives very remarkable variations. The young have all the variations above described, and in addition the following: —

1. Forms which at a comparatively early age have an abdomen and tubercles like the adult of var. *Gaudryi* of *Cor. Sauzeanum.*

2. Three specimens with young, having the typical broad abdomen of *latum*, but speedily changed by growth so as to resemble the young of *Cor. orbiculatum.*

3. One specimen has sides flattened, pilæ numerous and single, approximating to the adult *Bucklandi* in aspect.

4. Another has single pilæ in the young and double in the adult, just the reverse of all other specimens yet observed.

5. Another has the double pilæ in the young, but the sides are gibbous instead of being flat or divergent, and it then speedily acquires convergent sides, becoming similar to *Cor. rotiforme.* The abdomino-dorsal diameter is less than usual, and the increase in size more gradual than in the typical form of *Cor. latum.*

These variations and resemblances all seem to be expressions of transient tendencies, except those which approximate to *Cor. kridion* and *rotiforme.* The agreement of the young forms as shown above, and of Fig. 15 and 21, Plate III., the similarity of the sutures of the young of *rotiforme*, Plate III. Fig. 10 a, and of *latum*, Fig. 23 a, show that the differences between these forms are not great, and consist mostly in the excessive development of the broad-abdomened whorl in some varieties of *Cor. latum.* All the specimens I have seen are also of small size, and seem to be the young of some yet unknown adult form similar to *Cor. Bucklandi.* The sutures of Quenstedt's *Amm. Bucklandi pinguis* agree remarkably well with those of *latum*, and lead us to hope that this may prove to be the adult. Certainly it is very distinct from the true *Bucklandi*, and the characteristics, so far as shown, are such as one might expect in the first senile stages of *Cor. latum*.

Coroniceras Bucklandi, Hyatt.

Plate III. Fig. 18. Summ. Pl. XII. Fig. 17.

Amm. Bucklandi, Sow., Min. Conch., II. p. 69, pl. cxxx.
Amm. Bucklandi, Ziet., Verst. Wurt., pl. xxvii. fig. 1.
Amm. Bucklandi, Phill., Geol. York, p. 1, pl. xiv. fig. 13.
Ariet. Bucklandi, Wright, Lias. Amm., p. 269, pl. i. fig. 1–3.
Amm. Bucklandi, Quenst., Amm. Schwab. Jura, pl. ix. fig. 1 (not fig. 2, 3).
Amm. Bucklandi costaries, Quenst., Ibid, pl. xi. fig. 1.
Amm. solarium, Quenst., Ibid, pl. viii. fig. 1–3.
Amm. sinemuriensis, D'Orb., Terr. Jurass. Ceph., p. 303, pl. xcv. fig. 1.
Amm. sinemuriensis, Quenst., Amm. Schwab. Jura, pl. xi. fig. 18–20.
Cor. sinemuriense, Hyatt, Bull. Mus. Comp. Zool., I., No. 5, p. 78.

Localities. — Lyme Regis, Semur, Basle, Aargau, Scheppenstadt, Schaichhof, Balingen, Tubingen.

Var. sinemuriense.

Plate III. Fig. 18.

This has young which closely resembles the young of *Cor. latum*. The breadth of the abdomen, divergent sides, immature folds, and tubercles are quite similar. The folds also begin with large tubercles on the first part of the second whorl. On the third quarter of the third whorl the true pilæ begin. After this the abdomen no longer increases so fast in breadth, and finally, upon the latter part of this volution, or the beginning of the fourth, this region is hardly wider than the dorsum, and the sides flattened. On the first or second quarter of the fourth whorl the pilæ become duplicate or triplicate, and the broad, thin, abdominally projecting tubercles characteristic of this species arise. These peculiar pilæ and tubercles occur, in some specimens, intercalated with single pilæ and tuberculated geniculæ bending forward upon the abdomen. The keel on the third quarter of the third whorl was well developed, and must have appeared considerably earlier. The channels were but slightly developed on the first quarter of the fourth whorl, though they have well defined ridges, and probably began later than the keel, somewhere perhaps upon the last half of the third volution; but this could not be ascertained with certainty. One specimen from Semur had but two divided pilæ upon the third whorl; after this they remained single to the fifth volution, the last observed. D'Orbigny's figure of *Amm. sinemuriensis* was taken from a young individual of about five and a half whorls, in which the pilæ are all divided. This is as exceptional in the species as are the specimens without any divided pilæ.

The superior lateral saddles are much narrower than the inferior laterals. The abdominal lobe is about one half longer than the superior laterals.

A fine specimen of this species from Semur, Plate III. Fig. 18, retains the peculiar characteristics of *sinemuriense* for five and a half volutions, with a similar rate of increase, and slightly divergent or flattened sides. These sides become then more rounded, the pilæ single, parting with their tubercles; and on the eighth volution, or perhaps sooner, the whorl assumes all the characteristics of the adult of *Cor. Bucklandi* of German authors. The pilæ are more widely separated, about six less on the eighth whorl than on the seventh; they are thick, solid, untuberculated, and the geniculæ bend abruptly and squarely forward on a level with or a trifle above the channel ridges, interrupting them with very slight elevations. The abdomen is flattened, but more or less rounding between the geniculæ, and its breadth is a trifle less than the dorsum, instead of being slightly broader, as in the young during the first five or six volutions. The channels sink into the abdomen, and the keel hardly shows above the lateral ridges.

The sutures on the third quarter of the eighth whorl in this specimen have an abdominal lobe about two fifths longer than the superior laterals, and the inferior lateral saddles are also two fifths deeper than the superior laterals.

A finely preserved specimen from Schaichhof agrees precisely in all its characteristics with the above, but on the first quarter of the tenth volution the inferior lateral saddles are about one third longer than the superior laterals. A specimen from Semur on the latter part of the tenth volution had an abdominal lobe about one third longer than the superior laterals. A slight rounding off of the abdomen, greater prominence of the keel, and shallowing of the channels, indicate the approach of old age in this specimen, whereas, at a corresponding age, the Schaichhof specimen still had the angular geniculæ and flattened abdomen of the adult.

The largest specimen of the *sinemuriense* variety, as shown by the young, was found in the Stuttgardt Museum. It measured about 610 mm. in diameter. There were some indications of old age, but the form of the whorl and the pilæ held their own wonderfully. There was also in the same Museum a specimen in which the pilæ had geniculæ on a level with the abdomen, and therefore very prominent, the channels excessively shallow, and keel broad and low; it was 375 mm. in diameter, and the channels had probably been deeper at earlier stages.

Of the specimens figured by Quenstedt in his "Ammoniten des Schwäbischen Jura," *Bucklandi*, Plate XI. Fig. 1, seems to belong to what we call true *Bucklandi*, as well as most of the figures of young on Plate X. The specimens figured as *Amm. sinemuriensis*, on Plate XI. Fig. 18–20, are doubtless the young of our *Cor. Bucklandi*, var. *sinemuriense*. These forms are not rare, but the adults must be rare, or they would not have escaped Quenstedt's attention.

Var. **Bucklandi.**

The stout English variety of *Bucklandi*[1] is a form with much larger and fewer whorls than *Bucklandi*, var. *sinemuriense*. The adult whorls are similar in their general characteristics, but the young in the stout English variety has very much larger whorls, with thick, sparse, single pilæ, like the German specimen in the Stuttgardt Museum described above and the young forms figured by Quenstedt.

The *Amm. solarium* of Quenstedt is founded upon large, senile specimens, as is shown by the fragments figured.[2] Their sutures, the huge fold-like, smooth

[1] Wright, Lias. Amm., pl. i. fig. 1–3

[2] Amm. Schwäb. Jura, pl. viii.

pilæ, and shallow channels, show this plainly. They probably belong to the typical variety of *Cor. Bucklandi*, though the evidence must be considered incomplete until the adults and young are known.

Coroniceras orbiculatum, Hyatt.

Coroniceras orbiculatum, Hyatt, Bull. Mus. Comp. Zool., I., No. 5, p. 78.
Amm. Bucklandi macer, Quenst., Amm. Schwab. Jura, pl. ix. fig. 2 (not fig. 1, 3); pl. x. fig. 5.
Amm. Bucklandi costosus, Quenst., Ibid., pl. x. fig. 1, 2.
Amm. Bucklandi, Quenst., Ibid., pl. xi. fig. 2 (not fig. 1).
Amm. oblongaries, Quenst., Ibid., pl. xiv. fig. 4.

Localities. — Semur, Scheppenstadt, Balingen.

The breadth and crowded aspect of the pilæ in the Scheppenstadt specimen on the fourth and fifth whorl, and the narrowness of the sides, resemble the characteristics of the same age in *Cor. Bucklandi*, var. *sinemuriense*, more than any other species of the same genus. The young whorls are much too small in all their dimensions, and the volutions too numerous for *Cor. Bucklandi*. The adult, with its prominent tubercles and with the dorsal broader than the abdominal region, shows a remarkable resemblance to *Cor. rotiforme*.

The last sutures on the ninth whorl have an even, rounded outline, due to the small size and regularity of the marginal lobes and the roundness of the marginal saddles, which are similar to those of *Cor. latum* on the fifth volution. The abdominal lobe is about one half longer than the superior laterals, the inferior lateral saddles exceed the superior laterals by about two fifths. The saddles and lobes, however, are broad and comparatively short in *Cor. latum* and in the young of other forms of Coroniceras. One specimen which is identical with this in the septal outlines shows the abdominal lobe on the eighth whorl to be one third longer than the superior laterals, and the superior lateral saddles are not quite one third longer than the inferior laterals.

One of the casts from Balingen measuring 288 mm. in diameter had about ten volutions. The increase in the transverse diameter of the whorl is more uniform and gradual than in *Cor. Bucklandi*, var. *sinemuriense*. On the latter part of the ninth whorl the pilæ show the approach of old age in the loss of their tubercles. The geniculæ also descend farther upon the sides, and are less abruptly joined to the abdomen, which therefore is more rounded and prominent than in the adult. The channels have become shallower, and finally lose their lateral ridges upon the latter half of the tenth whorl. The keel is still of considerable size, and thus acquires somewhat greater prominence than in the preceding stages. The breadth of the abdomen measured across the geniculæ is 6 mm. less than the breadth of the dorsum when measured through the umbilical shoulders on the second quarter of the tenth whorl, and 13 mm. less than on the fourth quarter of the same volution.

The abdominal lobes were not visible on the last quarter of the ninth whorl, but the inferior lateral saddles were one sixth deeper than the superior laterals. On the second quarter of the tenth whorl the abdominal lobe was one half longer than the superior laterals, and the inferior lateral saddles were one third deeper than the superior laterals.

The young are generally identified with the young of *bisulcatum* in France and Germany. They resemble this species very closely, but have more divergent sides, whorls much stouter, and do not have the smooth period so fully shown in the young. They equally closely resemble in worn specimens the untuberculated variety of *Verm. Conybeari*, and are often, especially in large specimens, mistaken for *Conybeari* when the tubercles are either slightly developed or obscured. All of these resemblances, however, are merely transient, and not of the same value as the precise agreement of the younger and older stages in this species and in *Bucklandi;* it is in fact a more highly specialized bucklandian form, with better defined channels and smaller and finer pilæ. The resemblances in the aspect of the young to *Cor. latum* are not sufficient to unite the species.

Canavari, in his Unterer Lias v. Spezia,[1] describes and figures *Cor.* (*Ariet.*) *sinemuriense*, Pl. XX. Fig. 1, which may be the young of that species. *Cor.* (*Ariet.*) *Monticillense*, Fig. 3, 4, and *rotiforme*, Fig. 12, may be both the young of the last named, or of some other allied species. *Ariet. multicostatus* does not resemble, so far as the lateral view given in Fig. 7 allows one to see, any species that we know.

FIFTH, OR AGASSICERAN BRANCH.

The shells are discoidal only in the radical species and lower members of the same genetic series; in the more specialized and higher forms of the same series the involution may exceed that of the shells of any series previously described, except Schlotheimia. Thus, in shells in which the geniculæ are absent, the whorl may pass inwards beyond the area of the abdomen, and embrace the sides. The umbilicus, however, so far as observed, has never been entirely covered in. Degeneration of the form of the whorl, i. e. flattening and convergence of the sides, narrowing of the abdomen, and the advent of fold-like pilæ, may take place at an early nealogic stage in some species, and may be characteristic of entire series. The keel is, however, retained even in extreme old age. The keel takes on a distinct aspect in one series of this branch, Agassiceras, and is transitional to the true hollow keel of Oxynoticeras.[2]

AGASSICERAS.

The characteristics which distinguish this genus are principally due to the exceedingly immature aspect of the lower forms, the shortness of the living chambers, and the development in the higher species of tuberculated pilæ in association with highly convergent sides and angular keeled abdomens without channels. The young of the radical species, *Agas. lævigatum*, are remarkable for

[1] Paleontogr., XXIX.

[2] Quenstedt considers it to be a true hollow keel. See below, in the description of *Agas. Scipionianum*.

the prolonged existence of the goniatitic proportions, which are generally confined to næpionic stages of growth in other Ammonitinæ. They are also very similar in some of the nealogic and adult stages, both in form and characteristics, if we except the sutures, to Psiloceras.[1] The sutures acquire the deep arietian abdominal lobe quite early in life. The sutures of the higher species, *Agassiceras Scipionianum*, are very similar to those of Coroniceras. The affinities of *Agas. lævigatum* and *Ast. obtusum*, and also those with Psiloceras, have been fully discussed elsewhere.[2] In the clinologic stage the abdomen becomes more acute, and the sides smooth. Neumayr has lately redescribed this genus in part under the name of Cymbites.[3]

Agassiceras lævigatum, Hyatt.

Plate VIII. Fig. 9-14. Summ. Pl. XIII. Fig. 1.

Amm. lævigatus, Sow., Min. Conch., pl. 570, fig. 3.
Amm. lævigatus, Opp., Die Juraf., p. 81.
Amm. abnorme, Hauer, Unsymm. Amm. Hierl.-Schich., Sitz. Akad. Wien, XIII. pl. i. fig. 11-17.
Cymbites globosus, Geyer, Ceph. Hierl.-Schich., pl. iii. fig. 26.

Localities. — Lyme Regis, Semur.

This species has an exceedingly immature or næpionic form. It seems frequently to complete its growth in five whorls. The aperture has a simple pointed rostrum, the lateral edges slightly flaring, with a broad shallow constriction, Pl. VIII. Fig. 12, very similar to the aperture of Oppel's type of *Amm. planorbis*.[4] The living chamber is about one half a volution in length.

Var. A, Plate VIII. Fig. 11. This is smooth during four volutions, and the pilæ, if present, are developed only on the last whorl. The whorls are more compressed than in other varieties, and the umbilicus not so deep.

Var. B, Plate VIII. Fig. 9, is smooth only during the first three or three and a half whorls, and then has immature folds like those of var. *plicatum* of *Psil. planorbe*. The younger whorls are wider than in other varieties, and the umbilicus deeper.

Var. C has the pilæ much more distinct, but the period at which they appear is the same as in the preceding variety. The pilæ are apt to cross the abdomen, forming slight ridges. This, like all other characteristics, is found more or less also in other varieties.

Var. D, Plate VIII. Fig. 10-12, is founded on the presence of a faintly defined siphonal ridge. This includes members of other varieties, regardless of the time at which the pilæ are developed, their greater or less prominence, and

[1] A paper by E. Haug, "Ueber Polymorphidae," Neu. Jahrb. Mineral., 1887, II. p. 92, gives an interesting account of this genus, in which he substantially agrees with our descriptions, but insists upon the keelless character of the whorls. If we are correct, this is an adventitious character common enough in dwarfed forms, or arrested development in some individuals or in the varieties of the same species, but a variable within the species, and not a generic character.

[2] See pages 65, 66.

[3] Jahrb. Geol. Reichsans., XXVIII., 1878, p. 64, note.

[4] We have studied Oppel's type of this species, and found that Oppel's figure gives the lateral curves of the aperture in an exaggerated form, and the constriction too deep. The real aperture is therefore more like that of *lævigatum* than it appears to be in his figure.

the breadth or thinness of the whorls. Some of these have stouter adult whorls than usual. If the slight siphonal ridge were absent, there would be a closer resemblance in form to *Psil. planorbe*, var. *erugatum*. The young have at first deep umbilici, due to the abrupt umbilical shoulders, Plate VIII. Fig. 10, 13, 14, common to the Goniatitinula and early næpionic stages of the Arietidæ. This stage is succeeded by flatter whorls and less abrupt umbilical shoulders, which last in some cases throughout the first three whorls, but the fourth whorl is apt to increase fast enough to be somewhat broader than the third. The aspect of the umbilicus when the fourth whorl is completed is thus altered in such specimens from deep to shallow, just as it changes at much earlier stages in other species after the earlier goniatitic proportions are outgrown. In some specimens this change takes place much earlier. The pilæ are introduced generally after the second stage of growth, and but very rarely before the reduction in the comparative breadth of the whorl begins. The sutures are also immature on the fourth whorl, but the abdominal lobe is considerably deeper than the superior laterals, as among true Arietidæ. The other lobes are pointed, and the saddles serrated.

The Museum at Semur and the Museum of Comparative Zoölogy afford ample material for tracing the connections between this species and *Agas. striaries.* Quenstedt, in "Ammoniten des Schwäbischen Jura," p. 106, has also noted the affinities of this species and *striaries.* According to Oppel, it appears in the bed immediately above the Bucklandi bed, and in the Museum of Stuttgardt is a specimen in the Geometricus bed from Degerloch. In England, however, it is usually found associated with *Deroceras planicosta* in the Obtusus zone, and at Semur with *Schlot. angulata*, and above this in the Geometricus bed. The specimens described and figured by Hauer and Geyer from the Hierlatz fauna seem to be unquestionable, since no other species with which we are acquainted has the peculiarities of this form.

Agassiceras striaries, Hyatt.

Plate IX. Fig. 14, 15. Summ. Pl. XIII. Fig. 6.

Amm. striaries, Quenst., Der Jura, p. 70, pl. viii. fig. 5.
Amm. striaries, Quenst., Amm. Schwäb. Jura, p. 105, pl. xiii. fig. 24–26.
Psiloceras planilaterale, Hyatt, Bull. Mus. Comp. Zoöl., I., No. 5, p. 73.

Locality. — Semur.

Sides of the whorls in adult specimens may be either flattened or decidedly gibbous, and also either plicated or smooth. Abdomen is very broad, depressed, convex, smooth or very slightly ridged by lines of growth. The position of the siphon is often indicated by a ridge. The young are smooth for the first three whorls, the plications begin to appear on the fourth whorl. These observations were made upon five specimens in the Museum of Comparative Zoölogy, which had been labelled *Amm. planorbis* by M. Boucault; but they differ from that species in the smaller size and greater proportional bulk of the whorls, the breadth and depressed convex form of the abdomen, and the presence of a siphonal ridge.

Several specimens of this species in the Stuttgardt Museum, Upper Bucklandi bed, from Balingen, showed living chambers, as pointed out to me by Professor Fraas, always much shorter than in *planorbe*, and the sutures distinct. The peculiar folds appearing on some shells, and the form and aspect of the whorls, like those of the nealogic stages of *Scipionianus*, show that their affinities are in the direction of this species. The examination of the originals of Quenstedt's descriptions from Pforen fully sustained the above, and a fine suite of the same species at Semur, in the corresponding horizon, exhibited several forms transitional to the young of *Scipionianus*.

Professor Mösch, in the Museum of the Polythenic at Zürich, showed me several specimens of *striaries*, in which the keel was so faint as to be hardly perceptible, and the striations no better marked than in Psiloceras. These were named *psilonotus*, and were found at Salins associated with typical *striaries*. The apertures are also similar to those of *Psil. planorbe*.

Agassiceras Scipionianum, Hyatt.

Plate VII. Fig. 11-15. Plate X. Fig. 11-13. Summ. Pl. XIII. Fig. 7.

Amm. Scipionianus, D'Orb., Terr. Jurass. Ceph., p. 207, pl. li. fig. 7, 8.
Amm. Scipionianus, Quenst., Amm. Schwab. Jura, pl. xiv. fig. 1-3 (not pl. xvii.).
Ariet. Scipionianus, Wright, Lias Amm., p. 289, pl. xiii. fig. 1-3; pl. xix. fig. 8-10.

Localities. — Whitby, Semur, Arton in Luxemburg, Gmund.

This species varies exceedingly. Some of the young show a crenulated keel, and they may also be either smooth or pilated on the sides. The abdomens are keeled, and occasionally, though very slightly, channelled. The form of the whorl in the young may be either very gibbous, Plate VII. Fig. 11, 12, or comparatively compressed. The pilæ also vary from comparatively thin and depressed to prominent and well defined, with or without tubercles; they may also be very numerous or few in number, and be very distinct, or thick, awkward-looking folds. It has been commonly supposed that the true affinities of this fossil were with the *margaritatus* group, but its development is altogether peculiar, and its sutures are distinctly arietian. There are two varieties of this species with distinct nealogic stages but similar adults; one, as described above, very gibbous and heavily pilated,[1] and another more compressed at all stages, and approximating to *Agas. nodosaries*.[2] The latter may be identical with *Agas. nodosaries*, or it may be distinct; the materials at hand are not sufficient to determine this question.

In old age the tubercles are suppressed, the sides become flatter and more convergent, the geniculæ bend less abruptly and curve slightly forward, the channels disappear, but the keel remains very prominent and sharp. The clinologic stage just before the pilæ become obsolete is very similar to the adult of *Ast. Collenoti*, but the shell is not so involute.

The young of this species has the gibbous volutions so characteristic of *lævigatum* and *striaries*. The sides are at first divergent, but they become nearly

[1] Plate vii. fig. 11, 12; pl. x. fig. 11, 12.

[2] Plate x. fig. 13; pl. vii. fig. 15.

parallel on the latter part of the second whorl; the dorsum also broadens, and the umbilical shoulders become more abrupt. On the third volution the sides are parallel, the dorsum and abdomen of the same breadth, and the latter elevated into an obtuse ridge. This ridge on the fourth whorl becomes a true keel, unaccompanied by channels, though there are traces of their formation. The increase of the abdomino-dorsal diameter of the whorl after this period speedily elevates the abdomen, and proportionally decreases the transverse diameter of the shell on the latter part of the fourth volution, destroying even the faint traces of the channels mentioned above. On the fifth volution the sides become slightly convergent, and this convergence increases very slowly on the sixth volution.

Thick and widely separated folds appear on the early part of the third whorl, but rapidly grow into true pilæ. The geniculæ may become tuberculated on the fifth volution, or they may remain permanently without tubercles; there is, however, great variation with regard to their prominence and number.

The duration of the different stages of growth also varies; in some specimens the abdomen remains flattened through the keel-forming stage until the first quarter of the fifth volution is reached. In one specimen the pilæ are reversed in position, bending posteriorly, but subsequently begin slowly to change to a natural position on the fifth volution. A number of the specimens from Semur have the pilæ but very slightly or not at all developed. None of them seem to reach beyond four and a half volutions, and their small size may possibly be due to the same cause as the absence of the pilæ.

On the early part of the fourth volution the abdominal lobe is considerably longer than the superior lateral lobes, which in turn are shorter than the inferior laterals. The inferior lateral saddles are slightly deeper than the superior laterals. On the latter part of the same volution the abdominal lobe has increased in length, and the superior lateral saddles are shallower; the inferior lateral saddles become deeper proportionally, and the lateral lobes are nearly equal in length, the inferior laterals still remaining, however, slightly the longest. The marginal lobes are very minute, and remain so, the sutures having a comparatively even outline for that reason. In some specimens the lengthening of the abdominal lobe continues until the superior lateral saddles are almost obliterated; in others, the lobes and saddles may remain with about the same proportions as in the stage of development last described.

There are two specimens in the Stuttgardt Museum, from the Geometricus bed, but they do not show the young, or give any better clue to the true development. There are also three in the Stuttgardt Museum, from the Pentacrinus bed near Krumenacher, which appear to be the yoang of this species, or of *Scipionis*. One of them, with the shell present, shows all the peculiar marks of *Agas. striaries*, while another, a cast, is so broad on the abdomen, and the fold-like pilæ are so prominent, that it looks remotely like the young of *Cor. Sauzeanum*. The three are identified as young of *Cor. Sauzeanum*, but the young of this last is very distinct in the sutures and other characteristics. A specimen in the collection at Semur, from the same horizon, under the name of *Amm. lævi-*

gatus, maintains the aspect of *striaries* until a late period of growth, and then develops the keel and form of *Scipionianus*; and there is also another fossil, which is exactly similar to the later, but still immature, stages of *Scipionianus*.

The keel may, perhaps, have a hollow above the siphon, such as Quenstedt describes in his "Ammoniten des Schwäbischen Jura," Plate XIV. Fig. 1, but the inner or nacreous layer does not form a partition between the interior of the shell and the interior of the keel, nor does the black layer occur above this partition, as in *Oxyn. oxynotum* and others, which have true hollow keels. In the specimens examined, the keel was elevated, as in Quenstedt's figure, but the siphon laid directly against the shell layers, which filled the interior of the keel, and there was no black layer.

Agassiceras nodosaries, HYATT.

Amm. nodosaries, QUENST., Der Jura, p. 78, pl. viii. fig. 8; Amm. Schwab. Jura, I. pl. xvii. fig. 1-3.

Locality. — Bempflingen.

The specimen of this species in the Museum of Comparative Zoölogy is less compressed than those figured by Quenstedt, but it shows that *nodosaries* is probably quite distinct from *Scipionianus*. The whorls are more compressed than in the latter, but the tubercles and pilæ are retained until a much later age. These same distinctions are, of course, still more marked when the species is compared with *Scipionis*. The exact horizon was not marked on our specimen. The cast measured 160 mm., and the outer whorl 60 mm., the same whorl at the beginning being somewhat less than 30 mm.; the greatest transverse diameter of the same was about 30 mm., and the least about 20 mm. Our specimen is, therefore, a trifle larger than the inner whorl of the fragment figured by Quenstedt in "Ammoniten des Schwäbischen Jura," Plate XVII. Fig. 1, at the point marked "k." It is also of about the same diameter as his abdominal view of the same whorl marked "q." The keel is also in the same condition, being coated with matrix, the geniculæ are bent and run nearly to the keel, there are no channels, and on the younger part of this whorl the keel is well preserved and prominent. Quenstedt's specimens were found in the Tuberculatus bed. It is not unlikely that the compressed variety of *Agas. Scipionianum* described above ought to be transferred to this species, but we have not been able to gather sufficient evidence to settle this question.

Agassiceras Scipionis, HYATT.

Plate IX. Fig. 12, 13. Summ. Pl. XIII. Fig. 8.

Amm. Scipionis, REYNÈS, Plates.
Amm. Scipionianus olifex, QUENST., Amm. Schwab. Jura, pl. xvii. fig. 7-10 (not pl. xv.).

Locality. — Semur.

The shell of this species is smooth at an early age, and quite similar to the old stages of *Scipionianus* in form and characteristics, but it is more involute. Quenstedt's figures and descriptions of his *Scipionianus olifex* appear to apply to this species. His specimen as figured is, however, younger, and consequently less involute, the pilæ are without tubercles, and the general aspect similar. His shell was, according to his figure, notably more involute than *Scipionianus*, and this agrees also with a specimen in the Museum of Comparative Zoölogy. This last is larger than that figured by Quenstedt, and, though comparatively senile and quite smooth on the outer whorl, is more involute than any specimen of *Scipionianus* and has a more compressed and more acute whorl. My notes taken at the Museum at Semur say, "the *Scipionis* of Reynés is only a less involute form of *Scipionianus*," but it is probable that the specimen observed at Semur may have been exceptional, and either extremely old or a pathological example.

Geyer, in his Liass. Ceph. Hierlatz b. Hallstadt, mentions *Cymbites globosus*, Plate III. Fig. 26, a young form of *Agas. lævigatum*, as cited above, and also an *Ægoc.* indet., Plate III. Fig. 13, which, if not a specimen of *Agas. Scipionianum*, is a very close ally. These are small shells, as is usual in that locality.

The *Ægoc. Cocchi*, Canav., Unter. Lias v. Spezia, Plate XIX. Fig. 11, may be a young specimen of *Scipionianum*, but we cannot venture to refer it to this genus.

ASTEROCERAS.

The form of the whorl is noticeably less discoidal than in the preceding series, except in *Ast. obtusum*. The abdomen in adults is usually narrower, the sides are flatter and more convergent, as well as broader, than is usual in Coroniceras. The involution is not limited to the abdomen, and the whorls tend to grow inwards, covering more or less of the sides. The pilæ are fold-like, bending forward on to the abdomen, and in most species smooth and without geniculæ. The young have very stout gibbous whorls with divergent sides, which become more and more convergent in the nealogic stages, and remain so throughout life. The keel is constant in all the young and adult specimens, but the channels are often very shallow, and sometimes absent.

The sutures have a deep abdominal lobe, but the lateral lobes are apt to be short and pointed, and the saddles broad. They are similar to those of Coroniceras, but the marginal lobes are rarely so long as in that genus. In old age the abdominal lobe and the lateral lobes and saddles are of about the same length, but become broader proportionally, the inferior lateral saddles become shallower, and this occurs also in many dwarf forms, which of course are prematurely degraded. These senile changes are more marked than in Coroniceras, though the old age is not otherwise noticeably different. The genus with relation to other genera of the Arietidæ is notably geratologous, or in other words the shells exhibit characteristics similar to those of the senile stages of Coroniceras, and these characteristics may be reproduced in the adult, and even in the nealogic stages. Each species and individual, however, also has a senile stage in which decline is manifested unmistakably, and during this stage the whorl becomes still more convergent, more involute, and smoother, and the sutures more degenerate, but the keel, so far as observed, though it may become much depressed, never wholly disappears. Probably this does occur in extremely aged specimens, in what we have called the nostologic stage, but such extreme examples have not yet been seen by the author.

First Subseries.

Asteroceras obtusum, Hyatt.

Plate VIII. Fig. 4-8. Plate IX. Fig. 1. Summ. Pl. XIII Fig. 2.

Amm. obtusus, Sow., Min. Conch., II. p. 151, pl. clxvii.
Amm. obtusus, D'Orb., Terr. Jurass. Ceph., p. 191, pl. xliv.
Amm. obtusus, Quenst., Amm. Schwab. Jura, p. 141, pl. xix. fig. 2, 3.
Ast. obtusus, Hyatt, Bull. Mus. Comp. Zool., I., No. 5, p. 79.
Ariet. obtusus, Wright, Lias Amm., p. 293, pl. xxi. fig. 1–5.
Amm. Smithi, Sow., Min. Conch., IV. p. 148, pl. cccevi.
Amm. Smithi, Quenst., Amm. Schwab. Jura, p 140, pl. xix. fig. 1.
Amm. Turneri, Ziet., Verst. Würt., p. 15, pl. ii. fig. 5.
Amm. Turneri, Quenst., Amm. Schwab. Jura, p. 143, pl. xix. fig. 10–13.
Amm. stellaris, Hauer, Ceph. Lias Nordostl. Alpen, pl. v. fig. 1–3.
Ægoc. sagittarium, Tate et Blake, Yorkshire Lias, pl. vii. fig. 2.
Ægoc. sagittarium, Wright, Lias Amm., p. 355, pl. lii. fig. 1–5; pl. lxii. a, fig. 1–6.
Ægoc. Slatteri, Wright, Lias Amm., p. 374, pl. l. fig. 1–5 (not fig. 6–8)
Amm. capricostatus, Quenst., Amm. Schwab. Jura, pl. xix. fig. 14, 15.

Localities. — Lyme Regis, Whitby, Robin Hood's Bay, Boll, Balingen, Bempflingen, Salins, Besançon, Adnet.

Var. sagittarium.

A specimen from Bempflingen has pilæ, which cross the abdomen. Specimens in Quenstedt's collection from the same locality show this peculiar deformation, to which he calls attention,[1] and compares them with *sagittarium*, but does not seem sure of the identification, since in another place (p. 252) he appears to admit Wright's association of *sagittarium* with *Jamesoni*. Blake states that his types came from the lower part of the Oxynotus bed, that is, from the Obtusus bed of other authors. This fact, and the obvious agreement of the sutures and pilæ with *capricostatus*, Quenst., and the *Turneri* deformation common in South Germany, and their differences when compared narrowly with *Jamesoni*, leave but little doubt that Wright was in error in thinking this form occurred in the *Jamesoni* bed, or was identical with *Jamesoni*. The specimens figured represent quite completely what is perhaps the most remarkable degradational series of the Lias. The resemblance of one of Wright's figures, Plate LII. Fig. 1, 2, to the forms of Wæhneroceras, especially *Wæhn. latimontanum*,[2] is a remarkably good example of morphological equivalence.[3] Others among these deformed specimens, both in England and Germany, resemble *Microceras planicosta* in the

[1] Amm. Schwab. Jura, p. 145.

[2] Unter. Lias, Mojsis et Neum., Beitr., II. pl. xx.

[3] A very remarkable example of morphological equivalence caused by a wound is figured by Neumayr in his "Stamme des Thierreichs," 1889, p. 82. The shell of a keeled and channeled species has been broken on the abdomen, and beyond the wound the characteristics have changed so as to resemble those of Schlotheimia.

depressed form of the whorl, and the coarse pilæ which cross the abdomen have a similar broad, flattened aspect. The siphonal saddle, according to Wright's figures, Plate LXII. A, seems to have suffered considerable alteration from what it is in the typical form of *obtusum.* The lobes and saddles of the Bempflingen specimens have the regular differences of one half to one third in the lobes, and the abdomen is unusually broad.

There is a specimen of variety D, from Lyme Regis, in which for a short space the keel has been pressed inward and the sides ruptured. While on the recovery from this injury the abdomen retained a flattened aspect, it is about as broad as that of some forms of *sagittarium,* and otherwise similar. Narrow folds and furrows are noticeable crossing the abdomen, which correspond to similar small folds and furrows on the sides. The effect of the rupture is otherwise noticeable in the temporary absence of the pilæ and the greater intervals between the next two pairs of sutures. This example shows that there may be a tendency to vary in the direction of Microceras, which is produced in some specimens by disease, and in others by wounds. Such characteristics were not observed in the later stages of diseased specimens. They probably disappeared in course of growth, just as the similar characteristics of the young of *Cor. Sauzeanum* were suppressed in the adult stages.

The forms of this species may be divided into several varieties, according to the adult characteristics, and the slower or quicker development of the keel, channels, and form.

Var. B.

This has flattened sides, pilæ not very prominent, but running nearly to the base of the keel, and the channels are very narrow as well as shallow.

Var. C.

This is the normal *Turneri* of Zieten, and has the pilæ reaching nearly to the base of the keel in the nealogic stages, and perhaps in the adult. In all other characteristics, even in the prominence of the pilæ, it agrees with variety D.

Var. D.

Plate IX. Fig. 1.

This is the typical form, and has well rounded, gibbous sides, prominent pilæ, broad abdomen, broad shallow channels, and a depressed keel.

Var. E.

Plate VIII. Fig. 4 8.

This is similar, but has deeper channels and a keel more prominent, narrower and more convergent sides in the adult, showing some resemblance to *Ast. Turneri.* Hauer's specimen of *Amm. stellaris* figured in "Nordöstlichen Alpen" belongs to this variety, and is not identical with the true *stellare.*

The pilæ may be gradually introduced by a series of plain folds, or by tubercular folds, Plate VIII. Fig. 4, 5. The whorl is smooth in specimens having the first mode of development for two and a quarter volutions. The increase is gradual, so that well defined pilæ are not produced until the last of the third or first quarter of the fourth whorl. An English specimen of variety A has large tubercles on the second quarter of the third whorl. These continue at long intervals, only about two to a quarter of a whorl. The true pilæ do not begin to appear until the third quarter of the fourth volution. Even then these are exceedingly oblique and fold-like, and, though they soon assume the aspect of true pilæ, retain their obliquity until the second quarter of the fifth volution. Another English specimen shows acceleration by developing similar tubercles on the last quarter of the second volution, and also by the development of perfect straight pilæ on the second quarter of the fourth volution. A third specimen of variety E, from Lyme Regis, has tubercles beginning on the last quarter of the second whorl, and perfect pilæ on the last part of the first quarter of the fourth volution.

VAR. Smithi.

The British Museum possesses a card with several young specimens of the variety *Smithi*, which at first appear to be identical with the full grown *lævigatum* or *striaries*. They have short living chambers, becoming more or less contracted at the apertures, and fold-like pilæ with striations. They have not, however, the peculiar form of the young of *lævigatum*, Plate VIII. Fig. 10, 13, nor similar sutural digitations, and the living chamber is about three fourths of a volution in length. It is interesting to note here the fact, that acceleration in the development of the tubercles and pilæ occurs in variety E, which has more involute shells than other varieties.

Ast. obtusum has characteristic sutures, and the number of specimens usually exhibiting these parts were also favorable for testing the diagnostic value of the proportions of the lobes and saddles in the definition of the species. We have made large numbers of measurements, of which the following are selections. The fractions express the differences between the abdominal and superior lateral lobes, or the inferior and superior lateral saddles. The abdominal lobe and inferior lateral saddles being always longer, the fraction expresses at the same time the proportionate lengths in equal divisions of these two.

A specimen of variety B, from Robin Hood's Bay, has three sutures on the third and two on the fourth quarter of the fifth volution, with a difference of only two fifths between lobes and saddles, and one septum on the third quarter, in which the lobes are equal, the saddles remaining unchanged. One from Teuchsloch bei Bempflingen has lobes varying from one fifth to one third, and saddles from one sixth to two thirds. A specimen of variety C, from Boll, has these proportions in none of its sutures, but either two fifths or one half between the lobes, and one fifth or one third between the saddles. Comparisons were made upon sutures of the same age in each case. Another specimen of this variety from Boll, having similar gibbous sides, has similar proportions between the lobes and saddles, with exception of the eighth suture, in which the difference of the lobes is only two fifths, and that between the cells only one fourth. This shows that the proportions in stouter specimens from Boll are not due to the greater prominence of the pilæ and gibbosity of the sides, nor is there any marked deviation from the usual rounded outline of either lobes or saddles. A specimen of variety D, from Lyme Regis, has sutures with lobes differing one half with great uniformity, but saddles differing one half to one third or one fourth, irrespective of this constancy between the lobes. A specimen from Lyme Regis shows that there is no correlation between these proportions and the variations in outline of the inferior lateral saddles. Thus, in the Lyme Regis specimens, No. 1 has the inferior lateral saddles flattened and rounded; No. 2, pyramidal, with two marginal saddles forming a club-shaped expansion at the top; No. 4, straight sides and slightly concave base; No. 5, like No. 1 again; and No. 7, like No. 4.

The sutures of the first specimen described from Bempflingen as having the microceran pilæ, have the usual proportions of others. A specimen from Lyme Regis has lobes differing from one half to three fifths, the saddles, however, with remarkable constancy, remaining about one half, as far as measured. The wounded specimen described above had lobes and saddles, varying from one half to the excessive difference of five sevenths, and the extremes of difference were not the nearest to the fractured portion of the shell, but some sutures removed from the fracture. A small specimen from Whitby, on the third quarter of the fourth volution, showed lobes differing from one half to three fifths, and saddles from nearly equal to one third. A somewhat larger specimen from Lyme Regis had lobes differing three fourths, and the saddles three fourths and two thirds on the first quarter of the sixth volution. On the right side of a specimen from Lyme Regis a rare distortion occurs. The first auxiliary lobes are obsolete, or at any rate only represented by a marginal lobe, and the first and second auxiliary saddles form a solid bank.

By combining all of these observations, it becomes possible to trace a series of modifications. There is evidently (1) a very immature form or variety, in which a microceran aspect is assumed through pathological causes; (2) a variety in which a low keel, very shallow narrow channels, flat sides, and depressed pilæ are developed much more quickly than in this malformed variety; (3) a variety in which the development of pilæ, channels, and keel is still more accelerated, and combined with more gibbous sides and more prominent pilæ in adults; (4) a variety in which development of the pilæ is accelerated, accompanied by the advent of broader and deeper channels, and a more prominent keel in the later stages. The specimens from Salins and Besançon are dwarfs, having resemblances to *Turneri*, Ziet.

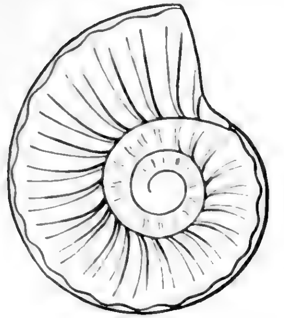

FIG. 34

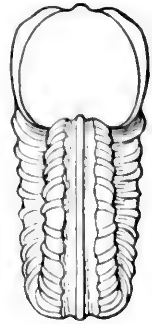

FIG. 35.

VAR. **quadragonatum,** HYATT.

Localities. — Lyme Regis, Semur.

A form in the Museum of Comparative Zoölogy, represented in Figures 34, 35, closely resembles the stout variety of *obtusum*, but exaggerates the characters of that form and of variety B. Though young, it has a more subquadragonal whorl than is usual in the adults of *obtusum*, var. B, a flatter abdomen and broader channels, and quite distinct pilæ, with a tendency to the formation of tuberculated geniculæ, though actual tubercles are not present. The diameter is 53 mm. The outer whorl is 20 mm. on the sides, and the transverse diameter the same. The sides are about parallel, the abdomen flat, distinct, sub-angular, and geniculæ are present. The abdominal part of the pilæ do not bend forward, but pass on to the abdomen and interrupt the channel ridges. The ridges are well marked, though not so prominent as in *Turneri*.

It is evidently a modified form of *obtusum*, in which the pilæ by a very slight increase in the geniculæ would become tuberculated. Dumortier, in his "Études Pal. Bassin du Rhone," describes a specimen of *obtusum* having eight or nine irregular nodes upon the young whorls until 20 mm. in diameter, and gives these as characteristic of the young of his specimens. They probably belonged to this variety, in which the young are more strongly marked in this way than is usual in other varieties of *obtusum*.[1]

There is a large specimen in the Museum of Comparative Zoölogy, from Lyme Regis, 500 mm. in diameter. Though considerably altered by pressure, the last whorl has the aspect of var. *quadragonatum*, and the normal form is comparatively slightly altered on the third quarter of this volution. It is here only 115 mm. in abdomino-dorsal diameter, which is considerably less than would occur in any equally large specimen of other varieties. There are pseudo tubercles on the outer whorl, but these may in large part be due to distortion of the pilæ by

[1] The similarity of *Arietites stellæformis*, as figured by Wahner, Unter Lias, VI, pl. xxv., to Asteroceras may be simply a case of parallelism, due to clinologic degeneration in some species, which may, however, belong to an entirely different genus. The umbilical whorls are heavily though sparsely tuberculated, and the outer whorls are, in our opinion, those of an old shell. See also page 100, note 3, above.

pressure. The keel is low and broad, as in *obtusum*, though prominent enough to show above the lateral ridges when seen from the side. D'Orbigny's figure of *obtusum* is correct, and gives this variety as it occurs at Semur, the abdomen sometimes being wider than the dorsum, instead of being narrower than or about equal to the dorsum, as in all other varieties.

There is a normal specimen of this species in the Museum at Stuttgardt, collected in the Upper Bucklandi bed at Göppingen. The majority of specimens, however, belong to the Obtusus bed just above this.

Confusion, as remarked above, is not infrequently occasioned by the resemblances of the senile stages in *Cor. Bucklandi* to the adults of *obtusum* and *Brooki*. Sometimes even old specimens of *Cor. trigonatum* and *Gmuendense* are mistaken by paleontolongists of experience and reputation for *obtusum*, especially if the inner whorls are concealed. The larger and older specimens of *obtusum* are apt to acquire the more abrupt umbilical shoulders which are characteristic of the young and adult of *Ast. stellare*.

Asteroceras stellare, Hyatt.

Plate IX. Fig. 2, 3. Plate X. Fig. 1, 2.

Amm. stellaris, Sow., Min. Conch., I. p. 211, pl. xciii.
Amm. stellaris, Ziet., Verst. Würt., p. 15, pl. ii. fig. 5.
Amm. Brooki, Quenst., Amm. Schwäb. Jura, p. 116, pl. xv. fig. 2, 3 (not pl. xx., xxi).
Ariet. Brooki, Wright, Lias Amm., p. 295, pl. xxii. fig. 1–6.
Amm. obtusus suevicus, Quenst., Amm. Schwäb. Jura, pl. xx. fig. 1.

Localities. — Semur, Lyme Regis, Gmünd, Tubingen.

The nealogic stages are similar to the older ephebolic stages of var. E of *Ast. obtusum*. In point of fact, the two forms run into each other by intermediate varieties, and can be separated only by artificial lines. The young in one specimen from Whitby exhibited on the first quarter of the fifth volution channels as deep, keel as prominent, and an abdomen considerably narrower than those of the most highly modified forms of *Ast. obtusum*, var. E, on the last quarter of the sixth whorl, over a whorl and a half later. In a specimen from Lyme Regis the development is parallel with that of *obtusum*, var. E, until the first quarter of the sixth whorl, then the sides became flattened, the pilæ depressed, and the abdomen narrowed to the area of the channel ridges.

Sowerby's types, figured by Wright, are young specimens, and exhibit very completely the fact that the young may develop the characteristics of the species at a comparatively early stage, and are more highly modified as a rule than the adults of *obtusum* in any variety.

The sutures on the sixth volution of a specimen from Gmünd had lobes differing two thirds and saddles one half; and on last quarter of same, the lobes differed three fourths and saddles two thirds. In an older specimen from Semur, on the second quarter of the seventh whorl degeneration had already begun, the lobes differing only one fifth to one sixth, and saddles about two fifths. This and the fold-like character of the pilæ and trigonal form showed that old age had fully begun on this whorl. There are two specimens of *stellare* in the Museum of Comparative Zoölogy, which are so similar to *Ast. Turneri* that they differ in only one characteristic, namely, the shallowness of the umbilicus, due to the gradual curvature of the sides. In *Ast. Turneri* the breadth of the dorsum, and the consequent abruptness of the umbilical shoulders, is a marked peculiarity, even at an early nealogic stage. These specimens were in the nealogic stage; if older, they would probably also have shown a less amount of involution than in *Ast. Turneri*. This last species becomes generally, though not invariably, larger in five volutions than the former in the course of five and a half. Specimens of *stellare* also approximate very closely to *Ast. acceleratum*; they differ, however, in the less involution of the whorls, and in other correlative characteristics.

Depressed tubercles similar to those of the young of *obtusum* appeared, in the only specimen in which they could be detected, on the last quarter of the second whorl, and true pilæ on the third quarter of the third whorl, earlier by one volution than in var. E of *obtusum*. Thus even in this unimportant character acceleration appears to have taken place as it had in other characters.

There is one specimen of this species in the Museum of Stuttgardt, from the Geometricus bed of Göppingen, though it is more common in the Obtusus bed. The largest specimen in this Museum reached a diameter of 450 mm. (Pl. X. Fig. 1, 2). The last whorl was perfectly smooth, the abdomen had become subacute, and the channels obsolescent, resembling those of the adults of *Ast. Collenoti*.

Asteroceras acceleratum, Hyatt.

Plate IX. Fig. 4. Plate X. Fig. 3.

Locality. — Semur.

The involution covers two fifths of the sides on the sixth whorl, and one half of the second quarter of the eighth, whereas in *Ast. stellare* the extreme limit of involution is one third. The whorl is similar to that of this species, but is much broader abdomino-dorsally. The umbilical shoulders are large and abrupt, the dorsum much broader than the abdomen, the latter being but little wider than the area of the channels. The latter are very broad and shallow, with smooth but depressed lateral ridges. The keel is well marked, but depressed as in *obtusum*. The abdomen is therefore quite different from that of either *Brooki* or *Turneri*.

The young are similar to *stellare* until a late nealogic stage, and differ only in the greater involution of the whorls in later stages, and in the earlier development of the senile folds and trigonal form. The umbilicus could be observed in only one specimen. In this the pilæ began with coarse folds on the last quarter of the second whorl, which developed into true pilæ on the first quarter of the fifth whorl.

The largest specimen from Semur measured 202 mm., and had completed the seventh, and part of the eighth volution. The breadth of the first quarter of the eighth whorl measured on the sides was 77 mm. There is a specimen in the Museum of Stuttgardt, labelled *Amm. stellaris*, found at Göppingen in the

Geometricus bed, and one, broken across, from the Obtusus bed at Balingen. The last (Pl. X. Fig. 3) shows the young with shallower channels and flattened sides, somewhat similar to *Ast. obtusum* at an older period.[1] The sides of the young, however, are flatter and broader than I have yet seen in any variety of *stellare*, and more like those of an aged *Cor. trigonatum*. The characteristics of the nealogic stages and of the adult are evidently geratologous. This specimen is 258 mm. in diameter. The whorl of the adult is smooth, and of same shape as the senile stage of *Ast. obtusum*, and the sutures also agree exactly with those of the old of that species. Comparing it with a specimen of *Turneri* from Endigen of about the same size, it is seen that the latter has a much broader abdomen, deeper channels, more trenchant keel, and keeps its pilæ and form intact until a much later age, than *Ast. acceleratum*, and it does not increase in size so fast, is not so involute, and grows much larger. There are also several very fine specimens from Endigen, which enable us to connect *acceleratum* with *stellare* without the aid of the similar varieties from Semur or Gmünd, and they are regarded as so connected by Professor Fraas, who has labelled them *Amm. obtusus*. There is a series of five perfect specimens belonging to the Stuttgardt Museum, sufficient to convince the most sceptical. Nevertheless, it differs in the form of the young and in the adult from either *stellare* or *obtusum*, being both more involute and more accelerated in its mode of development. It is, as a rule, identified with *Brooki*, and it bears the same relation to *obtusum* that *Ast. impendens* bears to *Turneri*.

SECOND SUBSERIES.

Asteroceras Turneri, HYATT.

Plate IX. Fig. 8, 9. Summ. Pl. XIII. Fig. 3.

Amm. Turneri, Sow., Min. Conch., V. p. 75, pl. cccclii.
Aster. stellare, HYATT, Bull. Mus. Comp. Zoöl., I., No. V. p. 80.
Amm. compressaries, QUENST., Amm. Schwäb. Jura, p. 126, pl. xvii. fig. 4–6.
Amm. cf. obtusus, QUENST., Ibid., p. 143, pl. xix. fig. 9.
Amm. undaries, QUENST., Ibid., p. 148, pl. xx. fig. 2–6.
Amm. Turneri, QUENST., Ibid., p. 142, pl. xix. fig. 5 (not fig. 6–8).
Arietites Turneri, WRIGHT, Lias Amm., p. 292, pl. xii. fig. 1–6.

Localities. — Lyme Regis, Gloucester, Semur.

The amount of involution on the third quarter of the sixth whorl is two fifths of the side. The abdomen is broader, the channels more deeply sunken and broader, and the keel thinner and less immature in its aspect, than in *Ast. stellare* or *Ast. acceleratum*. The sides also are flatter, and the dorsum is but very slightly broader than the abdomen. The umbilical shoulders are abrupt, but the umbilicus is hardly so deep as in *acceleratum*, the lateral increase of the shoulders by growth being considerably less than in that species, though greater than in typical varieties of *obtusum*. The pilæ are thinner, more numerous, and do not have the

[1] This figure is erroneous in one important particular. The youngest part of the abdomen visible in the figure, as seen from the front, is much flattened, whereas in the specimen it was but slightly more depressed than in the older part of the same whorl, represented as trigonal immediately below.

fold-like character common in those species. They are more acute and about equally prominent near the dorsum, and also on the edge of the abdomen, and often interrupt the channel ridges. The earliest period examined was the third quarter of the fifth whorl. One specimen, from Lyme Regis, had a much narrower channel area than in *obtusum* of the same age, and the pilæ reached nearly to the base of the keel; in another, from Gloucester, the channels were better developed, but extremely narrow. This species even on the fifth volution had a better developed keel, deeper and more distinctly marked channels, and flatter sides, than any variety of *Ast. obtusum, stellare*, or *acceleratum*.

One specimen from Semur on the second quarter of the sixth whorl had lobes differing from two fifths to three fifths, and saddles from two fifths to one half.

Senile characteristics begin to appear on the latter part of the seventh whorl. The pilæ diminish to large folds on the second quarter of the eighth whorl, and subsequently disappear altogether. The channels also increase in breadth and diminish in depth. The keel acquires greater prominence in the clinologic stage on account of the shallowness of the channels, but finally becomes depressed. The largest specimen measured had about eight whorls, and the diameter was 327 mm.

A fine series of this species is in the Museum of Stuttgardt. These shells became smooth at variable ages. One from Balingen, about 113 mm. in diameter, had become entirely smooth; another from Endigen nearly half a whorl older had still very prominent pilæ. The peculiar form of the whorl, the deep channels and flat sides, hold constantly, however, in these, as well as in a young specimen from Balingen, labelled *Amm. obtusus*, which also belongs to this species. This last is beautifully preserved, and may be compared with *obtusum* of the same age and perfection.

The forms identified by Oppel in the Museum at Munich as *Amm. Turneri* precisely accord with the above.

The adult specimens of one variety of *Turneri* and a large variety of *Arnioceras*, found together in the Planicosta bed at Lyme Regis, are quite similar, and have led to confusion in names, though the young are distinct, and the pilæ of Arnioceras are not bent or curved as in *Ast. Turneri*. The same error has been also repeated by Quenstedt in his identification of *Amm. cf. obtusus*,[1] a variety of *ceras* from Ofterdingen, with the English form of this species as figured by Wright, i. e. with the young as shown in Wright's plate.

Another source of confusion lies in the resemblances of fragments of the more discoidal variety of this species, when of considerable size, to *Ver. Conybeari*. One fragment of an outer whorl from Lyme Regis in the Museum of Comparative Zoölogy is very similar to a *Conybeari* of the same size. It has pilæ not quite so straight, the geniculæ form an even curve with the pilæ, and the abdomino-dorsal diameter is greater in proportion than is common in that species. The abdomen is precisely similar in its keel and channels.

[1] Amm. Schwab. Jura, pl. xix. fig. 6-8 (not fig. 5).

Asteroceras Brooki, Hyatt.

Plate IX. Fig. 5-7. Summ. Pl. XIII. Fig. 4.

Amm. Brooki, Sow., Min. Conch., II. p. 203, pl. cxc.
Amm. Brooki, Quenst., Amm. Schwäb. Jura, pl. xx. fig. 11, 12; pl. xxi. fig. 1 (not pl. xv.).
Ariet. Brooki, Wright, Lias Amm., p. 280, pl. vi. fig. 4, 5.

Localities. — Lyme Regis, Bempflingen?

The pilæ are very close together and well defined on the first quarter of the third volution. On the last quarter of the sixth volution, peculiar geniculæ are formed by the abrupt bending of the straight pilæ, which contrast forcibly with the more gradual curves of these parts in *Ast. Turneri*. On the first quarter of the sixth whorl these are even better marked, owing to the depression of the abdominal parts and greater distance of the geniculæ from the channel ridges. There are, however, specimens in both species which do not differ in their pilæ at any stage, and are precisely intermediate in all characteristics (Plate IX. Fig. 5–7). The channels are perfectly well defined, and the lateral ridges are entire. The channels broaden out rapidly on the latter part of the fifth whorl, but do not increase perceptibly in depth, and have probably already reached their full adult development.

The differences between the young of this species and the young of *Ast. Turneri* are considerable. The young of the latter throughout the fifth volution had a whorl with a dorso-abdominal diameter but very little longer than the transverse, while at a still later stage and in the adult the dorso-abdominal diameter is two sevenths longer than the transverse. This last is about the proportion of the same diameter upon the first quarter of the fifth whorl in the young of *Ast. Brooki*. The sides begin to be convergent at a much earlier age in *Brooki*, and the resemblance to the old of *Turneri* becomes very close. The amount of involution is also one half on the latter part of the fifth whorl and the early part of the sixth volution, while in *Turneri* of the same age it is only one fourth, — about the same as in the young of *Brooki*.

The pilæ retain their distinctness and the channels increase in depth and breadth by growth, while the abdomen remains throughout much narrower than in *Ast. Turneri*. The increase of the dorso-abdominal diameter of the whorl by growth is more rapid in proportion to the transverse than in *Turneri*. The old shell even on the first half of the eighth whorl envelops more than half of the preceding whorl. This contrasts very decidedly with *Turneri*, which at the same age is less involute, and the transverse diameter of the whorl near the dorsum is but little shorter than the sides, the breadth of the abdomen being only about two fifths less than that of the sides. In this species the dorsal diameter is nearly a third less than the breadth of the sides, and the breadth of the abdomen is two thirds less.

The largest specimen measured had seven and a half volutions, and the diameter was 241 mm.

In the Museum of Stuttgardt from the Obtusus bed there is one specimen of this species labelled *Amm. Turneri*, Sow., Pleinsbach, No. 4187.

Asteroceras impendens, Hyatt.

Plate X. Fig. 6-9.

Ariet. impendens, Wright, Lias Amm., p. 302, pl. xxii. a, fig. 1-5.
Ariet. Collenoti, Ibid., p. 304, pl. xxii. a, fig. 6-9; pl. xxii. b, fig. 1-3.
Amm. Fowleri, Buckm., Murch. Geol. Cheltenh., pl. xii. fig. 7.
Amm. impendens, Quenst., Amm. Schwab. Jura, p. 151, pl. xx. fig. 7-10
Ariet. impendens, Blake, Yorkshire Lias, pl. vi. fig. 7.

Localities. — Semur, Lyme Regis.

This species differs from *Brooki* in the greater amount of the involution, the smaller size, the earlier age at which the same form of whorl is passed through, and the earlier age at which degeneration begins.

In Wright's "Lias Ammonites" the figures of *Brooki*, *impendens*, and *Collenoti* show in the clearest manner what are the proper limits of the species. The figure of *Brooki*, on Plate VI. Fig. 4, is taken from the less involute form, which retains its pilæ until a late stage of growth; that of *Collenoti* on Plate XXII. B is an old and very large individual of *impendens*, which approximates to *Brooki*, but has the usual difference in the amount of involution and begins to show degeneration of the pilæ also earlier than is common in *Brooki;* that of *Collenoti* on Plate XXII. A, Fig. 6–8, is a yet more accelerated form, growing old and losing pilæ, etc. earlier than in the specimen shown on Plate XXII. B. The figure of *impendens* itself is still more accelerated than the specimen figured on Plate XXII. A, Fig. 6–8, and has also somewhat stouter whorls. The young figured on Plate XXII. A, Fig. 4, is similar to the adult of the true *Ast. Brooki*, having the same form, pilæ, and involution until a late nealogic stage.

All of these forms have the broad abdomen, the peculiar channels, and the young like *Brooki*, and are quite distinct from the true *Ast. Collenoti.* They are undoubtedly transitional forms connecting the two species. Those who wish may join them, but, as we have previously said, all the series and about all the species of the Arietidæ are closely connected by intermediate forms and modifications, and, to be really consistent, we must then also include the entire family under a single specific name. We doubt if any paleontologist would secure serious support if he attempted to do this.

Asteroceras denotatum, Hyatt.

Amm. denotatus, Simps., Foss. Yorkshire Lias, p. 76.
Ariet. denotatus, Wright, Lias Amm., pl. vi. fig. 1 (*Collenoti* in the text, p. 304).
Amm. tenellus, Simps., Foss. Yorkshire Lias, p. 97?

This species has been universally placed either with *Brooki* or *Collenoti.* It is, however, quite distinct from either of these forms. If one compares the figure of *denotatus* by Wright with the young of *impendens* figured by the same author on Plate XXII. A, Fig 4, and that of the young of the same species by Quenstedt, Amm. Schwäb. Jura, Plate XX. Fig. 8, it will be seen that *denotatus* stands just between *impendens* and *Collenoti.* The young of *impendens* is much less involute, and shows the same stout whorl as in the adult, a form which is in strong contrast with the greater involution and flatness of the shell of *denotatus*. On the other hand, *denotatus* as figured by Wright, when compared with the accurate figure of adult *Collenoti* by D'Orbigny and of the young by Dumortier, shows that the latter is a form which is smooth, acute, and geratologous to an extreme degree at a much earlier age than either *denotatus* or *impendens*.

Asteroceras Collenoti, Hyatt.

Plate IX. Fig. 10-11 b. Plate X. Fig. 10. Summ Pl. XIII. Fig 5.

Amm. Collenoti, D'Orb., Terr. Jurass., I. p. 395, pl. xcv.
Aster. Collenoti, Hyatt, Bull. Mus. Comp. Zoöl., I., No. 5, p. 80.
Amm. Cluniacensis, Dumort, Étud. Pal. Bassin du Rhone, p. 148, pl. xxv. fig. 8-10.
Ægoc. Slatteri, Wright, Lias Amm., p. 374, pl. l. fig. 6-8 (not fig. 1-5).

Localities. — St. Thibault, Semur.

D'Orbigny's two original specimens now in the Museum of Comparative Zoölogy show that his figures are faithful. The pilæ in a specimen from St. Thibault, figured on Plate IX. Fig. 10–11 of this memoir, arise as lateral folds on the last quarter of the second volution, and become fully developed on the third whorl. On the first quarter of the third whorl, the keel appears, and on the second quarter the channels, but these are at first only linear depressions. At this stage the involution is about one third. On the second quarter of the fourth whorl, the channels are still shallow, but have depressed, lateral, entire ridges, the pilæ being prominent near the dorsum and disappearing on the edge of the abdomen before reaching the channel ridges. The involution is now about one half. The transition from the rounded whorl of the early nealogic stage to the acute form characteristic of the species takes place with extraordinary rapidity during the first quarter of the third volution. The usual intermediate stage, common in other species having a quadragonal or stout whorl with more or less depressed abdomen and flattened parallel sides, is entirely omitted. During the fourth whorl the smooth inflected zones, which represent the channels in this species, become developed, and the pilæ are better defined. On the first quarter of the fifth volution the elevation and sharpness of the abdomen increase, but no obvious changes occur in other characters; the involution of the whorl exceeds one half of the side of the preceding whorl. At this stage and immediately preceding it the resemblance to the adult of *denotatus* is extremely close, except of course as regards the difference of size and the superior sharpness of the abdomen. On the last part of fifth volution degenerative changes begin, the pilæ rapidly disappear, and the channel zones become less distinct.[1]

In D'Orbigny's other specimen, from Champlony near Semur, the pilæ are equally obsolescent on the last part of the third whorl, and on the first quarter of the fourth they are represented but faintly on the sides.

In another specimen, figured on Plate X. Fig. 10,[2] from the same locality, the pilæ are entirely absent, being represented only by lines of shell growth, or hardly perceptible folds, even on the first part of the fifth volution. On the

[1] Figured by D'Orbigny, Terr. Jurass , pl. xcv. fig. 6, 7.
[2] Also figured by the same author on pl. xcv. fig. 8.

second quarter of the fifth whorl in the St. Thibault specimen, the channel ridges are still raised lines marking the angular junctions of the sides and smooth channel areas. On the last part of the same whorl in the third specimen just mentioned, and in fact on the second quarter, even this angularity has almost wholly disappeared, the channels being obsolete, the keel therefore additionally prominent. The involution of the last part of the fifth whorl covers three fourths of the sides of the preceding whorl, exclusive of the channel area and the keel, which would somewhat increase this amount.

Oppel refers this species to the young of *Guibalianus*, our *Oxyn. Greenoughi*, in which, however, he was probably mistaken. The specimens in our possession show that this species has not been correctly quoted as coming from any other localities than Côte d'Or, the basin of the Rhone, and perhaps Hierlatz.

Sutures of the first specimen described above on the third quarter of the fourth whorl had lobes differing from one third to one half, and saddles about one third; and the third specimen on the first quarter of the fifth whorl had lobes differing one third and saddles a trifle less. The outlines of the suture are similar to those of Coroniceras and Asteroceras. Three saddles are to be seen upon the side, the inferior laterals being deeper than the superior laterals, as in other species, but the first auxiliaries are unusually large, nearly as deep as the inferior laterals, and very broad. The abdominal lobe, as stated, is from one half to one third longer than the superior laterals, and the superior lateral saddles about one third shorter than the inferior laterals. There is therefore no ground for the reference of this species to the genus Amaltheus, as has been supposed by some authors. According to Oppel this species is found in the Tuberculatus bed, and though Oppel probably never saw a true *Collenoti*, this statement is approximately correct. Dumortier's specimens of *Collenoti* (*Cluniacensis*) were found in his Planicosta bed immediately above the Oxynotus bed, and all of his beds above the Bucklandi and Davidsoni (Striaries) beds are equivalents of the Birchii or Tuberculatus zone at Semur. D'Orbigny's originals were reported as coming from the *Gryphea arcuta* beds, but this was evidently considered to be doubtful by Oppel, even before Dumortier found his specimens.

The extraordinary series figured and described by Wright from the Oxynotus bed, under the name of *Slatteri*, are widely distinct. The figures of the shell and sutures we have quoted above are certainly taken from a species which is very closely allied with the true *Collenoti*. It is assuredly an Arietian, with affinities allying it to *obtusum*, and comes nearer to *Collenoti* than any other species in respect to involution, smoothness, form of whorl, and abdomen. The other members of *Slatteri* as figured are probably diseased specimens of *obtusum*.

The keel of this species was examined very carefully to determine whether it was solid or hollow, and it was found to be solid.

A dwarf form of *Ast.* (*Ariet.*) *stellare* is figured by Geyer in his "Lias Ceph. d. Hierlatz b. Hallstadt," and his *Ast.* (*Oxyn.*) *Collenoti* is certainly very similar to, if not identical with, the French form of that name. *Asteroceras* (*Ariet.*) *stellaforme*, Wäh., Mojsis. et Neum., Beitr., VI., Plate XXVI., seems to be a species of this group occurring in the Kammerkahr Alps. The young being heavily tuberculated and the pilæ inclined towards the apex, the umbilicus reminds one of *Ast. obtusum*, var. *quadragonatum*. If it should prove identical when the young are examined, it would be interesting as showing the early occurrence of this species.[1]

SIXTH, OR OXYNOTICERAN BRANCH.

OXYNOTICERAS.

This genus was formerly considered by the author as a distinct family[2] from the Arietidæ. The similarity of the adult sutures, their mode of development, and the affinities of Oxynoticeras with Agassiceras, which it has been possible to trace more fully since the publication of Dumortier's "Études Pal. du Bassin du Rhone," show that the genus belongs properly to the Arietidæ, notwithstanding the hollow keel. The earlier nealogic stages have the psiloceran form, and the later nealogic stages have the form and characteristics of *Agass. striaries*, while the adult sutures are unquestionably arietian.

Baron Schwartz, to whom we are indebted for being made aware of the importance of the hollow character of the keel among the Ammonitinæ, was at the time of our visit at Tübingen searching for specimens of *Oxyn. oxynotum* in which the structure of the keel could be studied. Several specimens were subsequently found by the author in the collections at Stuttgardt and Semur, which showed the essentially hollow interior of the keel in *oxynotum*, and also in *Greenoughi*, *Guibali*, and *Lotharingum*. The late stage of growth at which it appears, and the early senile stage in which it completely disappears, are very marked in *Guibali*, and especially in *Lotharingum*.

The young of *Oxyn. Greenoughi* and *Guibali* are very similar in several varieties to those of *Agas. striaries*, and in *oxynotum* they are almost identical with this species.[3] The young of *Lotharingum*, however, have more accelerated development, and skip these *striaries*-like forms, beginning at a very early stage to resemble the adult of *Greenoughi*.

These facts appear to justify the conclusion that the first appearance of the hollow keel occurred in a genus whose origin is traceable by developmental characteristics to the arietian species *Agas. striaries*, and whatever its subsequent value, whether characteristic of families or common to larger groups, it must be here considered as of generic importance, and certainly not sufficient to outweigh other characters, which bind the oxynoticeran series to their associates among the Arietidæ of the Lower Lias.[4]

Oxyn. Greenoughi is in every way very nearly allied to *oxynotum*, and some varieties, especially among the German forms in the Museum of Stuttgardt, have more acute abdomens than the true *Greenoughi*, approximating very closely to the

[1] See notes on pages 100 and 205.

[2] Proc. Bost. Soc. Nat. Hist., XVII. p. 230, 1874.

[3] See description of *Oxyn. oxynotum*.

[4] If, as supposed by Quenstedt, a hollow keel also existed in Agassiceras, this argument is much strengthened, since this genus is in our view more decidedly arietian in its characteristics than Oxynoticeras.

stouter varieties of *oxynotum*. On the other hand, the duration of the *striaries*-like stage in *Greenoughi*, the sutures of the adult, which are simpler or more arietian in outline than in *oxynotum*, and the essentially hollow keel, seem to indicate an independent origin directly from *Agas. striaries*. The specimen of *Greenoughi* in the Museum of Stuttgardt, in which the hollow keel was observed, had the outer shell of the keel remarkably thick, but the interior evidently hollow, while in the French specimens at Semur the shell of the keel was of usual thickness. The former may possibly indicate a transition to *oxynotum*.

Oxyn. Guibali, however, by the resemblances of the young to the adult of *Greenoughi*, and by the younger period at which the adult characteristics of the species are inherited, is apparently a direct derivative from *Greenoughi*. The same reasons would also apply to *Lotharingum*, in which the young lose the *striaries*-like stage almost entirely, and repeat only the adult form and characteristics of *Greenoughi*. These characteristics, the continual decrease in the duration of the adult stages, and the earlier period at which the senile stage of decline makes its appearance in each successive species, indicate that these three species belong to a distinct subseries from *oxynotum*. The earliest representatives are found in the Tuberculatus bed at Semur, and in the Oxynotus bed of Dumortier in the basin of the Rhone. The different species seem, therefore, to form two subseries; one consisting of *oxynotum* and its allies, and another composed of *Greenoughi*, with *Guibali* and *Lotharingum* and their allies, but all on the same geological horizons.

First Subseries.

Oxynoticeras oxynotum, Hyatt.

Plate X. Fig. 4, 5, 14-22, 27 Summ. Pl. XIII. Fig. 9, 10.

Amm. oxynotus, Quenst., Petrefactkunde, XCVIII., pl. v fig 11; Amm Schwab. Jura, pl xxii. fig. 28-49.
Amaltheus oxynotus, Wright, Lias Amm., pl. xlvi. fig. 4-6.
Amm. oxynotus, Dum., Étud. Pal. Bassin du Rhone, pl. xxxiii. fig. 2, 3, 5 (not fig 1, 4).

Localities. — Lyme Regis, Cheltenham, Stonehouse, Gloucester, Hanover, Pliensbach, Balingen, Salins.

The young are at first smooth, and in this early stage resemble closely Psiloceras. They may continue to retain this smoothness and the rotundity of the abdomen until the specimen is 12 mm. in diameter, as figured on Plate X. Fig. 17. Their sides then become flatter, and slight folds and striations appear. The resemblance to *Agas. striaries* is so decided in some young specimens, that, if found independently, no one would hesitate to place them in the same genus as closely allied species. This same resemblance also necessarily includes a close likeness in the young to *Psil. planorbe*. The sutures are also similar to those of *Agas. striaries*, as may be seen in collections at Stuttgardt, where there is a very fine series of exceptional varieties collected by Professor Fraas.

The keel appears much later in the *striaries*-like forms figured on Plate X. Fig. 4, 5, than in the normal forms figured on Plate X. Fig. 16-18, but in all varieties the arietian characteristics of the sutures are apparent. The keel on its first appearance seems to be solid, though I could not, as in the case of

Oxyn. Lotharingum, determine this with absolute precision. If this could have been unquestionably settled, the evidence of descent from *striaries* would have acquired additional probability.

There is also an interesting variety which resembles the young of *Amaltheus margaritatus*, having even the crenulated abdomen, as figured on Plate X. Fig. 19. This leads into a variety having a blunter and deeply crenulated abdomen, as in *Phylloceras Boblayi*, and also resembling it in form, though distinct in the sutures (Plate X. Fig. 20). The involution, however, is irregular, decreasing with age, instead of preserving the normal amount of increase, though the specimens did not exceed an inch in diameter. These and Quenstedt's observation and figures, especially in his "Ammoniten des Schwäbischen Jura," show that all crenulated specimens in this group are probably pathological, and also in most cases dwarfish.[1]

The typical form, figured on Plate X. Fig. 18, prevails in the majority of specimens, and the resemblance of these to the young of *striaries* is very much obscured by the early development of the compressed adult form, the sharp keel, and characteristic sutures of the species.

The structure of the keel in one specimen at Semur was plainly visible (Plate X. Fig. 27). The external shell enveloped the cavity of the keel and the internal nacreous layer formed a convex floor, but the space between these two, instead of being hollow as in *Oxyn. Greenoughi*, was filled by layers of shell. These were thickest at the centre and gradually diminished to either side. Their attenuated lateral extensions formed a third layer between the outer shell and the nacreous lining, but how far this extended upon the sides was not ascertained. The dark-colored layer, which was considered an essential characteristic of a fully developed hollow keel by Baron Schwartz, is also present, lying just above the nacreous lining and a little on one side.

Besides these forms, there is at Semur, identified as a form of *Lotharingus* by Reynés, a variety of this species which attains the large size of 393 mm. Even at this size the characteristic form of the adult is maintained, though the involution is perceptibly less, the umbilicus being quite open. *Oxyn. oxynotum* is the only species of the group which attains as large size in its normal variety without losing the keel, and therefore I think the specimen belongs to this species. The examination of old and young forms at Semur enables us to state, that in extreme old age, when the shell is about 335 mm. in diameter, the form sometimes changes. The keel becomes very broad, a depressed zone makes its appearance on the sides near the umbilicus, and the involution becomes so much less that I have compared the aspect of the umbilicus to that of *Amm. Romani.*

The examination of specimens of *oxynotum* in the École des Mines at Paris showed a very thin external layer of shell near the abdomen, a thicker internal

[1] The small specimens figured by Canavari on Plate VI. of the work so often quoted above, as *Amaltheus margaritatus* and *actæonoides*, and *Ariet.* (*Oxynoticeras*) *Castagnolai*, are probably all related to these peculiar pathological forms, and are, notwithstanding their close imitation of the characteristics of *Amaltheus*, really only morphological equivalents. Canavari has himself referred *Castagnolai* to Oxynoticeras, and this is evidently an entirely distinct species from that figured by Wähner as *Castagnolai*, which in our opinion is a species of Caloceras

layer, which formed the partition above the keel, and above this again a succession of finer layers; but these did not fill up the interior of the keel completely. A hollow portion or zone filled in the fossil with pyrites, occupied the outer half of the interior of the keel. My notes and sketches make no mention of any dark layer in these specimens.

Oxynoticeras Simpsoni, Hyatt.

Summ. Pl. XIII. Fig. 11.

Amm. Simpsoni, Simps., Amm. York. Lias, p. 37.
Amaltheus Simpsoni, Wright, Lias Amm., p. 392, pl. xlvii. fig. 4–7.
Amm. oxynotus (pars), Dum., Étud. Pal. Bassin du Rhone, pl. xxxiii. fig. 1, 4? (not fig. 2, 3, 5).

Locality. — Whitby.

This species is quite different in form, sutures, and the amount of involution, and it is better to hold it as distinct than to confuse it with *oxynotum*.

It is admirably figured by Wright. The shell is considerably more tumid, the whorl thicker and stouter than in *oxynotum*, and this peculiarity is observable even in the young. The amount of involution is greater, and consequently the umbilicus is smaller, than in that species. The margins of the sutures are much simpler, especially as regards the auxiliary lobes and saddles than in *oxynotum*. It is intermediate in all its characteristics between *oxynotum* and *Lymense*, and this is an additional reason for separating it from the former.

If we are right, either this species or a form transitional to it is found in the basin of the Rhone.

Oxynoticeras Lymense, Hyatt.

Summ. Pl. XIII. Fig. 12.

Amaltheus Lymensis, Wright, Lias Amm., pl. xlvi. fig. 1–3; pl. xlvii. fig. 1–3; pl. xlviii. fig. 1, 2.
Amm. Sæmanni, Dum., Étud. Pal. Bassin du Rhone, p. 154, pl. xl., xlii.
Amm. oxynotus, Hauer, Ceph. Nordostl. Alpen, pl. xiii. fig. 3, 4, 8, 9 (not fig. 6, 7).

Locality. — Lyme Regis.

This is merely a more involute form of *Oxyn. oxynotum*, which deserves a separate name on this account, but is closely related to that species.

Oxynoticeras numismale, Hyatt.

Amm. oxynotus numismalis, Quenst., Amm. Schwäb. Jura, p. 289, pl. xxxvii. fig. 1–3, 6, 7 (not fig. 4, 5).
Amaltheus Wiltshirei, Wright, Lias Amm., pl. xlviii. fig. 3.

Locality. — Boll.

This species has, according to Quenstedt's figures, young similar to the adults of *oxynotum*, and the adult has a hollow keel. This is lost in old age, the whorl becoming rounded as in *Lotharingum*. It seems to be an extremely geratologous form of the first subseries surviving in the Middle Lias. The sutures are oxynoticeran in outline, and confirm this view of the affinities of the species.

Quenstedt considers it identical with *Oxyn. Oppeli*, which is, however, a stouter form at the same stages of growth. He also erroneously identifies it with *Oxyn.*

Lymense as described by Wright. The senile stages separate it from the last, though it is probably closely allied, and might be considered a variety if occurring in the same bed. Wright's *Wiltshirei*, which seems to be identical, was found in the Henleyi bed of the Middle Lias.

Second Subseries.

Oxynoticeras Greenoughi, Hyatt.

Plate X. Fig. 30. Summ. Pl. XIII. Fig. 13.

Amm. Greenoughi, Sow., Min. Conch., II. p. 71, pl. cxxxii.
Amm. Greenoughi, Hauer, Ceph. Nordöstl. Alpen, p. 46, pl. xii.
Amm. oxynotus, Hauer, Ibid., pl. xiii. fig. 6, 7 (not fig. 3, 4, 8, 9).
Amaltheus Greenoughi, Wright, Lias Ammonites, p. 384, pl. xliv.
Amaltheus Guibalianus, Wright, Ibid., p. 385, pl. xlv.
Amm. Guilbalianus, D'Orb., Terr. Jurass. Ceph., p. 259, pl. lxxiii.
Amm. Guibalianus, Reynés, Plates (pars).
Amm. Guibali, Reynés, Ibid.

The examination of German specimens led to the conclusion that this species was closely allied to *oxynotum* in development and in sutures, and the splendid suite of this species at Semur enabled us to solve all difficulties.

Here also we were able to compare it with specimens of the true *Collenoti*, D'Orb., the originals of which are in the Museum of Comparative Zoölogy, and they have not the slightest claim to be considered identical. Oppel was probably led astray by what he supposed to be the types in D'Orbigny's collection.

Reynés has divided this species into three forms, not very readily distinguishable by their adult characteristics, but quite distinct when their development and old age are studied. His principal observations on *Lotharingus*, *Guibali*, and *Greenoughi* were made in the Museum at Semur. We however refer his *Guibali* to *Greenoughi*, because of their close resemblance in development and old age, and, in order to avoid the use of a new name, distinguish the next species, his *Guibalianus*, as *Guibali*. This also is justified by the types in the Semur collection, in several of which these names are interchanged. The true *Guibalianus*, D'Orb., as may be seen by comparison of the original specimen and the Semur collection, has more abrupt umbilical shoulders, a more open umbilicus, less involute whorls, and retains the keel and typical form of the whorls until a later stage of growth than any of the group except *oxynotum*.

The shell sometimes attains the size of 235 mm. before any marked change of form is observable, and in one specimen reached the size of 410 mm. before the keel disappeared. Finally, however, the keel begins to disappear, and eventually all traces of it vanish in the rounded abdomen. The form, however, seldom changes as completely as in *Guibali*. The length of the ribs, whether they are all long or alternately long and short, is a characteristic of great variability, and is of no use in distinguishing the species.

There are, so far as we have seen, no representatives of this subseries in the South German basin, and this observation is sustained by Quenstedt's "Ammoniten des Schwäbischen Jura," which does not contain a single undoubted form of this subseries. Quenstedt's *Amm. Guibalianus* is not a true *Greenoughi*, and is properly referred by him to the *radians* group. An error is also shown by the use of this name for a species of the Middle Lias, since *Guibalianus* does not occur above the Lower Lias.

The species as figured by Wright is a large shell, about 475 mm. in diameter, which has already lost the keel and pilæ, the abdomen being rounded. The internal whorls of the original are heavily pilated, but the last whorl and a half are smooth. Sowerby's figure is taken from a very large and aged specimen, and the pilations shown in the umbilicus indicate a shell with heavier folds at the same age than exist in either Hauer's or Wright's figures. Wright's descriptions, however, coincide with Sowerby's figure, and the old of Sowerby's shell has a completely elliptical aged whorl. The size at which senility affects the shells, and the general characters and aspect of these figures, are the same as in *Greenoughi*. The young forms figured by Hauer may possibly be the young of this species; they seem to be too heavily pilated for the young of *oxynotum*.

Oxynoticeras Guibali, Hyatt.

Pl. X. Fig. 28, 29, 31. Summ. Pl. XIII. Fig. 14.

Amm. victoris, Dum., Études Pal. Bass. du Rhone, II. p. 136, pl. xxxi., xlii.
Amm. Guibali, Reynès, Plates (pars).
Amm. Guibalianus, Reynès, Ibid.

Locality. — Lyme Regis?

The keel of this species may begin to disappear in some specimens even at the size of 100 mm. In one specimen of the Semur collection this is accompanied by a singular and marked lateral deflection of the hollow keel, and at the size of 170 to 180 mm. it had wholly disappeared, and the outer whorl had a very broad and gibbous abdomen; the sides, however, remained convergent and rounded.

There is a specimen of this species from Lyme Regis in the Museum of Comparative Zoölogy, which was found associated in the same slab with *Cal. carusense* and *raricostatum*. The diameter of this specimen is 145 mm. The keel is not present on the cast, as is usual in this species, but it had probably been present in the perfect shell, and evidently not impaired by age; the whorl and involution of the sides were also not altered from the adult condition. A section showing the inner whorls had been formed by fracture, and the outlines of these, the hollow keel, and the amount of involution of the whorls, are the same as in *Oxyn. Guibali*.

Amm. victoris, Dum., is evidently closely allied to *Greenoughi*, but, as figured by Dumortier, presents very peculiar sutures. It attains a large size before losing the keel, though one was seen by Dumortier which at a diameter of 456 mm. had no keel. It may prove to be a form which is transitional between *Greenoughi* and this species.

Oxynoticeras Buvigneri, Hyatt

Amm. Buvigneri, D'Orb., Terr. Jurass. Ceph., pl. lxxiv.
Amm. Buvigneri, Dum., Études Pal. Bass. du Rhone, p. 147, pl. xxxiv.

The original is not correctly figured by D'Orbigny. The specimen is altered by compression, and this distortion is represented in his figure as natural; it has one side more compressed than the other, and this side has been selected in his figure as characteristic of both sides. The abdomen of the original also possesses a keel, which is not shown in the figure. The figure is, however, near enough to that given by Dumortier to enable one to identify it as the same, and the fact that it has a keel is an important point in this connection. It is much more involute than any species of the *Greenoughi* subseries except *Lotharingum*, but from this last it can be distinguished by the much larger size attained before the keel is lost. Dumortier's specimen reached the diameter of 126 mm., and D'Orbigny's that of 184 mm., without perceptible marks of senile degeneration. We regard this difference as an uncertain characteristic, but have no means of verifying the connection with *Lotharingum*.

Oxynoticeras Lotharingum, Hyatt.

Plate X. Fig. 23-26. Summ. Pl. XIII. Fig. 15.

Amm. Lotharingus, Reynés, Plates.

In this species at the size of 100 mm. the keel had almost disappeared, and the pilæ in several instances crossed the abdomen. The abdomen had become rounded, but the involution had not perceptibly decreased. The umbilicus is smaller in the adult, the whorls stouter in proportion than in the preceding species, and the characteristic form and aspect of *Greenoughi* are found only in the young. The younger stages had a solid keel, the hollow keel occurring only at later stages of growth and in adults, and it suffered from degeneration and finally disappeared in the senile stage. This is one of the most interesting examples yet discovered of the similarities of the old and young stages in the same individual. The resemblances which usually exist between the old and young shell are also present, and the absence of the hollow keel in extreme old age shows how seriously the organization may degenerate after the adult period, even with regard to the most important structural differentiations.

Oxynoticeras Aballoense, Hyatt.

Amm. Aballoense, Dum., Études Pal. Bass du Rhone, p. 141, pl. xxvii. fig. 1, 2; pl. xxviii. fig. 1; pl. xxxviii. fig. 1-3; pl. xl. fig. 1.

This species as described and figured by Dumortier seems to be quite different from *Greenoughi*, and yet the stouter specimens of that species certainly approximate to it quite closely. We have not the means at hand of finding by comparison whether the principal characteristics cited by Dumortier, namely, the deep umbilicus and abrupt shoulders of the whorls on the edge of the umbilici, are present also in *Greenoughi*, and therefore retain the separate appellation given by him. There is also a possible relationship with the *Oxyn. Oppeli* of the Middle Lias, which makes it desirable to keep it separate, for the present at least, from *Guibalianum*. If it is a distinct species, or even a distinct variety, of *Greenoughi*, it may be the immediate ancestor of *Oppeli*.

Oxynoticeras Oppeli, Schlön.

Summ. Pl. XIII. Fig. 16.

Oxynoticeras Oppeli, Schlön., Zeit. deutsch. Gesells., XV. p. 515.
Amm. Oppeli, Schlön., Paleontogr., XIII. p. 161, pl. xxvi fig. 4, 5.
Amm. Oppeii, Dum., Études Pal. Bass. du Rhone, p. 125, pl. xxxv., xxxvi.
Amm. oxynotus numismalis, Quenst., Amm. Schwab. Jura, p. 298, pl. xxxvii., fig. 4, 5 (not fig. 1-3, 6, 7)

The peculiar stout form of this species at the same age distinguishes it readily from the Middle Lias congener of the same name described and figured by Quenstedt.[1] The stout form of the young, gibbous sides, and the blunted abdomen, show that it may have been a member of a subseries in which *Aballoense* was the first representative in the Lower Lias. The figure by Dumortier exhibits a prominent keel even at the diameter of 165 mm. Schlönbach's specimens did not completely lose the keel until over 500 mm. in diameter.

Geyer in his Liass. Ceph. Hierlatz b. Hallstadt gives *Oxyn. oxynotum*, *Guibalianum*, and a form allied to the latter under the name of *Oxyn. cf. Collenoti*; also two undetermined species and a distorted form, named *Oxyn. Janus*. These are all small and dwarfish, except the first, which, however, cannot be called large, the largest individual measured by Geyer having been found to be only 74 mm. in diameter.

[1] Amm. Schwab. Jura, pl. xxxvii. fig. 1-3, 6, 7.

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TABLE I.—Genealogy of the Arietidæ in the Basin of South Germany, after Quenstedt,

NOTE.—Q.= Quenstedt, and O.= Oppel.

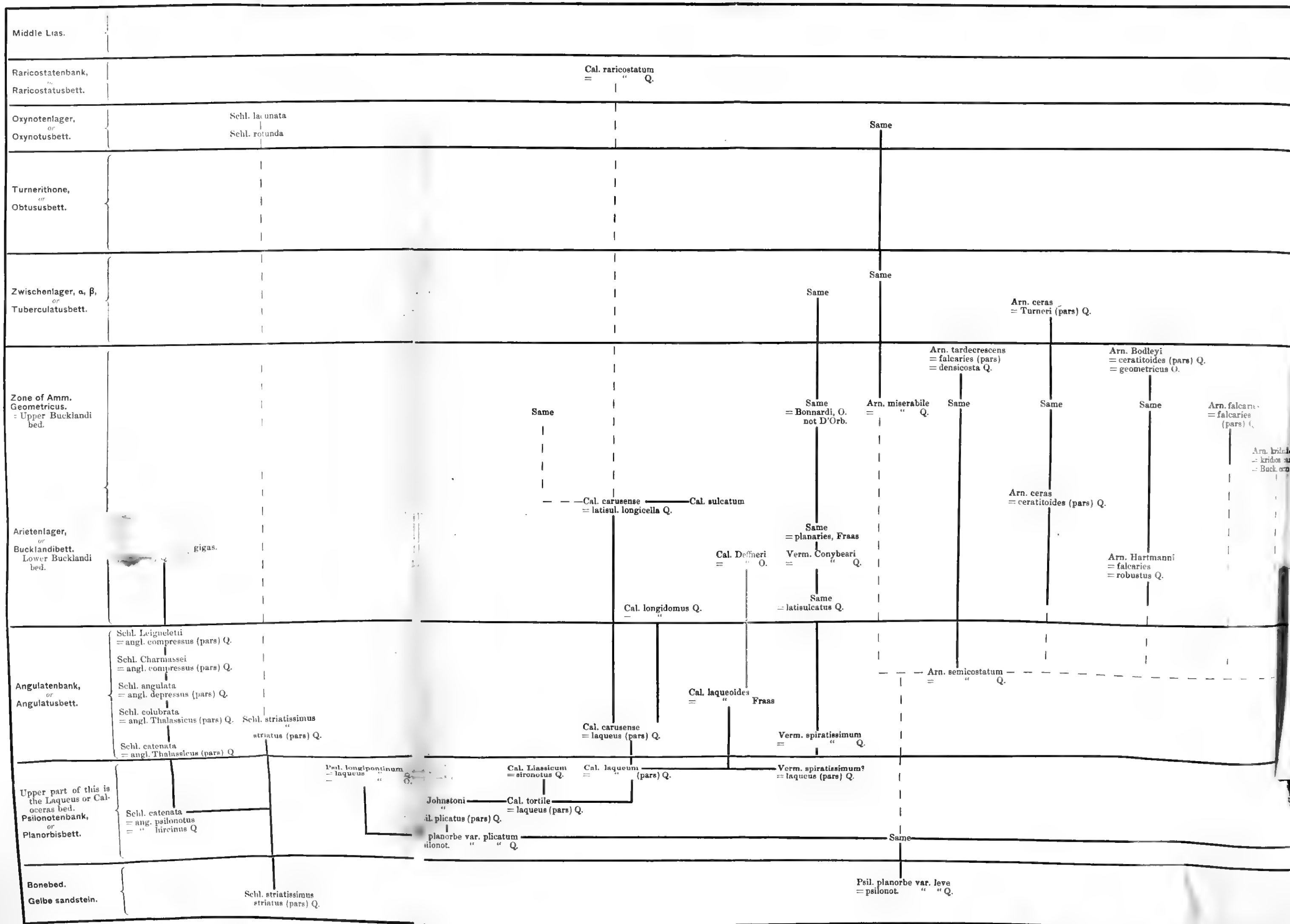


TABLE II.—Genealogy of the Arietidæ in the Basin of the Côte d'Or, after Collenot and the Collections at Semur, and Boucault's Collection in Museum of Comparative Zoölogy.

NOTE. — R. = Reynès, and Coll. = Collenott.

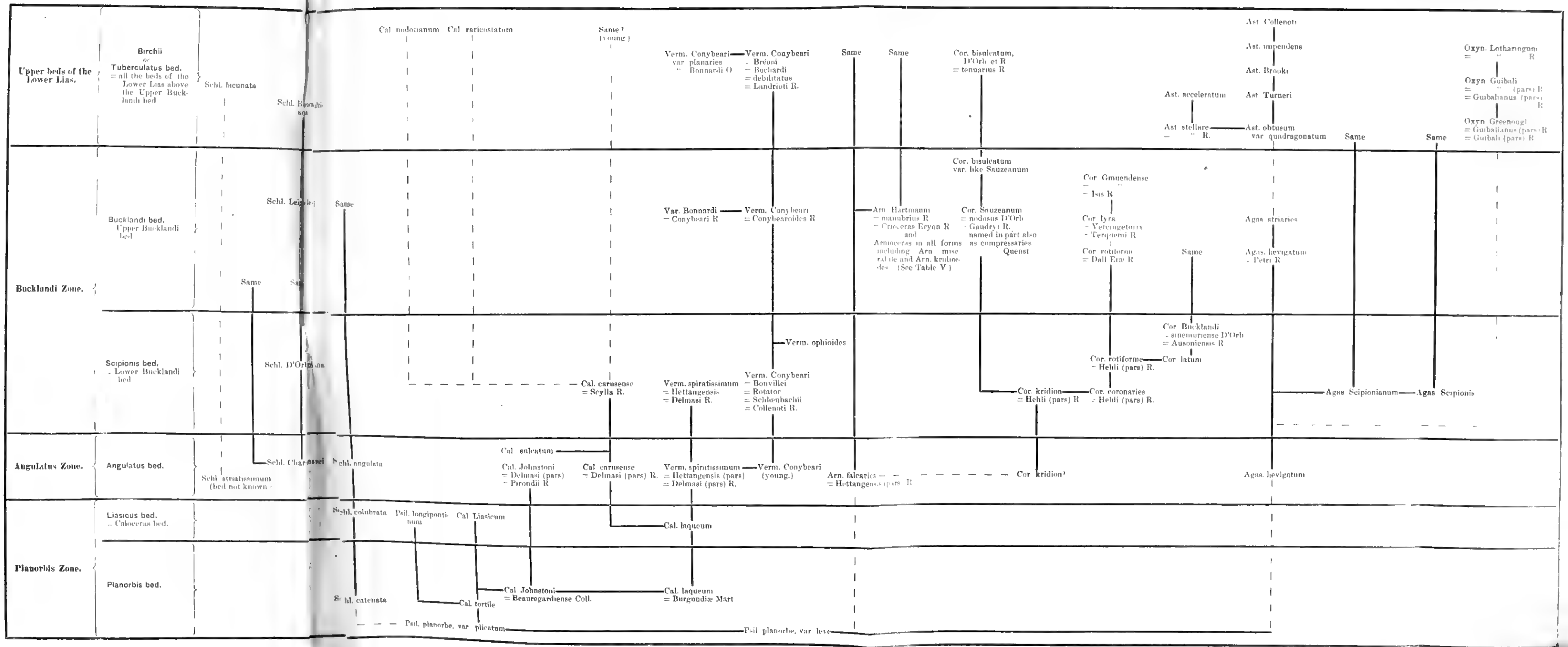
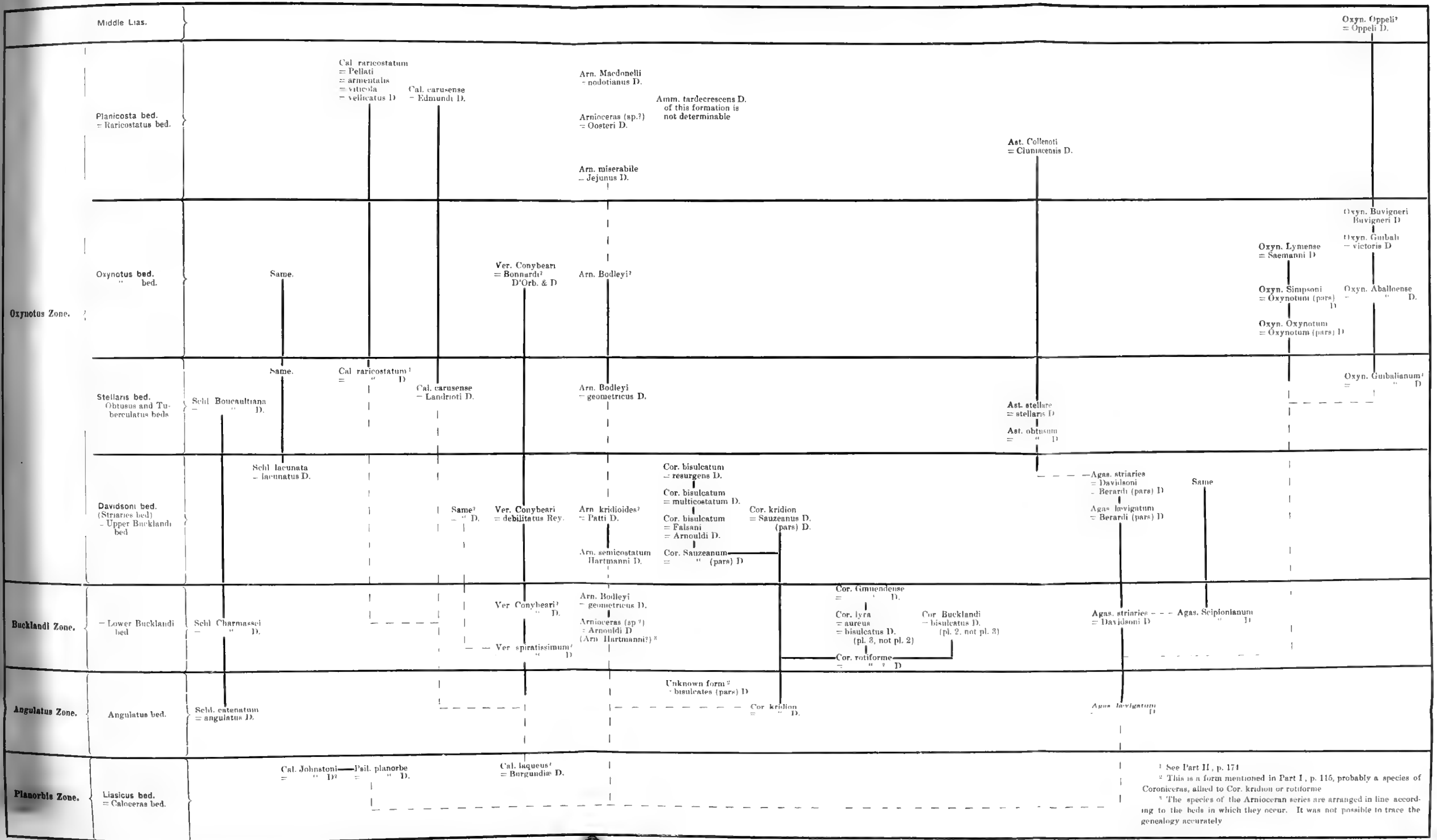


TABLE III.—Genealogy of the Arietidæ in the Basin of the Rhone, after Dumortier.

NOTE.—D. = Dumortier.



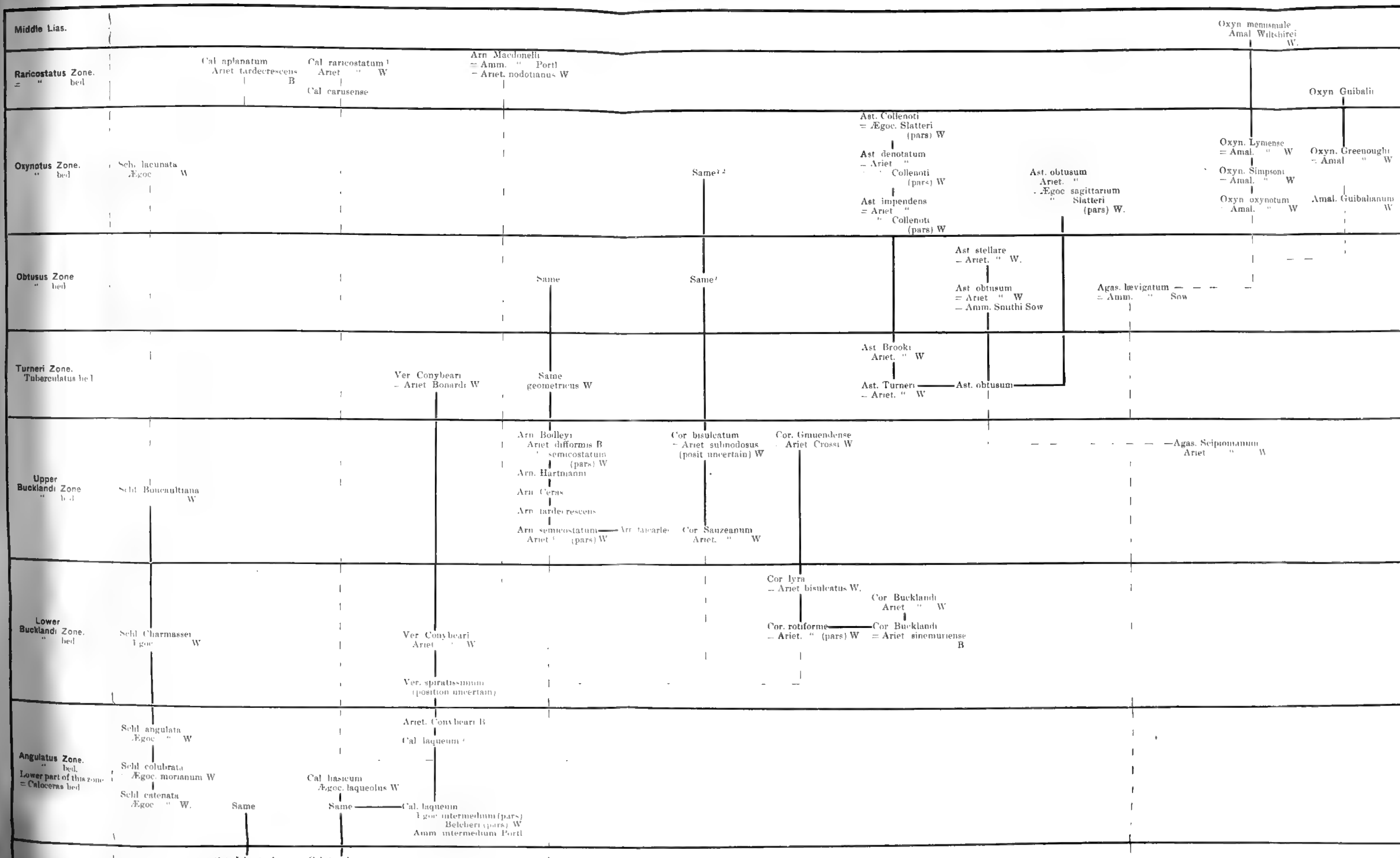
[1] See Part II, p. 174

[2] This is a form mentioned in Part I, p. 115, probably a species of Coroniceras, allied to Cor. kridion or rotiforme

[3] The species of the Arnioceran series are arranged in line according to the beds in which they occur. It was not possible to trace the genealogy accurately

TABLE IV. — Genealogy of the Arietidæ in the Basin of England, after Wright and various Collections.

NOTE. — W. = Wright, and B. = Blake.

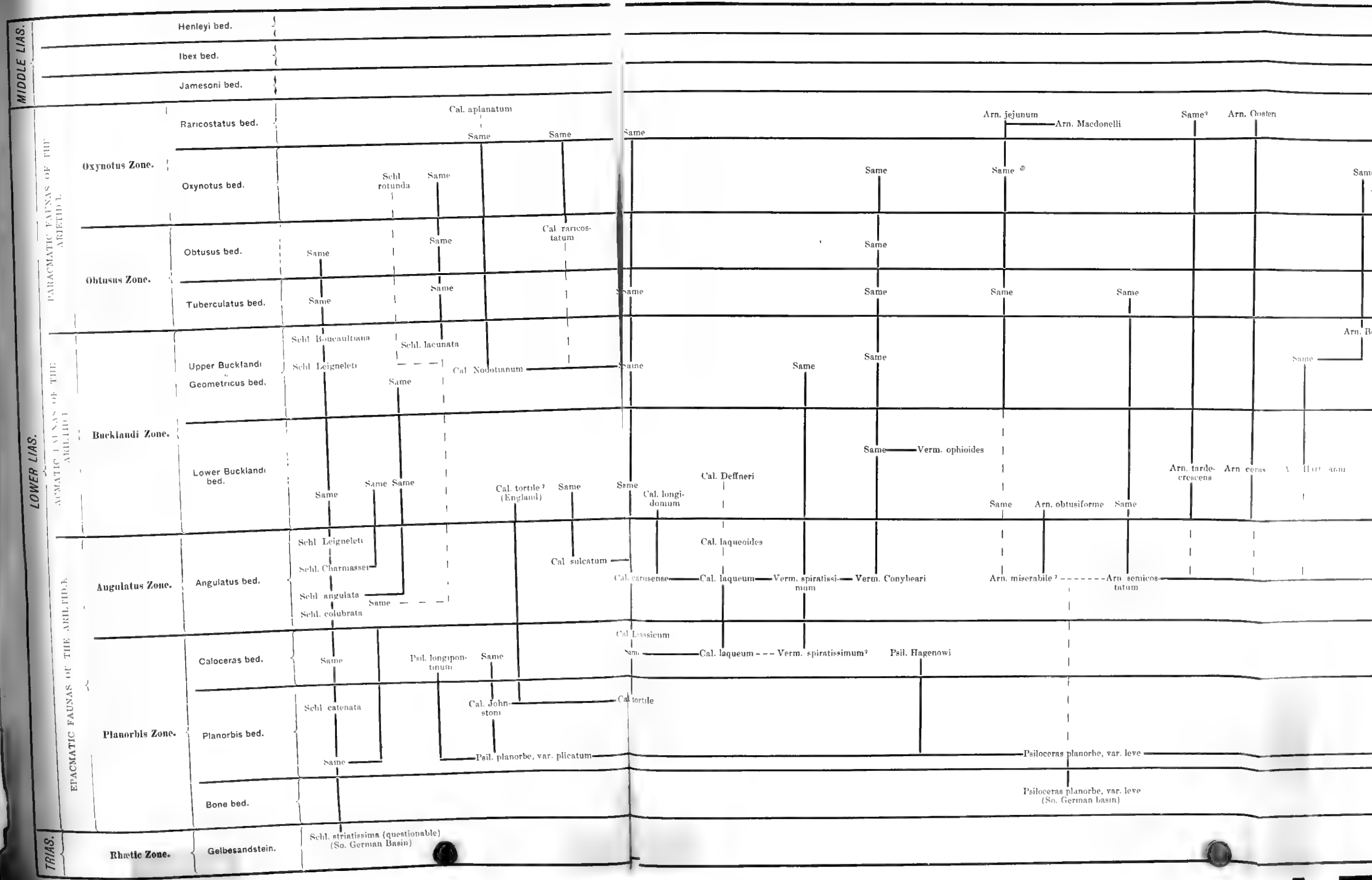


[1] May also occur in Oxynotus Zone, according to Wright.

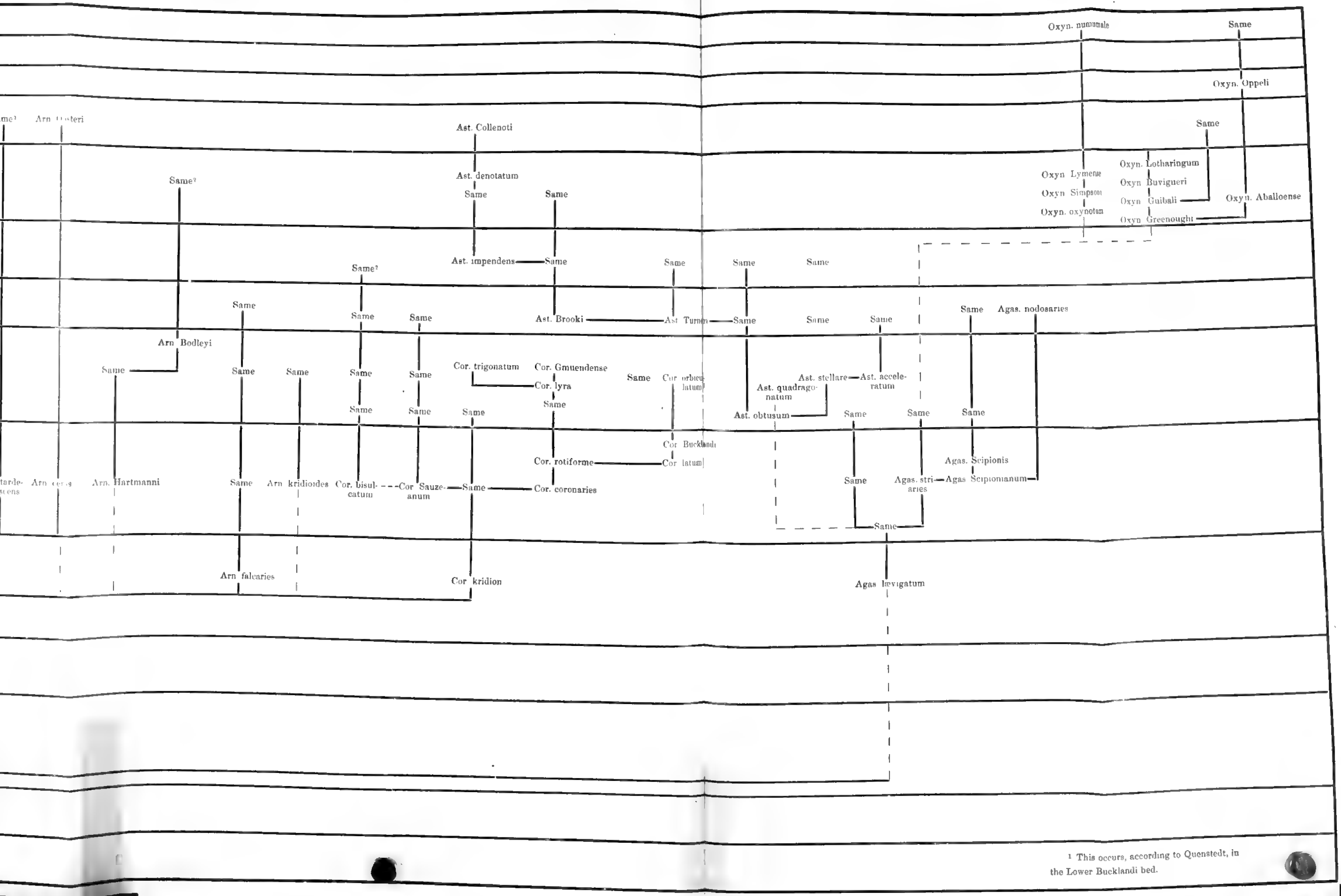
[2] See Wright's Plates, pl. 6, figs. 2 and 3.

[3] The lines connecting the species of Arnioceras indicate genetic bonds only in a very general way. The true succession of the forms is not given in this part of this table.

TABLE V. — Genealogy of the Arietidæ in the

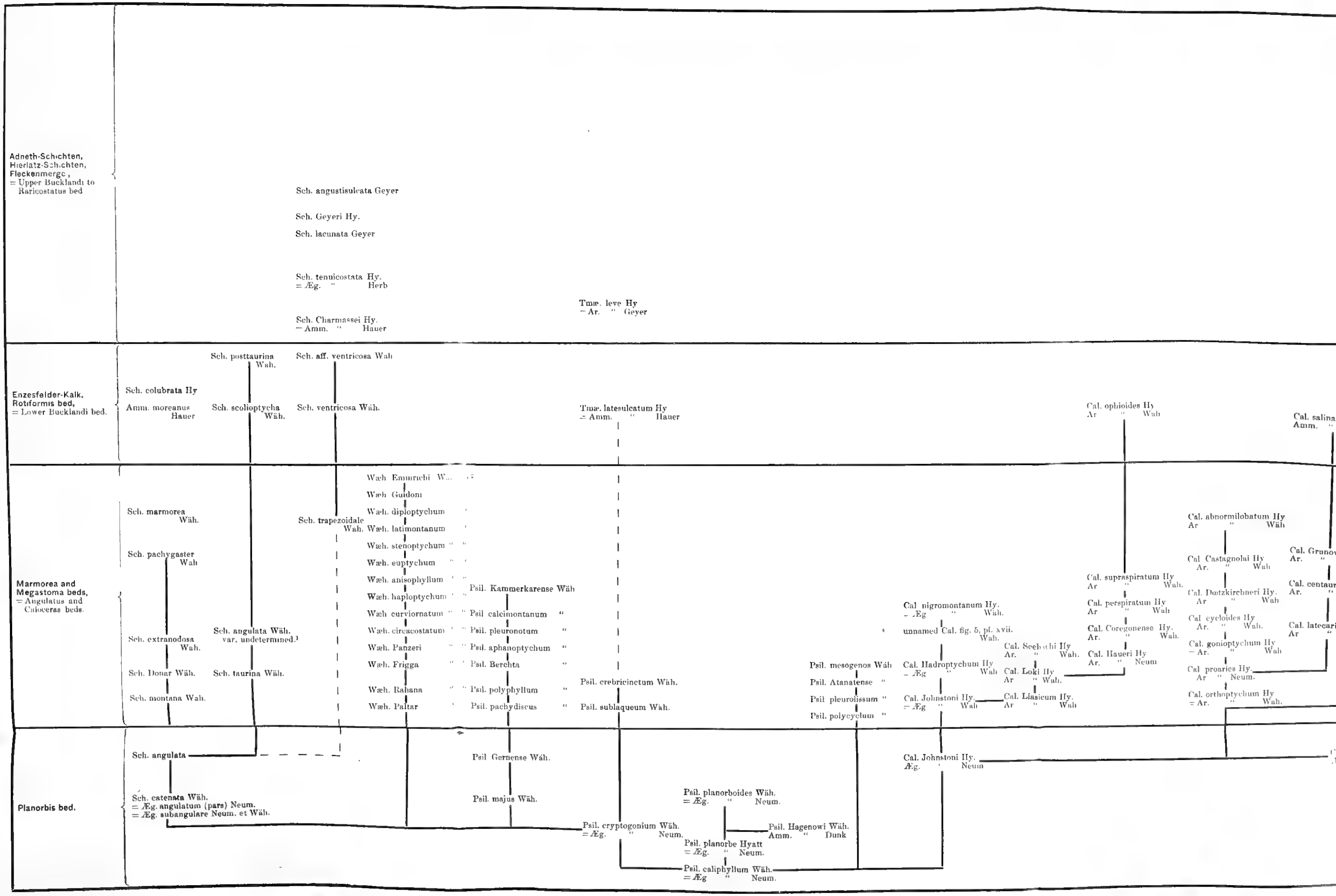


the Arietidæ in the Province of Central Europe.

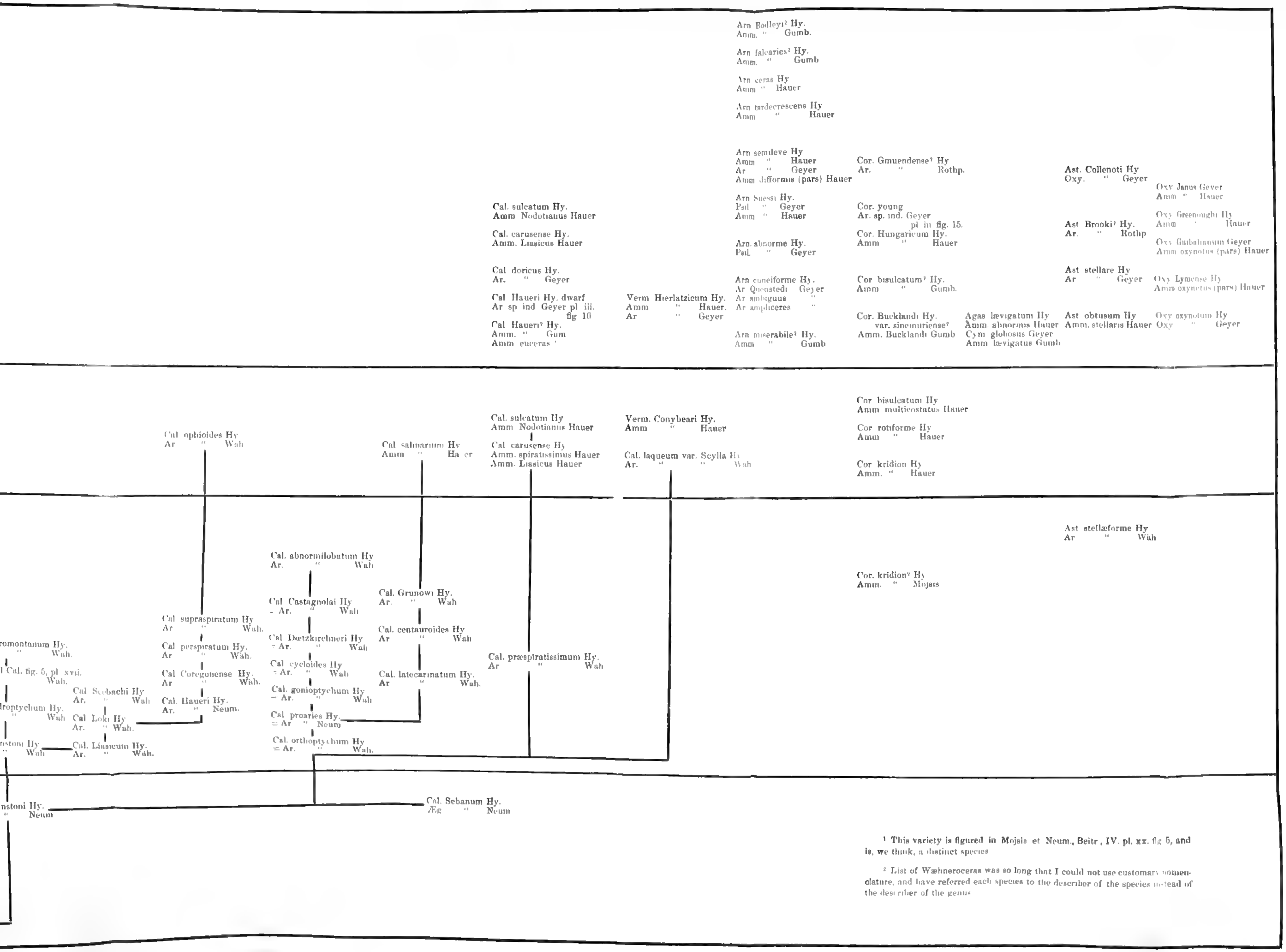


¹ This occurs, according to Quenstedt, in the Lower Bucklandi bed.

TABLE VI. — Genealogy of the Arietidæ in the Mediterranean Province, after Hauer, Neumayr, Wähner, M



Province, after Hauer, Neumayr, Wähner, Mojsisovics, Herbich, Gümbel, Geyer, and Rothpletz.



[1] This variety is figured in Mojsis et Neum., Beitr, IV. pl. xx. fig 5, and is, we think, a distinct species

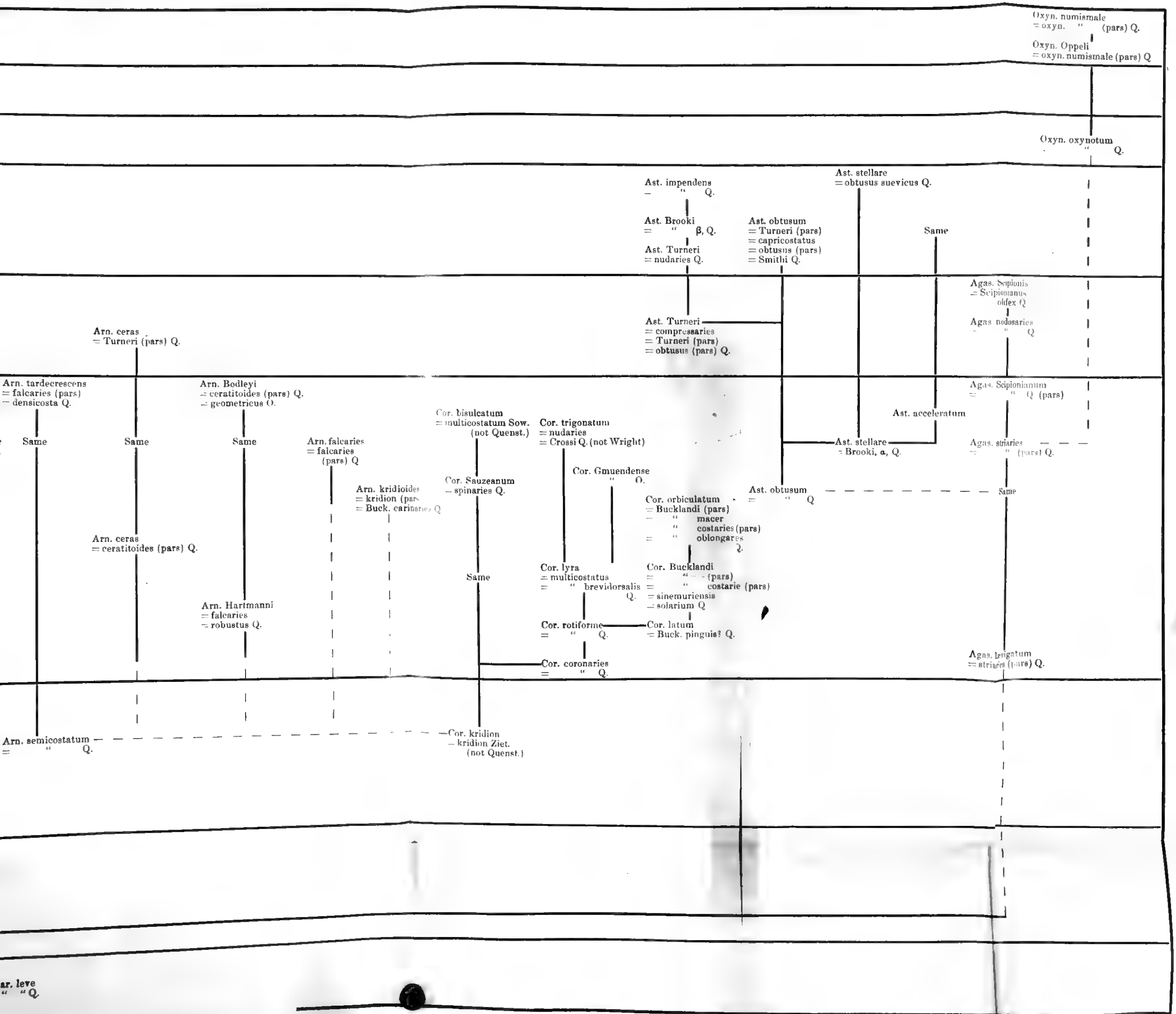
[2] List of Wæhneroceras was so long that I could not use customary nomenclature, and have referred each species to the describer of the species instead of the describer of the genus

[illegible]

[illegible]

n of South Germany, after Quenstedt, Fraas, Oppel, and their Collections.

E. — Q. = Quenstedt, and O. = Oppel.



EXPLANATION OF PLATES.

All specimens not otherwise described are in the collection of the Museum of Comparative Zoölogy, and all not mentioned as "casts" have the shell present, either in part or as a whole. Paul Roetter drew the figures in outline by measurement; the author redrew all the specimens using these outlines, but testing the accuracy of the measurements before they were finally placed on stone. The outlines in the Summary Plates were sketched by the author, and redrawn by Miss Pierson. Unless otherwise specified, the figures are approximately of natural size, although the process of reducing by photography from the enlarged drawings has introduced some slight deviations from the measured diameters of the originals.

PLATE I.

Psil. planorbe. Fig. 1, cast with incomplete living chamber, showing folds at an early stage of growth. Fig. 2, suture much enlarged. Loc. Whitby. Fig. 3, 4, cast with similar folds in the young, but smooth in the adult. Fig. 4 a, young of Fig. 4 enlarged. Loc. Neuffen. Fig. 5, 6, cast of the more involute variety, loc. Balingen. The specimen has distorted sutures, showing the broad abdominal lobe and the large median saddle on one side, but is otherwise normally formed.

Cal. Nodotianum. Fig. 7,[1] specimen reduced to less than one half, showing incomplete living chamber. Fig. 8, sutures enlarged. Fig. 9, a fragment of a cast showing sutures and part of living chamber. Fig. 10, section of four whorls. Fig. 11, a cast. Fig. 11 a, section of last whorl. Loc. Semur.

Cal. tortile. Fig. 12, specimen with portion of living chamber. Fig. 13, same, portions of the two outer whorls removed, showing their rounder outlines. Fig. 14, suture of same, enlarged. Loc. Semur.

Cal. carusense.[2] Fig. 15, cast of the younger stages, broken out of the interior of an adult specimen, loc. Balingen. Fig. 16, cast, loc. St. Thibault.

Verm. spiratissimum. Fig. 17, cast, living chamber incomplete, loc. Nellingen. Fig. 18, specimen with distinct channels, developed at an early age, loc. Semur.

Cal. sulcatum. Fig. 19, specimen with incomplete living chamber, showing the smooth young in the centre. Fig. 20, suture of the same, enlarged. Loc. Semur.

Verm. ophioides. Fig. 21, cast of a broken specimen, showing the well developed channels and keel in the young, and the early appearance of the pilæ. Figs. 22, 23, sutures of this and an older specimen, enlarged. Loc. Semur.

Cal. raricostatum. Fig. 24, specimen, showing the senile metamorphoses. Fig. 25, section of last two whorls, showing the corresponding change of form for comparison with Fig. 25 a, the adult of the same variety.[3] Loc. Balingen.

[1] This figure is not numbered.

[2] See Plate II. Fig. 1.

[3] See Plate VI. Fig. 15, for the *Johnstoni*-like variety.

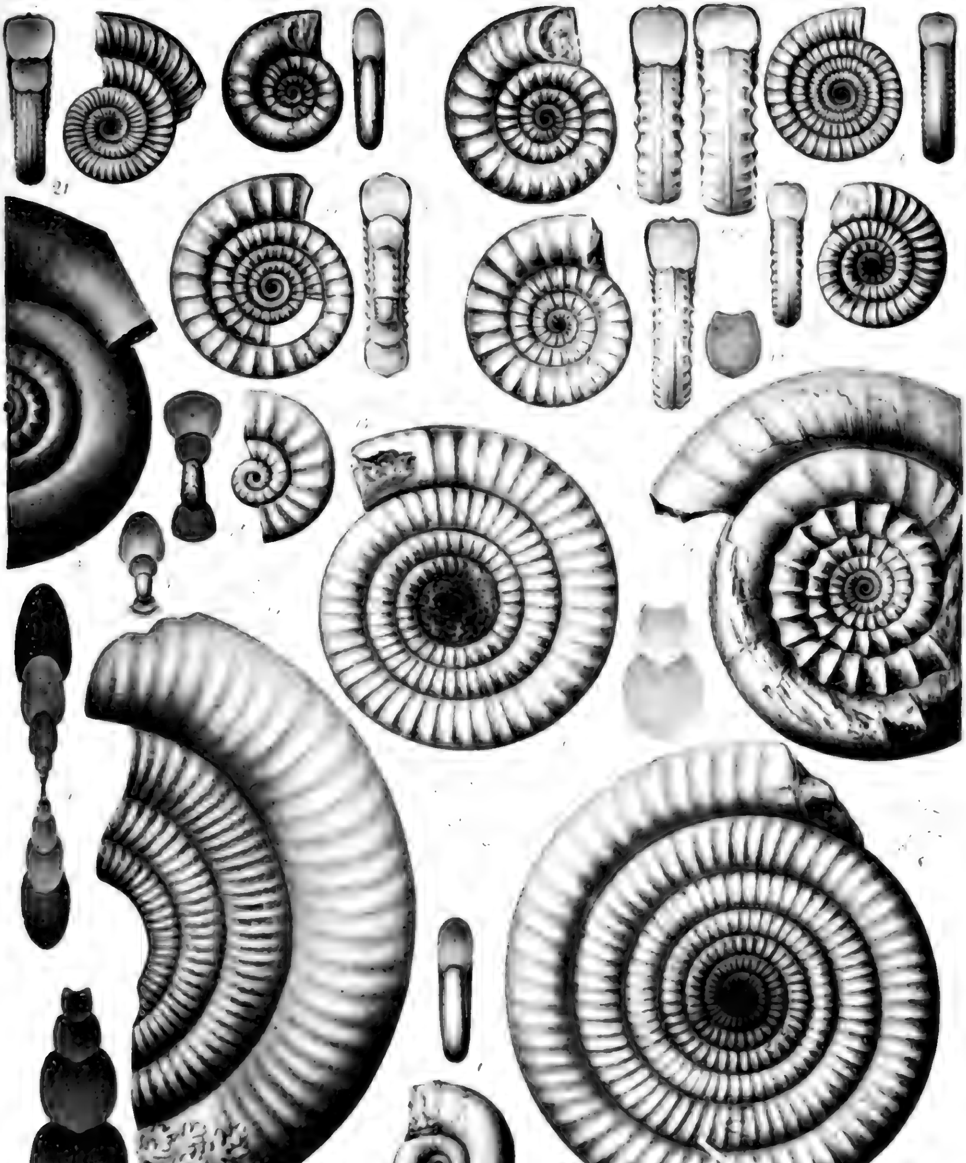


PLATE II.

Cal. carusense.[1] Fig. 1, specimen reduced to one third, showing incomplete living chamber and old age. Fig. 2, the same broken so as to show sections of the old whorls and the depressed abdomen of the adult stage. Fig. 3, enlarged adult sutures, also shown on Fig. 1. Fig. 3 a, same, but very old, also shown on Fig. 1. Loc. Semur.

Arn. miserabile. Fig. 4, large smooth specimen, with sutures and incomplete living chamber. Fig. 5, cast with sharp abdomen and gibbous sides, living chamber incomplete. Fig. 6, enlarged sutures of the same. Fig. 7, var. *cuneiforme*, with incomplete living chamber. Loc. Semur.

Arn. obtusiforme. Fig. 8, section of a cast, showing form of internal whorls. Fig. 9, specimen with incomplete living chamber. Fig. 9 a, enlarged sutures of fig. 9. Loc. Semur.

Arn. semicostatum. Fig. 10, variety with incomplete living chamber, the young remaining smooth until a late period of growth and ribs immature, loc. Semur. Fig. 11, cast, with ribs earlier developed than in Fig. 10, and slightly more prominent. Fig. 12, young from same blocks of limestone. Fig. 13 a, sutures from other young specimens on the same block, of different ages, all natural size. Loc. Whitby. Fig. 14, cast with folds in the extreme young stage and true pilæ beginning afterwards; otherwise the form is perfectly normal, loc. Basle. Fig. 15, normal variety with deep channels. Fig. 15 a, suture of the same, enlarged. Fig. 16, specimen with incomplete living chamber, channels developed at an earlier age than in normal variety, and abdomen broader and flatter in proportion than is usual in the species at any age. Loc. Semur.

Arn. Hartmanni.[2] Fig. 17, cast, loc. Bonnert. Fig. 18, suture of the same, enlarged.

Arn. tardecrescens. Fig. 19, cast of a young specimen with incomplete living chamber. Fig. 19 a, enlarged suture. Loc. Yorkshire.

Arn. ceras. Fig. 20 and 20 a, specimen with incomplete living chamber, a very broad abdomen, and deep channels, loc. Semur.

Arn. tardecrescens. Fig. 21 and 22, sutures of a specimen of a normal form (abdomen narrower than the last), at the diameters of 63 mm. and 83 mm. Loc. Semur.

Arn. Bodleyi. Fig. 23, broken specimen, showing planorbis-like folds on the young shell, with living chamber incomplete. Fig. 24, more involute variety with similar fold in the young and incomplete living chamber. Fig. 24 a, suture of the same, enlarged. Loc. Semur.

Arn. falcaries. Fig. 25, young with slight tubercles on the geniculæ. The last quarter is part of the living chamber. Fig. 26, larger specimen, ribs not tuberculated or arising from tubercles as in the above, and keel very prominent. Fig. 27, cast with deep channels and abdomen very narrow. Loc. Semur.

Arn. kridioides. Fig. 28, specimen showing the smooth young, the early period at which the pilæ begin, and the similarity of the umbilicus to that of a normal species of Arnioceras. Loc. Basle.

[1] See Plate I. Fig. 15, 16.

[2] See Pl. III. Fig. 1, 1 a.

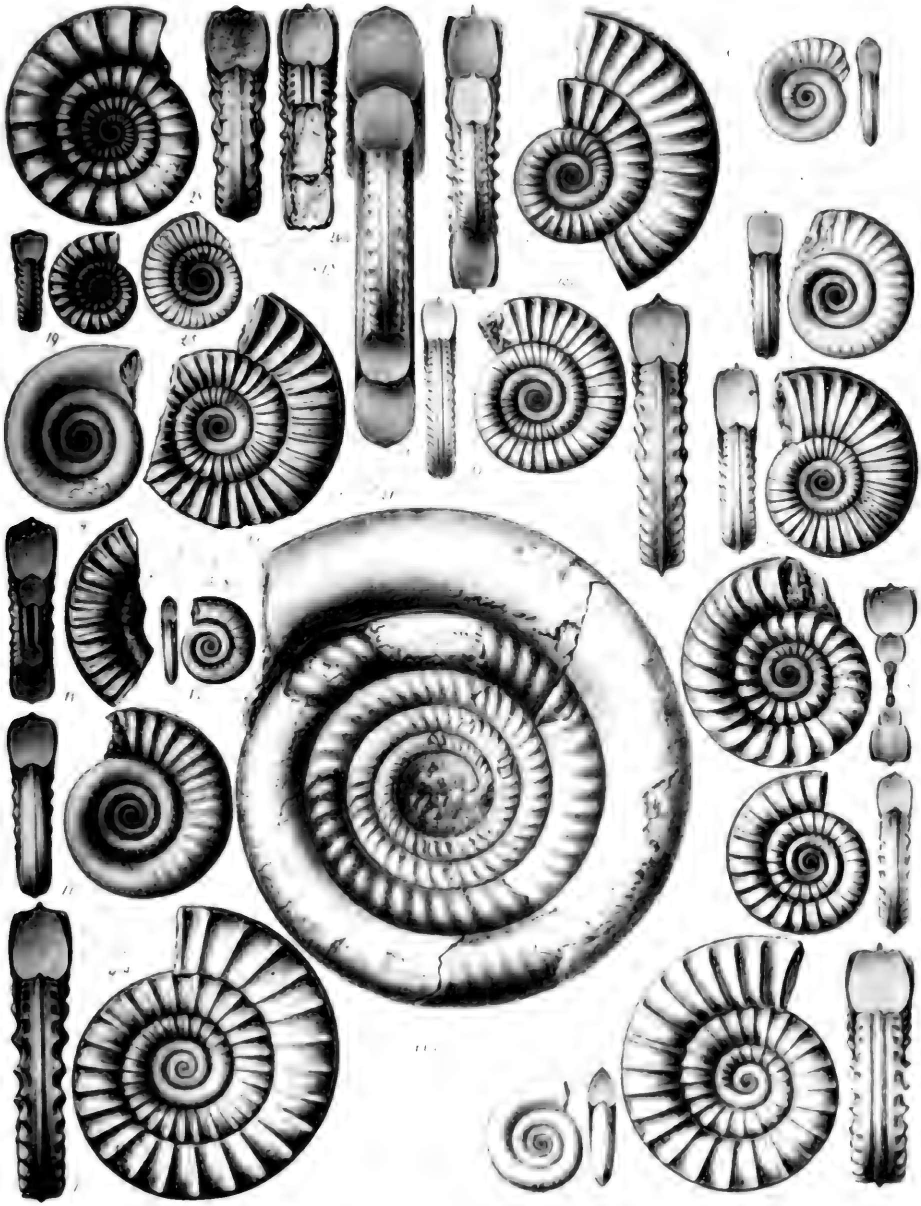


PLATE III.

Arn. Hartmanni.[1] Fig. 1, 1 a, cast. Fig. 1 shows the thick shell lying on the keel of the cast. Loc. Lyme Regis.

Cor. kridion. Fig. 2, young. Fig. 2 a, outline of young suture of Fig. 2, enlarged. Fig. 3, cast. The last volution in this represents the living chamber. Loc. Balingen.

Cor. rotiforme, var. A. Fig. 4–4 a, young smooth stage and suture. Fig. 5, 6, 8, 8 a – 10, 10 a, older stages of same. Fig. 7, 11–13, pathological cases with pilæ crossing the abdomen. Loc. Semur. Fig. 14, 15, 15 a, 16, *kridion*-like variety of this species. (Fig. 14, loc. Stuttgardt; Fig. 15, 16, loc. Balingen.) Fig. 17, 17 a, variety with discoidal form and large tubercles, figure reduced to about two thirds, loc. Semur. Fig. 17 b, sutures.

Cor. Bucklandi, var. **sinemuriense.** Fig. 18, figure reduced to less than one half, showing the divided pilæ of the young (*sinemuriense* stage), and the solid Bucklandian pilæ of the adult, loc. Semur.

Cor. latum. Fig. 19, young with narrow abdomen. Fig. 22, older stages of same variety, showing affinities for *Cor. rotiforme* and *Bucklandi*. Fig. 20, section of young of variety with broader abdomen. Fig. 21, 23, 23 a, older stages and suture of same. Loc. Semur.[2]

[1] See Plate II. Fig. 17.

[2] These specimens all appear to be in the nealogic stages of development.

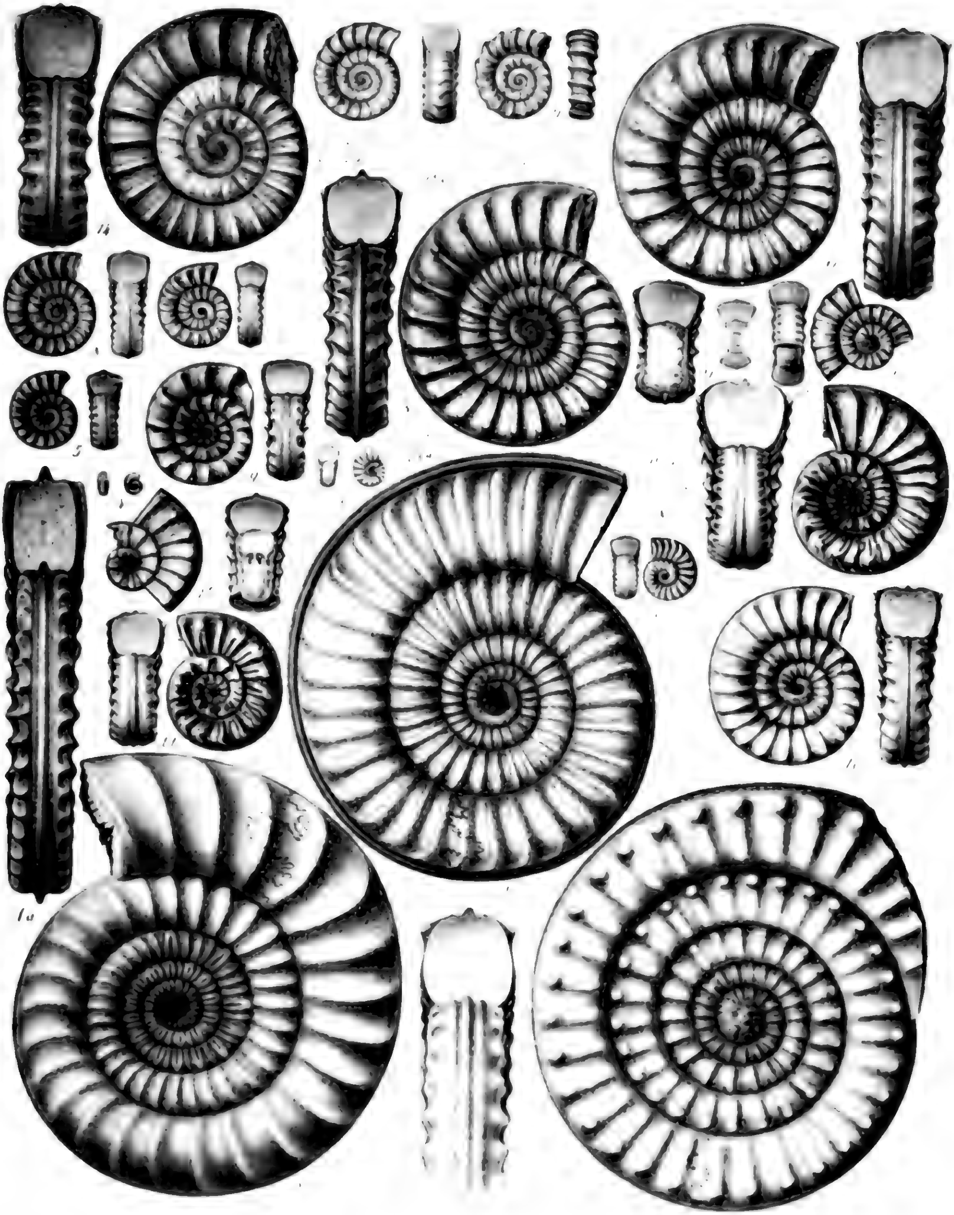


PLATE IV.

Cor. lyra.[1] Fig. 1, young of variety with broad abdomen and closely arranged pilæ. Fig. 2, young of var. B, with narrower abdomen and rounded sides. Fig. 3, older stage of same variety. Fig. 4, 5, nearly full-grown stage of same variety. Loc. Semur. Fig. 6, 7, full-grown stage of variety with narrower abdomen, flattened sides, and closely arranged pilæ, figure reduced to about one half, loc. Filder. Fig. 8, young of same variety as Fig. 1, but transitional to var. B. Fig. 9–11, young of var. C. Fig. 11 a, suture of same. Fig. 12–14, young of variety like Fig. 1, 1 a, and Fig. 8, but with narrower abdomen and more flattened sides. Loc. Semur. Fig. 15, 16, old specimen of var. C, with very convergent sides, and tubercles considerably reduced, diameter 250 mm., loc. Gmünd. Fig. 17, sutures on the inner side (dorsum),[2] loc. Semur.

[1] See Plate V. Fig. 1–3.

[2] All the specimens figured were casts.

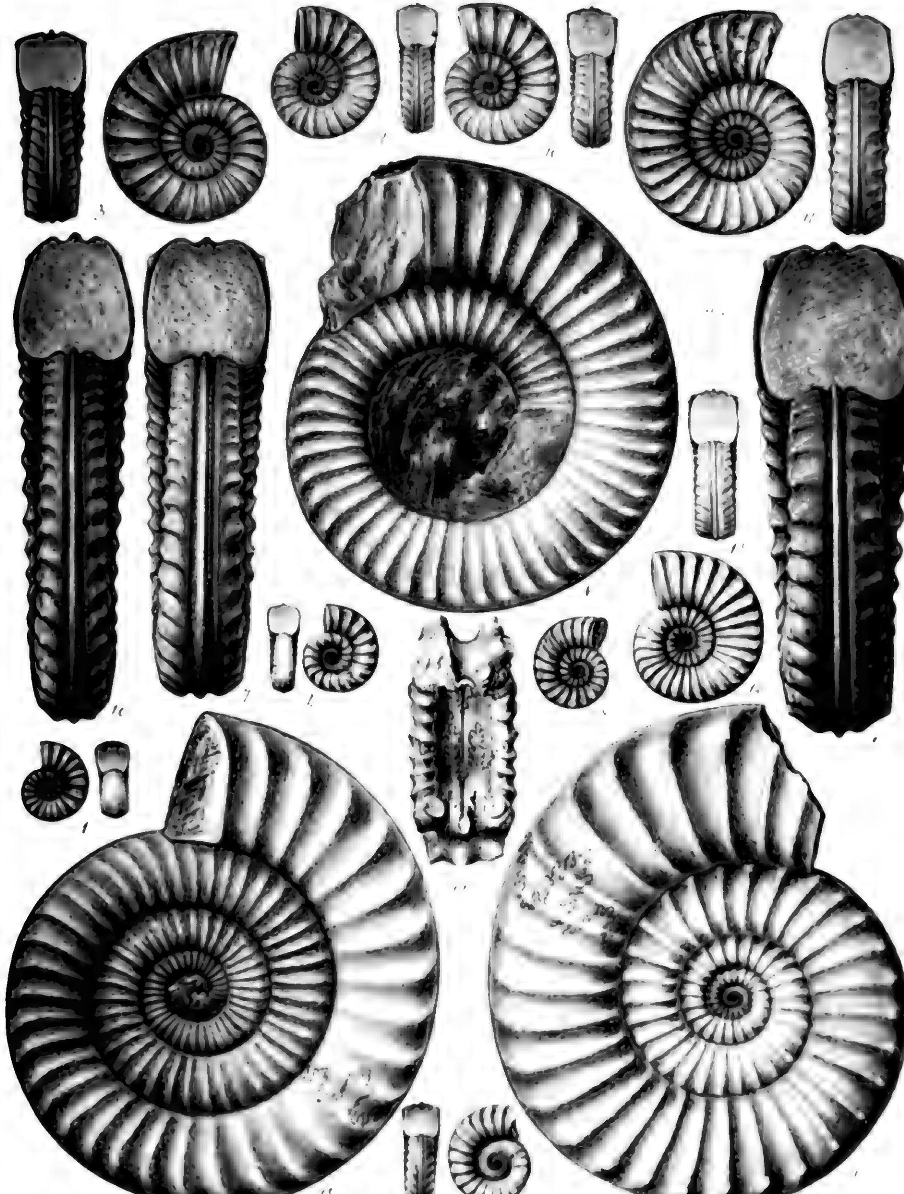


PLATE V.

Cor. lyra.[1] Fig. 1–3, half-grown shell of same variety as Fig. 6, 7, Plate IV., showing how narrow the abdomen is in some specimens before the shell was full grown. Fig. 3 a, suture, slightly older than that delineated on Fig. 2, showing the changes which had taken place. Loc. Semur.

Cor. Gmuendense.[2] Fig. 4, half-grown specimen, exhibiting variety with discoidal form and compressed whorls, figure reduced to less than one half. Fig. 5, full-grown specimen of same variety with marks of approaching old age upon the last whorl, figure reduced to less than one half. Loc. Semur. Fig. 6, specimen in which the wider abdomen and young proportion of Fig. 4 were maintained until a much later stage than in Fig. 4 or 5, figure reduced to about one half. Fig. 7, umbilicus of Fig. 6, about natural size, to show the smoothness of the young whorls. Loc. Aargau. Fig. 8, 9, same variety as Fig. 5, but showing the effects of senile decline in the convergence of the sides, degeneration of the pilæ and tubercles, diameter 205 mm., loc. Semur.

[1] See Plate IV.

[2] See Plate VI.

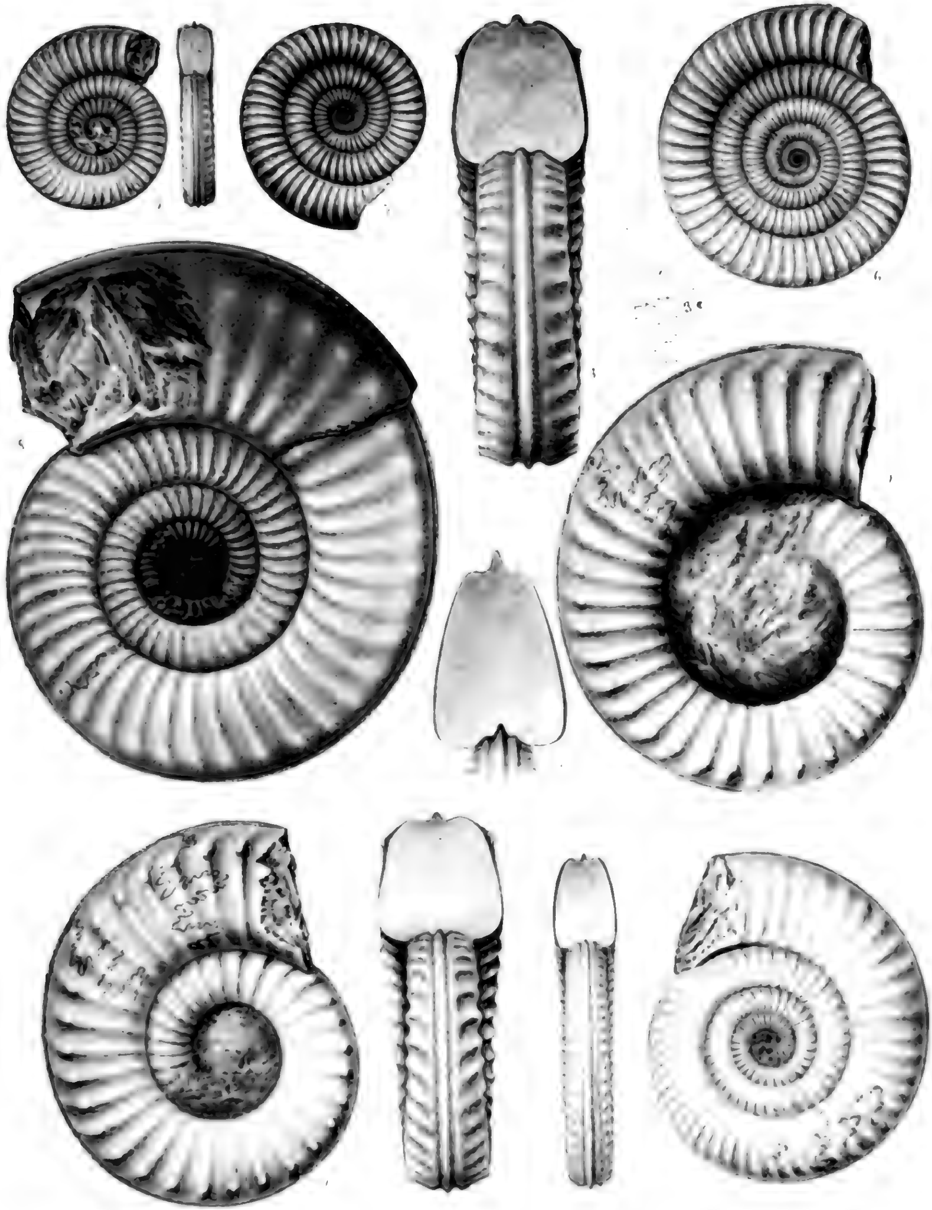


PLATE VI.

Cor. Gmuendense. Fig. 1, 2, figures reduced to about one third, taken from a specimen which exhibited compressed whorls and convergent sides at an older stage than in the specimens figured on Plate V. Old age is apparent also in the two closely approximated sutures of outer whorl. Loc. Aalen.

Cor. trigonatum.[1] Fig. 3, large variety, having stouter and more numerous whorls, and arriving at the same stage of senile decline later than in the smaller variety described in the text, figure reduced to about one third. Loc. Aalen.

Cor. Sauzeanum.[2] Fig. 4, young, loc. Whitby. Fig. 5, another older specimen, loc. Semur. Fig. 6, another specimen, broken across, showing embryo, and having keel just beginning to be perceptible on the outer whorl. Fig. 7, centre of same section enlarged, showing young whorls. Fig. 8, specimen like Fig. 12, in having no keel on the outer whorl. Fig. 9, variety in which both tubercles and keel appear at an earlier stage. Loc. Whitby. Fig. 10, 11, same variety, showing stouter form of young and earlier developed keel. Fig. 12, 13, D'Orbigny's type, showing the prolonged duration of the smooth stage, and absence of the keel. Fig. 14, adult of var. *Gaudryi*. Loc. Semur.

Cal. raricostatum.[3] Fig. 15, *Johnstoni*-like variety, loc. Balingen.

[1] See also Plate VII. Fig. 1, for side view.

[2] See Plate VIII. Fig. 1–3.

[3] See Plate I. Fig. 24, 25.

PLATE VII.

Cor. trigonatum. Fig. 1, old specimen of the stout variety, showing adult suture and the closer approximation and degenerative changes in lobes and saddles in old age, figure reduced to about one third. Loc. Aalen.[1]

Cor. bisulcatum. Fig. 2–4, young. Fig. 5, 6, young with earlier developed and more prominent pilæ. The coarse heavy pilæ of the last figure are remarkable, and the young has also a broader abdomen and a form like an older stage of *Cor. latum*. Fig. 7 shows the decrease in breadth of the abdomen with age, which is also seen in Fig. 6. Fig. 8, older stage, with suture. Fig. 9, 10, nearly full-grown stage of same variety. Loc. Semur.

Agas. Scipionianum.[2] Fig. 11, 12, young of gibbous variety. Fig. 13, 14, young, showing development of pilæ from folds. Fig. 13 a, 14 a, enlarged sutures also indicated upon corresponding figures. Fig. 15, front view of same specimen as that of Plate X. Fig. 13. Loc. Semur.

[1] See, for ventral view of same, Plate VI. Fig. 3.

[2] See Plate X. Fig. 11–13. Summ. Pl. XIII. Fig. 7.

PLATE VIII.

Cor. Sauzeanum.[1] Fig. 1–3, var. *Gaudryi*, older and younger whorls of the same specimen, loc. Leicestershire. Fig. 3 a, dorsum showing sutures.

Aster. obtusum.[2] Fig. 4, 5, young of var. E, showing large tubercles and broad abdomen. Fig. 6–8, older stage of same specimen. Loc. Lyme Regis.

Agas. lævigatum. Fig. 9, side view of var. B, with living chamber. Fig. 10, var. D, section showing the extremely broad young and secondary helmet-shape of the later whorls, which are like those of Psiloceras except of course in the keel (the outline of the centre is uncertain except as regards the breadth). Fig. 11, var. A, showing the absence of a keel. Fig. 12, var. D, showing outline of aperture and living chamber, loc. Semur. Fig. 13, very stout young, showing the goniatitic form, and striations like those of *Agas. striaries.* Fig. 14, section of variety from Lyme Regis.[3]

[1] See Plate VI. Fig 4–14. [2] See Plate IX. Fig. 1.

[3] All these figures are enlarged about two diameters, except Fig 9 and 12, which are about natural size.

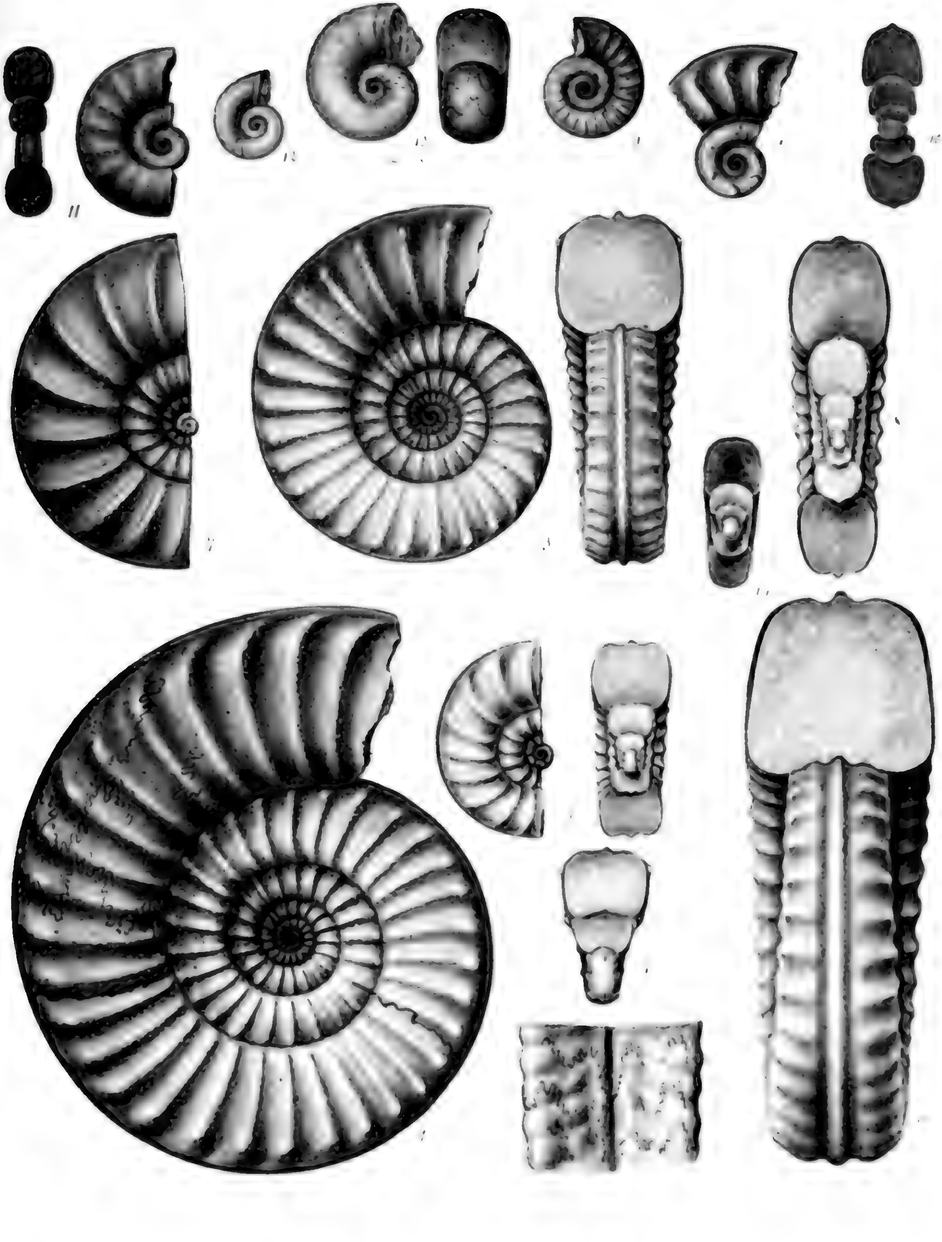


PLATE IX.

Aster. obtusum.[1] Fig. 1, var. D, loc. Lyme Regis.

Aster. stellare. Fig. 2, 3, figures reduced to about two thirds, loc. Tübingen.

Aster. acceleratum.[2] Fig. 4 shows variety having the nearest approximation to *Aster. stellare.* The section is similar to that of Fig. 9, but is more involute. Loc. Semur.

Aster. Brooki. Fig. 5, 6, stout-whorled, broad-abdomened variety, approximating to *Turneri*, but with broader sides at the same age. Fig. 7, older stage of the same variety. Figures reduced to about two thirds. Loc. Lyme Regis.

Aster. Turneri. Fig. 8, 9, old specimen, figures reduced to about two thirds, loc. Semur.

Aster. Collenoti.[3] Fig. 10, young, showing compressed form and acute abdomen. Fig. 10 a, b, the same more enlarged, but the figures fall short in depicting the acuteness of the abdomen, and by improper shading show a keel which has no existence. Fig. 11, young and older stage; the young are again too rounded, the outer whorl is however approximately accurate. Fig. 11 a, b, centre of same more enlarged, showing the involute form of even this early stage, but the front view is not sufficiently compressed. Loc. Semur.

Agas. Scipionis. Fig. 12, 13, lateral and sectional view of young, loc. Semur.

Agas. striaries. Fig, 14, 15, variety with flattened sides and broad abdomen, loc. Semur.

[1] See Plate VIII. Fig. 4, 8.

[2] The umbilical shoulders are not made abrupt enough in this figure, and the umbilicus is shallow as in *Aster. stellare*, instead of being deep as in this species. See Plate X. Fig. 3.

[3] See Plate X. Fig. 10.

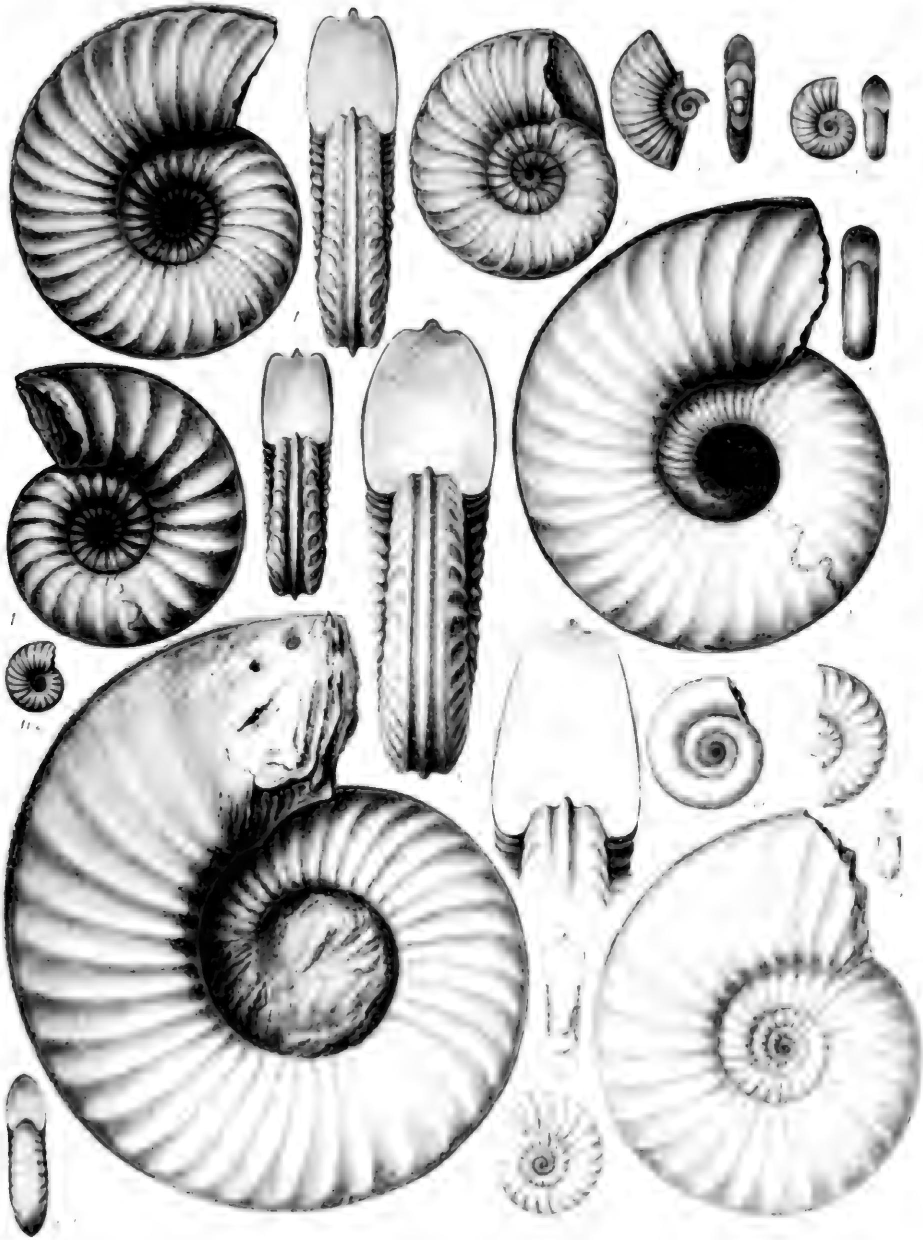


PLATE X.

Aster. stellare.[1] Fig. 1, 2, drawn from a sketch of a specimen in the Museum of Stuttgardt, 450 mm. in diameter, showing extreme modifications in old age, loc. Göppingen.

Aster. acceleratum. Fig. 3, drawn from sketch of specimen in Museum of Stuttgardt, 258 mm. in diameter, showing premature senility, loc. Balingen.

Oxyn. oxynotum. Fig. 4, 5, young of *striaries*-like variety, magnified twelve times, loc. Balingen.

Ast. impendens. Fig. 6, young magnified four diameters. Fig. 7, abdominal view of same, showing the early age at which the convergent sides, deep channels, and prominent keel are developed. Fig. 8, 9, older stage of same specimens. Loc. Semur.

Aster. Collenoti.[2] Fig. 10, full-grown specimen, natural size, showing ribbed young, loc. Champlony, near Semur.

Agass. Scipionianum.[3] Fig. 11, 12, var. *spinaries* of Quenstedt, loc. Gmünd. Fig. 13, older specimen of same variety, with more compressed whorls and less prominent tubercles, loc. Semur.

Oxyn. oxynotum. Fig. 14, abdominal view of young with part of whorl removed, magnified three diameters. Fig. 15, same specimen when whole. Loc. Balingen. Fig. 16, young with prominent pilæ and keel, loc. Gloucester. Fig. 17, young in the Museum of Stuttgardt, showing absence of the keel until a late stage of growth, and exhibiting similarity to the [illegible] of *Agass. lævigatum* and *striaries*. Fig. 17 a, suture of same enlarged. Fig. 18, ordinary aspect of the young. Fig. 19, pathological case with crenulated abdomen, like the *margaritatus* forms. Fig. 20, young of a variety, with folds on the abdomen. Loc. Balingen. Fig. 21, 22, adult, loc. Salins.

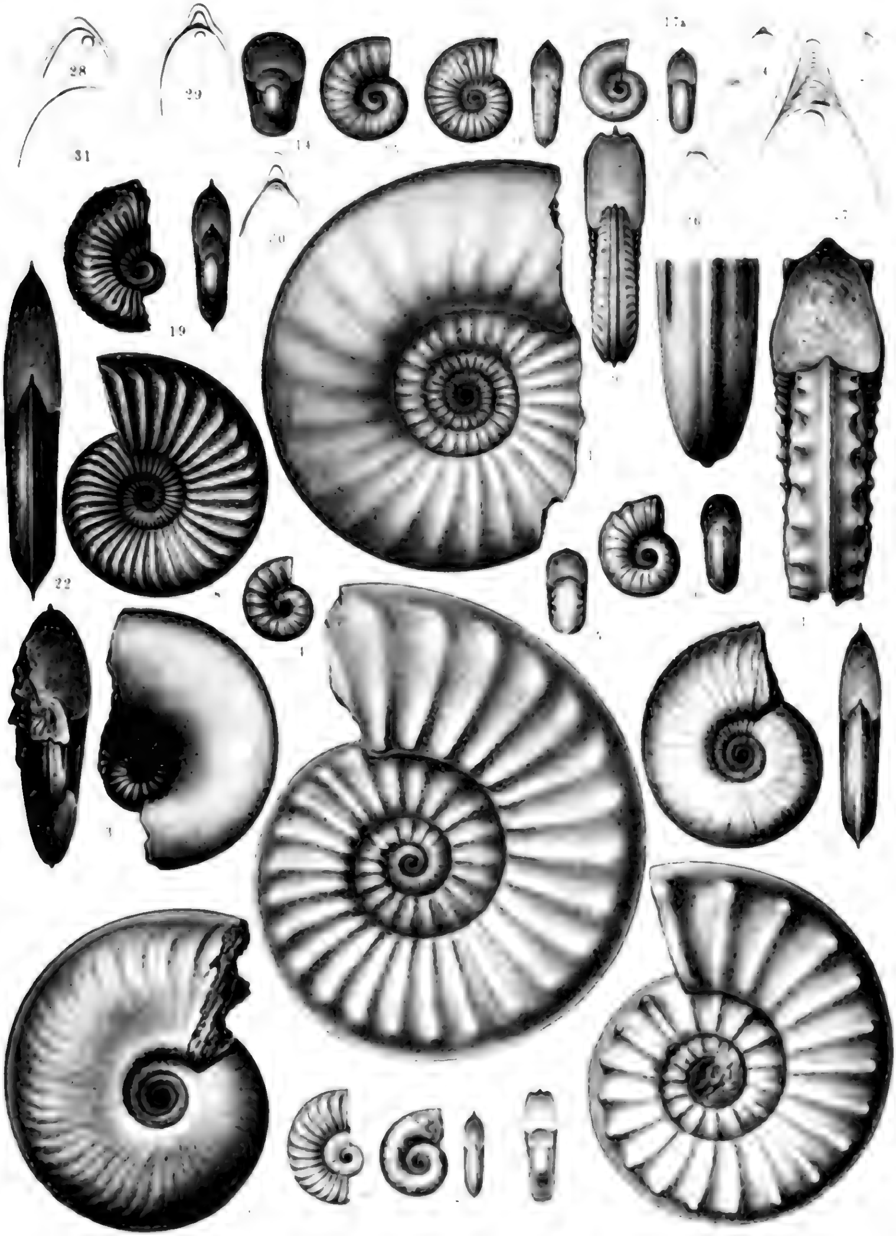
Oxyn. Lotharingum. Fig. 23–26, showing solid keel in young, hollow keel in adult, and partly obsolescent keel in old age of specimen in Museum at Semur.

Oxyn. oxynotum. Fig. 27, showing hollow keel filled with layers of shell in specimen at Museum of Semur.

Oxyn. Guibali. Fig. 28, 29, 31, drawn from sketch of specimen in the Museum of Semur, showing solid keel in young, hollow keel in adult, and absence of keel in old age.

Oxyn. Greenoughi. Fig. 30, enlarged perfect specimen of hollow keel in adult, loc. Stuttgardt.

[1] See Plate IX. Fig. 2, 3.
[2] See Plate IX. Fig. 10, 11.
[3] See Plate VII. Fig. 11–15.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SUMMARY PLATE XI.

This and the following two Plates, XII. and XIII., have been prepared from various sources, as well as from specimens already figured in the preceding plates, in order to illustrate the association of forms in all the series described in this Memoir. The sequence in each series is accurate, with certain exceptions, where it has been found necessary to alter to some extent the exact order of the species. These alterations have been noted below, and most of the forms necessarily omitted in this summary may be traced by comparing the plates with Table IV., "Genealogy of the Arietidæ in the Province of Central Europe." The species of the Mediterranean Province figured in these plates, and not mentioned in that table, have been more or less noted or described in the chapter on "Descriptions of Genera and Species," and are Fig. 7–13 and Fig. 17–19 on Plate XI., and Fig. 10 on Plate XIII. The remainder all occur in the Jurassic Province of Central Europe.

The connecting bars designate affinity, and show the genesis of the forms. No attention has been paid to the geological horizons, but representative forms, or, as they have been called in the text, morphological equivalents, have been placed on the same, or nearly the same, horizontal lines in the three plates. This has brought out very completely the curious discordance which occurs in the normal progressive series in the centre of the Arietidæ, as given on the right of Plate XI. and the whole of Plate XII. in the genera Caloceras, Vermiceras, Arnioceras, and Coroniceras. Their quadragonal whorls, and deep channels and keels in adults, and the absence of involute forms, are in marked contrast with Schlotheimia, Wæhneroceras, and the more involute forms of Psiloceras, on the left of Plate XI., and the geratologous series at the other extreme of the group, Asteroceras, Agassiceras, and Oxynoticeras, as illustrated on Plate XIII.

Psil. planorbe, var. **leve**, Fig. 1; var. **plicata**, Fig. 2.

Psil. aphanoptychum (sp. Wäh.), Fig. 11.

Psil. Kammerkarense (sp. Wäh.), Fig. 12, shows the more involute and plicated form.

Psil. mesogenos (sp. Wäh.), Fig. 13, is an involute shell really belonging to the true Levis stock, and therefore somewhat out of place at the top of the direct descendants of var. *plicatus*, but it is placed there for comparison with its morphological equivalents in other series.

Wæh. curviornatum (sp. Wäh.), Fig. 7, has the pilæ on the abdomen, a trifle too strongly shaded; but this form is undoubtedly distinct from *Schlot. angulata.*

Wæh. haploptychum (sp. Wäh.), Fig. 8, is one of the typical forms of this genus, and the contrast between this and *Schlot. angulata* is well shown.

Wæh. toxophorum (sp. Wäh.), Fig. 9, is a degenerate shell, having compressed whorls, and pilæ crossing the abdomen, as in the proximate radical *Wæh. curviornatum.* It is, however, more involute.

Wæh. Emmerichi (sp. Wäh.), Fig. 10, shows a notably involute shell, with degenerate pilæ and compressed whorls.

Schlot. catenata, Fig. 3, gives the tongue-shaped connections between the pilæ on the abdomen, but they are somewhat too strongly shaded.

Schlot. angulata, Fig. 4, is evidently a transition to the next species.

Schlot. Charmassei, Fig. 5. The whorl is more involute, but the degenerate characters of compression in the whorls and shallowing of the abdominal channel begin to appear.

Schlot. Boucaultiana, Fig. 6. The involution has attained its maximum, and the degeneration of the pilæ and channel is well marked.

Cal. tortile, Fig. 14. The young in the centre of the umbilicus shows the close relationship to *Psil. planorbe*, var. *plicata*, below.

Cal. carusense, Fig. 15, has similar smooth young to that of *tortile* below, and has no keel in the nealogic stage.

Cal. Nodotianum, Fig. 16, is very similar to *carusense*, but with more compressed whorls and better developed pilæ.

Cal. cycloides (sp. Wäh.), Fig. 17, shows compressed degenerate whorls.

Cal. Castagnolai (sp. Wäh.), Fig. 18, is more degenerate than the last, but slightly more involute.

Cal. abnormilobatum (sp. Wäh.), Fig. 19, is a dwarfish and more degenerate form than *Castagnolai*, but has more involute whorls.

Cal. sulcatum, Hyatt, Fig. 20, shows smooth young, as in Fig. 15, and the growth of the pilæ from tubercles on the edge of the abdomen in the young.

Cal. Deffneri, Fig. 21, has the pilæ and tubercles too heavy, but it shows that the young is similar to that of *Cal. sulcatum* below, and that the pilæ have no abdominal extensions.

Cal. laqueum, Fig. 22, is an extreme form of this species, which approximates very closely to a true *spiratissimum*, differing however in the sutures and in the age at which the keel appeared. This figure is therefore placed to the right, and under *Verm. spiratissimum.* The less specialized varieties of this species, which would have stood between *Cal. tortile* and *Cal. carusense*, have not been figured.

Verm. spiratissimum, Fig. 23, shows typical form, with keel developed early, and but slight channels.

Verm. Conybeari, Fig. 24, shows normal untuberculated variety, with stout whorls and deep channels.

Verm. ophioides, Fig. 25, exhibits the tuberculated pilæ and concentrated development of this species, as shown in the early age at which the tubercles appeared.

SUMMARY PLATE XII.

Psil. planorbe, var. leve. Fig. 1 shows the dwarfed, but very common form of this variety, which is evidently a close ally of the next, *Arn. miserabile.*

Arn. miserabile. Fig. 2 represents the acute but keelless variety of this species.

Arn. obtusiforme, Fig. 3, is not very similar to *miserabile*, but the evidence of gradations places it in this relation.

Arn. semicostatum, Fig. 4. The figure represents the nearly full-grown shell, but it may be easily seen that, if the keel were absent, the smooth whorls of the young would closely resemble the adult whorls of *Psil. planorbe*, var. *leve.*

Arn. Hartmanni, Fig. 5, exhibits young and adult characters like those of the preceding.

Arn. tardecrescens, Fig. 6, belongs to another subseries of forms than that in which it is placed, but it serves to show that quadragonal whorled shells with channelled abdomens existed in this genus.

Arn. Bodleyi, Fig. 7, shows a slightly degenerate compressed whorl, and is the terminal form of the subseries containing *Hartmanni.*

Arn. kridioides. Fig. 8 gives a view of the transition between Arnioceras and the lowest species of Coroniceras. The smooth young straight pilæ and divergent sides of the adult whorl are clearly shown.

Cor. kridion. Fig. 9 shows that the tuberculated pilæ, smooth young, and form of whorl are exactly intermediate between *Arn. kridioides* and *Cor. Sauzeanum.*

Cor. Sauzeanum. Fig. 10 shows the later nealogic and ephebolic stages, having the peculiar divergent sides, flattened abdomen, and prominent tubercles of a typical coroniceran form. The young, however, still retain the smooth aspect, indicating derivation from Arnioceras.

Cor. bisulcatum. Fig. 11 shows the very deep channels and peculiar flat abdomen of this species.

Cor. rotiforme. Fig. 12 represents a form similar to *Cor. coronaries.*[1]

Cor. Lyra, Fig. 13. This is as a rule much smaller than *rotiforme.* The sides are more convergent, and the whorls more compressed and less numerous than in that species.

Cor. Gmuendense, Fig. 14, shows degeneration in the compressed whorls of the adult as compared with *Lyra.*

Cor. trigonatum, Fig. 15, exhibits still more clearly than in *Gmuendense* the effects of the premature development of old age characters. The early stage at which they appear is represented in the widening of the spaces between the pilæ. This shell was inferior in size only to *rotiforme*, and much larger than *Gmuendense.*

Cor. latum, Fig. 16. This is the extreme form of this genus, and has in proportion to its age and size more divergent sides and a broader abdomen than any other. It may be, as described in the text, the young of a yet undiscovered adult, but is not the young of the next form, *Bucklandi.*

Cor. Bucklandi. Fig. 17, shows the very stout bulky form of this species, its pilæ, and the divided pilæ of the early stages of the *sinemuriense* variety. This species is not inferior to *rotiforme* in size.

[1] The size of the plates did not permit the use of larger specimens, and therefore these figures do not properly represent the comparative size of the different species in the genus Coroniceras.

SUMMARY PLATE XIII.

Agas. lævigatum. Fig. 1 shows the more compressed variety of this species.

Ast. obtusum. Fig. 2 shows the stouter variety with well marked channels (a little too deeply shaded), with stout gibbous whorls and broad abdomen. This has young almost identical with the adults of the stout varieties of *Agas. lævigatum.*

Ast. Turneri. Fig. 3 shows typical variety, with flattened sides and deep channels. It is notably more involute than *obtusum.*

Ast. Brooki. Fig. 4 shows an extreme involute variety of this species, with very convergent sides and narrow abdomen. The channels are almost obliterated, and the keel very prominent.

Ast. Collenoti. Fig. 5 gives a view of this remarkable dwarfed form, in which degeneration of the pilæ and the channels and convergence of the sides have produced morphological equivalence with *Oxyn. oxynotum* and *Guibali.* The amount of the involution is, however, greater than in any preceding species of the same series.

Agas. striaries. Fig. 6 gives a view of the adult, with a decided keel.

Agas. Scipionianum. Fig. 7 shows the stouter, heavily tuberculated variety, which has young almost identical with the stouter varieties of *Agas. striaries.*

Agas. Scipionis. Fig. 8 shows an aged specimen in the Museum of Comparative Zoölogy, with extremely involute whorls, but keel still prominent. The degeneration of the adult as regards the pilæ and form can, however, be inferred from this figure. The old of *Scipionianum* at the same age is much less changed, and does not exhibit increased involution of the whorls.

Oxyn. oxynotum, Fig. 9, 10. The first figure shows the young of a variety in which at an early stage there is close likeness to the young of *Agas. striaries,* and the adults of *Agas. lævigatum.*

Oxyn. Simpsoni. Fig. 11 shows the stouter form and slightly greater involution of the whorls in this species when compared with *oxynotum.*

Oxyn. Lymense. Fig. 12 shows the greater involution of whorls as compared with any preceding form of the same subseries, and the very acute degenerate whorl.

Oxyn. Greenoughi. Fig. 13 shows the stout form of the whorls better defined, and pilæ of this subseries as compared with the *oxynotum* subseries.

Oxyn. Guibali. Fig. 14 shows more involute whorls than in *Greenoughi.*

Oxyn. Lotharingum. Fig. 15 shows the smaller size of this species, and the degeneration of the pilæ. The involution of the whorls is, however, greater than in any preceding species.

Oxyn. Oppeli. Fig. 16 shows the extremely involute form of the Middle Lias. The stout whorls indicate that no great amount of degeneration had taken place. It may have been a direct descendant of *Greenoughi.*

SUMMARY PLATE XIV.

The three preceding plates do not illustrate the biological relations of the Arietidæ as a whole with sufficient clearness, and this plate has been added for the purpose of supplying the deficiency. The series of Psiloceras has been placed in what may be deemed its true position, between the Plicatus stock and the Levis stock; otherwise, the arrangement is the same. The resemblances of the morphological equivalents in each series can be readily seen by following the forms along horizontal lines from left to right. The independence of the origin of these representative forms can be studied by following up the series in vertical lines, which represent descent. To a large extent, also, the more obvious differential characters which distinguish each series become appreciable by the same process.

Psil. planorbe, var. leve, Fig. 1; var. **plicata,** Fig. 2.

Schlot. catenata, Fig. 3, is the radical of this series.

Schlot. angulata, Fig. 24, is evidently a transition to the next species. The artist has exchanged Fig. 4 with Fig. 24.

Schlot. Charmassei, Fig. 5. The whorl is more involute, but the degenerate characters of compression in the whorls and shallowing of the abdominal channel begin to appear.

Schlot. Boucaultiana, Fig. 6. The involution has attained its maximum, and the degeneration of the pilæ and channel is well marked.

Wæh. curviornatum (sp. Wah.), Fig. 7, is undoubtedly distinct from *Schlot. angulata*, and is one of the radicals of this series.

Wæh. haploptychum (sp. Wah.), Fig. 28. The artist has exchanged Fig. 8 with Fig. 28.

Wæh. toxophorum (sp. Wah.), Fig. 9, is a degenerate shell, having compressed whorls, and pilæ crossing the abdomen, as in the proximate radical *Wæh. curviornatum*. It is, however, more involute.

Wæh. Emmerichi (sp. Wah.), Fig. 10, shows a notably involute shell, with degenerate pilæ and compressed whorls.

Cal. tortile, Fig. 11, is the radical of this series.

Cal. carusense, Fig. 12, has similar young to that of *tortile* below.

Cal. Nodotianum, Fig. 13, is very similar to *carusense*, but with more compressed whorls and better developed pilæ.

Cal. cycloides (sp. Wah.), Fig. 14, shows compressed degenerate whorls.

Cal. Castagnolai (sp. Wah.), Fig. 15, is more degenerate than the last, but slightly more involute.

Cal. abnormilobatum (sp. Wah.), Fig. 16, is a dwarfish and more degenerate form than *Castagnolai*, but has more involute whorls.

Cal. laqueum, Fig. 17, is an extreme form of this species, which approximates very closely to a true *spiratissimum*. This figure is therefore placed to the right, and under *Verm. spiratissimum*.

Verm. spiratissimum, Fig. 18, shows typical form, with but slight channels.

Verm. Conybeari, Fig. 19, shows normal untuberculated variety, with stout whorls and deep channels.

Verm. ophioides, Fig. 20, exhibits the tuberculated pilæ of this species.

Psil. aphanoptychum (sp. Wah.), Fig. 21, is one of the Plicatus stock of Psiloceras.

Psil. Kammerkarense (sp. Wah.), Fig. 22, shows the more involute and plicated form of this subseries.

Psil. mesogenos (sp. Wah.), Fig. 23, is an involute shell belonging to the true Levis stock.[1]

Arn. semicostatum, Fig. 4. The figure represents the nearly full-grown shell. But if the keel were absent, the smooth whorls of the young would closely resemble the adult whorls of *Psil. planorbe*, var. *leve*. The artist has exchanged Fig. 4 with Fig. 24.

Arn. Hartmanni, Fig. 25, exhibits young and adult [illegible]

Arn. tardecrescens, Fig. 26, belongs to another [illegible] is placed, but it serves to show that quadrangular [illegible] existed in this genus.

[1] Two subseries ought to have been shown here [illegible] been placed in the same line. A similar liberty has been taken [illegible] this does not interfere with the truthful presentation of [illegible]

Arn. Bodleyi, Fig. 27, shows a slightly degenerate compressed whorl, and is the terminal form of the subseries containing *Hartmanni.*

Arn. kridioides. Fig. 28 gives a view of the transition between Arnioceras and the lowest species of Coroniceras. The smooth young straight pilæ and divergent sides of the adult whorl are clearly shown. The artist has exchanged Fig. 8 with Fig. 28.

Cor. Sauzeanum. Fig. 29 shows the later nealogic and ephebolic stages, having the peculiar divergent sides, flattened abdomen, and prominent tubercles of a typical coroniceran form. The young, however, still retain the smooth aspect, indicating derivation from Arnioceras.

Cor. rotiforme. Fig. 30 represents a form similar to *Cor. coronaries.*

Cor. Lyra, Fig. 31. This is as a rule much smaller than *rotiforme.* The sides are more convergent, and the whorls more compressed and less numerous than in that species.

Cor. trigonatum, Fig. 32, exhibits the effects of the premature development of old age characters. Fig. 1 on the extreme right shows the dwarfed form of *Psil. planorbe*, var. *leve*, from which both the arnioceran as well as the agassiceran series may have been derived in Central Europe.

Agas. lævigatum. Fig. 33 shows the more compressed variety of this species.

Agas. striaries, Fig. 34. The striations were too fine to be represented.

Ast. obtusum. Fig. 2 shows the stouter variety with well marked channels with stout gibbous whorls and broad abdomen. This has young almost identical with the adults of the stout varieties of *Agas. lævigatum.*

Ast. Turneri. Fig. 36 shows typical variety, with flattened sides and deep channels. It is notably more involute than *obtusum.*

Ast. Brooki. Fig. 37 shows an extreme involute variety of this species, with very convergent sides and narrow abdomen. The channels are almost obliterated, and the keel very prominent.

Ast. Collenoti. Fig. 38 gives a view of this remarkable dwarfed form, in which degeneration of the pilæ and the channels and convergence of the sides have produced morphological equivalence with *Oxyn. oxynotum* and *Guibali.* The amount of the involution is greater than in any preceding species of the same series.

Agas. Scipionianum. Fig. 39 shows the stouter, heavily tuberculated variety, which has young almost identical with the stouter varieties of *Agas. striaries.*

Agas. Scipionis. Fig. 40 shows an aged specimen in the Museum of Comparative Zoölogy, with extremely involute whorls, but keel still prominent. The degeneration of the adult as regards the pilæ and form can, however, be inferred from this figure. The old of *Scipionianum* at the same age is much less changed, and does not exhibit increased involution of the whorls.

Oxyn. oxynotum, Fig. 41, 42. The first figure shows the young of a variety in which at an early stage there is close likeness to the young of *Agas. striaries*, and the adults of *Agas. lævigatum.*

Oxyn. Simpsoni. Fig. 43 shows the stouter form and slightly greater involution of the whorls in this species when compared with *oxynotum.*

Oxyn. Lymense. Fig. 44 shows the greater involution of whorls as compared with any preceding form of the same subseries, and the very acute degenerate whorl.

Oxyn. Greenoughi. Fig. 45 shows the stout form of the whorls better defined, and pilæ of this subseries as compared with the *oxynotum* subseries.

Oxyn. Lotharingum. Fig. 46 shows the smaller size of this species, and the degeneration of the pilæ. The involution of the whorls is, however, greater than in any preceding species.[1]

Oxyn. Oppeli. Fig. 47 shows the extremely involute form of the Middle Lias. The stout whorls indicate that no great amount of degeneration had taken place. It may have been a direct descendant of *Greenoughi.*

[1] The extreme old age of this form is marked by decrease in the amount of involution of the whorl, and also by the loss of the prominent hollow keel.