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THE SHELL STRUCTURE OF THE MOLLUSKS

BY

O. B. BØGGILD

WITH 15 PLATES AND 10 FIGURES IN THE TEXT

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VIDENSKABERNES SELSKABS SKRIFTER

NIENDE RÆKKE

NATURVIDENSKABELIG OG MATHEMATISK AFDELING

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INDHOLD

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Introduction.

In the present treatise I propose to give a systematical description of the structure of molluskan shells. My main object is partly to determine the distribution of the two essential constituents, calcite and aragonite, and partly to describe the form and aggregation of the single elements of those constituents. My first intention was to include all calcareous shells in this examination, but I have omitted to do so, partly because of the enormous material, partly because of the mostly rather uniform structure of other shells. True, many of these possess interesting features, but in most instances their construction is very primitive whereas in other instances, as in the corals, they are built up in a very inarticulate manner which is difficult to examine and describe. On the contrary we find, in the mollusks, the most interesting structures, although in many instances very complicated, often, also, quite peculiar and paradoxical. It is quite impossible, I think, to give any explanation of these aggregations to which we find no analogon in inorganic nature, but I hope that a comparative survey will have some value, both for the systematics and with regard to the determination of shells, especially the fossil ones.

The work can, of course, never be complete because of the enormous amount of material. The description of the single families will show that many of them are subject to such great variations that we were obliged to examine hundreds of species to obtain an adequate idea of the shells. I hope, however, that I have succeeded in finding out the essential characters of the larger families and the more common genera. It was necessary to confine the examination to adult shells, omitting all evolutionary stages, and to the main part of the shell, especially the middle part, omitting all special features at the margin and in the hinge of the bivalves where the structure is so complicated that it can hardly be made out. Equally I have omitted any examination of calcareous elements other than the shells proper, such as the operculum and the spiculum amoris.

The shell structure has been examined by very many previous authors; most of the descriptions are, however, to be found in the special zoological or palæontological literature and are, in most instances difficult to find. Many of them are very detailed and exact, but for the most part they only include one species, or, at all events, different species belonging to the same family, so they have no great value for our present purpose, which is a comparison between as many forms as possible. Some of these papers are cited in the following. Of more systematical descriptions I have only found two; the most complete is that of Carpenter, but what he gives, is mostly the form of the single elements in a random section (mostly the horizontal one), and the perfect form is only found out for some of the more simply formed elements. A much more modern description is given by Cayeux who especially gives excellent figures; the description however, gives, more of a system of the structural elements than one of the mollusks themselves, rather few of which have been examined. Cayeux also confines himself too much to the description of the phenomena as seen in the single section, and accordingly we may see that the same structure, as the crossed lamellar one of the bivalves, is described in one place as "structure fasciculée" and in another place as "structure intercroisée".

Many authors confine themselves to the determination of calcite and aragonite, which will be treated in the next chapter.

Almost all the material used for the present examination originates from the museums in Copenhagen; most of the recent forms I have obtained in the Zoological Museum and most of the fossil ones in the Geological Museum. It is my duty here to express my most cordial thanks to the officials of those museums, for having procured the large material.

The Constituents of the Shells.

Almost all molluskan shells consist of two elements, calcite and aragonite, and only two exceptions are known, viz. the somewhat doubtful groups of the *Torellellidae* and the *Conulariidae*, which consist of a phosphoritic substance. Among other shells we find the same constituents, and only the *Foraminifera Porcellanea* form an exception, as they consist of an amorphous carbonate of lime, which, in all probability, is identical with the substance described by Lacroix as ctypeite. I know very well that other authors deny the existence of this substance as a special modification of carbonate of lime, and assume that it must be a special aggregation of elements of aragonite. I think, however, that it is quite impossible that any such aggregation should be able to produce the weak double refraction which is so characteristic of the substance in question. I have, however, not treated the question in more detail, especially because of the difficulty of obtaining material enough for a perfect examination of the said *Foraminifera*.

In 1901 Agnes Kelly published a paper, in which she expressed the theory that the so-called aragonite of the shells represented a special modification of carbonate of lime which she called conchite. This has been denied by all later authors treating the problem, and it seems that we must give up this name as Debye diagrams taken of aragonite from the shells show exactly the same lines as one of true aragonite. It is obvious, however, that the constants of the aragonite from the shells are not exactly identical with those of other aragonite; the axial angle is distinctly smaller and the indices of refraction also have somewhat different values. The axial angle, to be sure, is very variable in the relatively few instances where it can be distinctly seen, for, in some instances, no aperture at all is seen while, in others, it is very distinct, although always smaller than that of aragonite proper. As a maximum 2 E is found to be 27°, while in aragonite it is ca. 31°. The indices of refraction have been determined with much more certainty, and while aragonite proper has the indices $\alpha = 1.5331$, $\beta = 1.6816$ and $\gamma = 1.6859$ the corresponding values have been determined (especially by Dr. MELCZER whose examinations were always performed with the greatest possible care and exactness) at: $\alpha = 1{,}523$, $\beta = 1.659$, and $\gamma = 1{,}662$. These values have been obtained by means of the total refractometer which is, however, not very practical where the single crystal individuals are so exceedingly small. The immersion method has the advantage of being available in all instances, and shows the difference between both substances very plainly. If the powder is placed in monobromnaphthalene ($n =$ ca. 1.66) we shall find that every grain of aragonite proper will possess, in one position, a refraction distinctly greater than that of the fluid, while, in the grains of the shell substance, we never find this great refraction, the grains in one position entirely disappearing.

Although the question cannot be considered as perfectly settled, I think it most probable that the substance of the shells is an aragonite, although a very marked variety, and in the following I designate it by that name.

Means of distinguishing between Calcite and Aragonite.

From earlier times many methods have been used for determining the two main substances of the shells but most of them are too uncertain, or can only be used in exceptional cases.

The cleavage can be distinctly observed in the calcite in such instances where the individuals are comparatively large, but those instances are rather rare and in most of the shells it is impossible to find any cleavage. On the other hand, the individuals of the aragonite are always so small that it is impossible to find any trace of cleavage, and on the whole this property is, of course, of very restricted value.

The occurrence of twin lamellæ has been used, by AGNES KELLY, as a proof of calcite. In my experience such lamellæ never exist, and I think that there must be some mistake here.

Etching figures have been used, especially by LEYDOLT, for distinguishing between the two substances; these figures, however, can only be produced in the comparatively few instances where we have rather large individuals and have, of course, no practical value.

The hardness was used by NECKER for determining the shell substance; this property, however, is so difficult to determine with exactness and at the same time so variable according to the directions in the crystal and the whole aggregation, that it can give no exact results, and we see that those obtained by NECKER are not very correct.

The specific gravity is here, as in other respects, one of the best properties for determining a mineral and has been used by many authors. As is well known, the shell substance is always mixed with some organic substance which makes its gravity smaller than that of the pure mineral. Mostly, however, the amount of this substance is not very large, and by using a fluid of exactly the same gravity as the calcite, we almost always find that the calcite will swim, while the aragonite will fall to the bottom. Only in such instances where the amount of impurity is comparatively large, or where the substance in question is found in very small amounts, the method will give no result.

The reaction of MEIGEN also gives very good results and only fails where the layer to be examined is so thin that it cannot be isolated.

Refraction is the best of all properties for determining minerals and is, at the same time, the only property which can be used in all instances. It may be determined in the common section in Canada balsam as the lowest index of refraction (α) of the aragonite of the shells has a value of 1.523, nearly the same as that of the balsam, while the lower index of refraction of the calcite (ε) has a value of only 1.4863. In all instances where the elements of the shell have a regular arrangement one will always, in a section of the proper direction, be able to distinguish between the two minerals, while, in the relatively few instances where the individuals are irregularly oriented, one may find in each section in the calcite some individuals which have a lower refraction than that of the balsam, while for the aragonite none such can be found.

The axial angle has been used, especially by AGNES KELLY, but it has no great value for the determination. Firstly it can only be seen in the comparatively few large elements, and secondly it is very variable; as mentioned above, it may, in the aragonite of the shells, vary from almost 0° up to ca. 27°, and in the calcite, too, there is a rather wide range of variation, as the angle may go up, in some instances, to ca. 20°.

The alteration by heating of the aragonite has been used for the determination. Because of the small individuals this property cannot, however, be observed with certainty, and it may be confounded with the loosening of the shell substance produced by the burning away of the organic substance.

My determinations were, in all cases, made by means of the refraction; in many instances I have secured them by means of the specific gravity and of the reaction of MEIGEN.

In the altered shells the determination of the original substance must be undertaken in quite another manner. As the aragonite of all palaeozoic and many younger shells has been changed entirely into calcite, their original composition must be inferred from a consideration of the shell in question. If it consisted originally of calcite, it has, in most instances, preserved its original structure, which is easily recognizable and is exactly the same in all individuals of the same species. If it consisted originally of aragonite, it is irregularly built (an instance is shown in pl. XV, fig. 5), and different individuals may behave very differently as to the form and size of the elements. In some instances, however, this determination will not lead to absolute certainty; firstly the structure of the original calcite, as in the upper layer of many gastropods, may be so irregular that it cannot easily be distinguished from a pseudomorphous structure, and secondly the calcite, in some instances, may have become altered. Otherwise it is impossible to explain that, in some individuals of a Palaeozoic gastropod, we find a regular prismatic layer, while, in others, we cannot detect any trace of it.

In other cases the state of fossilization may greatly facilitate the determination of the constituents. In the chalk and the rather similar rocks belonging to the Danian formation of Denmark all existing shells consist of original calcite, and all aragonitic shells have totally disappeared or are only found as casts.

Distribution of Calcite and Aragonite in the Shells.

Each shell, or each special layer of a shell, consists either of calcite or of aragonite. It has been suggested, by some authors that in some instances (as in the *Patella*) a mixture of both substances occurs, but I have never been able to find such a mixture, and I think that there must be some mistake here.

It is only among the mollusks that we find both calcite and aragonite in the same shell. As a rule the upper part consists of calcite and the under part of aragonite. Only two exceptions are known, the *Pectinidae*, where we find an aragonitic layer between two calcitic ones, and the *Haliotidae*, where we may find the opposite distribution. In the other classes of animals each shell only consists of one of the minerals.

In the following table I give a list of the distribution of calcite and aragonite and other substances in the shells. The list must be considered fairly complete for the mollusks only. As to the other classes it must necessarily be somewhat incomplete as they have never been very thoroughly examined; it is partly a result of the observations of former authors (Rose, Sorby, Cornish and Kendall, Agnes Kelly, Bütschli a. o.) and partly of my own observations.

Distribution of the Substances in the Shells.

calcite	calcite + aragonite	aragonite	other substances
Foraminifera perforata			*Foraminifera Porcellanea* (amorphous carbonate of lime)
Calcispongiae			
Tetracoralla 1)			
Some *Hexacoralla* 2)		Mostly *Hexacoralla*	

calcite	calcite + aragonite	aragonite	other substances
Mostly *Alcyonaria*		*Helioporacea*	
Heliolites?		*Plasmopora*?	
Tabulata 1)			
		Hydrocorallinae	
		Stromatoporidae? 3)	
Echinodermata			
Serpulidae			
Bryozoa			
Craniidae			Mostly *Brachiopoda inarticulata* (phosphorite)
Brachiopoda articulata			
Aviculidae pt., *Anomiidae*, *Ostreidae*	Mostly *Anisomyaria*	*Ambonychiidae*?, some *Myalinidae*?	
		Modiolopsidae?, some *Mytilidae*	
	Some *Chamidae* and *Caprinidae*, *Rudistae*	Mostly *Isomyaria*	
		Scaphopoda	
		Amphineura	
Bellerophon sp.	*Neritidae*, some *Haliotidae*, *Euomphalidae*, *Fissurellidae* and *Trochonematidae*	Mostly *Prosobranchia*	
	Cyclobranchina		
	Janthinidae, *Scalariidae*, some *Litorinidae*, *Muricidae*, *Purpuridae*, *Fusidae* and *Capulidae*	Mostly *Ctenobranchinae*	
		Heteropoda	
		Opistobranchia	
		Pteropoda	
		Hyolithidae	
Tentaculitidae			*Torellellidae* and *Conulariidae* (phosphorite)
		Pulmonata	
	Some *Orthoceratidae*	Mostly *Nautiloidea*	
Aptychus		*Ammonoidea*	

calcite	calcite + aragonite	aragonite	other substances
Belemnoidea (*rostrum*)		*Belemnoidea* (*phragmocones*?)	
		Spiriophoridae	
Argonauta		*Sepioidea*	
Cirripedia, Ostracoda, Trillobitae 5)			*Decapoda* (phosphorite, calcite or both 6)

Notes:

1. Cayeux (pp. 417—18) suggests that the Palaeozoic corals have consisted of aragonite and that the transformation, in such instances where we find a regular fibrous structure, should have taken place in such a manner that the original structure should have been retained. In the many examples of transformed aragonite which I have observed I never have seen the original structure preserved in the orientation of the calcite individuals. Among the many *Tetracoralla* which I have examined I have, in most instances, seen an orientation of the calcite which must be original. As to the Tabulata, which possess a still more regular structure, it is also absolutely certain that they have consisted of calcite.

2. Among the single corals from the chalk and the Danian deposits of Denmark we find several which are perfectly preserved and must be assumed, therefore, to have consisted of calcite, while others are totally altered; different individuals of the same species always behave in the same manner. The calcitic corals belong to the genera *Sphenotrochus, Ceratotrochus, Epitrochus, Coelosmilia* and *Parasmilia*, but of most of these we also have aragonitic species. Cornish and Kendall, too, mention (p. 72) a calcitic coral (*Parasmilia centralis*) from the chalk. The system of these corals ought, perhaps, to be revised with regard to the mineralogical composition. Among the rather few recent corals which I have examined, I have found no calcitic ones.

3. Among the few forms examined I have as a rule found no trace of any regular orientation of the calcite individuals hence I think that the shell has consisted, originally, of aragonite. Only in one or two instances were traces of an original structure seen.

4. Agnes Kelly (p. 54) describes the shell of *Serpula* as consisting of aragonite (conchite); I have examined many *Serpulidae* and have always found that they consisted of calcite, arranged in a rather peculiar manner. It is, of course, impossible to deny that there may be some exceptions.

5. In the handbooks of Zittel the dorsal shell of the trilobites is described as consisting of alternating lamels of carbonate and phosphate of lime. Among the many forms, which I have examined, I have never found any trace of phosphorite and I think that there must be some mistake.

6. The shells of the *Decapoda* are very variable; in the few instances which I have examined, I have found the following:

a. The shell consists entirely of calcite: the Senonian *Callianassa Faujasi*, the Danian forms *Dromiopsis rugosa* and *laevior*, and the Eocene forms *Coeloma bicarinatum* and *Lobocarcinus Paulino-Würtenbergensis*.

b. The shell consists entirely of a phosphoritic substance: *Astacus fluviatilis* and the Eocene form *Xanthopsis Leachii*.

c. The shell is composed of both substances in such a manner that some parts are entirely phosphoritic while others are calcitic, and large parts consist of a mixture of both: *Homarus vulgaris*, the Turonian *Harpactocarcinus quadrilobatus* and a Turonian *Callianassa sp.*

It is possible that the composition may be different in different parts of the animal and it is also possible that it may alter with the age of the animal. This examination can only be considered quite temporary.

The above list will give the impression that the distribution of the main substances is quite accidental, and it will of course be rather hopeless to find any cause for it. The occurrence of the one or the other of the two main substances, or of both of them in the same shell, seems to be caused mainly by physiological processes in the animal itself, and is only with great uncertainty brought into connection with the physical properties of the surrounding medium.

The temperature, which is an essential factor in the formation of inorganic calcite and aragonite, seems to be of no consequence to the animals. True, there exist no statistics of the proportion of these substances in the different seas, but we receive the general impression that both of them are represented, to a very high degree, both in the tropical and the arctic seas, and at any rate we find no distinct influence of the temperature in that respect.

Between the salinity of the water and the composition of the shells there seems, on the other hand, to be a more pronounced connection. If we disregard the articulates, especially the crustaceans, which are not very thoroughly examined, it is well known that most of the shell-bearing animals disappear in the fresh water where we find only relatively few forms of the gastropods and the bivalves, and as these forms consist mostly of aragonite, also in sea-water, they are not especially suited for a comparison. It is very obvious, however, that almost all the forms which consist of both elements are confined to salt-water. Especially among the *Mytilidae* we find that most members of that family, which are built up of calcite + aragonite, are found in salt water, whereas the comparatively few living in brackish or fresh water, as the *Congeria* and the *Dreissensia*, are purely aragonitic. I have only found one example of calcite-bearing shells among all the mollusks living in fresh water, viz. the genus *Neritina*, all members of which examined by me possess a very thin, upper calcitic layer.

Any more direct influence of the salinity of the water upon the composition of the shells is not to be found. If we compare specimens of the same species of *Neritina* from fresh water with others from brackish water, we shall find that both possess a thin calcitic layer which is not more developed in the latter specimens than in the former. And the same is found in *Mytilius edulis.* Specimens of that animal from water of the least possible salinity (0.5 %) are very small and thin as compared with those from salt water, but the relative amounts of calcite and aragonite are almost the same in both forms.

The relation between the chemical and the mineralogical composition of the shells seems to be of a rather peculiar kind. As to chemical analyses it will suffice to refer the reader to the paper of CLARKE and WHEELER[1]) who have cited many former analyses and have made a great many new ones. The authors themselves point out the fact that all aragonitic shells are non-magnesian while most of the calcitic ones are magnesian; they, however, name some striking exceptions from the latter rule. With the more perfect knowledge of the mineralogical composition of the shells which we now possess, it is possible to make clear the above-named rules, in a more statistical way. It is a general rule, from which there is no exception, that all aragonitic shells are non-magnesian, but the calcitic ones behave in a more complicated manner. This is clearly seen from the following table where the numbers of the different percentages of $MgCO_3$ are given after the analyses stated by CLARKE and WHEELER.

% $MgCO_3$	Number	% $MgCO_3$	Number
0—1	17	6—7	10
1—2	11	7—8	8
2—3	4	8—9	14
3—4	0	9—10	18
4—5	3	above 10	71
5—6	5		

From this table we receive the impression that the calcitic shells may be divided into two groups, one of which is quite as non-magnesian as the aragonitic shells, while the other is strongly magnesian, and there are almost no transitional forms between the two groups. We should be inclined to think, indeed, that they represented two different minerals, but it is impossible to find any other difference between them than the composition itself, as all physical properties are exactly the same and also the DEBYE spectra of both are identical with the spectrum of common calcite.

The two groups are far from evenly distributed among the different classes of calcitic animals. To the magnesian group belong all analysed *Spongiae*, *Alcyonaria*, *Echinodermata*, and *Argonauta*, as also all analysed calcitic algae. Also the decapods which, as mentioned above, may consist of calcite or phosphorite or of a mixture of both, contain a large amount of magnesia. The same is the case with the *Foraminifera porcellanea* which consist of an amorphous carbonate of lime; it seems that this substance stands in a nearer relation to calcite than to aragonite.

All analysed *Cirrhipedia* are non-magnesian as also the rather few instances of gastropods and bivalves (*Placuna*, *Pecten* and *Purpura*).

On the other hand we find both magnesian and non-magnesian calcitic shells among the following groups of animals: The *Foraminifera perforata*, the analyses of which are stated by CLARKE and WHEELER; the *Sphaerodina* contain

[1] U. S. Geol. Surv. Professional Paper 102, 1917, and 124, 1922.

small amounts of magnesia while *Pulvinulina*, *Tinoporus* and *Polytrema* are highly magnesian. Among the annelids we find both kinds, as also among the *Bryozoa*. As to the brachiopods there seems to be the constant rule that all analyses of the articulate ones show a very low percentage of magnesia, whereas the two analyses of *Crania* cited by the authors show rather high percentages (3.4 and 8.63 $MgCO_3$).

The Alteration of the Aragonite.

It is a well known phenomenon that all aragonitic shells, through the long geological periods, will either disappear or be transformed into calcite. This process is of very great importance for the formation of the common limestone, which has probably, in most instances, originally been formed by a loose accumulation of calcareous shells of different kinds. As the aragonite is less stable than the calcite, the circulating water will dissolve the aragonite and will thereby obtain a large amount of material for cementing the rest of the shells together into a compact rock. The process of limestone formation is, however, very complicated and may depend upon many other circumstances, as the temperature, the pressure and the different impurities of the rock; hence the time necessary for the formation of the solid limestone is very variable in the different places. Where we find a comparatively old rock like chalk, which has kept its original loose consistency, it seems natural to assume that it must have contained, from the beginning, very few aragonitic elements. On the other hand it is obvious that, in the still older limestones, which, in most instances, are perfectly cemented, a dissolution and redeposition of the calcitic elements must also have taken place.

The way in which the original aragonite is transformed into calcite may be somewhat different in the different rocks. In most instances it seems that the aragonite is gradually loosened, and in many places we find it reduced to a loose, powdery mass still possessing traces of the original structure; afterwards the aragonite may entirely disappear. If the surrounding rock is of a more solid kind, a cavity is left which, in most instances, is filled up by calcite, forming, in this manner, a perfect cast of the original shell which may look quite fresh as to external appearance, whereas, in thin sections, it is seen to consist of irregularly grained calcite. If the surrounding rock is not of such a solid consistency, the aragonitic shells may entirely disappear, and no trace of them will be found. In chalk, e. g., most aragonitic shells have disappeared, and only some of the largest of them are seen as impressions.

In other rocks the aragonite may behave in quite a different manner; in the alpine Triassic we may find shells possessing a perfectly unaltered aragonite while in others we may find that only part of the shell possesses such a consistency while other parts are transformed into calcite, and there is a sharp boundary line between both parts.

The time necessary for the complete transformation of the aragonite is very different in the different rocks. On the one hand we may find it quite unaltered from the Triassic formation, while, on the other hand, we may find even younger Tertiary rocks without any trace of it. Upon the whole the percentage of unaltered aragonitic shells will increase from the Triassic to the Quaternary.

There may be many causes of the very different lifetime of the aragonite, but undoubtedly the most essential is the purity of the limestone. It is a general rule that in the purest of them, containing up to 95 % or more of carbonate of lime, the aragonite will disappear rather quickly; hence we find none of that substance left in the chalk or in our limestones of the Danian formation, both being equally pure. On the other hand we find that such limestones from the Mesozoic formations in which the aragonite is still preserved, contain a larger amount of clay, and it seems that a percentage of only 10 to 20 is enough for preserving the aragonite as long as possible. I am not able to explain the cause of this phenomenon. In rocks containing very little carbonate of lime, such as siliceous or ferrugineous rocks, the calcareous shells are mostly altered rather quickly, and the calcitic ones are not preserved very much longer than the aragonitic ones.

The Shell Structures.

In the following will be given a description of the different modes of aggregation, according to which the elements of the shell substances are arranged. Many of them are the same as those found in the inorganic substances, and we may here use the usual terms, but, on the other hand, we find many modes of arrangement peculiar to the shells, and there exists no fixed terminology for them.

The homogeneous Structure.

This peculiar form of aggregation, of which I know no typical representative among the inorganic minerals, is characterized by the following properties. In ordinary light we see, in the typical forms, no structure at all, whereas, with crossed nicols, we find an extinction in one direction in such a manner that the main axes are parallel through large parts of the shell (the axis of the aragonite is here, as elsewhere, the crystallographical c-axis, being at the same time the acute bisectrix, and behaving, in all respects, like the main axis of the calcite). The common position of that axis is the vertical one, normal to the surface of the shell, so that each part of the shell which is parallel to the swinging directions of the nicols will be dark, whereas, in oblique positions, it will show an interference colour. But there are many exceptions from this rule, the axes being placed in an oblique or horizontal direction, as is seen e. g. in the different species of *Lima* (fig. 6).

As we see no elements at all in the typical homogeneous structure, it is impossible to tell what form the single individuals possess. They may be prismatic or lamellar or, perhaps, otherwise arranged. In many instances, however, we find transitions from that structure to various others, giving indications, in such instances, of the real structure. Among such transitional structures may be named the following: The homogeneously prismatic structure, which is seen e. g. in the upper layer of a *Mytilus*, there is a weak trace of a prismatic arrangement which may be very pronounced in some places, in others very indistinct or quite negligible. In the homogeneously foliated structure there are, in the same manner, indications of a foliated structure. A rather common structure is the homogeneously grained one, being mostly characterized by the existence of a homogeneous ground mass in which are distributed small grains of the same substance with a quite accidental orientation. Their amount may be so large that the homogeneous mass is only observed in the very thinnest sections. In other instances we find in a homogeneous substance weak traces of a crossed lamellar structure suggesting that the whole layer possesses that structure but of exceedingly small dimensions.

The homogeneous structure is most typically developed among the calcitic shells and here we find the only examples of an abnormal orientation of the axes. Outside the mollusks the *Foraminifera perforata* and the trilobites possess that structure, and here the axes have the normal orientation, while among the *Serpulidae* we often find a layer of an impure, homogeneously grained substance the axes of which are abnormal and have a transverse orientation. Among the mollusks we find that structure in the upper layers of the *Limidae* and in some of the *Mytilidae*, the axes here possessing another abnormal direction, mostly the radial one.

The homogeneous, aragonitic structure is, as far as I know, confined to the mollusks. The axes always have the normal orientation. In some instances, as in the *Heteropoda*, the *Pteropoda* and some of the *Nuculidae* and *Cyprinidae*, that structure may build up the whole shell, whereas, in many other cases, it may be found as an upper or under layer or both. Its distribution will be shown in the systematic part.

The prismatic Structure.

This structure is so well known from inorganic nature that it does not need any further explanation; it may be divided into three groups: the normal, the complex, and the composite prismatic structure.

The normal prismatic structure, which is by far the most common among the three groups, is characterized by the fact that each prism consists of one single crystallographical individuum. According to their general appearance they may be divided in different manners; the diameters may be very variable and they may be described as fine or coarse.

According to their form the prisms may be designated as regular or irregular. The former are bounded by straight and parallel lines (pl. I, fig. 1) while the latter have more or less irregular boundaries (pl. XII, fig. 3 and 6). Also the cross sections may behave very differently; the most regular have the form of polygons (pl. I, fig. 3) while, in other instances, they may have more or less indented boundaries (pl. VII, fig. 3). If the form of the prisms is very irregular we have all possible transitions to the irregularly grained structure.

The prisms may be single or branched. Especially in the upper prismatic layers in the families *Aviculidae*, *Pernidae* and *Pinnidae* we find that the prisms get thinner and branched at their upper end. Only in such instances where this phenomenon is especially pronounced have the prisms been described as branched.

The prisms may be more or less distinct or easily visible. The most distinct prismatic structure is found in the above named families where there is a special layer of some organic substance intercalated between the prisms (pl. I, fig. 1 and 3). In other instances, where there is no such layer, or only a very exiguous one, the visibility of the prisms depends mostly upon the orientation of the optic axes. If these are strictly parallel in adjoining prisms, it may be very difficult to see the boundaries between them.

The orientation of the prisms in relation to the shell may be very variable; most common is what we may call the normal orientation with the prism axes placed vertically, normally to the surface of the shell, but we also find, in many instances, an oblique position in the radial (longitudinal) plane (pl. X, fig. 6, pl. XII, fig. 3). More rarely horizontal prisms are found, either radial or longitudinal.

Also the orientation of the optic axes may be very variable. The extinction is regular if the axes throughout the whole layer have nearly the same direction (pl. XV, fig. 2), and irregular if their directions are variable (pl. XV, fig. 3). In most instances, however, a majority of the axes have nearly the same direction, while others may deviate up to 90°. A quite irregular extinction is characterized by the axes being orientated quite accidentally without any main direction.

The extinction is called normal if the axes, or the main part of them, are parallel to the prism axes, and abnormal if they have some other main direction. There is, in that respect, a great difference between the aragonitic and the calcitic prisms; therefore it will be most practical to consider the two substances separately.

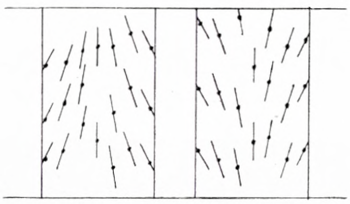
Most prisms consisting of aragonite have a perfectly normal orientation of the optic axes, and their variations are for the most part rather small. Also the orientation of the prisms themselves is mostly the normal, vertical or somewhat oblique one, the most pronounced exception being *Ervilia podolica*, the shells of which possess an upper layer of horizontal, radial prisms (pl. VII, fig. 5).

Among the calcitic prisms there is a very great variation both in the orientation of the prisms and in the orientation of their optic axes, and we may find all possible abnormal orientations. Most commonly, however, we find the normal orientation of both kinds of axes, as in *Avicula*, *Pseudomonotus*, *Pinna*, *Perna*, *Vulsella*, *Trophon*, *Neptunea*, *Belemnites*, *Argonauta* a. o. Very commonly, however, we find an irregular orientation of the optic axes (as e. g. in *Pterinea, Myalina, Purpura,* a. o.). Radial (longitudinal) prisms with optic axes of the same direction are found in *Modiola Cottae, Lithodomus lingualis, Fissurella crassa, Haliotis, Acmaea* a. o.

Among the prisms with abnormal optic axes we find all possible combinations: Vertical prisms with horizontal and radial axes are found in species of *Meleagrina, Monotis* and *Inoceramus.* Vertical prisms with horizontal and concentrical (transverse) axes occur in *Orthoceras annulatum*, whereas *Inoceramus Lamarckii* has vertical prisms with oblique optic axes.

Oblique prisms with horizontal and longitudinal axes are found in *Litorina.*

Patella (Helcioniscus) radians has horizontal and longitudinal prisms with horizontal and transverse axes, whereas the opposite combination (transverse prisms with longitudinal axes) is found in the *Neritidae.* On the other hand we find in the brachiopods horizontal (radial and concentrical) prisms with vertical axes.



a *b*

Fig. 1.

A special kind of prismatic structure is that which we may call dependently prismatic: each prism is formed by further growth of the individuals of the common crossed lamellar structure in such a manner that each prism has one of the two directions of the optic axes. In calcitic shells (where the crossed lamellar structure is very rare) that kind of prism is only found in the uppermost layer of *Avicula Münsteri.* Among the aragonitic shells we find it most typically in the undermost layers of the *Limidae* and the *Spondylidae* and also, perhaps, in many of the subordinate layers of the complex structures of other bivalves.

The complex prismatic structure is characterized by the fact that each prism possesses the aggregation called above (p. 15) the homogeneous one. In ordinary light it cannot be distinguished from the common prismatic structure, but with crossed Nicols we see that extinction does not occur in the same direction for the different parts of the prisms. The arrangement of the axes is shown in fig. 1. Along the middle axis of each prism they are placed parallel to the main direction of the prism, but at the outer parts they become gradually more obliquely orientated. Owing to this arrangement we see, in the polarized light, a black line in the middle part of each prism if this is placed parallel to the directions of the Nicols but, by turning the preparation, this line passes, in parallel position, to the outside of the prism. The axes have a feathery arrangement and we may distinguish between a downward (*a*) and an upward (*b*) feathery arrangement. In the first instance the black line passes to the right if the preparation is turned to the right. In cross sections of the prisms we see in both instances, in the polarized light, the common uniaxial figure, the black cross and the rings of interference colours. The complex prismatic structure has been falsely interpreted by various earlier observers, as mentioned below in the description of the *Nayadidae.*

This structure is most typically developed in the said family, and also in the *Trigoniidae* where it is more indistinct, and where it shows a very remarkable divergence in the opposite direction (upwards). In both instances the shell consists of aragonite. Among the calcitic shells we find a peculiar complex prismatic structure in *Inoceramus* (*Haploscapha*) *grandis*; radial sections give the typical picture of this kind with upward diverging axes, but the axes themselves are orientated normally to the positions given in fig. 1 *b*, having a perfectly or nearly horizontal position.

The composite prismatic structure consists of larger prisms (prisms of the first order) each of them being composed of fine prisms (of the second order) arranged in a feathery manner, like the axes of fig. 1. This structure is most typically developed in the upper layer of most members of *Nucula* (pl. II, fig. 5 and 6); the prisms of the first order are placed horizontally, in the radial direction, and only form one layer; the prisms of the second order diverge towards the margin. Similar structures, but more irregular, are found among the *Erycinidae* and also in the thick, upper layer of *Buccinum undatum*, but here the prisms of the first order are placed almost vertically and the prisms of the second order diverge downwards.

A transition between the common and the composite prismatic structure is found in such instances where we have a layer of fine prisms, mostly orientated horizontally in the radial plane, and possessing a feathery arrangement only in the radial section, whereas, in the horizontal section, they are perfectly parallel. This arrangement is common among the *Lucinidae*, the *Veneridae* and the *Donacidae*.

The two structures named are built up of aragonite only. The small prisms may behave in different manners; for the most part they are of the common kind (each prism consisting of one individual), but they may, in some instances, be of the complex kind. In the first instance the optic axes are orientated in the normal manner, nearly parallel to the prism axes, but in other instances they may have an abnormal orientation in a direction which is oblique, or normal to the prism axes. This is one of the few instances where an anomalism of this kind is found in an aragonitic structure.

The foliated Structure.

This structure, which is much less common than the prismatic one, is characterized by the fact that the layer in question is built up of more or less regular parallel leaves. If regular, the leaves are always horizontal, parallel to the surface of the shell. The orientation of the optic axes may be variable; in *Bellerophon* (pl. VIII, fig. 6), and in *Tentaculites* (pl. XIII, fig. 2) they are placed normally to the leaves, whereas in *Placuna* they have an oblique position while, in *Patella fluctuosa* (pl. X, fig. 2), they are horizontal in the radial direction.

In other instances (most members of the *Spondylidae, Pectinidae, Ostreidae* and *Anomiidae*) the orientation of the leaves is very irregular, sometimes horizontal, and sometimes oblique or quite vertical. The whole structure may, in sections, be very similar to a cross bedding in sandstone (pl. I, fig. 5, pl. II, fig. 1). The optic axes of the irregularly orientated leaves always take a rather accidental position.

The typical foliated structure is always built up of calcite; in the aragonitic shells it is replaced by the following structure.

The nacreous Structure.

This is rather common among the three main groups of the mollusks, the bivalves, the gastropods and the cephalopods, while it is never found outside the mollusks. It is so well known that it may be treated here rather briefly. For a more detailed description the reader is referred to SCHMIDT (especially in Zool. Jahrb., Abt. f. Anat. Bd. 45, 1921, where the earlier literature is cited). The nacreous substance is characterized by the fact that it consists of thin leaves, all of the same thickness and equidistant, being separated by equally thin leaves of some organic substance. The thickness of each leaf is a little below 0.001 mm, and the leaves are, of course, only visible with the highest magnification. The leaves are always placed in the horizontal plane or are only slightly oblique, parallel to the lines of growth of the shell. The optic axes are always normal to the leaves. Because of the intercalation of organic leaves a piece of nacre is slowly dissolved in acids. In the fossils the organic structure has disappeared and the leaves are hardly seen directly but the characteristic lustre is very finely preserved in most instances. In acids the fossil nacre is quickly and entirely dissolved.

With ordinary magnification the leaves are not seen, and the nacreous layer mostly resembles the homogeneous substance (e. g. pl. I, fig. 1, and pl. II, fig. 5). In other cases there may be seen a more or less distinct prismatic structure in the nacre (pl. IX, fig. 2 and 3, pl. XIII, fig. 5).

The nacre always consists of aragonite; earlier authors sometimes mention this substance in calcitic shells, like that of the oyster, but calcite is never built up in the perfectly regular manner characteristic of true nacre and never shows the same fine, coloured lustre.

The grained Structure.

This structure, which may be considered the most imperfect of all the aggregations, is very rare in the shells. It consists of more or less irregularly formed grains, and the optic orientation is also quite irregular. As mentioned above we find, among the calcitic layers of some gastropods, all transitions between the prismatic and the irregularly grained structure, the last named being found in *Janthina* (pl. XI, fig. 5), and in some species of *Scalaria*. Very finely grained layers are found in part of the shell of *Sepia* (aragonite) and in *Argonauta* (calcite).

More commonly we find that a layer of another consistency, especially of the homogeneous kind, may be penetrated by a great number of irregularly orientated grains, which then form only part of the aggregation. This is especially observed in the upper layer of some bivalves, and contributes to make the whole shell more opaque.

The Structure of larger Crystal Individuals.

Only in a very few instances do we find that a shell, or a large part of it, consists of one crystal individual, always calcite, showing large and distinct cleavage faces. As is generally known this structure is characteristic of all echinoderms. Among the mollusks it is found only in two cases, in *Perna lanceolata*, and in the genus *Actinocamax*; the description of these forms is found in the systematic part.

The crossed lamellar Structure.

This is without doubt the most specialized among all the aggregations. It is the most common and characteristic structure of the four classes of the mollusks. In the class of the *Cephalopoda* it is not found, however. Outside the molluscs the structure is never found.

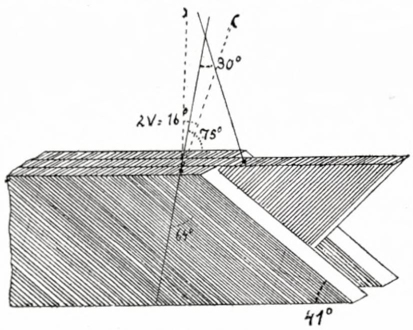


Fig. 2.

The most common and perfect crossed lamellar structure is built up of aragonite. The corresponding calcitic structure has never been described before; it occurs in the families *Aviculidae, Ostreidae,* and *Patellidae*, and a more thorough description of the structure in question will be given in the systematic part. On the other hand the common, aragonitic crossed lamellar structure is, in all four classes, so similar in all essentials that I have found it most appropriate to describe it for all classes in general.

The structure has been described by many previous authors (as de Bournon, Rose, Gray, Carpenter, Bowerbank, Sorby, Biedermann, Schmidt a. o.), but these descriptions of animals chosen for the most part at random are not very uniform and not always quite correct, and I think, therefore, that it will be proper to give a new description of the essential features of the phenomenon.

The layer in question is built up of larger lamels (lamels of the 1st order) three of which are seen in fig. 2. Each lamel has a nearly rectangular form with the longer axis placed in the horizontal direction, parallel to the surface of the shell, whereas the shorter axis, in most instances, has a vertical position. The lamels are built up of numerous smaller lamels, of the 2d order, which are orientated normally to the face of the lamels of the 1st order but form with their edge an angle of 41°. In two adjoining lamels of the 1st order the lamels of the 2d order are inclined in opposite directions; this produces the characteristic crossing of these lamels at angles of 82° or 98°. Each lamel of the 1st order, in spite of its composition of smaller lamels, forms a single crystal individual with a perfectly uniform extinction. The acute bisectrix (the crystallographic c-axis of the aragonite) forms with the edge of the lamel an angle of 75°, and the angle between the extinctions of adjoining lamels is, of course, 30°, while the angle formed by the bisectrix and the lamels of the 2d order attains a value of 64°. The plane of the lamels of the 1st order, at the same time the optic axial plane. The axial angle is, as stated above, very variable. The figure shows the greatest value measured, being for $2\,E = 27°$ (for $2\,V = 16°$). The various other values of the angles given above are also highly variable and must be considered as mean values with variations of up to 10 degrees or more. The values stated are, however, found in all the four classes of mollusks possessing the structure in question, and they cannot be used for distinguishing between these classes.

As to the dimensions and forms of the lamels there may be rather large differences between the different shells, and the different classes of animals may, in some instances, be directly distinguished from each other by means of them. Most divergent are the *Amphineura*, the fine and regular lamels of which (pl. VIII, fig. 5) can hardly be confounded with any of the other shells. In the three other classes, the bivalves, the *Scaphopoda* and the gastropods, it will be difficult to find any property which makes an absolute distinction between them, but we shall find rather characteristic differences which may, in most instances, characterize them.

The length of the single lamel the of 1st order may probably reach several millimetres. In most instances, however, even the most regular of them are pointed out and disappear, giving place to new ones. In horizontal sections, parallel to the surface of the shell, their aspect will be rather variable, but we may distinguish three types between which, however, there are found all possible transitions.

1. The type characteristic of the upper layers of most gastropods and found also in some bivalves is the most regular of all, as shown in pl. IX, fig. 6, pl. X, figs. 1—3, pl. XII, fig. 1, a. o. The boundaries, in most instances, are fairly rectilinear and parallel and, although we see that the lamels are pointed out and branched, these phenomena are not very prominent in comparison with the other types.

2. The type shown in pl. XI, figs. 1—4, pl. XII, fig. 4, pl. XIII, figs. 1, 3 and 4 a. o. is characteristic of most under layers of the gastropods. The lamels are short and very irregularly formed and branched.

3. Characteristic of many bivalves, and also of the *Scaphopoda,* is the type shown in pl. V, fig. 4, pl. VII, fig. 7 and pl. VIII, fig. 3. Here the lamels are also short and branched, but they have grown together in a very peculiar manner, forming a network with more or less pronounced rhomboidal figures.

The breadth of the single lamel may be equal to the thickness of the whole layer in question but here, in many instances, we also find more or less irregular forms. Generally the gastropods are the most regular, and we often find the lamels perfectly regularly formed with parallel boundaries and with a quite vertical position, as shown in pl. XI, fig. 9. More rarely we find oblique positions, as in pl. IX, fig. 7, and in pl. X, fig. 1, and still more rarely a peculiar zigzag form, as shown in pl. IX, fig. 7. In the *Scaphopoda* the lamels are vertical but rather irregular and branched (pl. VIII, fig. 2). Most peculiar are the bivalves. Although there may be found many exceptions the common rule is that the lamels are, in their under part, rather regular and nearly vertical but, upwards they get bent and reclined, and in many instances perfectly horizontal or assume other positions. At the same time the lamels get thinner, more irregularly formed and in most instances not so distinctly visible. Examples of these lamels are seen on pl. III, fig. 4, pl. V, fig. 5, and pl. VI, figs. 2—3.

The lamels of the 2nd order are exceedingly small. In transverse sections we may see them rather indistinctly with the highest magnification and we may conclude that the thickness is a little below 0.001 mm. The length and breadth of them cannot be measured as it is impossible to see if each single lamel passes through the whole lamel of the 1st order or if they are interrupted.

What substance separates the lamels of the 2nd order we do not know. The whole amount of organic matter in the shells in question is very small (about 2 %), and if there were intercalated organic lamels between the calcareous ones, they would be of such small dimensions that they were quite invisible. The crystallographic orientation of these lamels is very doubtful. As mentioned above, they form an angle of about 64° with the c-axis of the aragonite, and, as their plane is normal to the optic axial plane (100), they must be parallel to some dome of the form (0kl). Among these the form (023) forms with the c-axis an angle of 64° 20′, which value is nearly the same as that given above, but this form is not known among the faces found in aragonite, and we should not, at the outset, expect that the lamels should be orientated in that direction. Furthermore the angles measured undergo great variations, and in many instances they deviate so much that they do not correspond with the above-mentioned form. For comparison we may consider the calcitic shells possessing a similar structure. In the shell of *Avicula* the angle between the optic axis and the lamels of the second order is 77°, and in *Gryphaea* and *Patella* the corresponding angles are respectively 82° and 55°; these angles correspond very badly with those for the more common rhombohedra, and it is at the outset very improbable that the faces in question should belong to some scalenohedron, among which we should easily be able to find all possible inclinations to the basis. It seems, therefore, that the lamels of the 2nd order are orientated in a manner which must be designated as rather accidental, without any visible connection to the crystallographical elements of the two substances building up the lamels.

The orientation of the lamels of the 1st order is markedly different in the four classes of mollusks. In the bivalves they are placed in the concentrical direction, and only in very few instances *(Mesodesmidae* and *Mactridae)* do we find lamels orientated more or less regularly in the radial direction. In the gastropods, on the other hand, we generally find three layers of which the uppermost and undermost ones have transverse lamels while the middle one has longitudinal lamels. The various exceptions from this rule may be seen in the systematic part.

The crossed lamellar structure certainly contributes to give the whole shell very great solidity. It is well known that an aggregation of fine elements, especially fine threads intimately mixed, is much stronger than a larger crystal of the same kind. As examples of such fine aggregations may be named achate, nephrite, serpentine a. o. The crossed lamellar structure is built up in such a manner that we get the impression that the purpose of the whole construction has been to bring about the greatest possible strength of the shell. The lamels of the 2nd order seem to be very tough and elastic, and are not easily broken across, and because of their arrangement in crossed positions the lamels of the 1st order are also rather difficult to break across. On the other hand there is a marked division between two adjacent lamels of the 1st order, and if a shell consists totally, or mainly, of one layer of these lamels, we find that it breaks rather easily in that direction. But in the great majority of shells this point of weakness is counterbalanced in most efficient ways. If we disregard those instances where the strength is produced by layers of another structure, we find essentially two ways of holding the lamels together. In the gastropods this is managed by the arrangement of the lamels in alternative layers with longitudinal and transverse directions, and in the bivalves, where the lamels are almost always arranged in the concentrical direction, they are commingled in the irregular manner described above, so that they are not easily parted from each other.

The complex Structure.

This structure is the most intricate of all and the details cannot, probably, be determined with full certainty. In most essentials it seems, however, to be rather uniform, and as it builds up large parts of the mollusk shells, especially the under layers of many bivalves, I have thought it correct to class it as a special kind of structure. It always consists of aragonite.

In most instances the layer in question consists of sub-layers of two kinds one of which is finely prismatic while the other is of a special kind which may properly be designated as complex crossed lamellar.

The complex crossed lamellar structure, which is highly characteristic of the structure in question, is characterized by the fact that we see, in all vertical sections of the same layer, the crossing of the lamels which is so characteristic of the common crossed lamellar structure, if seen in sections parallel to the lamels of the 1st order. We see the thin lamels of the 2nd order placed in the common orientation with an obliquity of about 41°, and with the common extinction forming an angle of about 64° with these lamels. But it is clear that the whole structure must be rather indistinct because of the mixture of the lamels of the 1st order placed in all possible directions. The structure may look rather different in different shells, and also in different parts of the same shell, and I shall here only give a description of it in such instances where the elements are as coarse and distinct as possible, as we find it in the shell of an *Isocardia*. It seems, however, that most other shells are built up according to the same scheme.

In the shell of an *Isocardia* we see distinctly, as shown in pl. III, fig. 3, that the layer in question is built up of rather coarse prisms, and on closer examination we shall see that each of them has a rather complicated structure which I have tried to demonstrate in fig. 3, which shows a vertical section of one of these prisms together with parts of two adjoining ones. From the walls of the prism we see the lamels of the 2nd order protruding into the prism, but the common crossing of them is only found in the upper and lower part of the prism, whereas in the largest, middle part, they, are not crossed at all. As all vertical sections of the prisms are quite alike we must imagine that the lamels of the 1st order are placed normally to all the walls of the prisms, in the same manner as the septa of a coral. The extinctions also are drawn in the figure. Next to the walls we have the common angle of 64° with the lamels of 2-d order, or of 75° with the whole layer while, along the prism axis, we see a parallel extinction produced by the lamels of the 1st order standing normally to the section, and there is a gradual transition between the two extinctions.

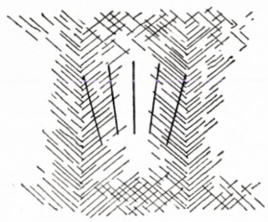


Fig. 3.

We shall see that, in this manner, each prism very much resembles those described above (p. 18) as belonging to the complex prismatic structure. But in most instances we see distinctly the oblique lamels as a sign of the structure in question. The most typical example of this structure is shown in pl. III, fig. 3.

In other shells the elements of the complex crossed lamellar structure are not arranged in prisms but are more irregularly distributed. Pl. VI, fig. 4 shows such a structure where we see the lamels of both directions forming a zigzag pattern. There are all possible transitions between both kinds of arrangement. Another, very irregular arrangement is seen in the shell of *Nerita* (pl. X, fig. 1).

In horizontal sections the complex crossed lamellar structure looks rather different. Where we have a more regular prismatic arrangement, we shall see cross sections of the prisms which show, between crossed Nicols, more or less regularly the uniaxial figure with the black cross and rings of interference colours (pl. V, fig. 7, and pl. VII, fig. 4). Otherwise the structure is more irregular (pl. V, fig. 5, and pl. VII, fig. 3.)

As stated above, the layers of the complex crossed lamellar structure in most instances alternate with finely prismatic layers. The prisms have mostly very irregular extinctions but, because of their fineness, their structure cannot be examined with certainty. Mostly the prismatic layers are very thin and only form a small part of the whole complex layer, but the opposite may be the case, as in the shell of *Durga*, where thick prismatic layers alternate with thin ones of the crossed lamellar structure (pl. III, fig. 2). A very special kind of arrangement is found in the shell of *Chama* (pl. III, fig. 5), where irregularly formed parts with a complex crossed lamellar structure are distributed in a thick prismatic layer.

Terminology.

In order to make the description short and uniform I have found it convenient to introduce various new terms or to use some terms formerly known in a sense not corresponding exactly to that commonly used. Below I give a list of all such terms about which there may possibly be any doubt.

The following terms are explained in the foregoing part of the work:

The homogeneous structure, see p. 15.
The dependent prismatic str., p. 18.
The complex prismatic str., p. 18.
Downward and upward diverging arrangement or axes, p. 18.
The composite prismatic str., p. 19.
The crossed lamellar str., p. 21.
The complex str., p. 24.
The complex crossed lamellar str., p. 24.

The optic axes. The axis of calcite is the common optic axis. In the aragonite the axis is the crystallographical c-axis, being, at the same time, the acute bisectrix.

Fine and coarse. As the shell elements are for the most part much smaller than those commonly found in the inorganic aggregations, these terms have here a special signification. Generally the boundary between both kinds here lies at about the dimension 0.02 mm.

The main directions in the shell:

Distal is the direction towards the margin or aperture of a shell.

Proximal is the opposite direction, towards the hinge or spire.

The commonly used terms outer and inner sides or layers are here replaced by upper and under, and the shell is, of course, imaginal to be placed in a horizontal position with the outside upwards. An element normal to the surface, is accordingly termed vertical (a), and one parallel to the surface is called horizontal (b). For the vertical section in the longitudinal (or radial) plane a distinction is made between the two kinds of oblique directions, the inclined (c) and reclined (d) ones, which is best explained by the drawing (fig. 4).

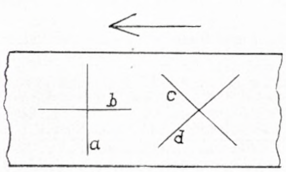


Fig. 4.

A double-pointed arrow (↔)shows the radial (longitudinal) direction in all figures in which this direction is represented (all horizontal or vertical and radial sections), and in all shells where this direction deviates from the opposite (transverse or concentrical) one.

A single-pointed arrow (<) shows the same direction, under the same conditions, and at the same time points towards the distal side of the shell in all instances where this direction deviates from the opposite (proximal) one.

It is clear that, because of the irregular form of most shells, the three main directions of the sections cannot be very exact. A section which, in one small part of the shell, is strictly concentrical, must, in most instances, change, in other parts, into an oblique direction. A so-called horizontal section can in most instances only have that orientation in a single point, and the different layers will be seen as concentrical rings, the outermost of which represent the upper layers of the shell.

Systematic part.

(The system of ZITTEL: Grundzüge der Paläontologie, I. Invertebrata, from 1915 is used).

I. Class: Lamellibranchiata.

As to the shell structure there is so large a difference between the two main divisions of the bivalves that they can hardly be said to have anything in common, the main difference being that the shells of the *Anisomyaria*, with very few exceptions, consist partly or totally of calcite, while the *Homomyaria*, with a few exceptions, consist of aragonite.

1. Order: *Anisomyaria*.

As stated above, it is characteristic of these bivalves that almost all of them contain calcite in their shells, which mineral in some instances forms the outer layer, in others the whole shell. Only a few members of the *Mytilidae* (*Dreissensia* and *Congeria*) and probably also some of the older families, as the *Ambonychiidae* and the *Modiolopsidae*, consist of aragonite. As to the *Dreissensia* and *Congeria* it is characteristic that these forms are the only fresh-water members of the whole order which have been examined. The shell structure in the order is so variable in the different families that there can be said very little in general; the crossed lamellar aragonitic structure which is so common in the gastropods and in the *Homomyaria*, is rather rare here (*Limidae*, *Spondylidae*, *Congeria* and *Dreissensia*), but where found it is always concentrically arranged as in the *Homomyaria*. Aragonite with a nacreous structure is most typical for the bivalves here in question.

Aviculidae.

As to the shell structure this family falls into two divisions which have seemingly nothing in common.

1) The main division; the shells of the recent forms consist of two layers, an upper one, calcitic, and an under one aragonitic, strongly nacreous. In the older forms the aragonite is mostly altered, but in many of them there are distinct traces of its former existence. The calcite of this group is for the most part prismatic.

Avicula sp. (recent). The shell consists of two layers, an upper one, calcitic, and a lower one, aragonitic and nacreous (pl. I, fig. 1). The two layers are of almost the same thickness; a more exact statement of their proportions is here, as elsewhere, of no great value, as the aragonitic layer always gets thicker towards the hinge and disappears towards the margin. The calcite prisms are very regular and distinct (separated from each other by an interstitial mass) and there is no trace of any ramification as is found in the *Meleagrina*. In most instances the optic axes are normally orientated, but there are very many exceptions where the orientation is quite irregular.

Among the older *Aviculae* I have found the same structure in all Tertiary members, among which I have examined: *A. phalenacea* (Miocene), *A. trigona, A. microptera, A. media* and *A. fragilis* (all Eocene); all these have the aragonitic layer preserved, whereas *A. faxensis* (Danian) only possesses the prismatic layer while the aragonite is transformed into an irregularly grained calcite. *A. Moutoniana* (Turonian) possesses a prismatic layer which is essentially more irregular, although rather distinct.

The still older *Aviculae* have no regular prismatic structure but a rather irregular calcite, which, however, in some instances has an indistinct prismatic structure, while in other instances there is no trace of any regular structure at all. It is almost impossible to prove whether or not this calcite is primary, but in one instance (*A. gryphaeata,* alpine Triassic), where the aragonitic layer is still well preserved, it is not conceivable that the much more stable calcite should have been transformed. The other forms examined have no aragonite left, and because of the irregular calcite, its former existence is not easily proved. Examples of this almost structureless form we find in *A. anomala* (Cenomanian), *A. contorta* and *A. inaequiradiata* (Rhaetic) and in *A. crinita* (Devonian). All other Aviculae examined belong to the second division.

Meleagrina margaritifera (recent). The prismatic layer is very regular, and upwards the prisms are ramified in a peculiar manner, getting very thin close to the surface. The optical orientation of the prisms is the opposite of the common one most individuals lying normally to the prism axes in the radial direction; here, too, there are, however, many exceptions with a quite irregular orientation.

Because of its regular and typical structure *Meleagrina* has been much examined by previous authors. Of these Biedermann (p. 15—17) especially describes the curious transversal lines in the interstitial masses between the prisms and the round, air-filled cavities in the same mass. Also Römer (p. 468) and Karny (p. 230—240) give detailed descriptions of the shell structure; the prisms drawn by Karny are by much less regular than those described by me, and the optical orientation is described by him as quite irregular. Schmidt (p. 150) draws attention to a composite optical structure of the single prisms which, however, is for the most part not very marked.

Of the genus *Pterinea* I have especially investigated the *P. retroflexa* (Ordovician and Silurian). In some instances I have found a very regular prismatic structure with a quite irregular optical orientation, while, in other specimens, I have found no regular structure at all. A regular prismatic layer with irregular optical orientation I have also found in other species, as in *P. plana* (Devonian), while *P. fasciculata* (Devonian) does not show any distinct structure.

In *Monotis substriata* (Liassic) I have found a very regular prismatic structure with rather uniform extinction, the crystallographical axes lying in the radial direction, as in *Meleagrina*. In *M. salinaria* (Alpine Triassic) I have not succeeded in finding any distinct structure. In *Pseudomonotis Clarai* (Alpine Triassic) I have found a rather regular prismatic structure with rather uniform extinction with normal orientation of the axes.

In *Halobia rugosa* (Alpine Triassic) there is only a very thin, homogeneous layer with vertical axes.

2. Of the second group of the *Aviculidae* I have found no younger (Tertiary or Quaternary) representatives, it is, however, almost quite certain that they can have possessed no aragonite. Many of the shells are very well preserved with the original upper and under surfaces and in some instances, especially the Russian *Aucellae*, they were found in rocks in which the aragonite of other shells was perfectly preserved. It is characteristic that the hinges of most of the members of this group are well preserved and consist of primary calcite, whereas in other shells, they possess a lower aragonitic layer that mostly forms the main part of the hinge, the calcitic layer thinning out here to almost nothing. But the most characteristic feature of this group, to which many *Aviculae* and all *Aucellae* belong, is the behaviour of the calcitic layer.

The calcite has a very rare structure otherwise known only in some *Gryphaeae* and in some members of the *Patellidae*, viz. a crossed lamellar structure very much resembling the aragonitic structure so common among most mollusks. The principle of the arrangement of the particles is the same in all instances. The whole stratum of ruler-shaped lamels of 1st order standing vertically on the surface of the shell either in a concentrical or a radiating direction, and each of the lamels of the 1st order being composed of very thin lamels of the 2nd order arranged in an oblique direction in such a manner that, in the alternating lamellae of the 1st order they retain the same inclination but are turned to the opposite side. The two calcitic arrangements of this kind, on the one side the *Patella*-structure and on the other side the *Aucella-Avicula*-structure and the *Gryphœa*-structure, resemble each other in so far that, in contrast to the corresponding aragonitic structure, lamels of the 2nd order lie much more flatly, but in other respects they are so essentially different from each other that there can be no closer relation between them; and this must also be considered very improbable because of their slight systematical affinity.

The essential angles of the *Aucella-Avicula*-structure are given in fig. 5 which shows some close-lying lamels of the 1st order; we must remember, of course, that the angles cannot be measured very exactly as the material itself is not very perfect. The obliquity of the lamels of the 2nd order is 17° (in *Patella* 13°), the angle between the optic axis and the direction of the said lamels is 77° (in *Patella* 35°)

and consequently the angle between the directions of extinction in two adjacent lamels of the 1st order is 30° (in *Patella* only 6°). The chief difference between them is, however, that the main axis of the calcite, the direction of the extraordinary ray, which, being in possession of the greater velocity of light, is drawn as the long limb of the cross, is orientated in a nearly normal position in relation to the lamels of the 2nd order, while in *Patella* the opposite is the case. Because of the flat orientation of the reflecting lamellae of the 2nd order it is possible to observe the structure directly on the under surface of the shell in the calcitic crossed lamellar shells, while in the common, aragonitic shells the reflections are not visible outside.

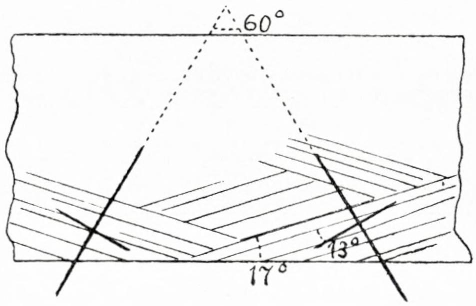


Fig. 5.

In the genus *Avicula* I have found this structure in the following members: *A. pectinata* and *A. danica* (Senonian), *A. macroptera* (Neocomian), *A. Münsteri* (Upper Jurassic) (pl. I, fig. 2), *A. costata* and *A. elegans* (Middle Jurassic), *A. Sinemuriensis* (Liassic) and *A. bavarica* (Rhaetic). In *A. Münsteri* the crossed lamellar calcite passes upwards into a peculiar prismatic, structure, not related to that otherwise found in the family. The prisms are almost quadratic in transverse sections and are optically rather complicated; it seems that the single individuals of each prism form a continuation of the lamels of the underlying layer.

Of the genus *Aucella* I have examined *A. costata* (Middle Jurassic), *A. volgensis* (Neocomian), *A. sp.* (Aquitanian), and *A. concentrica* (Neocomian); they all behave in a similar manner, the upper layer of the shell consisting of the crossed lamellar structure, which, however, passes downwards into a foliated structure with the folia parallel to the surface and producing a peculiar micaceous lustre on the underside of the shell. The optical orientation of these folia is parallel to that of the lamels of the upper layer and alternates in the same manner between one of them and the next.

An *Aucellina gryphaeoides* (Gault) shows the typical *Aucella-Avicula*-structure.

Ambonychiidae.

I have examined different forms belonging to this old family, viz: *Ambonychia corrugata* (Ordovician), *A. sp.* (Silurian), *Cyrtodonta sinuata* and *Mytilarca sp.* (both from the Silurian), without finding any trace of a regular structure. I, therefore, think it most probable that the shells of this family consisted of aragonite, but it is very difficult to prove it with certainty.

Pinnidae.

In a *Pinna* sp. (recent) there are two layers, an upper, calcitic, prismatic, and a lower, aragonitic, nacreous layer. The prisms, which are seen in transverse section in pl. I, fig. 3, are very regular and at the same time distinct, with an interprismatic substance. The orientation of the optic axis is unusually regular, parallel to the direction of the prisms. Of older *Pinnae* I have examined *P. decussata* (Upper Cretaceous), *P. sp.* (Liassic) and *P. flexistria* (Carboniferous); they all of them have only the prismatic layer preserved which is very similar to that of the recent *P.*

No other kind of mollusk shells have been examined so thoroughly as those of the *Pinna* although their structure is as simple as possible. Among other anthors may be cited: De Bournon, I, p. 327 ff., Gray, p. 791, Carpenter, 1844, p. 4 ff., 20 ff., Rose, p. 78 ff., Biedermann, p. 42—71, Römer, p. 468 ff., Karny, p. 208—230, Cayeux, p. 474 ff., 481, Schmidt, p. 148 ff. who give very detailed descriptions of all possible properties of both layers and also of their development. Although in themselves very interesting these descriptions have not so much significance for the present work which is of a more systematic kind, and where it is necessary to point out only the essential characters which may serve for a comparison between the different genera and families. From the investigations cited we may conclude that there is very little difference between the different species of *Pinna.*

Pernidae.

The members of this family behave very much in the same manner as those of the *Pinnidae* and of the main part of the *Aviculidae,* possessing an upper prismatic layer consisting of calcite and a lower nacreous one consisting of aragonite. The last named has been observed not only in the recent forms but also in several of the older ones, and we may, therefore, assume that it is universal in the family. One *Perna* forms a very curious exception from the common type and bears no resemblance to any other known shell.

Of the genus *Perna* I have examined a recent species which has regular prisms with a very regular extinction; of the older ones I have only had occasion to examine the *P. lanceolatus* (Pläner) which possesses the above named peculiar structure. There is a distinct calcitic layer under which a thick layer of irregularly grained calcite suggests a former nacreous layer. The calcite of the upper layer forms one continuous individual orientated in such a manner that one cleavage face is always parallel to the surface; the main axis forms, of course, an angle of 45° with the surface and its inclination is in all instances turned to the proximal side. It is the only example among the shells where I have found any influence of the cleavage upon the orientation of the calcite individuals.

The genus *Inoceramus* is well known because of its thick layer of large prisms which, however, towards the hinge pass gradually into flat lamellae. In *I.* (*Catillus*) *maximus* (Turonian) the extinction is rather irregular but for the most part normal; the prisms are upwards ramifited as in *Meleagrina. I.* (*Haploscapha*) *grandis* (Upper Cretaceous) has, on the other hand, a very regular extinction, but the axes lie in a radial direction; each prism has, however, a distinctly complex optic structure with the directions of extinction diverging upwards (see p. 18). In *I. Lamarckii* (Turonian) the extinction is very irregular but most axes are reclined at an angle of c. 45°. *I. Brogniarti* (Turonian) has a quite irregular optic orientation of the prisms. In other species of *I.* as *I. concentricus*, *I. sulcatus* and *I. subsulcatus* (all Turonian) for the most part only the nacreous layer is left.

The genus *Inoceramus* has been described by CAYEUX, who mentions the different possibilities with respect to the optic orientation of the prisms.

The rather thin prismatic layer of *Gervillia* has generally rather irregular prisms and mostly a very irregular extinction. I have examined the following species: *G. socialis* (Triassic), *G. anceps* (Neocomian), *G. pernoides* (Jurassic) and *G. inflata* (Alpine Triassic): the last named form has, in some specimens, the nacreous layer very well preserved.

Limidae.

The shells of the recent species of *Lima* consist of three layers, an upper one of calcite and two of aragonite. Of these the uppermost possesses a crossed lamellar structure with the lamellae of the 1st order, which are concentrically arranged, very regular, for the most part resembling those of the gastropods. The undermost layer, which is sometimes very thin but in other instances constitutes more that half of the whole shell, has a prismatic structure with fine, not very regular prisms, which are connected with the lamellae of the overlying layer in the same way as in the shell of *Spondylus* (see later on). Among the older forms which I have examined, I have found no aragonite, but in some instances the former existence of this substance is indicated by a distinct layer of irregularly grained calcite.

MISS KELLY (p. 51) has found that the whole shell of *Lima hians* consists of calcite, but according to my investigations this cannot be correct. The properties given by her, especially the specific gravity = 2,65—268 and ε = 1,468, must have been determined in the upper layer alone.

The calcitic layer, which is of the greatest value for the comparison with the older forms, has a very characteristic structure which is hardly found in any other family. As a rule it may be said to be homogeneous with the axes lying in a radial direction but there are many variations from this scheme. The homogeneousness is not always perfect but passes into a more or less distinct prismatic structure with parallel extinction of the prisms, and the direction of the axes undergoes large variations in all dimensions. If we consider the radial cross sections, we shall find the following variations, as shown in fig. 6 where the long arm of the cross signifies the relative axis of largest velocity (the projection of the main axis of the calcite in the plane of the section); the arrow shows the direction towards the margin of the shell.

1. The axes are horizontal or almost so; this structure is found in *L. proboscidea* (Jurassic), the shells of which however, are, very badly preserved and partially altered into chalcedony.

2. All axes are reclined, mostly at c. 45°; *L. lineata* (Triassic) and *L. punctata* (Liassic).

3. All axes are reclined but in the upper part more flat-lying, becoming gradually steeper downwards: *L. tenuistriata* (Jurassic), *L. gigantea* (Liassic), *L.* (*Plagiostoma*) *exaltata* (Liassic) and *L.* (*Pl.*) *punctata* (Liassic).

4. At the upper surface the axes are horizontal, downwards they are more and more reclined: *L. testis* (Paleocene) and *L. Holzapfeli* (Danian).

5. In the uppermost part the axes are inclined: thereupon they become gradually horizontal and more and more reclined. This is the structure in two recent species of *Lima* which I have examined and in *L. nodulosa* (Liassic): in the last named form, however, the structure is rather irregular.

6. The axes are first horizontal and then reclined, then again horizontal and at last more and more reclined: *L. Hoperi* (Turonian and Senonian).

7. The axes in the upper part are reclined. Downwards they become gradually vertical and at last inclined: this peculiar structure is found in *Lima (Plagiostoma) rigida* (Jurassic).

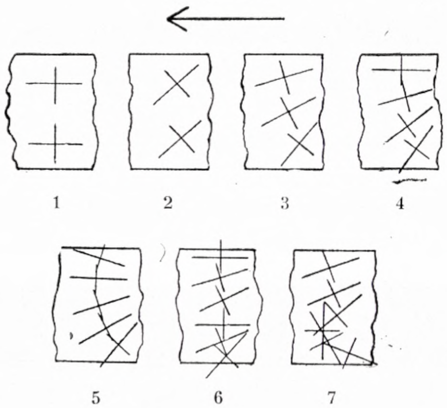


Fig. 6. Lima.

If seen in concentrical cross sections or in sections parallel to the surface, the shells in some instances possess a parallel extinction showing that the main axis of the calcite is orientated in the radial plane, but in other instances, especially in the three last named groups, we find very large deviations from the parallel extinctions. The main axes of the calcite must, in those instances, be orientated in a very complicated manner, if considered in space, and I shall not try to describe these structures in more detail. I have seen no other instance among the mollusk shells where there is a pronounced difference between the directions to the right and to the left.

Lima hians (recent) forms an exception to the type of the family, the calcitic layer being irregularly foliated as in *Spondylus*, *Pecten* and *Ostrea*.

Vulsellidae.

The members of this family possess two layers, an upper prismatic one, consisting of calcite, and a lower nacreous and aragonitic layer.

In *Vulsella hians* (recent) the prisms are rather regular, thin (c. 0.01 mm), and possess an almost perfectly normal extinction. The prisms are ramified at their upper end.

In *Malleus albus* (recent) the prismatic layer is divided by horizontal walls in to different layers, the prisms of which have very different thicknesses, the thickest being almost 0.07 mm. The prisms of each layer are ramified at their upper end. The prisms are rather regular, but their extinction is very variable; in most cases however, it is normal.

The shell of *Malleus* has been described by LEYDOLT who mentions partially or totally empty cells, which I have not found in the species at my disposal. KARNY (p. 230—240) gives more detailed descriptions and drawings of the structure of *M. albus*, to which the reader is referred. His statement that there are in the main two different extinctions, forming an acute angle with the axis of the prisms, is not correct, according to my observations.

Pectinidae.

The *Pectinidae* have undergone a very peculiar evolution in geological times. Beginning, as far as can be ascertained, with a very common structure, a prismatic calcitic layer and a crossed lamellar aragonitic one, they assumed structures in the later periods which are absolutely divergent from all other known ones. As the material of the oldest forms is not very well preserved and rather scanty, it will be most natural to begin the description with the later ones, the Tertiary and Quaternary, which are generally well preserved.

All shells which are perfectly preserved with the exception only of those of *Amussium* consist of three layers, the upper of which is calcitic, while the middle one is aragonitic and the lower one calcitic, as shown in fig. 7 and in pl. I, fig. 5. The aragonitic layer begins far from the margin of the shell and is rather thin and not easily visible because of its transparency; the lower calcitic layer is only found in the proximal part of the shell, and in the hinge itself it quite dominates the two other layers. This lower, calcitic layer has an irregularly foliated structure somewhat resembling that generally found in the upper layer of the newer Pectens, but it is somewhat coarser. In the mesozoic members of the family the aragonite rarely exists, but in that case the lower calcitic layer is wanting and in other instances it is easily seen that it has not existed, the lower part of the shell being totally altered into irregularly grained calcite, which is always a good indicator of the former existence of aragonite.

Fig. 7. Pecten.

As stated above, the aragonitic layer has been found in all later members of the family examined, not alone of the genus *Pecten* proper but also of the genera (or subgenera) *Chlamys, Vola* and *Hinnites.* Its structure is prismatic and the prisms are very straight and regular, very thin (up to 0.01 mm in diameter), and their extinction is generally exceedingly regular, parallel; in other instances, however, somewhat more irregular. The only mesozoic *Pecten* with preserved aragonite, which I have found, (*P. aequivalvis,* Liassic), possesses the same layer, but under that there is, in the part next to the hinge, another, thicker layer of aragonite with the crossed lamellar structure which is so common among the other mollusks and with the lamellae, as usual, arranged in the concentrical direction. There is no aragonite preserved in the still older shells of *Pecten* but it is perhaps most probable that the aragonite originally possessed the very common, crossed lamellar structure, and that this was afterwards replaced by the prismatic one.

The genus *Amussium,* a recent species of which I have examined, seems to differ from other *Pectinidae* in several respects. The upper layer of calcite, possessing the common, irregularly foliated structure, is rather thin, and under this there is found a relatively thick aragonitic layer with crossed lamellar structure and with the lamellae, as usual, in the concentrical direction. Under this layer follow the radiating ledges consisting of calcite which is, of course, quite isolated from the upper calcitic layer. In the part of the shell next to the hinge there is, under the ledges and, between them, under the first-named aragonitic layer, another aragonitic layer with a similar prismatic structure to that found in the other members of the family. Of the older *Amussiums* I have only had occasion to examine the two Jurassic forms, mentioned later, and they have their ledges solidly connected with the upper calcite. Their structure must, of course, originally have differed essentially from that described above.

The upper calcitic layer, which constitutes the greater part of the whole shell, is the only one suitable for comparison with the older forms, so it will be described here in somewhat more detail. The great majority of *Pectens* possesses one of the two structures, with some transitions which we may call respectively the irregularly foliated and the zigzag-lamellar; the former is the commonest among the younger forms whereas the latter is only found among the Jurassic and Cretaceous forms. Only the oldest of all *Pectens* of which I have had material at my disposal, the Palaeozoic and Triassic ones, possess other, prismatic structures.

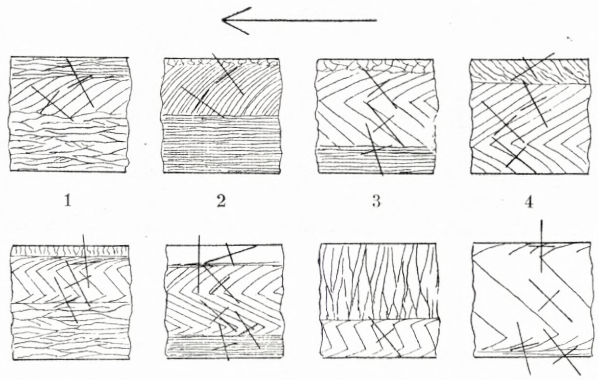
The irregularly foliated structure is not easily described and is also rather variable. As a rule the shell is built up of thin leaves, which are mostly horizontally orientated and give rise to the characteristic cleavage of the shells in question. In some shells, or in some parts of the shell, the leaves are rather straight but in other places they are curved or obliquely placed, or, in some instances quite vertical. Often they intersect each other like a cross-bedding. The optic axis is in the main vertical but generally the leaves have no perfect extinction, and we must assume that the closelying, very thin, leaves possess a different optic orientation. It is the same structure which is so characteristic of *Spondylus*, *Ostrea* a. o. (compare pl. I, figs. 5—7, and pl. II, figs. 1 and 2). Recent forms of this group are *P. vitreus*, *P. aratus* and *P. septemradiatus*, furthermore *Chlamys opercularis*, *Hinnites pusio*, *Vola zigzag* and *maxima* and *Amussium sp.* Of Miocene forms we have *P. gigas* and *P. tigerinus*, of Cretaceous forms *P. dentatus* (Senonian), *P. Brogniarti* and *P. Cottaldinus* (both Neocomian), of Liassic forms may be mentioned *P. Pollux*.

Some of the *Pectens* of the 1st group may be said to form a transition to the next group as, in a certain layer near the surface, the lamellae have a tendency to take an oblique position, but this phenomenon becomes more distinct and regular in the following species which are consequently nearly related to the zigzag-lamellated *Pectens*, although the zigzag structure proper only begins when two or three layers are orientated in oblique positions in alternating directions. As typical transitional forms may be mentioned *P. elongatus* and *lamellosus* (Neocomian) and *P. fibrosus* (upper Jurassic) which have the structure shown in fig. 8,1; the section, like all the others in the figure, is a radial cross section, and the arrow points towards the margin of the shell. We shall see that a large, lower part of the shell possesses the irregularly foliated structure, and that over this layer there is another with reclined foliae passing upwards into another irregularly foliated layer which, however, is more finely foliated than the lower layer. The extinction of the folia is nearly normal to their plane.

Vola quinquecostata and *V. striatocostata* (both Upper Cretaceous) possess a very similar structure but both the under and the oblique layer are much more regular and finely lamellated; the upper layer is irregularly grained (fig. 8,2).

The zigzag-lamellar structure. As a first instance we may take *P. Mantelli* (Senonian) (fig. 8,3); the lower layer is very finely and regularly foliated with an almost normal, or somewhat inclined extinction, and above this layer we have two layers of oblique lamellae, the lower ones inclined and the upper ones reclined, curiously enough, however, with almost the same extinction in such a manner that the under lamellae have nearly parallel, the upper ones nearly normal extinction. The uppermost layer is irregularly grained.

In *P. sublaevis* (Kimmeridgian) the large, lower part of the shell is taken up by the two lamellar layers similar to those described above (fig. 8,4); the uppermost layer consists of irregular, inclined prisms with reclined axes.



1 2 3 4

5 6 7 8

Fig. 8. 1. Pecten elongatus. 2. Vola quinquecostata. 3. P. Mantellii. 4. P. sublaevis. 5. P. textorius. 6. P. undulatus. 7. P. incrustatus. 8. P. disciformis.

The following *Pectens* have a triple zigzag structure with an under and upper layer of reclined lamellae, whereas the middle layer has inclined lamellae; the extinction is always inclined. Fig. 8,5 shows the structure of *P. textorius* (Liassic); the large, lower part of the shell has the irregularly foliated structure, and above this we have the zigzag structure with the upper and under layers rather narrow. The uppermost layer is irregularly prismatic. Very similar to this is *P. aequivalvis* (Liassic), (pl. I, fig. 6).

P. undulatus (Senonian) (fig. 8,6, and pl. I, fig. 4) possesses a very regular structure; the undermost layer is similar to that of *P. Mantellii*; the two upper layers of the zigzag lamellae are rather broad. The uppermost layer has no distinct structure but strongly reclined axes and a thin transitional layer underneath that has the axes vertical. *P. serratus* (Senonian) and *P. cretosus* (Upper Cretaceous) possess similar structures.

The small forms *P.* (*Amussium*) *incrustatus* (Middle Jurassic) and *P.* (*Amussium*) *personatus* (Liassic) possess the structure shown in Fig. 8,7. The shell proper consists only of the zigzag layers, the middle one of which has broad but rather irregular lamellae. Above these layers there is a very irregularly prismatic and very thick layer which is possibly only an incrustation since it very similar to certain inorganic calcitic formations.

The most distinct of the structures in question is seen in *P. disciformis* (Middle Jurassic) (fig. 8,8). The greater part of the shell is formed by the middle zigzag layer which has unusually broad lamellae (up to 0.2 mm); the undermost lamellae pass gradually over into a finely foliated layer possessing upwards an almost vertical axis and downwards an oblique one. Similar structures are seen in *P. stewartianus* (Middle Jurassic) and *P. orbicularis* (Senonian).

In the preceding part we have only considered the zigzag structures in the plane of the radial cross section. Observation of sections in other directions will show us that the lamellae are prolonged in a concentrical direction as shown in fig. 9 which gives a diagrammatic drawing of that of the zigzag layers which has the parallel extinction, e. g. the middle layer of *P. disciformis*. In concentrical cross sections we see that extinction of the lamellae has an obliquity of 16°, alternately to the right and to the left, and in sections parallel to the surface we find in the same way an obliquity of 20°. This shows that the real optic axes are placed in a very peculiar manner; they have all the same obliquity in relation to the surface of the shell, but they are alternately inclined to the right and to the left. In such instances where the lamellae are sufficiently broad it is possible to observe with the magnifying lens that one of the cleavages of the calcite is orientated nearly parallel to the surface.

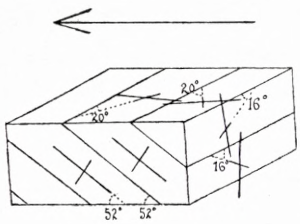


Fig. 9. Pecten disciformis.

The prismatic structures. The few pre-Jurassic *Pectens* which I have had occasion to examine are all prismatic but very different from each other as to the arrangement of the prisms.

P. laevigatus from the "Muschelkalk" has the whole shell built up of large prisms which lie in the radial direction; every prism reaches from the upper to the under side of the shell and its breadth (in the concentrical direction) is ca. 0.2 mm. The optic axes are orientated normally to the prisms and lie in the concentrical direction.

P. sp. from the "Muschelkalk" has a regular prismatic structure as known from *Pinna* a. o., with distinct, vertical prisms. The optic axes are generally parallel to the axes of the prisms, but there are many exceptions to that rule.

P. (Pseudamussium) Redesdalense (Carboniferous) has almost the whole shell constructed of irregularly grained calcite, suggesting the former existence of aragonite. Only a thin upper layer possesses an irregular and somewhat doubtful prismatic structure with very irregular extinctions; the optic axes, however, are in many instances not very far from the normal orientation.

Of course, no certain conclusions as to the evolution of the Pecten shell can be drawn from so few examples.

The shells of the *Pectinidae* have not been very much treated in the literature. Rose (p. 88) finds that the shell consists of calcite; Carpenter (1844, p. 19) gives a description and drawings of the common *Pecten* structure and in another place (1847, p. 95) he mentions a very thin prismatic layer in *P. nobilis*. CORNISH and KENDALL (p. 71) determine the shell of *P. opercularis* as consisting of calcite; this is certainly incorrect and, after what was stated above, we must assume that all *Pectens* have both calcite and aragonite in their shells. SCHMIDT (p. 171) finds that the smallest elements of the *Pecten* shell consist of fine crystal needles.

Spondylidae.

The shells of this family are very similar to those of the Limidae in so far as they consist of the same three layers, an upper one of calcite and two of aragonite. Of these the uppermost one has the crossed lamellar structure with the lamellae orientated in the concentrical direction, and the undermost one is prismatic (pl. II, fig. 7). As in the *Lima*, the prisms are, in a peculiar manner connected to the lamellae of the overlying layer, but here in the *Spondylus* the structure is much more distinct than in the *Lima*. Seen from the side (in vertical sections of the shell) the prisms are very straight and regular but seen in transverse sections (in sections parallel to the surface of the shell) they have a very irregular undulating contour. In polarized light the extinctions of the prisms are parallel to those of the lamellae of the overlying layer in such a way that one half of the prisms extinguish together with one set of lamellae, the other with the other set. The individuals of the lamellae of course protrude as prismatic figures through the lower layer.

It is only in some recent numbers of *Spondylus* and *Plicatula* that I have observed this structure; in the older members of the family which I have examined the aragonite no longer exists, but there are, in some instances, signs of its former existence.

The calcitic layer is fairly alike in all members of the family and has the same irregularly foliated structure which is characteristic of many *Pectens.* Only in *Spondylus faxensis* (Danian) there is a perfectly homogeneous upper layer with horizontal, radial axes. Of other *Spondyli* I have examined *S. spinosus* (Senonian) and *S. latus* (Turonian); furthermore *Plicatula Ravni* (Paleocene), *P. placuna* (Gault) and *Dimyodon Nilssoni* (Senonian).

BOURNON (p. 326) describes the shell of *Spondylus gaederopus* as consisting of two layers, the upper one coloured and foliated (the calcitic) and the lower one colourless and compact (the two aragonitic layers which are easily confounded with each other). ROSE (p. 88) describes the shell of Spondylus as consisting entirely of calcite.

Anomiidae.

The shells of the *Anomiidae* consist exclusively of calcite, the structure of which is the more or less irregularly foliated; there is, however, some difference between the different genera. All species of *Anomia* examined by me possess an irregular structure very much resembling that of *Spondylus* and *Ostrea*, whereas *Placuna* is composed of rather regular folia the axes of which are not quite normal but somewhat reclined. Almost the same structure is found in the shell of *Placunopsis undulata* (Senonian).

Both Gray (p. 794) and Carpenter (1844, p. 19) describe the shells in question as nacreous. I think, however, that there is a great difference between the two structures and that no calcitic shell can be said to be typically nacreous; they have a much more pearly lustre, very much resembling leaves of gypsum or mica or other minerals with prominent cleavage. The folia of the shells of Placuna and Anomia are easily separable from each other, which is not the case in the aragonitic, nacreous shells, and the calcitic "nacre" never possesses the perfectly regular building characteristic of true nacre. The comparison made by Carpenter between the shell of *Placuna* and those of the brachiopods, holds good for most sections but the essential property of the brachiopods, that they are composed of thin, lying prisms, makes them totally different from the shells here in question. In his second paper (1847, p. 95) Carpenter describes a very thin, prismatic layer in *Anomia ephippium*, which species I have not had occasion to examine. Schmidt (p. 169—171) describes the smallest elements of the shell of *Placuna* as consisting of very thin and narrow leaves.

Ostreidae.

I found no trace of aragonite in the shells of the recent oysters which I examined, nor did I find any in the fossil members of the family, of which I have examined many which are seemingly very well preserved, and which originate from formations in which other shells have their aragonite preserved. We must conclude, therefore, that the aragonite is entirely absent in this family.

As is well known, the structure of the oyster shells is of a most irregular kind and a regular structure only occurs in a few members of the older *Gryphaeae.* The typical structure of most shells is the irregularly foliated which bears some resemblance to that found in the *Pecten* and the *Spondylus* but as a rule even more irregular with the folia turned in all possible directions, although in most instances they are nearly horizontal, which gives rise to the characteristic pearly lustre of the shell. There is no difference between the different genera into which the members of the family are commonly grouped. In the following species the said structure seems to make up the whole shell: *Exogyra conica* (pl. II, fig. 1) (Neocomian), *O. Haidingeriana* (Alpine Rhätian), *Exogyra canaliculata* (Danian) and *E. virgula* (Kimmeridgian). In the different species to be described later on, with the exception only of the three described last *Gryphaeae*, we have the same structure combined with other ones.

An upper prismatic layer is found in some instances but does not seems very common. In *Ostrea edulis* we find such a layer consisting of rather regular and distinct prisms which, in their upper part, are curved in a characteristic manner and reclined. The extinction of the prisms is very irregular although a large part of them have the axes orientated in the normal direction. *Alectryonia Marshi* (Jurassic) possesses a thin prismatic layer, not alone at the outer surface but also at the inner surfaces towards the numerous large cavities in the shell; the prisms are irregular and their extinction is also very irregular. The prisms forming an upper layer of the shell of *Gryphæa angulata* (recent) are still more irregular. In no other shells of the oysters have I observed any prismatic layer.

It is a characteristic feature of many oyster shells that the layers of normal consistency alternate with others more or less porous which have all their elements placed vertically. The common oyster, *Ostrea edulis* (pl. II, fig. 2), possesses numerous such layers of a chalky consistency, consisting of very fine, vertical folia; in sections parallel to the surface of the shell these folia are orientated in all possible directions. Their extinctions are not quite normal but always somewhat oblique, and as the folia of the main substance behave in the same manner it would seem that the building elements are the same in both layers. Quite similar layers are found in the shells of *Gryphaea angulata* (recent). In some of the older members of the family there is the well known vesicular structure which is produced by thin, vertical walls placed at rather a long distance from each other; for the most part the cavities are filled up by later formed calcite crystals so that the original form of the leaves is not distincly seen. The best known instance of this kind is the *Gryphaea vesicularis* (pl. II, fig. 3) (Senonian and Danian), in the shells of which layers of the normal structure alternate with the cellular ones. *Ostrea hippopodium* (Turonian and Senonian) has a similar structure. In *Ostrea reflexa* (Danian) the normal layers are reduced to thin films, the numerous layers of the cellular substance making up almost the whole shell.

As stated above, there are some of the older *Gryphaeae* which possess a crossed lamellar structure; it is possible that there are among the other members of this family or the adjoining ones transitions from the ordinary, irregularly lamellated structure to that here in question, but it is not possible to decide this more exactly. The only shells where the structure is quite distinct are *Gryphaea arcuata* (Liassic), *G. signata* (Callovian) and especially *G. Cymbium* (Liassic) (pl. II, fig. 4). The structure is in all essentials very much the same as that of *Aucella* and *Avicula*, so that fig. 5, p. 31 will give rather a good picture also of the structure of these *Gryphaeae*. The angles, which, because of the imperfect parallelism of the elements, cannot be measured with great exactness, are somewhat divergent from those of the figure. The obliquity of the lamellae of the 2nd order is 12° (instead of 17), the obliquity of extinction is 8° (13), and the difference between the extinctions of the two sets of lamella is, consequently, 40° (60). The elements are not so well arranged as in all the other crossed lamellar structures, and especially the fine lamellae of the 2nd order are not strictly parallel in the same lamel of the 1st order so that we obtain no perfect extinction of these in any position. Because of the flat-lying lamellae of the 2nd order their reflections are easily visible on the surface of the shell with the naked eye and especially on the fresh cleavage faces obtained by breaking the shell into pieces. We see on such faces a brillant moire structure, and we see that the lamellae are not very regularly bounded by straight lines but that they are rather short and generally get gradually thinner at the ends.

An observation by L. v. Buch that the fossil oysters have prisms in which we may see the cleavage faces of the calcite crystals makes it probable that he has seen the grained calcite filling the cells of *Gryphaea vesicularis* a. o. Carpenter (1844, p. 19) describes the structure of the oyster's shell as "subnacreous"; he has observed the prismatic layers of *Ostrea* and *Gryphaea*. Rose (p. 84 ff.) gives a more detailed description of the shells of different oysters and determines their substance as calcite. Furthermore, investigations by Sorby (p. 62) and Tullberg (p. 37) may be cited.

Myalinidae.

The material at disposal does not allow of a certain determination of the shells of this family. *Myalina recurvirostris* (Carboniferous) possesses a very regular prismatic, upper layer with quite irregular extinction, and under that the main part of the shell consists of irregularly grained calcite suggesting the former existence of aragonite. *M. Keokuk* (Carboniferous) has a very irregular and somewhat doubtful prismatic layer, whereas *M. subquadrata* (Carboniferous) has the whole shell built up of quite irregularly grained calcite.

Modiolopsidae.

Here, too, the material at disposal is very scanty so that it is not possible to ascertain with full certainty the original structure of the shells. In *Myoconcha Stampensis* (Liassic) there is some aragonite preserved but only as an earthy mass which does not permit us to state the original arrangement of the particles; on the other hand there is no calcite with the exception of a small amount of so irregular a structure that it must be assumed to be of secondary origin. *M. Curionii* (alpine Triassic) only possesses an irregularly grained, calcitic layer. *Modiolopsis Nilssoni* (Silurian) has seemingly very well preserved shells which, however, in sections, show an absolutely irregular structure indicating a secondary origin. It is, of course, probable that the shells of this family originally consisted of aragonite.

Mytilidae.

As to the shell structure this family may be divided into two totally different groups; the first, the main group, comprises all the salt water forms, the second the fresh water forms *Congeria* and *Dreissensia*.

1. The shells of the main group, if in a well preserved state, consist of two layers, an upper one, mostly very thin, calcitic, and a lower one, aragonitic. Only in some of the oldest members there seems to have been no calcitic layer. The structure of the calcite is typically homogeneous or indistinctly prismatic with the axes horizontal in the radial direction or nearly so; the aragonitic layer is nacreous and only in a few instances partially prismatic.

The common *Mytilus edulis* (recent) possesses a thick calcitic layer of blue colour; the axes are strongly reclined and in the upper part nearly horizontal. The structure is markedly irregular, being sometimes perfectly homogeneous and sometimes finely prismatic, and the prisms may, in some instances, be very indistinct, in others more marked, and there may be sharp boundaries between the different parts. The directions of the prisms are nearly parallel to those of the optic axes, though generally a little more horizontal so that each prism gets a somewhat oblique extinction. The aragonitic, white layer is normally nacreous.

The shells of *Mytilus* have been described by various previous authors. CARPENTER (1847, p. 99) finds no distinct organic structure in any of the layers; TULLBERG (p. 14) gives a very detailed description of the formation of the shell. EHRENBAUM (p. 6 ff.) describes the structure in all details. CAYEUX (p. 479) refers the calcitic layer of Mytilus to his "structure fasciculée", his pl. 49, fig. 3 shows dictinct and rather broad (c. 0.04 mm) prisms which are very finely striated in different directions. I must confess that I have not been able to find any similar structure. A good photograph of very fine, isolated needles is given by SCHMIDT (p. 149).

Of older *Mytili* I have examined *M. mirabilis* (Upper Jurassic) which has a very thin, calcitic layer, homogeneous, with nearly horizontal axes and under that a rather thin layer consisting of nacreous aragonite which is partially preserved, partially altered into grained calcite. A thick, lower layer consists of grained calcite but shows traces, in some places, of a fine prismatic structure with quite vertical prisms. It is not possible to prove that these prisms consisted of aragonite, but it is most probable that we have here a relict of an original prismatic, aragonitic layer.

The Genus *Modiola* behaves in all essentials like *Mytilus*. *M. Modiolus* has a thin calcitic layer with a rather irregular structure but for the most part nearly horizontal axes and under that the nacreous layer; but in that there is a thin prismatic, aragonitic layer. The prisms are apparently very distinct but on closer examination we see that there is a system of distinct, black lines running through the middle of the prisms while their boundaries are not very distinctly marked. The whole structure is much like that of the *Mytilus mirabilis*. Another recent *Modiola* has a very thin, calcitic layer, indistinctly prismatic with horizontal, radiating prisms and the axes nearly orientated in the same direction; a prismatic aragonite here forms the under side of the shell. *M. elegans* (London Clay) has no prismatic, aragonitic layer; the calcitic layer is perfectly homogeneous. *Septifer Cottae* (Senonian and Danian) only possesses the calcitic layer which is indistinctly prismatic with horizontal prisms and horizontal axes, whereas *M. laevis* (Liassic) has a perfectly homogeneous calcite.

Lithodomus lingualis (Carboniferous) has a calcitic, prismatic layer with horizontal, radiating prisms and the axes orientated in the same manner.

2. The genera *Congeria* and *Dreissensia* differ from all other newer Anisomyaria examined by having no calcite in the shells; from the other *Mytilidae* they differ by the aragonite not being nacreous but possessing a crossed lamellar structure with the lamellae arranged, as commonly, in the concentrical direction. The aspect of the lamellae, as seen in a section parallel to the surface, is a typical rhomboidal; as seen in radial sections they are curved and reclined, and in both respects they show great similarity to the bivalves of the next section.

An entire contrast to the above-named, recent forms is a *Dreissensia tippana* from the Senonian Ripley formation, the shell of which is nacreous throughout; there is no trace left of any calcitic layer.

As will have been seen from the foregoing, there is very much variation in the structure of the shells of the Anisomyaria, the most common feature being the existence of two layers, an upper, calcitic and an under, aragonitic one, but both of them are very variable from one family to an other, and there is no visible correlation between them, all possible combinations being found. This will be clearly evident from the following table giving the typical structures for each family and omitting some more exceptional forms. For the sake of clearness I have divided the Anisomyaria in to the older and the newer forms, the first group comprising the Paleozoic and older Mesozoic ones and the second the younger Mesozoic and the Kainozoic ones.

Table of the Anisomyaria.

Family	Older forms	Newer forms	
	calcite	calcite	aragonite
Aviculidae, main part	prismatic or no regular structure	prismatic	nacreous
» *(Aucella-Avicula*-group)		crossed lamellar	none
Ambonychiidae	no regular structure		
Pinnidae	prismatic	prismatic	nacreous
Pernidae		prismatic	nacreous
Limidae		homogeneous	crossed lamellar + prismatic
Vulsellidae		prismatic	nacreous
Pectinidae	prismatic	irregularly foliated or zigzag lamellated	prismatic (+ an under calcitic layer)
Spondylidae		irregularly foliated	crossed lamellar + prismatic
Anomiidae		irregularly foliated	none
Ostreidae		irregularly foliated (rarely crossed lamellar)	none
Myalinidae	prismatic or no regular structure		
Modiolopsidae	no regular structure		
Mytilidae, main part	prismatic	homogeneous or indistinctly prismatic	nacreous or n. + prismatic
» *(Congeria-Dreissensia)*		none	crossed lamellar

Although the material from the older formations, which I have had at my disposal, is, in most instances, rather scanty, it will be obvious, however, that there is a great difference between the older and the newer forms both because the older forms only in some instances possess a regular structure and the only regular structure found is the prismatic one, even in such families in which the newer forms have other structures. It would seem, of course, that the prismatic arrangement is the most primitive, which was only what might be expected at the outset. As to those instances where no regular structure is found, it is very difficult to say anything certain about the original state of the shell. There are three possibilities: 1) The shell originally consisted of aragonite; it is most probable, then, that the structure may be exceedingly irregular, often with very large individuals. 2) The shell originally consisted of calcite the structure of which has been lost; at the outset we should find it rather improbable that such an alteration could take place, especially wenn we see other groups of animals, the shells of which are almost always preserved in their original state, e. g. the brachiopods, the trilobites and the Palaeozoic corals. We cannot, however, deny this possibility in some instances if we find one species as e. g. *Pterinea retroflexa*, the shells of which have sometimes a regular prismatic layer while it is not possible to find any such in many other specimens. We must assume, then, that the prisms have been dissolved whereupon the cavity has been filled up by a new calcitic mass, or that the prisms have fallen from each other and then given rise to the formation of crystals of calcite. 3) The irregular structure may be the original, calcitic one. To be sure, we know no instance of irregular calcite in any bivalve shell, but some of the gastropods possess such a structure; in that case, however, it is never quite irregular but there is a certain conformity in the behaviour of the single individuals as to size, transparency a. o. properties, as there is also generally some uniformity as to the form of the individuals. In many instances it may be difficult to say if we have an irregular structure or an indistinct prismatic one. As stated above, it is most probable that some of the older *Aviculae* possess such a structure.

2. Order. *Homomyaria.*

The shells of the bivalves belonging to this order are in most respects different from those of the former one. Calcite is very rare, being found only in some of the families with very thick shells, especially the *Rudistae.* The typical structure of the aragonite is the crossed lamellar structure of the form characteristic of the bivalves. The lamellae of the 1st order are, with very few exceptions, only concentrically arranged; if seen in radial cross sections they are almost always very irregular, becoming thinner or ramified, and often obliquely placed or curved. If seen in sections parallel to the surface they are generally not bounded by parallel lines, as in the gastropods, but form a characteristic rhomboidal network. In concentrical sections we see the lamellae of the 2nd order forming a system of fine oblique lines crossing each other at nearly the same angle as in the gastropods. The lamellae of the 1st order are generally very fine and it requires a good magnifying lens to detect them upon fracture faces of the shell.

Although the crossed lamellar structure is the most typical one, it is in many families combined with other structures and in other families it is entirely missing. On the other forms of aragonite found in this order few general remarks can be made, as there is rather a large range of variability; the nacreous structure, so common among the Anisomyaria, is rather rare here.

As there is no distinct difference between the shells of the three main groups of the Homomyaria, viz. the Desmodonta, the Heterodonta and the Taxodonta, we shall treat them together in the following.

Nuculidae.

The shells of this family must be divided into three groups which have very little to do with each other; the genus *Nucula* has representatives in all groups, whereas other recent genera examined all belong to the third group.

1. The lower part of the shell consists of a generally rather thick nacreous layer while the upper part has a structure which may be designated as composite prismatic; each of the radiating ledges which are characteristic of most of the forms in question forms a prism of the 1st order which is composed of very thin prisms of 2nd order arranged in a feathery manner, the feathers diverging in the distal direction. The extinction of the smaller prisms is rather irregular, most of the optic axes are, however, parallel to the axes of the prisms. Most of the newer *Nuculae* examined, the recent *N. nitida* (pl. II, fig. 5) and *nucleus*, the Tertiary *N. Mayeri* (Miocene) *N. Greppini* (Oligocene) and *N. similis* (Eocene) (pl. II, fig. 6) belong to this group. Among the Mesozoic forms I have only found this structure in *N. pectinata* (Gault).

2. *Nucula trigona* (Eocene) has no nacreous layer; the whole shell is built up of very fine crossed lamellae, curved and reclined.

3. There is no nacreous layer; the shell is homogeneous or very indistinctly prismatic. The axes are vertical on the under side of the shell but upwards they are curved and reclined. In the upper part the homogeneous structure is more indistinct and passes gradually into the very finely grained. *Yoldia arctica* (recent), *Leda pernula* (recent) and *L. Deshayesiana* (Oligocene) belong to this group. The last named form has the axes more turned round than is usual, in such a manner that they are horizontal a little under the surface, and at the surface inclined. The oldest *Nuculae* with the shells preserved, *N. Hammeri* (Middle Jurassic) and *N. lineata* (alpine Triassic), belong to this group. The state of preservation of this form, which is among the oldest of all aragonitic shells preserved, is peculiar. Some parts of the shell are seemingly absolutely preserved and quite solid, not earthy like many of the other aragonitic shells from the Tertiary and Mesozoic formations, whereas other parts are transformed into irregularly grained calcite. All other Mesozoic *Nuculidae* and, of course, all Paleozoic forms examined have been totally transformed into calcite.

Judging by the genus *Nucula* the structure of group 3 must be the most primitive; from that the crossed lamellar structure may have been developed by a more gradual transition while the structure of group 1 seems to bear no closer relation to the other two.

Arcidae.

The members of this family are very much alike, the greater part of the shells being built up of crossed lamellae, as is usual in the concentrical direction; the lamellae are markedly curved and reclined in the upper part of the shell and in some instances almost horizontal. Otherwise they are much more regular than in most other bivalves and their aspect in sections parallel to the surface is almost as in the gastropods. Only in the proximal part of the shell there are, on the under side, other structures, as a thin, dependent prismatic layer and a layer of a very irregular structure, coarsely prismatic with a very complicated optical orientation. Among the forms examined there are representatives of the genera *Arca, Pectunculus, Limopsis* and *Cucullaea.*

The genus *Arca* was described by Bournon (p. 326) who points out the analogy of their shells to those of *Strombus*; Schmidt (p. 173) equally compares the shells of *Arca* with those of the gastropods, his photograph only shows the lamellar structure in the middle part of the shell while I have always found it extending to the upper surface. It must be remembered, however, that the lamellae in the upper part have another direction and are not distinctly visible if the section is not placed in the radial direction. The shell of *Pectunculus* is described by Rose (p. 97) as "faserig"; the description given by him of the directions of the threads is not easily understood. Cayeux gives a very good photograph of the shell of *Pectunculus* (his pl. 51, fig. 4); his under layer ("couche lamelleuse, str. entrecroisée") shows what I have described above as the irregular layer, whereas his upper layer ("Couche dite prismatique") is the crossed lamellar layer.

Nayadidae.

The shells of *Unio, Anodonta* and *Margaritana* are constructed in a very regular manner. Uppermost there is a generally rather thin prismatic layer with regularly formed prisms; each prism is optically perfectly homogeneous with feathery and downward diverging axes (as shown in fig. 1, a). The thicker under layer is nacreous.

Because of the regular structure the shells of this family have been described by many previous authors; Carpenter (1847 p. 97) gives the main features of the shell. Rose (p. 83) erroneously determines the prismatic layer as being calcitic. Biedermann (p. 8—71) gives very detailed descriptions of the development, structure and optics of the shells in question, to which the reader is referred; his conclusion that the single prism "gewissermassen aufgefasst werden kann als eine Säule aus übereinandergeschickteten scheibenförmigen Sphärokrystallen" cannot, however, be considered as correct and shows that he has only observed the prisms in sections parallel to the surface. Römer (p. 439—468) has also investigated the structure of the shells in question very thoroughly; he shows that the explanation of Biedermann cannot be correct, but on the other hand he gives an explanation which, according to my observations, is also incorrect, viz. that each prism should represent a part of a large spherocrystal (his textfigs. 2 and 3). The existence of the feathery structure is inferred from the fact that the prism, in a parallel position, in polarized light shows a black line of equal thickness through the whole length while in an oblique position the black line moves to one side but retains its orientation parallel to the axes of the prism, whereas a spherocrystalline structure would produce a black line thinner at the end turned towards the centre while, if the preparation were turned, it would take an oblique position. It is also uncorrect when Römer concludes that there may be a gradual transition from the prism of *Anodonta* to that of a *Pinna.* Besides the fact that the one is aragonitic, the other calcitic, there is the great difference that the *Anodonta* prism has the structure which is here called homogeneous, while the *Pinna* prism consists of a single crystal individual. KARNY (p. 240—259) gives an explanation, in all essentials correct, of the structure of the prisms in question. In his fig. 18 we must, however, imagine that the upper end of the prism is turned downwards as the figure would otherwise show the elements diverging upwards, which is not the case for the prisms of that family. SCHMIDT (p. 152 ff.) gives very good descriptions and figures of the optics of the shells in question but curiously enough he arrives at the same result as that obtained by BIEDERMANN that the prisms are segments of spherocrystals. Also TULLBERG (p. 34) gives a description with figures of the shell of *Margaritana*.

Trigoniidae.

The shells of the *Trigoniidae* in certain respects much resemble those of the foregoing, possessing an upper prismatic layer and a lower nacreous one. The prisms are for the most part strongly reclined and their form is very irregular; some of them are extinguished simultaneously in all their parts, while others have a rather indistinct feathery structure with upward diverging axes. The nacreous layer, which constitutes the greater part of the shell, is very regular downwards, and possesses a prominent lustre; in its upper part it is rather impure with an indistinct prismatic structure which makes the lustre much weaker and interrupted; it may be traced, however, up to the first-mentioned prismatic layer. The nacreous lamellae, which are quite horizontal in the lower part, get gradually strongly inclined upwards. Besides a recent *Trigonia* I have examined *T. Bronni* and *T. navis* (Jurassic) which are both rather well preserved, whereas all other older Trigoniae examined are altered into grained calcite.

CARPENTER (1847, p. 101) describes both the upper cellular (prismatic) layer and the lower, nacreous one of *Trigonia.*

Astartidae.

The shells are rather uniform, possessing an upper crossed lamellar and an under, prismatic layer (pl. III, fig. 1). The crossed lamellar layer, forming the greater part of the shell, has, as is usual, the lamellae placed in the concentrical direction; they are very fine and, especially in the under part, sometimes become gradually quite invisible, passing into a homogeneous layer. Typically the lamellae are vertical in the lower part but passing upwards get gradually more reclined, becoming, sometimes, quite horizontal; in many instances the whole upper part of the layer is very irregularly constructed. The lamellae, when seen in a section parallel to the surface, mostly show the typical bivalve structure, although somewhat more straight-lined than in most bivalves, forming in this manner a transition from the *Arcidae* to the following families.

The under, prismatic layer is mostly confined to a smaller part of the shell next to the hinge; it is generally rather thin. The prisms behave somewhat differently in the different genera. In *Astarte* and *Nicania* each prism consists of one individual; the form of the prisms is rather irregular, their extinction for the most part very regular with the optic axes parallel to the prism axes. In *Cardita* and *Venericardia* the prisms are of a more complex nature.

Forms examined are *Astarte borealis, A. semisulcata, A. compressa* and *A. elliptica* (all recent), *A. Reimersi* (Miocene) and *A. porrecta* (Jurassic); *Nicania* Banksi (recent). Furthermore *Cardita borealis* (recent), *C. Jouanneti* (Miocene), *C. tenuicosta* (Gault) and *Venericardia imbricata* (recent).

Astarte borealis was described by EHRENBAUM (p. 18) who finds two substances which are quite distinct although the difference between them is said to consist only in a slight variation in colour. Both layers are said to consist of lamellae, and the prismatic layer is not mentioned. CAYEUX in his pl. 50 gives two excellent figures of the shell of *Cardita*; fig. 2 ("couche prismatique") shows the typical bivalve mode of orientation of the crossed lamellae when seen in a section parallel to the surface, while fig. 5 ("couche lamelleuse") shows the prismatic layer interrupted by lines of growth.

Crassatellidae.

The *Crassatellidae* much resemble the members of the foregoing family, the shells being built up of concentrical, crossed lamellae; there is, however, no under, prismatic layer. The lamels are very fine and strongly curved in such a manner that downwards they are nearly vertical and upwards gradually reclined and, in a certain layer, almost horizontal, whereupon, in the uppermost layer, they get almost vertical. Downwards the lamels get gradually more and more indistinct, passing into an almost homogeneous layer which is also for the most part strongly lamellar because of the succession of former inner surfaces of the shell. As examples of *Crassatella* I have used *C. divaricata* (recent), *C. tumida* and *C. lamellosa* (Eocene).

Megalodontidae.

Of this family I have found no members with the shells preserved other than *Megalodon pumilus* and *Durga crassa* (both from the Jurassic). They are very much alike and show a very peculiar structure. The shell consists of two layers, an upper, homogeneous or very indistinctly prismatic one with vertical axes, and a lower one constituting the greater part of the shell, of the complex type with many alternating layers of two kinds (pl. III, fig. 2). The one is prismatic with rather irregularly formed prisms and with the optic axes in the *Durga* almost vertical, while in the *Megalodon* they are somewhat more divergent; the other is of that very complicated kind which may be designated as complex crossed lamellar, showing the crossing lines in both kinds of transverse sections.

Isocardiidae.

There is no little similarity between the shells of this family and those of the former. There is an upper layer with a homogeneous structure which, however, in the greater part is finely grained. Under that layer the greater part of the shell consists of many layers of a complex crossed lamellar structure between which there may be exceedingly thin layers with a finely prismatic structure. This is the structure of the Tertiary species *Isocardia Forchhammeri* (pl. III, fig. 3) (Miocene), whereas *I. cor* (recent) is in so far different as the lower layer, which is also much thinner than the upper one, is less complicated and encloses no prismatic layers.

Chamidae.

In the species of *Chama* examined there is no calcite; the shell consists of two layers, of which the upper one is crossed lamellar with concentrical lamellae (pl. III, fig. 4). The lamellae are rather coarse and downwards rather regular, almost vertical or somewhat reclined, whereas, in the upper part of the shell, they are strongly reclined or quite horizontal, the whole structure being very irregular here. The lower part of the shell is somewhat similar to that of the foregoing families with an alternation of prismatic and complex crossed lamellar structures. The distribution of these two elements is, however, very peculiar, as they do not form regularly alternating layers but are more or less irregularly mixed together. In a *C. sp.* (recent) we find irregularly bounded crossed lamellar spots distributed in the prismatic layer (pl. III, fig. 5) whereas in the Eocene forms, *C. rustica, C. lamellosa* and *C. ponderosa* the distribution of the two elements is somewhat more regular.

Carpenter (1847, p. 100) gives a description of the shell of a *Chama* to which he ascribes a cellular structure; his drawing, which gives a rather good picture of the lamellar layer (c) and the prismatic one (a) as seen in a section parallel to the surface, he explains as showing the cells cut in different directions. Cayeux (p. 480, pl. 50) gives a photograph of a concentrical section showing, in all probability, the irregular upper part of the shell.

In the other genera of this family I have found no aragonite preserved but there are, in some instances, distinct signs of its former existence. On the other hand there is, in almost all of them, a calcitic layer, the structure of which is prismatic although very variable. In *Requienia ammonia* (Neocomian) there is a regular, prismatic layer with coarse (up to $^1/_2$ mm. thick) prisms which are vertical with very regular, vertical optic axes. Similarly in *Caprotina texana* (Cretaceous) and in *Diceras arietinum* (Upper Jurassic), whereas in *D. Luci* (Tithonian) there are two calcitic layers, a lower one consisting of very coarse, horizontal, radiating prisms with the optic axes mostly parallel to the axes of the prisms, and an upper one consisting of finer prisms which are reclined and strongly curved in such a manner that they are nearly horizontal downwards, and upwards increasingly vertical. The optic axes are also reclined but not curved so that each prism obtains in one place a parallel extinction and in all other places an oblique one. *Gyropleura Münsteri* (Senonian) possesses the most peculiar structure; it is true that large parts of the shell are rather irregularly built, but sometimes there are, over rather large areas, only two individuals, a lower and an upper one, sending acute triangular indentations into each other. The direction of these indentations is reclined, and the optic axes of both individuals are also reclined but in different degree.

In the handbooks of Zittel a. o. it is commonly stated that the shells of the *Chamidae* consist of a prismatic and a porcellaneous layer; as to the *Chama* itself this statement is not correct as the crossed lamellar structure is the most typical for what is commonly called porcellaneous. The other genera may possess the two said layers but I have not succeeded in finding any of them with the aragonite preserved and in the literature there is no direct statement to that effect.

Caprinidae.

The material which I have had at my disposal of this family is too small to draw any certain conclusions about the structure. Only in *Plagioptychus Partschii* (Cenomanian) I have found an original calcite forming a thin layer of rather irregular prisms with rather irregular extinction, while the thick, lower part of the shell consists of irregularly grained calcite suggesting the former existence of aragonite. In *C. adversa* and *C. quadritesselata* (both Cenomanian) I have found no regular structure at all.

In the handbooks of ZITTEL the shells are described as consisting of a prismatic layer and a porcellaneous one between which there is a porous or cellular layer. It is most probable that both the last-named layers consist, or have consisted of aragonite.

Rudistae.

The shells of the *Rudistae* consist of two layers, an outer, generally very thick, calcitic, one, and an inner, relatively thin, aragonitic one. It is true that I have in no instance found the aragonite preserved, but in the best specimens at disposal it is altered to a loose, chalklike substance, and in others to an irregularly grained calcite. Its former existence cannot, however, be doubted both in the inner layer of the shell and also in the inner tabulae of the *Hippurites.*

The calcitic part of the shell behaves in two, quite different manners. In most of the genera *Sphaerulites, Radiolites* and *Biradiolites* it possesses a peculiar cellular structure whereas in all species of *Hippurites* and in some of the other genera it possesses a compact prismatic structure of a more common kind. As most of the labels in the Museum of Copenhagen are of rather old date, it may be possible that the genus is not correctly determined, and it may be that the compact structure will really include all members of the genus *Hippurites* and the cellular one all the other genera mentioned.

An examination of the cellular shells shows that the cells are bounded by two essentially differently constructed elements. The one of them, which we will call the tabulae, possesses a prismatic structure with the prisms placed normally to the plate, while the others, which we will call the walls of the cells and which are orientated, in one or two dimensions, normally to the tabulae, likewise possess a prismatic structure but with the prisms, which form only one layer, orientated parallel to the walls and normally to the tabulae, all prisms, in that manner, being turned in the same direction throughout the whole shell.

The orientation of the tabulae is in many instances that which is, in other shells, called the concentrical one, normal to the cylinder axis of the animal, but in other instances it may be parallel to the surface (as in many members of the genus *Biradiolites*) or take an oblique position between both. In the typical *Sphaerulites* they extend into the protruding leaves and are orientated parallel to their surface.

The tabulae consist of an exceedingly thin, intransparent layer on the one side of which is found the above-mentioned prismatic layer (best visible in pl. IV, figs. 1 and 6) which is generally very irregular and with a very irregular extinction. In many instances (*Biradiolites cornu pastoris* (pl. IV, fig. 1), *B. speciosus*, *B. angulosus*, *Radiolites radiosus* (pl. IV, figs. 2 and 3), *R. triangularis*, *R. suecicus*, *Sphaerulites ventricosus*, *S. Beaumonti*, *S. cylindricus* (pl. IV, fig. 4) the prismatic layer is very thin (up to 0.02 mm. thick), while in others (*Biradiolites pseudo-Mauldei*, *B. foliace-alaeformis* (pl. IV, fig. 5), *B. canaliculatus*, *B. pseudo-cornu-pastoris* (pl. IV, fig. 6), *Sphaerolites calceoloides* it is essentially thicker and consists of coarser prisms. Generally the whole layer is, then, regularly arched, being thicker near the attachments of the cell walls than elsewhere.

The cell walls are more uniform than the tabulae, their thickness varying about 0.05 mm. As stated above, they consist of one layer of prisms (faintly visible in pl. IV, fig. 2) the extinction of which is generally rather irregular. While all the walls have a position normal to the tabulae, their form is very variable. In most instances (most of the above named species) they all form plane lamellae radiating from the axis of the animal (pl. IV, fig. 4, and pl. V, fig. 1), while in other instances (*Radiolites radiosus*, *R. triangularis*, *Biradiolites angulosus*) the main direction of the walls is the same, whereas, in certain parts of the shell, they get much more irregular, anastomosing and in this manner forming a real network. In other forms (*Biradiolites cornu pastoris* (pl. III, fig. 6), *Sphaerulites ventricosus*) the walls seem to form a perfect network throughout.

The dimensions of the cells are very variable among the different species and also in different parts of the same shell. The figures will give the best information on this point. Also in other respects there is much variation in the structure of the shells, and we shall possibly find sections of some of the named species which differ in some respect or other from the scheme given above. Notably we shall observe, sometimes, that large parts of the shell possess a compact prismatic structure (pl. IV, fig. 5), the exact extension of which it has not, however, been possible to ascertain. We may imagine that such parts have formed a skeleton in the main part of the shell which must have been very light and fragile at the time when the cells were not, as now, filled up by later formed calcite.

The other group of the *Rudistae* seems to have its shells consisting totally of compact prismatic calcite although it will be difficult to prove this with certainty if we do not make sections of all parts of the shell. Most typically (*Hippurites bioculatus*, *H. cylindraceus*, *H. sulcatus*, *H. canaliculatus*, *H. turgidus*, *H. organisans*) (pl. V, fig. 2) the prisms are fine (ca. 0.02 mm. thick) and possess a very regular extinction. Generally they are orientated nearly normally to the surface of the shell or in a more oblique direction, but in many instances they run rather irregularly. A section parallel to the surface often shows a feathery arrangement, much resembling that of some *Nuculae*. *H. cornu vaccinum* also has a prismatic structure but the prisms are very coarse (up to 0.5 mm. thick) and regularly placed normally to the surface.

In some *Rudistae* (*Radiolites lumbricalis, Sphaerulites dilatatus, S. speciosus*) I have not succeeded in finding any regular structure; some parts of the shell possess a rather coarse and mostly very irregular prismatic structure and I have found no distinct cellular structure in these forms.

Zittel in his various handbooks mentions two layers of the *Rudistae* without stating anything about the existence of aragonite in the inner layer; in his older editions (e. g. the English one of 1900) this layer is said to be "cellular-crystalline" in the "*Radiolitidae*" and "lacunary and prismatic" in the "*Hippuritidae*", while in the newer editions it is said to be "porcellaneous and consisting of closely lying, parallel leaves". As stated, above I have found no primary structure in the inner layer. In all editions of the handbook ZITTEL gives a drawing of the cellular structure of the Radiolites which seems to represent one of the forms with the most perfect network as *Biradiolites cornu pastoris* and *Sphaerulites ventricosus.* The remark of ZITTEL that the tabulae, together with the upper margin, often bear impressions of radial vessels, seems to indicate, on the other hand, that he has observed the common type and that the impressions referred to are the traces of the radial cell walls. CAYEUX describes the Rudistae under the heading "structure cellulo-prismatique" without remarking that all the elements of the cells possess a real prismatic structure which is the only one building up the calcitic part of all members of this family.

Erycinidae.

The shell of *Erycina sp.* (Eocene) consists of two layers the upper one of which is, in radial sections, very similar to that of some *Nuculae*, being finely prismatic with a feathery arrangement. There is, however, the difference that the axes are, in many places, nearly normal to the prisms and to the surface of the shell. The lower layer is crossed lamellar with concentrical lamellae. Of the other members of the family I have examined *Kellia sp.* and *Lasaea rosea* (both recent); because of the smallness of the shells it is very difficult to state the structure with certainty but it seems that they are built up throughout of crossed lamellae.

Tancrediidae.

The shells of *Tancredia axiniformis* and *T. Jarneri* (both from the Jurassic) consist of a perfectly homogeneous aragonite with normal extinction.

Lucinidae.

Of this family I have examined *Lucina borealis* a. o. recent *Lucinae, L. ornata* and *L. incrassata* (Miocene), *L. concentrica* (Eocene) and *Corbis lamellosa* (Eocene). The shell always consists of three layers and of these the upper one is prismatic with lying, radiating prisms; there is, however, much variation between the different forms, the prisms being sometimes strongly reclined and having sometimes a feathery arrangement (pl. V, fig. 3) and diverging towards the margin in the same manner as in some *Nuculae.* In sections parallel to the surface they sometimes show the same feathery arrangement and sometimes they are more regular and parallel. The prisms are mostly rather fine but sometimes they get much coarser and there may be, in that respect, great variations in the same shell. Equally the extinction is very variable;

usually it is parallel to the direction of the prisms but it may be the opposite, normal to the prism, or more or less irregular. In some forms we find a peculiar variation between different parts of the prisms as they have in some places a parallel and in others a normal extinction.

The middle layer always consists of crossed lamellae, concentrically arranged (pl. V, fig. 3). There is some variation as to the coarseness and distinctness of the lamellae but in the main they are rather uniform. In radial cross sections they are generally very regular, in sections parallel to the surface they show the arrangement typical of the bivalves (pl. V, fig. 4).

The lower layer is the most variable, being in some instances regularly prismatic (*Lucina concentrica* and *L. borealis*) and in others complex crossed lamellar as seen, in a horizontal section, in pl. V, fig. 5 (*L. ornata*, *L. incrassata* and *Corbis lamellosa*). In such instances, however, there may sometimes occur thin prismatic layers interrupting the lamellar ones. The prisms have the properties common to most aragonitic prisms of the bivalves; when seen in sections parallel to the prism axes (cross sections of the shell), they look very regular with parallel extinction, whereas in cross sections they are very irregularly formed. Sometimes their extinctions seem to be parallel to those of the overlying, crossed lamellar layer.

Conocardiidae.

Conocardium pygmaeum (Silurian) certainly possesses two layers in the shell, an upper, calcitic one, and a lower one originally aragonitic which is always altered into irregularly grained calcite. The calcitic layer has a prismatic structure with the very fine prisms lying in a radiating direction, but the structure is in most respects very complicated. All others species of *C.* examined (e. g. *C. bohemicum*, *C. artifex*) only consist of irregular calcite.

Præcardiidae.

All members of this family examined (e. g. different species of *Cardiola*, *Dalila* and *Dualina*) have the shells entirely altered, and there is no doubt that they consisted originally of aragonite, the primary structure of which is quite obliterated.

Cardiidae.

The *Cardium* shells are apparently all constructed after the same scheme and I have examined only a few species, *C. edule* and *echinatum* (recent) (pl. V, fig. 6), *C. girondicum* and *C. Partchi* (Miocene) and *C. porulosum* (Eocene). The radial cross sections very much resemble those of *Lucina* but on closer inspection it seen that the upper, apparently feathery, prismatic layer only forms a continuation of the crossed lamellar one and consists throughout of crossed lamellae. Their orientation is exceedingly complicated and it would seem that, in the ledges, near the surface, they possess a radiating direction.

The middle part of the shell is, as is usual, crossed lamellar with concentrical lamellae; downwards these are vertically placed and rather regular but upwards they are turned sharply towards the proximal side and often get very complicated and irregular.

The lower layer is of the same nature as in many other bivalves i. e. complex crossed lamellar, alternating, in some instances with thin prismatic layers. In sections parallel to the surface this layer generally shows a spherolitic structure as shown in pl. V, fig. 7.

EHRENBAUM (p. 19 ff.) gives a very thorough description and good drawings of the *Cardium* shells to which the reader is referred. He is the first to point out the common nature of the typical shell structure of the gastropods and the bivalves (the crossed lamellar structure). CAYEUX, in his pl. 49, fig. 4 og 5, gives two photographs of *Cardium edule* which give a good impression of the great variability of this species; the lower, lamellar, layer of CAYEUX is probably only the lower part of the crossed lamellar layer and not what is above called the lower layer.

Tridacnidae.

The shell of a *Tridacna sp.* (recent) has an especially simple construction consisting only of one layer of crossed lamellae orientated concentrically. The lamellae are, as usual, almost vertical in the lower part and gradually strongly reclined upwards. They are rather coarse (ca. 0.05 mm.) and regular, the sections parallel to the surface of the shell showing only faint traces of the common rhomboidal figures.

DE BOURNON (p. 325) describes a "*Camus gigantus*" as consisting of two layers of which the upper one is lamellar while the lower one is "compact" and consists of several layers; it is possible that the species referred to, of which I have had no material at my disposal, has an under layer of the common, complex structure. Also CARPENTER (1847, p. 100) mentions the shell of *Tridacna* but finds in it no organic structure but only one which he calls "corrugated" and which seems to be the lamellar structure as seen in a section parallel to the surface.

Cyrenidae.

As an example of this family I have examined the shell of the recent *Cyrena sumatrana* (pl. VI, fig. 4). It consists of two layers, an upper crossed lamellar one with rather fine, concentrical lamellae and, as usual, with the lamellae curved and reclined in the upper part. The lower layer is of the complex nature with alternating layers of the prismatic and the complex crossed lamellar kind.

Cyclas striatinum (recent) behaves essentially like this species. Its thin shells do not, however, permit of any exact survey. Furthermore the Oligocene form, *Cyrena semistriata* behaves in this way. In the other older forms examined the shells, however, behave in a somewhat different manner as the lower layer forms a gradual continuation of the upper one; downwards the lamellae get more and more indistinct and the structure becomes almost perfectly homogeneous. There is no possibility, then, of determining the more exact nature of it. The Eocene forms *Cyclas deperdita*, *Cyrena obovata* and *C. Gravisii* belong to this group. The *C. convexa* (Oligocene) forms a transition between the two groups, the lower part of the shell being mostly homogeneous and interrupted by thin layers of the complex crossed lamellar substance.

Among the different *Cyrenae* from the Wealden I have not succeeded in finding any with the aragonite preserved.

Cyprinidae.

The members of this family examined by me fall into two groups. One of them shows a great similarity to the common type of the bivalves, the shells consisting of two layers, an upper one with crossed lamellae, as usually concentrically arranged and curved and reclined, and a lower one of the complex crossed lamellar structure. *Cypricardia velicata* (recent), *C. oblonga* (Eocene) and *Cyprina Morrisii* (Eocene) belong to this group. The last named form has the lamellae in their upper part orientated in nearly the same manner as the *Cardium*.

The other group has the least visible structure among all bivalves, the whole shell being almost perfectly homogeneous with the axes in the lower part normal, and upwards somewhat reclined. There are such small traces of other structures that it is not possible to tell if this group has any connection with the first one. In *Cyprina islandica* (recent) the homogeneousness is obscured, however, by the existence throughout the whole mass of so many small grains that the extinction is in many places difficult to see; in the lower part of the shell, which is, perhaps, a representative of the common, complex structure, there are alternating layers of more transparent layers and finely grained ones. Most of the older *Cyprinae* examined are more perfectly homogeneous and transparent, thus *C. rotundata* (Oligocene) and *C. Syssollae* and *C. mosquensis* (both upper Jurassic).

A description of the shell of *Cyprina islandica* is given by Sorby who says (p. 62): "In *C. i.* we have another extreme case, in which the fibres perpendicular to the plane of growth are so short as to appear like granules, though the optic axes are still definitely oriented in the normal manner". I have not been able, however, to detect this structure. Ehrenbaum (p. 15 ff.) gives detailed descriptions and good figures of the shell in question.

Veneridae.

The shells of the *Veneridae* consist of two layers of which the lower one is generally perfectly homogeneous. There may, in some instances, be some irregularities, mostly in the form of traces of the complex structure; this is, however, always very indistinct.

The upper layer is rather variable, and there is a rather perfect transition between the different types:

1. The layer in question consists of crossed lamellae of the common, concentrical orientation; in radiating cross sections their orientation is almost normal to the surface of the shell. Downwards the lamellae pass gradually in to the homogeneous part of the shell, becoming more and more indistinct. *Lucinopsis undata* and *Petricola pholadiformis* (both recent) possess this structure.

2. The structure is similar to the foregoing one but the lamellae, if seen in the radiating cross section, are only vertical downwards, and upwards more and more reclined, getting perfectly horizontal in the uppermost part of the shell. *Venus texta* (Eocene), *Cytherea multilamella* (Miocene).

3. Similar to the foregoing group, but the lamellae, which are first vertical and upwards more and more reclined to almost horizontal, are again reclined in the uppermost part. *Cytherea incrassata* (pl. VI, fig. 2) (Miocene), *Venus obliqua* (Eocene).

4. This and the two following groups are, in the radiating cross sections, very similar to each other, showing the elements arranged in a feathery manner and diverging towards the distal side of the shell. The lines of growth, which are always orientated normally to the elements, get, of course, the form of more or less regular semi-circles with the convexity turned towards the margin of the shell. But the elements themselves are not alike in the three groups. The shells here in question consist still throughout in the whole upper layer of crossed lamellae. *Cytherea sp.* (pl. VI, fig. 3) (recent), *C. pedemontana* (Miocene), *C. semisulcata* and *C. laevigata* (Eocene) belong to this group.

5. The structure is rather complicated; the lower part of the upper layer still consists of crossed lamellae which, as usual, gradually pass into the underlying, homogeneous mass, but the horizontal and the upper, inclined elements consist of prisms, radially orientated, each prism, when distinctly seen, possessing a homogeneous structure with feathery arrangement of the crystal axes. *Venus gallina* (recent), *V. plicata* and *V. concentrica* (Pliocene) belong to this group.

6. The shells of the genus *Tapes*, among which I have examined *T. pullastra* (pl. VI, figs. 1 and 5) and *decussata* (both recent) and *T. gregaria* (Miocene), generally deviate from the common type of the bivalves; there is no trace left of any crossed lamellar structure, and the whole upper layer is built up of prisms in a feathery arrangement. There is rather a sharp boundary between the two layers. The prisms of the upper layer are, as in the former group, homogeneous with the axes arranged in a feathery manner and diverging towards the margin of the shell.

Donacidae.

The genus *Donax*, of which I have examined the three species *D. vittatus* (recent) and *D. affinis* and *D. transversus* (Miocene) have the shells constructed in a manner much like the 5th group of the foregoing family. Three layers may be distinguished (p. VI, fig. 7), the upper one with a feathery prismatic structure, just like that of the last group of the *Veneridae*, and under that a crossed lamellar layer which has a distinct boundary towards the upper layer but passes gradually in to the lower layer which is also homogeneous here. The upper layer is, however, rather complicated as there is, as also in some species of *Venus*, a system of internal radiating ledges, as seen in pl. VII, fig. 1, each ledge possessing a perfect feathery structure.

Tellinidae.

The shells of this family behave somewhat differently; the recent forms examined, *Tellina baltica* and *calcaria,* consist of two layers the upper of which is built up, in the common manner, of concentrical, crossed lamellae, (shown in a horizontal section in pl. VII, fig. 2), which, in the last named form, are rather coarse. The lower layer is of the complex type with alternating crossed lamellae and prismatic layers; here, too, the structure of *T. calcaria* is rather coarse. The crossed lamellae are seen in a horizontal section in pl. VII, fig. 3.

The shells of the Tertiary forms examined consist of three layers; the lowest layer is a homogeneous layer, which, however, in some places is replaced by a more complex structure. The middle layer consists of concentrical, crossed lamellae which downwards pass gradually into the homogeneous layer; the lamellae are strongly reclined. The upper layer, which is separated from the middle one by a sharp boundary, consists of radially arranged prisms which, in *Tellina zonaria* (Miocene) and *T. ambigua* (Eocene) are strongly reclined, forming, in radial cross sections, a continuation of the lamellae in the middle layer. In *T. corneola* and *Psammobia rudis* (both Eocene) the structure is essentially the same but the prisms of the upper layer form, in radial cross sections, a feathery figure in the same manner as was found in the two foregoing families.

The only descriptions of the shell of *Tellina* which I have found, are by Ehrenbaum (p. 28) and by Carpenter (1847, p. 102); here two figures are given (16 and 17) which show the common appearance of the crossed lamellae.

Solenidae.

The shells of *Solen,* among which I have examined *S. ensis* (recent), *S. vagina* (Miocene) and *S. siliquaria* (Eocene), consist of two layers the upper one of which is built up of concentrical, crossed lamellae which are very irregular, being sometimes exceedingly fine, in other instances rather coarse. The lower layer is of the complex type. The shell of *Solecurtus strigulatus* (Pliocene) possesses the same two layers but has still a thin, uppermost layer of radial, strongly reclined prisms the extinction of which is abnormal as the crystallographical axes are orientated in the radial plane but normally to the direction of the prisms.

Carpenter (1847, p. 105) gives descriptions and drawings of the shells in question but neither are easily understood as the orientation in relation to the shell is not stated. The straight prisms shown in fig. 43 must represent the crossed lamellae, and the stellular forms of fig. 42 are presumably a section parallel to the surface of the complex layer.

Scrobiculariidae.

The shells of this family examined by me have an upper layer of crossed lamellae in the common, concentrical orientation and a lower one which may be homogeneous or complex. *Scrobicularia plana* and *Syndosmya* (both recent) belong to this type, whereas *Syndosmya cfr. prismatica* (Miocene), besides the named layers, possesses an uppermost one of lying, radial prisms with a feathery arrangement and anomalous extinction, just like the last named member of the foregoing family.

The only description of these shells, which I have found, is by EHRENBAUM (p. 26 and 27) who mentions that the upper layer is built up of "Blättersysteme"; in the lower layer he finds "stalaktitenähnlich geformte Einlagerungen oder secundäre Hohlenausfüllungen". It is true that the complex layer may, in some instances, show figures like stalactites but I do not think it probable that there have been secondary alterations in the quite recent shell; and at all events I think it quite impossible to prove that such alterations have taken place.

Mesodesmidae.

The shell of *Mesodesma corneum* (recent) has a structure which is quite uniqe among the bivalves and bears more resemblance to that common to the gastropods. While the upper layer is built up of the common, concentrical, crossed lamellae, the lower layer possesses the same lamellae in the radial direction. The whole appearance of the lamellae, however, is that common to the bivalves and does not show the regularity which is so characteristic of the gastropods.

The shells of *Ervilia pusilla* and *podolica* (both Miocene) are of the more common type; the under layer is homogeneous, and the upper one consists of concentrical, crossed lamels. The last named form (pl. VII, fig. 5) possesses an uppermost layer of strongly reclined or almost horizontal, radial prisms.

Mactridae.

The shells of this family are very differently constructed, and their only common feature is the crossed lamellar, concentrical layer. This is, however, in many instances rather irregular.

In some species of *Mactra*, as *M. solida* (Pliocene) and *M. subtruncata* (recent), the whole shell consists of this layer, while in *M. laevis* (recent) the structure is essentially the same but with very large irregularities, for while the lamellae in the upper and the lower part of the shell are concentrically arranged, they are, in some instances, turned round in the middle part of the shell, so as to obtain an almost radial direction.

The shell of *M. semisulcata* (Eocene) is, in the upper part, built up of the concentrical lamellae, while in the lower part it is mostly perfectly homogeneous. The shell of *M. glabra* (Eocene) has, between the same two layers, a thin prismatic layer, while in *M. elliptica* (Pliocene) the upper layer consists of crossed lamellæ and the lower one is of the complex kind.

The shells of *Lutraria* seem to be more complicated; in *L. elliptica* (recent) the uppermost layer is very irregularly prismatic with vertical prisms; under that we have the crossed lamellæ which are both upwards and downwards concentrically arranged but in the middle part turned round to a perfectly radial position. In the shell of *L. sp.* (Pilocene) we have upmost the prismatic layer under which there is the crossed lamellar, concentrical layer, and under that we have a complex layer showing in sections parallel to the surface fine spherolitic figures (pl. VIII, fig. 4).

CARPENTER (1847, p. 103) describes the shell of *Mactra stultorum* and gives a figure of its upper layer which seems to indicate the existence in that form of a prismatic layer of which there are in other forms only small traces. His figure (19) of *Lutraria elliptica* shows the common appearance of the crossed lamellæ as seen in sections parallel to the surface. Here as otherwise CARPENTER describes this structure as consisting of fusiform cells cut obliquely.

Vlastidae.

The shells belonging to this old family have, of course, no aragonite preserved. The shell of *Vlasta pulchra* (Silurian) consists throughout of irregularly grained calcite from which we may conclude that it originally consisted of aragonite.

Grammysiidae.

This family behaves like the foregoing; in one instance, *Grammysia exarata* from Gothland, I found the shells totally altered into grained calcite.

Solenomyidae.

The shell of *Solenomya* is built up in a very peculiar manner. It is traversed by vertical walls of some organic substance; these walls lie very close upwards, and downwards their distance is larger and they more and more often interrupted, until, in the undermost part of the shell, they entirely disappear. The shell substance between the walls is mostly of a homogeneous nature, having the elements arranged in a feathery manner. In the undermost part it is perfectly homogeneous or indistinctly prismatic. In a recent *S. sp.* (pl. VII, fig. 6) the walls form more or less regular cells which may be polygonal or elongated in the radial direction, while in the Oligocene form *S. Döderleini* they are almost perfectly straigthlined and radial.

A description of *Solenomya australis* has been given by CARPENTER (1847, p. 106); the shell is more or less distinctly prismatic.

Pleuromyidae.

Of this family I have found only a few members with the aragonite preserved, and as the state of preservation is not very good, the structure is rather indistinct. *Pleuromya jurassi* from the Callovian has mostly a complex structure of the shell, showing distinct spherolitic figures in sections parallel to the surface; in some places, however, there are traces of a crossed lamellar structure with the lamellæ orientated sometimes radially and sometimes concentrically. *Gresslya Seebachi* (Liassic) and *G. Alduini* (upper Jurassic) have partly a homogeneous and partly a very fine and irregular prismatic structure.

Panopaeidae.

The recent members of this family examined by me (*Panopaea norvegica, Saxicava arctica*) have their shells constructed in a very similar manner which is, at the same time, rather simple. The upper layer is homogeneous, in its upper part it contains innumerable small grains of all possible orientations, the under part shows a faint and indistinct, fine prismatic structure. The lower layer is coarsely and generally irregularly prismatic.

The Oligocene forms, *Panopaea Meynardi* and *Héberti*, stand a little apart, having a more complex structure; the last named form has a lower layer of very irregular and indistinct, crossed lamellæ.

The shell of *Arcomya elongata* (Liassic) has a lower layer of a nacreous substance; the state of preservation does not permit examination of the upper layer.

Pholadomyidae.

The shells of *Pholadomya* are very differently constructed. *P. cuneata* from the Thanet sands has a very complicated structure which must, however, in most instances be designated as complex crossed lamellar; in sections parallel to the surface we see fine spherolitic forms.

Other members of the family, as *P. decorata* (Liassic), *P. margaritacea* from the London Clay, and *P. Puschi* (Oligocene) have a nacreous structure which extends almost throughout the whole shell; only in a thin upper layer there is a more complicated structure.

Anatinidae.

The shells of *Anatina sp.* and of *Pandora inaequivalvis* (both recent) mainly consist of a nacreous substance possessing, however, both upper and lower layers of a fine prismatic structure. The shells of *Thracia papyracea* and *T. villosiuscula* (both recent) and of *T. ventricosa* (Miocene) only possess the nacreous substance in a small part of the shell next to the hinge; otherwise they are irregularly prismatic or complex crossed lamellar.

A. Kelly (p. 52) states that the shell of *Pandorina* consists of a nacreous substance with an upper layer of fine prisms which she has proved to consist of conchite (aragonite). Carpenter (1844, p. 10) describes the upper layers of different forms of the family in question as showing a cellular structure (fig. 15) without any distinct cell-membrane. In the paper of 1847 (pp. 104—5) he gives more detailed descriptions of these shells to which the reader is referred. Besides the genera named he mentions the *Myodora striata* and *Lyonsia sp.* as having a nacreous consistency with an upper prismatic layer.

Myidae.

The shells of *Mya* consist of three layers, an upper one, homogeneous and at the same time fine grained, forming the relatively intransparent part of the shell. Under that we have a layer consisting of concentrical crossed lamels. This layer is very insignificant in *M. truncata* (recent) while, in *M. arenaria* (recent), it is a little thicker, and in *M. californica* (recent) it constitutes the main mass of the shell. The lower layer is always of the complex kind.

The genera *Corbula* and *Corbulomya* in so far differ from *Mya* that the upper, homogeneous layer is wanting or very insignificant, and the shells consist, of course, only of two layers, of which the upper one is crossed lamellar with concentrical lamellæ; these are mostly strongly reclined upwards, and in *Corbulomya complanata* (Eocene) they get perfectly horizontal and thereafter inclined, thus producing, in the radial section, a feathery structure. The lower layer is somewhat different; in *Corbula gibba* (recent), *C. carinata* (Oligocene) and *C. rugosa* (Eocene) it is of the complex kind, whereas in *C. subpisum* (Oligocene), *C. gallica* (Eocene), *C. concentrica* (Gault) and in the *Corbulomya* it is perfectly homogeneous.

It is characteristic of the shells of this family that the different layers are more loosely bound together than otherwhere. In the fresh shell they part easily from each other and in many of the fossil *Corbulae* they are quite loose so as to make it appear as if there were two shells accidentally placed one in side the other.

Carpenter (p. 103) gives detailed descriptions, accompanied by many figures, of the shell of *Mya*; it is, however, not easily seen what is shown by these, and I have found nothing similar to the different forms of "cells" drawn, especially in the upper, homogeneous layer. Also his description of *Corbula* (p. 104) is not easily understood. The description given by Ehrenbaum (p. 29 ff.) of the shells of *Corbula* and *Mya* in all essentials agrees with those given above. I dont believe, however, that it is possible to show, in the shell of *Mya*, any layer of radial, crossed lamellæ. These are, on the whole, exceedingly rare among the bivalves.

Gastrochaenidae.

I have only examined the shell of a recent *Gastrochaena*, which consists of two layers, an upper, thinner, irregularly grained one, and a lower one composed of concentrical, crossed lamellæ. I have had no tube of these animals at disposal, but Miss Kelly (p. 33) describes it as consisting of aragonite (conchite).

Clavagellidae.

Of this family I have only examined an *Aspergillum sp.* (recent). Both the shell and the tube consist of aragonite; the tube is prismatic with rather regularly formed prisms and an almost normal extinction. In the shell proper we have the same structure alternating with other layers which are very indistinctly prismatic or perfectly homogeneous.

Pholadidae.

The shell of *Zirphaea crispata* (recent) has a very irregular structure, the different parts of the shell being differently constructed. Three layers may, however, commonly be distinguished: an upper one which is mostly homogeneous with many small grains of diverging orientation; in other places it may be more coarse-grained. The middle layer is crossed lamellated with concentrical lamellæ; the type of these, when seen in horizontal sections, it highly different. The commonest are the rhomboidal figures which are typical of most bivalves though they are never so regular as here (pl. VII, fig. 7); in other places there may be seen more rectilinear or other forms of boundaries. The lower layer is homogeneous in some places, in others complex. The shells of *Gastrochæna dubia* and *P. candida* (both recent) possess similar structures.

The thin shells of *Teredo* and *Teredina* are still more irregularly constructed. Most of the shell is crossed lamellar but the lamellæ are sometimes concentrical and sometimes radial. There is no distinct lower layer but generally there is an upper one which is homogeneous or irregularly grained.

The tube of *Teredo* consists of calcite whereas that of *Teredina personata* (Eocene) consists of aragonite. The common rule seems to be that in those animals which have their tubes and shells grown together, as we have seen it in Aspergillum and Teredina, the aragonitic consistency of the shell has in some peculiar way the effect that the tube is built up of the same material whereas in the *Teredo*, where both are not closely connected, no such influence takes place.

The structure of the tubes is always rather irregular, prismatic. Although the regularity of the elements is no greater than in most inorganic deposits of carbonate of lime, every species examined possesses a special type of structure which may, in most instances, be distinguished from that of other species. The prisms of *Teredina personata* are thin and rather regular, the extinction is mostly normal, but there are some few individuals with strongly diverging axes. In that part of the tube which is in close connection with the shell the extinction of the prisms is distinctly the same as that of the two individuals of the crossed lamellæ. Among the tubes of *Teredo* we find all possible variations, some consisting of fine prisms and others of coarser ones; sometimes the prisms may be as broad as long and bounded by very peculiar angular lines consisting of alternating horizontal and vertical elements. The extinction may, in some species, be very regular, normal, in others almost quite irregular, the vertical orientation being only slightly more common than the horizontal one. A thinner, upper layer of the tube is almost always very finely prismatic or grained.

Already in Gray we find a description of the prismatic structure of a large *Teredo* from Sumatra. Carpenter (1847, p. 106) compares the structure of *Septaria gigantea* with that of a *Belemnites*; the more irregular form of the first-named is ascribed to the action of "calcigerous cells" in opposition to the "crystalline action" by which the spine of the *Belemnites* is supposed to be formed. Sorby (p. 58), on the contrary, concludes from the irregular form of the prisms that there is "no trace of true organic structure". Miss Kelly is the first to point out the different natures of the shell and the tube of *Teredo*.

It will be obvious from the foregoing description of the individual families that there is very great variation as to the structure of the shell in the group of the *Anisomyaria*, and it will be very difficult to give any clear exposition of the characters. True, some families are rather uniform, but others belong to several different types, in such a way that we do not get the impression that the structure, in such cases, can have any systematical value. If we would, in such instances, investigate still more species, we should probably find new structures. In the following table I have tried to give a summary of the results obtained, omitting many doubtful or exceptional examples. For many characteristic features of the structures the reader is referred to the foregoing descriptions.

The most striking feature, in opposition to the *Anisomyaria*, is the rarity of original calcite in the shell. I have not succeeded in finding any recent shell containing this mineral, and only in a few families, such as the Chamidae, the Caprinidae, the Rudistae and the Conocardiidae, has it been found in the fossil members. The calcite is always prismatic but very variably constructed.

The aragonite seems to have been wanting in no members of this group although, in many of the older forms, it is totally altered into the irregularly grained calcite. It is, in such instances, generally quite impossible to state anything about the original structure of the shell. In the following table I have omitted such families of which I have had so few or such badly preserved representatives at my disposal that I have not been able to obtain any certain impression of what may be the typical structure. For these families, such as the *Erycinidea*, the *Tancrediidae*, the *Tridacnidae*, the *Solenomyidae*, the *Pleuromyidae*, the *Gastrochaenidae* and the *Clavagellidae*, the reader is referred to the foregoing descriptions. For the more thoroughly examined families the following scheme may be given:

Nuculidae		horizontal prisms + nacreous
	or:	crossed lamellar
	or:	homogeneous-prismatic
Arcidae		crossed lamellar + complex
Nayadidae		downwards complex prismatic + nacreous
Trigoniidae		upwards complex prismatic + nacreous
Astartidae		crossed lamellar + prismatic
Crassatellidae		crossed lamellar + homogeneous
Megalodontidae		homogeneous-prismatic + complex
Isocardiidae		homogeneous + crossed lamellar + complex
Chamidae (Chama)		crossed lamellar + complex
Lucinidae		horizontal prisms + crossed lamellar + complex
Cardiidae		crossed lamellar + complex or homogeneous
Cyrenidae		crossed lamellar + complex or homogeneous
Cyprinidae		crossed lamellar + complex or homogeneous
	or:	homogeneous
Veneridae		crossed lamellar + homogeneous
	or:	horizontal prisms + crossed lamellar + homogeneous
	or:	horizontal prisms + homogeneous
Donacidae		horizontal prisms + crossed lamellar + homogeneous

Tellinidae		crossed lamellar + complex
	or:	horizontal prisms + crossed lamellar + homogeneous
Solenidae		crossed lamellar + complex
Scrobiculariidae		crossed lamellar + homogeneous or complex
Mesodesmidae		crossed lamellar + radially crossed lamellar
	or:	crossed lamellar + homogeneous
Mactridae		crossed lamellar
	or:	crossed lamellar + prismatic or homogeneous or complex
Panopaeidae		homogeneous + prismatic (sometimes nacreous)
Pholadomyidae		prismatic or complex
	or:	complex + nacreous
Anatinidae		prismatic + nacreous + prismatic
Myidae		homogeneous + crossed lamellar + complex
	or:	crossed lamellar + complex
Pholadidae		homogeneous + crossed lamellar + homogeneous or complex

As will be seen from the scheme, the crossed lamellar structure is the most common of all. Of the 25 families described it is found in all members examined in 16 instances, while in three families only some members possess this structure and 6 families are quite without it. The lamellae are always orientated in the concentrical direction, and only in the *Mesodesmidae* have I found radial lamellæ as a special layer, while in some other families there may be subordinate parts of the lamellar layer which have a more or less indistinct radial arrangement. The type of lamellæ is mostly that which I have formerly described as characteristic of the bivalves; the rhomboidal figures are most regular in the last families, especially in the *Myidae*, while in the first families they are more indistinct. When seen in radial cross sections the lamellæ are highly different as they are only in few instances straight-lined and either vertical or faintly reclined, but in most instances curved in such a manner that they begin downwards as vertical and then afterwards get more and more reclined and at last horizontal. In some instances we have an uppermost part which is either reclined or inclined whereby a feathery arrangement of the elements is produced. Sometimes the upper part of the layer is extremely irregularly constructed.

Only in a few instances (some *Nuculidae* and *Mactridae*) does the said, crossed lamellar layer form the whole shell. Most commonly we have an upper or a lower layer or both. The upper layer is of two essentially different kinds, either homogeneous, sometimes weakly prismatic, or consisting of horizontal prisms which are always orientated in a nearly radial direction, though rather differently arranged. Sometimes (some *Lucinidae* and *Tellinidae*) we have almost straight-lined and parallel prisms, horizontal, or almost horizontal, in other instances they are arranged in such a manner that, in radial cross sections, they show a feathery structure with the elements diverging towards the margin of the shell. Two types may here be distinguished: sometimes all the prisms are still lying in the radial plane in such a manner that, in sections parallel to the surface of the shell, they are all parallel (some *Veneridae, Donacidae* and *Tellinidae*), or, in the last named sections we also see a feathery structure (some *Nuculidae, Lucinidae* and *Donacidae*). Such shells always possess radial ledges, either on the surface or in some deeper lying part of the shell, and their structure may be described as composite prismatic (prisms in prisms). The single prisms of the second order may possess a parallel extinction or may be homogeneous with a feathery arrangement of the axes.

The layer under the lamellar one is mostly of the kind which I have called complex and which, in most instances, consists of alternating layers of complex crossed lamellar and prismatic structures, both of very variable types. In many instances we have, instead of this structure, the homogeneous one which, however, is connected with the former one by all possible transitions where there are traces of the complex structure of such small dimensions that it can hardly be recognized. In some instances we have both the named structures in the same shell in such a way that some parts are rather coarsely complex while others are more or less perfectly homogeneous. More rarely the lower layer of the shell is purely prismatic, which structure we find very pronounced in the *Astartidae* and more subordinate in the *Mactridae.*

The shells without the crossed lamellar structure may be divided into two groups one of which is characterized by the existence of a nacreous layer, which, in the bivalves, is never found in the same shell as the crossed lamellar one, while the other group has no such layer. The nacreous layer is almost always the undermost one, and only in the shells of the *Anatinidae* do we find an insignificant prismatic layer under it; the layer above the nacreous one is in most instances (*Nayadidae, Trigoniidae* and *Anatinidae*) normally prismatic, consisting of vertical or nearly vertical prisms which, however, are mostly of a complex kind. Only some of the *Nuculidae* possess an upper layer of horizontal, radiating prisms with a feathery arrangement, while, in the *Pholadomyidae,* we find an upper layer which may be designated as complex.

The bivalves which possess neither a crossed lamellar nor a nacreous layer may be rather differently constructed. The simplest is the building of some *Cyprinidae* and *Pholadomyidae* where the structure is homogeneous throughout, while, in other instances, as in some *Nuculidae* and *Pholadomyidae,* it is of a very similar kind, possessing only an indistinct prismatic structure. In other cases we find two distinct layers, as in the *Panopaeidae* where we have an upper homogeneous and a lower prismatic layer, in the *Megalodontidae* with an upper homogeneous or indistinctly prismatic and a lower complex layer and in some *Veneridae* (Tapes) with an upper layer consisting of horizontal prisms and a lower homogeneous one.

II. Class. Schaphopoda.

The shells of these animals seem to be constructed in a very uniform manner. There are, in most instances, insignificant upper and lower layers of a very indistinct structure, either homogeneous or finely prismatic or of a more complex kind, but the main part of the shell is built up of crossed lamellæ in a concentrical direction, normal to the axis of the tube. The most characteristic feature is that the appearance of the lamellæ is quite the same as that of the bivalves; in the radiating section they are rather regular, whereas in the section parallel to the surface they show the peculiar rhomboidal figures found in most bivalves. As examples I have examined *Antalis entalis* and other recent forms, *Dentalium Bouei* (Miocene) (pl. VIII, figs. 1—3), *D. rugiferum* (Paleocene) and *D. decussatum* (Gault). *D. Parkinsoni* (middle Jurassic) is totally altered into calcite but there are distinct traces of the original structure.

Cayeux (p. 484 and pl. 50) describes two different species of *Dentalium*. Of these the one (fig. 6) has the common crossed lamellæ whereas the other (fig. 5) has a foliated structure with the folia parallel to the surface. This must represent the lower layer in a complex form and similarly developed as in *D. rugiferum*.

III. Class. Amphineura.

There are certainly no other shells which possess such a complicated structure as those of *Chiton*. Not only are there rather large differences between the single species but in the same shell the different parts are highly variable. It will, therefore, be almost impossible to give any exact description of these shells but I shall point out the most characteristic features of one of the larger, recent forms, as the other forms examined seem to contain only modifications of the same elements. There may, in the *Chiton* in question, be discerned 5 elements which are never found all in the same place but arranged in such a manner that sometimes one of them is dominant and sometimes another. They may, however, be arranged in the following order which will always hold good in such places where two or more of them are found in the same part of the shell.

a. The upmost, dark coloured layer is, in opposition to all the following, found over the whole shell; it is porous, traversed by numerous, rather large holes or channels (pl. VIII, fig. 4). The orientation of the elements is very complicated.

b. Under that layer there is, in some places, a more uniform layer of homogeneous or indistinctly prismatic structure.

c. Under layer b or, in some instances, directly under layer a there, is a very complicated layer, found mostly in the outer parts of the shell, near the margin. It consists of rather broad, vertical lamellæ, orientated in the transverse direction (in relation to the whole animal but longitudinally in relation to the single shell). The lamellæ are divided into smaller parts by irregular walls. which generally makes the orientation of the elements very complicated (pl. VIII, fig. 4). In some instances, however, we find in sections parallel to the surface a rather regular, feathery arrangement in the single lamel.

d. Under the foregoing layers we find, in some places, a series of subordinate layers among which some consist of crossed lamellæ either in the longitudinal or in the transverse direction, while others seem to be indistinctly prismatic.

e. The undermost layer, which is especially developed in the middle part of the shell (near the axis of the animal), is certainly the most important of all and makes up half or more of the whole. It is very uniform, consisting of crossed lamellæ in the transverse direction. Although the fundamental angles are the same as in most mollusks the habitus of the lamellæ is quite unique. They are very regular and rectilinear, but they differ from those of other mollusks by being very fine (pl. VIII, fig. 5). In some of the larger species the thickness of the single lamel is almost 0.005 mm, and in the smaller forms they are so fine that they are hardly discernible. In sections parallel to the lamellæ (in the transverse sections) the two systems of crossed lamellæ of the 2nd order are, however, always distinctly seen.

A short description of the shell of *Chiton* is given by CARPENTER (1847, p. 114). CORNISH and KENDALL were the first to determine the shells as consisting of aragonite.

IV. Class. Gastropoda.

Very little can be said in general about the shells of these animals as there is a very great difference between the different groups. The *Aspidobranchina* have very variable structures among which the nacreous one is rather common, and the *Cyclobranchina* possess their special, peculiar structure. On the other hand the *Ctenobranchina*, the *Opistobranchia* and the *Pulmonata* are essentially alike and possess a very uniform structure. The *Heteropoda*, the *Pteropoda*, the *Tentaculidae* and the *Conulariidae* stand apart, their shells showing no affinity to those of the other gastropods.

As to the occurrence of calcite all gastropods are essentially alike and differ very much from the bivalves. The calcite must be said to be a rather accidental element and is not, as in the bivalves, connected to any of the main groups. A shell consisting entirely of calcite is found only in the *Tentaculites* and, perhaps, in a single form among the *Bellerophontidae*. Otherwise calcite only forms the upper layer of the shell, and we find the mineral in a great number of families in the large group of the *Prosobranchia*. In some instances most members of a family may possess the said layer while, in others, it may occur quite unexpectedly in one or a few members of a genus which otherwise consists entirely of aragonite. Connected with this accidental occurrence is the structure of the calcite which is generally very irregularly prismatic, much resembling an inorganic sinter formation. It must be pointed out, however, that all individuals of the same species are always alike, and for the strength of the shell the calcite mostly plays a great role, as the calcitic layer is generally rather thick, while the aragonitic part of the shell in such instances is correspondingly reduced in thickness. There are, however, other shells which possess only a very insignificant layer of calcite. Only in a few families, in which the calcitic layer is universal or almost universal, as in the *Neritidae* and especially in the *Patellidae*, the calcite assumes more regular and characteristic structures.

As to the gastropods from the older periods it will, of course, be very difficult, or almost impossible, to ascertain if they have originally possessed a calcitic layer as the structure of that layer is not very different from that of the later formed calcite. If, in the upper part of the shell, we find a uniform structure, more or less indistinctly prismatic and recurring in all individuals, we may conclude that we have here an original calcite.

A. Order. Prosobranchia.

In accordance with what was said above, there is no property common to the three divisions of this order, with the exception of the one that we may here accidentally find a calcitic, upper layer in the shell which is always wanting in the *Opistibranchia* and *Pulmonata*.

1. Suborder. *Aspidobranchina.*

This is the most variable division of the gastropods, and there can be said nothing in general about the structure of the shells with the exception of the negative statement that here we never find the very uniform structure which is so characteristic of the three last groups of the gastropods. The most characteristic feature is the common occurrence of a nacreous layer, but there are many families in which this layer does not exist.

Bellerophontidae.

The shells of the members of this old family almost always consist of quite irregularly grained calcite, showing that they originally consisted of aragonite. The only exception is a *Bellerophon* from the Ordovician of Bornholm, the shell of which consists throughout of a peculiar, foliated calcite possessing a characteristic micaceous lustre. The axes are somewhat irregularly orientated though mostly normal to the foliae. Without doubt we have here the original structure, and it is easily seen that this layer has constituted the whole shell (pl. VIII, fig. 6).

Pleurotomariidae.

The Palæozoic and most of the Mesozoic forms have their shells totally altered and no trace of original calcite is ever seen. Some of the Mesozoic forms have still retained their aragonite which is always nacreous, and more rarely we also find an upper layer which is homogeneously prismatic.

Fissurellidae.

The most characteristic feature of the shells of this family is that they always possess a crossed lamellar layer with concentrical lamellæ, and in most instances that layer forms the whole shell. The upper part of the layer is generally very irregular because of the sculpture of the surface of the shell; in a few instances, however, we find a feathery arrangement of the lamellæ, as in some bivalves. The lamellæ, if seen in the radial section, are generally strongly reclined or at the same time curved. The lamellæ behave most peculiarly in the lower part of the shell, where they generally get essentially broader than in their upper part, and at the same time they gradually obtain a more horizontal orientation, the two sets of lamellæ crossing each other at a very acute angle. This transformation is most pronounced in the genus *Subemarginula* (pl. IX, fig. 1) but the other genera, *Fissurella, Emarginula, Puncturella* and *Scutum*, show the same phenomenon. The flat-lying, broad and irregular lamellæ are distinctly seen with the naked eye on the under side of the shell. Sometimes we find, in the proximal part of the shell, next to the apex, a complex layer under the lamellar one, very much resembling that of many bivalves.

An upper, calcitic layer is only found in one species (out of eight examined), the recent form *Fissurella crassa*. This layer is thick and of a dark brown colour differing highly from the white aragonitic substance. With the naked eye it looks quite irregularly and rather coarsely grained, but in sections we see that both the prism axes and the optic axes have generally a horizontal orientation in the radial direction.

Haliotidae.

The shells of *Haliotis* (pl. IX, fig. 2) are rather uniform in so far as they have all a lower nacreous layer with a very fine lustre and an upper homogeneous layer which, however, is so filled up by small grains with diverging orientation that the homogeneous fundamental mass is only seen in the very thinnest sections.

The most peculiar feature of these shells is that they possess, in some instances, a calcitic layer inserted between the two aragonitic ones. The boundaries of that layer are always very irregular, and it may, in some places, be interrupted. It looks as if the two aragonitic layers had been torn away from each other and the cavity afterwards filled out by calcite, but such a formation must be considered impossible in the quite fresh shell. The calcite has a rather regularly prismatic structure with horizontal, radial prisms (pl. IX, fig. 3) and their extinction is rather regular and normal. As to the extension of this layer the different species are very variable. In *Haliotis ficiformis* we find it in the larger part of the shell, and it is wanting only in the proximal part; in another *H.* it is found only in the most distal part, next to the edge, while in *H. tuberculata* there are only a few small spots of calcite and in *H. pulcherrima* none at all.

A description of the shell of *Haliotis* has been given by CARPENTER (1847, p. 115). I must confine myself to a reference to this description as I have not been able to find the horny plates mentioned or the different forms of "cells" described and drawn.

Euomphalidae.

In the shells of this old family the aragonite is, of course, never preserved but it seems to have existed originally. In most members examined by me there is a prismatic layer which is sometimes rather regular and which indicates that the shell, in such instances, must have possessed an upper, calcitic layer.

Stomatiidae.

The shell of *Stomatella imbricata* possesses two layers of which the undermost one is nacreous while the upper one is homogeneous and finely and indistinctly prismatic. The shell of *Stomatia picta* seems to be constructed in a similar manner.

Turbinidae.

Of the genus *Turbo* I have examined several recent and Tertiary species and found them very much alike: the lower layer is nacreous and the upper one homogeneous and at the same time irregularly prismatic or grained (pl. IX, fig. 4).

Of *T. Parkinsoni* (Miocene) I have examined the operculum which consists, like the shell itself, of aragonite; the structure is very regularly composite prismatic. The prisms of the 1st order are coarse (up to $^1/_2$ mm broad), those of the 2nd order are very fine and arranged in a feathery manner.

The structure of *T.* has been described by Gray (p. 795) and by Carpenter (1847, p. 116).

Phasianellidae.

The shells belonging to this family have a rather complicated structure although the ground type must be said to be the same in all members examined. In *Phasianella bulloides* (recent) we find three distinct layers (pl. IX, fig. 5) which, however, are separated from each other by subordinate intermediate layers of different kinds. The upper layer is of a complex prismatic kind, while the middle one consists of concentrical, crossed lamellæ which, as seen in longitudinal sections, show a very peculiar aspect, being, with sharp angles, alternately inclined, vertical, reclined and again inclined. The undermost layer possesses a very complicated structure which, in the longitudinal section, generally seems to be prismatic.

Different Tertiary species of *P.* examined by me were rather small and their structure was not very distinct. They contain, however, the same three layers, the crossed lamellar one in most instances constituting the larger part of the shell. It is mostly somewhat more regular than in the shell of *P. bulloides*, the lamellæ being vertical in the lower part and upwards reclined.

Delphinulidae.

The shells of *Delphinula* behave in a somewhat different manner. Most commonly there is an upper layer which is irregularly prismatic and a lower, thick nacreous, one, and then there is, in some places, an undermost, very subordinate layer of a homogeneous kind. The recent species, *D. distorta*, the Miocene *D. scobina*, and the Eocene species, *D. Jouannettii, D. Lima, D. striata* and *D. calcar* all possess this structure.

As most of the fossil forms are rather small the entire structure is not easily ascertained, it is certain, however, that some of them differ essentially from the above named. *D. callifera* (Eocene) has the rare combination of an upper layer consisting of crossed lamellæ and a lower, nacreous one, while in *D. marginata* (Eocene) we find no distinct nacreous layer but an upper one with transverse, crossed lamellæ, while a thin, lower layer possesses these lamellæ in longitudinal orientation, which is, otherwise, very rare in this group of the gastropods.

Trochonematidae.

Of this family I have only had members of the Genus *Cyclonema* at my disposal, and there is, of course, no aragonite left in these very old shells. As to the structure of the calcite they behave very differently. Some, as *C. cancellatum* and *C. carinatum*, are quite irregularly grained and have probably possessed no original calcitic layer; *C. delicatulum* has a rather irregular prismatic layer, the prisms being bent in such a characteristic manner that we must assume that they form an original layer. Still more regular is the layer in *C. bilex* and *C. ventricosum*; the prisms are vertical and their optic axes are so nearly parallel that the layer is not far from being quite homogeneous.

Trochidae.

As to the shell structure this family is very uniform. There is an upper layer of a homogeneously prismatic kind; the prisms are mostly fine and regular, in some instances more irregularly arranged and sometimes coarser and composite. The under layer always is nacreous, and there may, in some instances, be found a very subordinate, homogeneous or irregularly constructed undermost layer.

Tullberg (p. 42) describes the shell of some exotic species of *Trochus*; he compares it with the shell of *Buccinum undatum*, and the uppermost layer may certainly be said to be similarly constructed in both forms. But I do not believe that we shall be able to find any layers in a *Trochus* corresponding to the second and third (crossed lamellar) layers of *B.*, and the similarity between the nacreous layer of *T.* and the fourth (equally crossed lamellar) layer of *B.* cannot be said to be very obvious.

Xenophoridae.

The shells of this family very much resemble those of the main part of the gastropods, as they are built up of alternating layers of transverse and longitudinal, crossed lamels. Because of the irregular form of the shells there are great variations in the distribution of these layers in the different parts of the same shell, and while, in some places, we find only one, transverse layer, several alternating layers may be seen in other places. The most typical structure, however, shows two layers, an upper one with transverse lamellæ and a lower one with longitudinal lamellæ. As to the aspect of the lamellæ, when seen in horizontal sections, it is nearly that which is typical of the main part of the gastropods, the lamellæ being rather regular and straight-lined (pl. IX, fig. 6).

Umboniidae.

In *Umbonium vestarium*, which is the only member of the family which I have had occasion to examine, the shell consists of three layers. The upper one is built up of transverse, crossed lamellæ which, in horizontal sections, have an aspect like moire, seen similarly in many bivalves. The middle layer is strongly nacreous and a rather insignificant, lower layer is more or less homogeneous. The callus of the same shell possesses a very indistinct, crossed lamellar structure.

While, in the handbooks of Cossmann and Fischer, the shell of *U.* is described as nacreous it is stated in the handbooks of Zittel, as characteristic of the whole family that the shell is without any nacreous layer. I think that there must be some mistake here.

Neritopsidae.

The shell of *Neritopsis moniliformis* (Miocene), the only member of this family examined by me, consists almost throughout of transverse, crossed lamellæ which are strongly reclined (at an angle of almost 45°). In the upper, strongly granulated part of the shell the lamellæ get very irregular, and here there is a special, subordinate layer consisting of thin, longitudinal prisms.

Neritidae.

The *Neritidae* possess some of the best characterized shells among all gastropods and cannot be confounded with any other families. An upper calcitic layer is never wanting, and as the characteristic colouring of these shells has its place in that layer, we can understand the well known feature that most of the fossil *Neritidae* still retain their original colour.

Only in one species out of many examined by me have I found no calcite; in *Nerita tricarinata* from the Eocene; but as the surface of the shells is very rough it is probable that the calcitic layer has fallen off. Lamarck, in his description of that species (vol. 6, p. 551) says that in certain individuals he still found the colouring intact and we may conclude, from this that these individuals possess the said layer.

The structure of the calcite may be designated as very irregularly prismatic; the prisms, however, do not resemble those of other gastropods as they are mostly very fine and undulating in a peculiar manner. The most characteristic feature is their orientation as they are placed in the longitudinal plane and are either horizontal or strongly reclined (pl. X, fig. 1), and still more peculiar is the orientation of the optic axes which are certainty somewhat irregular but mostly, however, horizontal, in the transverse direction, standing, of course, normal to the direction of the prisms.

As to the thickness of the calcitic layer there is a marked difference between the main genera of the family. Most *Neritae* have a thick layer (pl. X, fig. 1) which constitutes almost half of the mass of the shell or still more, and the thickness of which may rise to more that 1 mm. This holds good of the recent forms *N. polita*, *N. goldii, N. plicata* and *N. albicilla* and of the Miocene form *N. Plutonis*. Only in *N. (Semineritina) mammaria* do we find a very thin layer.

The genus *Velates* has an essentially thinner calcite ranging up to almost 0.1 mm in thickness (*V. conoideus* from the Eocene).

In the shell of *Neritina* the calcite is always exceedingly thin (pl. IX, fig. 7), constituting only a small percentage of the mass of the shell and having generally a thickness of 0.01—0.03 mm. The single prisms are, however, coarser than in the shell of *Nerita* as there is only one layer of prisms; the orientation is the same. It is worth noting that we find forms among the *Neritinae*, which live in perfectly fresh water, as it is otherwise an absolute rule, not alone among the mollusks but also among all other shell-bearing animals, as far as I know, that there does not exist calcite in the shells of fresh water or land animals. Of this genus I have examined a great number of species which have all essentially the same structure: the recent forms *N. fluviatilis, Philippinarum, concava* and *virginea,* the Miocene *N. expansa* and the Oligocene and Eocene *N. picta, vicina, Duchasteli, pisiformis, globulus* and *Saincenyensis.*

The aragonitic part of the shell mainly consists of transverse, crossed lamellæ which, in radial sections, are either vertical or more or less reclined (pl. IX, fig. 7, and pl. X, fig. 1). In horizontal sections they may be more or less irregular, mostly, however, especially in the shell of *Nerita,* they are very regular and straight-lined. Only in one instance, *Neritina Philippinarum,* is there a distinct layer of longitudinal, crossed lamellæ above the concentrical one.

Most *Neritae* have a special lower layer of the complex crossed lamellar type (pl. X, fig. 1) which is so common among the bivalves. In the *Neritinae* this layer is generally wanting or is exceedingly thin and indistinct.

Among the Mesozoic members of the family I have only examined the *Nerita subrugosa* from the Senonian. The aragonite is not preserved, but there is a calcitic layer possessing the common structure.

It will be seen that the structure of the aspidobranchine gastropods is very variable, and the different families have certainly no character in common unless it is some quite negative ones. The following table will give a summary of the typical structures, some more exceptional forms being here, as elsewhere, omitted for the sake of clearness.

As to the occurrence of calcite there is only one form (among the *Bellerophontidae*) which seems to have possessed a shell consisting exclusively of that mineral. With that exception it only constitutes part of the shell. Out of 15 families examined by me calcite has been found in the 5; it is universal in the *Neritidae,* common in the *Haliotidae, Euomphalidae* and rare in the *Fissurellidae.* In the *Haliotidae* the calcite, contrary to all that is known elsewhere, forms an intermediate layer which is only found in parts of the shell.

The structure of the aragonitic part of the shell is seen from the following scheme.

Pleurotomariidae		homogeneously-prismatic + nacreous
Fissurellidae		crossed lamellar
	or:	crossed lamellar + complex
Haliotidae		homogeneously-grained + nacreous
Stomatidae		homogeneously-prismatic + nacreous
Turbinidae		homogeneously-prismatic + nacreous
Phasianellidae		complex prismatic + crossed lamellar + prismatic
Delphinulidae		complex prismatic + nacreous + homogeneous
	or:	crossed lamellar + nacreous
	or:	crossed lamellar + longitudinally crossed lamellar
Trochidae		homogeneously-prismatic + nacreous
Xenophoridae		crossed lamellar + longitudinally crossed lamellar
Umboniidae		crossed lamellar + nacreous + homogeneous
Neritopsidae		horizontally prismatic + crossed lamellar
Neritidae		crossed lamellar + complex
	or:	crossed lamellar

The most characteristic structure is the nacreous one which occurs in all members of 6 of the 12 families examined and in the greater part of the 7th. The layer above the nacreous one is always of a but little characteristic kind, homogeneous and at the same time more or less indistinctly grained or finely prismatic. Under the nacreous layer there may, in some instances, occur another homogeneous layer.

Only in two instances there occurs a crossed lamellar layer above the nacreous one, a combination which was never seen in the shells of the bivalves.

For the shells without a nacreous layer the crossed lamellar structure is the most characteristic, and most commonly the lamellæ are transversely arranged, which is everywhere the case if the opposite is not stated. Only in two instances there are longitudinal, crossed lamellæ under the concentrical ones. Over the crossed lamellar layer there is in one instance a special layer consisting of horizontal, radiating prisms, while, on the under side of the lamellar layer a complex layer may sometimes be found, which however, is, mostly very subordinate.

Although the structure of the shells in question is by far not so variable as those of the bivalves, it will be obvious that they possess some characters which distinguish them from the other groups of the gastropods and approach them to the bivalves. Firstly the occurrence of the nacreous layer, which is not found in any other gastropod, and secondly the predominance of the transverse lamellæ. Such features as the occurrence of prismatically homogeneous or complex crossed lamellar layers are also highly characteristic of the bivalves.

2. Suborder. *Cyclobranchina.*

Although the shells of these gastropods are built up in a rather variable manner, they form a very well characterized group which cannot very well be confounded with any other. In many instances the structure is very peculiar and generally it is very complicated, with several layers. The different layers are distributed in a very imbricate manner, the uppermost one being at the same time thickest in the part next to the margin, while the lower layers are mostly confined to the region near the centre. This character is most pronounced in *Patella fluctuosa*, where the different layers almost have the form of concentrical rings. Only recent forms shall be described, but the Paleozoic forms, as different species of *Tryblidium*, also possess a special calcitic layer.

It is an essential character that all shells possess an upper layer of calcite which is mostly rather thick and in most cases, constitutes the whole part next to the margin. In the genus *Acmaea* (*Tectura*) the calcitic layer is very thin, especially in *A. virginea*, where it is only a thin film (up to 0.02 mm. thick) (faintly visible in pl. X, fig. 3).

As to the arrangement of the elements the calcitic layer is more regular than in other gastropods with the exception only of the *Neritidae*. In *Acmaea virginea* and *A. persona* we have one layer of horizontal prisms, as in *Neritina*, but here the optic axes are parallel to the prism axes. In *Scutellina fulva* there are also radiating prisms with parallel extinction, but the prisms are not quite horizontal but strongly inclined. In *Scurria sp.* the whole calcitic layer, which is very thick here, must be designated as homogeneously prismatic with radiating, almost horizontal prisms and with optic axes of the same direction. In *Patella fluctuosa* (pl. X, fig. 2) the calcite is foliated, shining with a micaceous lustre, as in many *Ostreidae*; the optic axes are still horizontal and radial. This orientation of the axes seems to be very characteristic of most members of the family.

The *Patella plicata* forms a transition to the next type, the calcite being still foliated but with the foliae irregularly arranged. There are traces of a crossed lamellar structure but the lamellæ are highly irregular and the optic axes are turned in all directions.

In *P. Bavia* and *P. vulgata* we have a mostly very regular crossed lamellar structure (pl. X, figs. 4 and 5), which is otherwise only found in some bivalves (*Avicula-Aucella* and *Gryphaea*). If we do not consider the position of the optic axes the structure very much resembles that of the said bivalves, the lamellæ of the 2nd order being much more flat-lying than in the corresponding structure of the aragonite. It is possible, of course, to see the reflections of these lamellæ on the under surface of the shell, and as the lamellæ are rather broad, they are easily seen with the naked eye. The angles characteristic of these lamellæ are the following (compare fig. 10): the obliquity of the lamellæ of the 2nd order is 13°, the angle between the optic axis and these lamellæ is 35°, and consequently the angle between the directions of extinction in two adjacent lamellæ is 96°. These angles are, of course, only approximate, as the whole structure is not very exact; practically we have, in the concentrical section, almost perfect extinction at the same time over the whole section, but as the axes of the two sets of lamellæ are nearly normal to each other we see, on turning the table of the microscope, alternately the one and the other of these sets possessed of a high relief because of its large refraction.

In *Patella rustica* we find both types of calcitic structures of the family, there being an upper, thinner layer of horizontal, radial prisms and a lower one which is crossed lamellar. Also *Helcion pellucidum* possesses both layers.

In *Patella (Helcioniscus) radians* we find a peculiar combination, the upper layer of the calcite being prismatic with irregular, vertical prisms and with very irregular extinctions; the lower layer is prismatic or foliated, with flat prisms placed horizontally in the concentrical direction, while their optic axes are horizontal and radial.

As to the structure of the aragonitic layers we find a still greater confusion. The different kinds of structure, characteristic of the mollusks are mixed together and hardly two of the species examined possess the same combination.

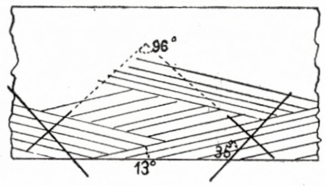


Fig. 10.

In *Patella Bavia* (pl. X, figs. 4 and 5) we find an upper layer of radial, crossed lamellæ after which follows a finely prismatic layer while the undermost layer consists again of radial, crossed lamellæ interrupted by thin prismatic layers. *P. plicata* has an upmost layer of concentrical, crossed lamellæ, then a complex crossed lamellar layer, and finally a radial, crossed lamellar layer. *P. rustica* has radial, crossed lamellæ and under them a complex crossed lamellar layer, which layer in *P. vulgata*, as in *P. (Helcioniscus) radians*, constitutes the whole aragonitic part of the shell, while in *P. fluctuosa* (pl. X, fig. 2) it forms only the upper part of the aragonite, the lower layer being here prismatic.

In *Scutellina fulva* the upper layer consists of concentrical, crossed lamellæ, the lower one is homogeneous and faintly prismatic. In *Scurria*, on the contrary, the upper layer is prismatic, the lower one concentrically crossed lamellar, and the same combination is found in *Acmaea virginea* (pl. X, fig. 3), while, in *A. persona*, there is, under the two above mentioned layers, a third consisting of radial, crossed lamellæ.

The species investigated, though rather a random selection, will be sufficient to show that the structures of both mineral substances are so variable that the picture of the whole is one of great confusion. We must expect that by examining still more species we shall find many more types. In order to establish a system on these different structures, it would certainly be necessary to undertake a thorough examination of the whole family.

The shell of *Patella sp.* has been described by Carpenter (1847, p. 112 and 113); the description, together with fig. 51, seems to indicate that we have here, as in *P. Bavia*, an under layer of radial, crossed lamellæ, and above that a prismatic layer. Sorby (p. 60) is the first to state that the shell of Patella consists of both calcite and aragonite. Cornish and Kendall (p. 70) have stated the same for *Tectura testudinaria*. On the contrary Miss Kelly (p. 52) has found that the shell of *Patella* consists of calcite, which is certainly not correct. In the first paper of Thiem there is a figure (p. 346) showing the radial section of *Helcioniscus ardosiaeus*; we see here a structure quite similar to that described above, an upper, calcitic, prismatic layer, under that another, calcitic, one with horizontal prisms or leaves and an undermost aragonitic layer which seems to be complex crossed lamellar. In his second paper he gives detailed descriptions of the shells of different species of *Scurria* and *Acmaea*. In his figure (30, p. 464) of *Sc. zebrina* we may distinguish the calcitic layer (o ostr), the prismatic aragonitic layer (u ostr), the concentrically crossed lamellar layer (hyp st), and an undermost radially crossed lamellar layer which I have not observed in the shell of *Scurria*. In the figure (31, p. 465) of *Acmaea cubensis* we see the thin, calcitic layer, which has no designation, the upper aragonitic layer (ostr) consisting of concentrical, crossed lamellæ, and the lower one (hyp) which is radially crossed lamellar. It seems somewhat inconvenient to give such distinct terms to the individual layers, as long as we do not know which layers correspond in the different forms. Later on (p. 478) he determines the mineralogical composition of the different layers through the reaction of Meigen and obtains some results which deviate highly from those obtained by others and which are certainly not correct. It must especially be pointed out as extremely doubtful that a layer may consist of both calcite and aragonite, as that would, in most instances, be easily detected by a microscopical examination through the different refraction of the two minerals.

Thiem's exposition (pp. 467—476) of the structure of the crossed lamellæ is most interesting. It is a fact that, in transverse sections of the lamellæ of the 1st order, we very often find them filled up by very fine, oblique lines runing in opposite directions in the two sets of lamellæ. But it is also certain that these lines do not represent the traces of the lamellæ of the 2nd order which are always, if visible, placed normally to the boundaries of the larger lamellæ. I am not able to give any explanation of these oblique lines which seem to be caused by a special optical phenomenon if the lamellæ are cut in a somewhat oblique direction. The figures of the crossed lamellæ, given by Thiem, are so complicated that they are only understood with great difficulty.

3. Suborder. *Ctenobranchina.*

The shells belonging to this large group are very uniformly built. The main structure is the crossed lamellar one in alternating layers, either transverse or longitudinal. The lamellæ are mostly regular and rectilinear, and only at the upper surface of the shell they pass gradually into an irregularly grained mass. Other aragonitic structures are very rare, and the greatest variations are produced by the existence of a calcitic layer in certain families.

From older times (Rose, Bowerbank a. o.) it is commonly stated that the shells of this main group of the gastropods consist of three alternating layers, of which the first and the third are transverse and the second longitudinal, or the opposite. As will be pointed out in the following, we shall see, however, that the last-named combination is never found outside the *Capulidae*, while the first-named combination, called the normal one in the following descriptions, is of course found in almost all families. True, we sometimes find an upper layer with longitudinal lamellæ but it is found only in connection with the common three layers, as a fourth, extra layer, and is always very insignificant and mostly only found in some few members of the same genus.

Solariidae.

All forms of the genera *Solarium* and *Bifrontia* examined by me belong to the common type with the upper layer transversely lamellated. In some instances both the second and the third layer is confined to a smaller part of the shell. The lamellæ are rather irregularly formed, especially those of the third layer.

Litorinidae.

In the recent forms *Litorina litorea, L. rudis* and *L. obtusata* there is a thick, upper layer of calcite, while in *L. flava* (recent), in *Lacuna divaricata* and *L. pallidula* (both recent) and in *Planaxis muricoides* (Eocene) there is no calcite at all.

The calcite is irregularly prismatic with reclined prisms (pl. X, fig. 6) the optic axes are also very irregularly orientated, mostly, however, crossing the prisms, horizontally and longitudinally.

The aragonite in all the abovementioned species is very uniformly built and possesses the common three layers with the upper one transverse. The lamellæ are rather irregular.

Among the older members of the family *Holopea sp.* (Silurian) seems to have possessed a prismatic, calcitic layer, while in *Litorina biferialis* (Carboniferous) there is no trace of such a layer.

The existence of the two mineral substances in *Litorina* was mentioned by Sorby (p. 60).

Cyclostomatidae.

Only a few members of this family were examined. The Eocene form *Cyclostoma mumia* possesses the common three layers with the first one concentrical, and the same may be said of the recent form *C. elegans* which, however, is in so far anomalous as the two under layers are so finely lamellated that the structure is difficult to observe and generally gives one the impression of being quite homogeneous.

Capulidae.

The shells deviate from the common type, as they only possess three layers of which the middle one has transverse (concentrical) lamels. As this layer is, in most instances, the thickest one, there is often a marked cleavage of the whole shell in the concentrical direction, which is more prominent here than in any other gastropod shell. The undermost, longitudinal (radial) layer shows quite the same characters as the transverse one which, in other gastropods of that group, is the lower layer; the lamellæ are irregularly formed (pl. XI, fig. 1), and their direction, in many instances, is rather oblique, forming an angle of up to 45° with these of the two upper layers. In no instance is there any trace of an undermost, transverse layer.

Numerous recent and Tertiary forms examined by me show the above structure. Some of the Silurian members of the family consist entirely of irregularly grained calcite and may, of course, have been built up in the same manner, while others possess distinct prismatic layers, as *Platyceras cornutum*, where the prisms show a characteristic zigzag form, reminiscent, to a certain degree, of some *Pectens*, while, in *Platyostonea gregarium*, they are of the commoner form.

Carpenter (1847, p. 114) describes the shells of *Crepidula* and *Calyptraea* as having rounded or polygonal cells. I have not been able to observe any such; they must surely be caused by some more secondary phenomenon.

Naticidae.

A large number of species were examined, both of *Natica* and of *Neverita*, *Lunatia* and *Sigaretus*. All have the common three layers with the upper one with transverse lamellæ. The lamellæ of the upper layer are very regular (pl. XI, fig. 2), whereas the radial lamels are rather irregular and the undermost, transverse ones very irregular.

CARPENTER (1847, p. 116) mentions pavement-like cells as occurring in the shell of a *Natica*. I have not seen any similar phenomenon.

Ampullariidae.

The members of this family examined by me behave quite like those of the *Naticidae* (pl. XI, fig. 3).

Already BOWERBANK describes the three layers of the *Ampullaria*.

Valvatidae.

The shells of the recent forms *Valvata piscinalis* and *V. carinata* have four layers of lamellæ with the first one longitudinal; the lamellæ are irregularly formed.

Paludinidae.

The shells of different species of the genera *Paludina* and *Vivipara* examined have three layers of which the first one is transverse (pl. XI, fig. 4). The lamellæ of this layer are very regular while those of the second layer are more irregular and those of the third very irregular; the directions of the lamellæ of the two last named layers differ widely from the normal scheme.

Hydrobiidae.

Members of the species *Hydrobia*, *Bythinia* and *Lithoglyphus* show a structure similar to that of the foregoing family. In the very thin shells the structure is, of course, not very distinct and the lamellæ are rather irregular.

Rissoidae.

Different species of *Rissoa* and *Alvania* were examined and most of them were built in the same manner as the two foregoing families. Only in *Rissoa letlandica* there are four layers the first of which has longitudinal lamellæ.

Janthinidae.

Some recent members examined by me (*Janthina prolongata*, *exigua* a. o.) have quite the same structure (pl. XI, fig. 5) deviating from that of all other gastropods of this group. The mostly very thin shells possess an upper, calcitic layer which is relatively thick, constituting half of the shell or more. The calcite is exceedingly irregularly built and must be designated as irregularly grained without any prismatic arrangement. The extinctions are also for the most part quite accidentally orientated, although a relatively large number of the axes are reclined in the longitudinal plane.

The aragonite consists of crossed lamellæ which are always transverse, and there is no trace of any second or third layer. The lamellæ are very fine and irregular.

Miss Kelly (p. 52) describes the shells as consisting of calcite, which is surely not quite correct.

Scalariidae.

This family forms a transition from the common type to that of the foregoing family. A calcitic layer is probably never wanting although it may, in some instances, as in *Scalaria gaultina*, be very thin and not quite certain. In most cases it is essentially thicker and constitutes the greater part of the shell, especially in the last whorl. The ledges for the most part consist entirely of calcite (pl. XI, fig. 7) but in other instances, as in *S. intumesecns* from the Oligocene, that side of them which is turned towards the spire is formed of aragonite. The structure of the calcite is variable. While it is very regularly prismatic in the last named species, the prisms are, in most instances, very irregular (pl. XI, fig. 7), and in some cases the structure must be designated as grained.

The aragonite consists, as usual, of crossed lamellæ, and in most cases there are the ordinary three layers with the first one transverse. In some recent forms, however, only the upper, transverse layer is formed, but its under part is then generally exceedingly irregular (pl. XI, fig. 7). The lamellæ are, on the whole, rather irregularly formed.

Both Cornish and Kendall (p. 70) and Miss Kelly (p. 52) describe the shells as consisting of calcite, which is certainly not correct for any species. Here, as in other instances, such a fault is very easily explained if we assume that only the outermost part of the shell, next to the outer lip, is examined, as the aragonite is so exceedingly thin here that it cannot be detected by means of a determination of the specific gravity.

Turritellidae.

Among many recent and older *Turritellidae* examined by me there is very little divergence. The structure is the common one with three layers the uppermost of which is transverse; the second, longitudinal, layer is in most cases very insignificant, and the lamellæ are mostly very irregularly formed.

Cayeux (p. 486) describes the Eocene form *T. terebellata* as consisting of the ordinary three layers.

Vermetidae.

The shells of *Vermetus,* of which I have examined some recent species, are built in the usual manner with three layers, the uppermost of which is transverse. There are, however, sometimes traces of a fourth or fifth layer. In the Eocene *Tenagodes* *striatus* the structure is essentially the same, but in some places thin, transverse layers are inserted in the thick longitudinal layer. In the Pliocene *Siliquaria anguina* the upper layer is also transverse while the undermost one is longitudinal, with many thinner transverse layers inserted in it. The lamellæ are on the whole rather irregularly formed.

Pyramidellidae.

Different species of the genera *Pyramidella, Eulima, Turbonilla, Cheilostoma* and *Diastoma* were examined and they were quite alike. The shell consists of three layers, the first of which is transverse; the lamellæ are rather irregularly formed.

Melaniidae.

The shells of different forms of the genera *Melania*, *Melanopsis* and *Pyrgularia* are essentially alike with the upper layer longitudinally lamellated and with four layers. The first layer is very thin and indistinct; the lamellæ of all the layers are, on the whole, rather irregularly formed.

Cerithiidae.

The shells are built up in the usual manner with three layers the first of which is concentrical. The longitudinal layer is mostly rather insignificant and the lamellæ of all layers are generally rather irregularly formed. Besides a large number of species of *Cerithium* I have examined members of the genera *Bittium, Potamides* and *Triforis*. The Eocene form *Cerithium giganteum* possesses some very subordinate layers which seem to be of a prismatic nature; the lamellæ of this large form attain a thickness of up to 0.15 mm.

Aporrhaidae.

The shells of *Aporrhais* and *Alaria* consist of the ordinary three layers with the first one transverse (pl. XI, fig. 7). The layers are considerably more distinct than those of the foregoing families, and the lamellæ are more regularly formed. The 3rd layer is divided into two sub-layers, both with an almost transverse orientation but differing a little from each other (pl. XI, fig. 8). In the foregoing families there have, in some instances, been found traces of sub-layers, but because of the irregularity of the lamellæ it has not been possible to establish their existence with certainty.

Strombidae.

The commonest type is the same as that of the foregoing family. There are three layers the first of which has transverse lamellæ and the layers are very distinct with regular lamellæ, those of the third layer being, however, less regular than the others. I have found no traces of any sub-layer like that mentioned above. The Eocene forms *Strombus dubius, ornatus* and *luctator, Rostellaria lucida, Rinella rimosa, Seraphs convolutus, Terebellum fusiforme* and the Gaultian form *Anchura carinata* belong to this type.

In the recent *Strombus gigas* there are four layers, all alternating, and the first one is longitudinal. The lamellæ are regular and rather broad (up to 0.1 mm.). Also the Gaultian form *Rostellaria Sowerbyi* has longitudinal lamellæ in the first layer.

Already Bournon (p. 312 and 318 ff.) describes the shell of *Strombus gigas*. He has only seen three layers the uppermost of which has longitudinal lamellæ; as the fourth layer begins at a distance from the outer lip of almost half a revolution it is easily understood how we may receive the impression that there are only three layers. In the drawing of Bournon (pl. 1, fig. 2) there is the fault that the lamellæ of the first and third layers are placed in an oblique position while they are in fact strictly normal to the surface of the shell. Also Rose (p. 89 ff.) gives descriptions and drawings of the three layers of *Strombus gigas*, and Tullberg (p. 42) mentions the same layers and, furthermore, an undermost layer, built like the uppermost one of Buccinum undatum. He does not state which is the species examined, and I have never observed any such layer in any form of *Strombus*.

Cypraeidae.

An Eocene *Cypraea sp.* possesses four alternating layers the first of which is longitudinal. All other species of *C.*, and of *Erato* and *Ovula* examined by me have the usual three layers with the first one transverse. The lamellæ are more or less regular.

The structure of *Cypraea* was already stated by Bowerbank.

Cassididae.

Different species of *Cassis* and *Cassidaria* examined by me all show the same structure with three alternating layers the first of which has transverse lamellæ (pl. XI, fig. 9, and pl. XII, fig. 2). The lamellæ of the two first layers are very regular (pl. XII, fig. 2), those of the third one less so.

The structure of *Cassis* was already stated by Bowerbank.

Doliidae.

The shells of *Dolium* are built up in exactly the same manner as those of the foregoing family.

Tritoniidae.

Different species of *Triton* and *Ranella* examined by me all show the same structure very much resembling that of the two foregoing families. In some instances there is a distinct fourth sublayer with transverse lamellæ which, however, form an angle of about 25° with those of the third layer.

Columbellidae.

The shells of *Columbella* behave exactly like those of the foregoing families.

Buccinidae.

Almost all members of this family belonging to the genera *Buccinum*, *Pseudoliva* and *Nassa* (pl. XII, fig. 4) examined by me, behave exactly like those of the foregoing families. Only *Buccinum undatum* forms an exception as the shell possesses a special, thick, upper layer, of which no trace is found in any of the other forms. The said layer is prismatic and bears a certain resemblance to the calcitic layer found in other gastropod shells, as it is considerably more transparent than the underlying lamellar substance. It consists, however, of aragonite, and the structure is very irregular, composite prismatic (pl. XII, fig. 3).

TULLBERG (p. 39 ff.) describes the four layers of *B. undatum* and gives good figures of the different sections of the shell.

Purpuridae.

Most members of this family examined by me, such as the recent *Purpura recta*, the Miocene forms *P. exilis*, *haemastoma* and a recent *Pentadactylus sp.*, show the common structure. In *Purpura recta* the lamellæ of the third layer have such an oblique position that they can hardly be said to be transverse (pl. XII, fig. 5).

In two instances, the recent forms *P. lapillus* (pl. XII, fig. 6) and *Rapana rapa*, there is a thick, upper, calcitic layer consisting of rather irregular prisms with an almost entirely irregular extinction.

Already DE BOURNON (p. 324) observed the two different substances forming the shell of *P. lapillus*, and SORBY (p. 60) determines these substances as calcite and aragonite. CORNISH and KENDALL (p. 70) have arrived at the same result.

Muricidae.

Most members of this family examined by me have their shells built up of four alternating layers (pl. XII, fig. 7) the first of which has longitudinal lamellæ. This layer is always thin and in some instances indistinct and interrupted, but I think that it is never entirely wanting. All forms of *Murex* and *Typhis* examined by me, and *Trophon Semperi* from the Miocene belong to this type.

All other species of *Trophon* examined by me (*T. clathratus* and *T.* (*Ocinebra*) *scalariformis*) possess an upper, calcitic layer with a prismatic structure with rather regularly formed prisms with a rather regular extinction. The aragonitic part of the shell has only three alternating layers the first of which has transverse lamellæ.

CORNISH and KENDALL mention (p. 70) that *Murex tortuosus* has a thick opaque inner layer, while the investment constituting the frills and varices is translucent. The specific gravity of the shell is 2.85, indicating that the greater part is aragonite. It is possible that we have here a calcitic layer but it may also be that the layer is constructed as in *Buccinum undatum*. I have not had any material of this species at my disposal.

Fusidae.

The most divergent is the genus *Chrysodomus* of which the following Pliocene and Pleistocene members were examined: *C. contraria*, *C. despecta* and *C. antiqua*. All of them have a thick upper calcitic layer built up of rather regular prisms with a rather regular extinction. The aragonitic part of the shell consists of the ordinary three layers.

The other members of the family have no calcite and consist of the common alternating layers. Mostly there are only three but in some instances there is a distinct upper one with longitudinal lamellæ. The genera *Fusus* and *Leiostoma*, a very large number of which I have examined, have mostly three layers and only some species, as the Eocene forms *L. pyrus*, *bulbiformis* and *incrassatus*, have four distinct layers. Of the genus *Fasciolaria* the Miocene forms *F. fimbriata* and *F. nodifera*, have four layers while the equally Miocene form *F. burdigalensis* only possesses three. The Miocene *Turbinella subcraticulata* has four layers. Some Eocene members of the genus *Pyrula* are also differently constructed: *P. clava* and *tricostata* have three, while *P. callosa*, *Condita* and *laevigata*, have four layers.

Bowerbank mentions the genus *Pyrula* as one of those which have three layers with the middle one with transverse lamellæ; as seen above, some *Pyrulae* have four layers, and he has here, as in other instances, not noticed the innermost, transverse layer. Sorby (p. 60) mentions the genus *Fusus* among those which have an outer calcitic layer; it is probable that he has examined some Chrysodomus. Cornish and Kendall state that *Fusus antiquus* (= *Chrysodomus antiqua*) consists of calcite and aragonite.

Volutidae.

The shells of *Voluta* possess the ordinary three layers; the third one may be divided into two sublayers none of which takes the exact transverse direction (pl. XII, fig. 8). The genus *Marginella* also possesses three layers while some species of the genus *Mitra* (*M. fusiformis* and *scrobiculata*) have an upper layer with longitudinal lamellæ.

Bowerbank gives the genus *Voluta* as an example of the gastropods with three layers the middle one of which has transverse lamellæ; I have found no instance among numerous species examined where there is an upper longitudinal layer.

Harpidae.

A few species of *Harpa* examined by me show the same structure as *Voluta*. Here the third layer is more distinctly divided into two sublayers the first of which has the lamellæ orientated in an oblique direction; as seen in the figure, pl. XIII, fig. 1, the lamellæ of the upper sublayer are more regularly formed than those of the lower one, although not so regular as those of the two upper layers.

Olividae.

The shells of different forms of *Oliva*, *Olivella* and *Ancillaria* examined by me all show the ordinary structure with three layers. There may, in some instances, be faint traces of an upper, longitudinal layer but it is not formed as a distinct, separate layer.

Bowerbank places the *Oliva* among the gastropods which have three layers of which the middle one has transverse lamellæ; there may, perhaps, be other species than those examined by me, which possess the said upper layer.

Cancellariidae.

Different Tertiary and Quaternary species of *Cancellaria* examined by me were all quite alike and built up of the ordinary three layers.

Terebridae.

The shells of *Terebra* are constructed in the same manner as those of the foregoing family.

Pleurotomidae.

A large number of species of the genus *Pleurotoma* and some examples of the genera *Mangelia, Bela, Drillia, Clathurella, Clavatula* and *Borsonia* were examined. The structure was the same in all instances, and the usual three layers being always present.

Conidae.

All shells of *Conus* consist of four layers, the first one having longitudinal lamellæ.

By Bowerbank these shells are stated to be composed of three layers, of which the middle one has transverse lamellæ; here, as elsewhere, he has not observed the innermost layer.

The shells of the large suborder of the *Ctenobranchina* are built essentially in the same manner although there may, of course, be different modifications of the common type. The differences are, however, in most instances not very marked, and it is impossible to distinguish these shells from each other only by means of their structure.

The common type, which is developed in all families with the exception only of the *Capulidae*, the *Janthinidae* and some of the *Scalariidae*, is a combination of three alternating layers of crossed lamellæ, those of the first and third layers being transverse and those of the middle one longitudinal. The lamellæ of the first layer are in most instances perfectly transverse, parallel to the lines of growth, although there may, in some instances, be characteristic deviations from that direction, the lamellæ forming a distinct, acute angle with the lines of growth. This, however, is an exception. The second layer too is rather regularly orientated, its lamellæ being, in most instances, normal to those of the first layer. But the orientation of the lamellæ of the third layer is highly irregular; in some instances they may be nearly normal to those of the second and parallel to those of the first layer, but as often they may be orientated in another direction, forming angles of up to 45° with the directions of the upper lamellæ. In other instances the third layer may be replaced by two sub-layers having different directions, of which one or both may deviate rather strongly from the transverse one. In no instance is there, however, any distinct fourth layer with longitudinal lamellæ.

As to the regularity of the lamellæ there are great differences both between the different families and between the different layers. As a rule the lamellæ of the first layer are most regularly formed, while those of the second layer are somewhat less so and those of the third one are always very irregularly formed, branched and fusiform. The substance forming the third layer is also generally different from that of the two first ones, being more transparent. If this layer is divided into two sub-layers there may be some difference between these, the upper one forming a transition, both as to the regularity of the lamellæ and the transparency of the substance, between the upper layers and the undermost sub-layer.

The different families behave very differently as to the regularity of the lamellæ, but there may, in some instances, also be a great difference between shells belonging to the same family. As a rule the lamellæ of the larger and thicker shells are more regularly formed than those of thin shells. The most regular structure is found in the last half of the families, from the *Aporrhaidae* to the *Conidae*, and it is obvious that the single layers have very sharp and distinct boundaries against each other and are easily visible to the naked eye. Among the first part of the families we find similarly distinct regular lamels and sharply bounded layers in the *Naticidae*, the *Capulidae*, the *Paludinidae* and the *Ampullariidae*, while the lamellæ in the other families are more irregular. The greatest irregularity prevails among the *Turritellidae* and the *Cerithiidae*, where the second layer is generally very indistinct and only developed in part of the shell while, in other parts, the first and third layers are merged in each other.

The relative thickness of the three layers may be rather variable. As a rule the first layer is always well developed; by the outer lip it forms the whole shell, but it gets gradually thinner as we approach the apex. The second layer commonly begins at a little distance from the lip and is at first very thin but gradually gets thicker until where the third layer begins, whereupon it generally gets thinner and thinner. The third layer begins rather far away from the lip; in the shells with a large first whorl, as in *Strombus*, *Conus* and *Cypraea*, we commonly find it at a distance from the lip of almost half a revolution, while, in the shells with a long spire, as in a *Terebra*, it only begins at a distance of many whorls from the lip. This layer commonly gets thicker and thicker next to the apex, but there are many shells where it is always rather insignificant.

The most common divergence from the ordinary type is formed by the existence of an uppermost layer with longitudinal lamellæ found in many families which, in this manner, come to be built up of four alternating layers. This uppermost layer is always relatively thin and it is, in some instances rather difficult to ascertain its existence as the lamellæ next to the surface of the shell are mostly rather irregularly formed. Where best developed the lamellæ of this layer are, however, perfectly distinct and regularly formed, and the layer surrounds the whole shell. All members of the families *Valvatinidae*, *Melaniidae* and *Conidae* examined by me possess four layers and so do those members of the *Muricidae* which have no calcitic layer. In the families *Rissoidae*, *Strombidae*, *Cypraeidae*, *Fusidae* and *Volutidae* some members have four layers while most of them only possess the usual three.

Other deviations from the normal type are the following: thin, subordinate layers of different kind are found in the *Vermetidae* and in *Cerithium giganteum*; in the genus *Cyclostoma* the second and third layers may be developed in a very imperfect manner, the structure of that part of the shell being almost homogeneous. In *Buccinum undatum* there is a special, thick, upmost layer of a prismatic consistency.

As mentioned above, there are three families which deviate essentially from the type. The *Capulidae* possess three alternating layers the first of which has longitudinal lamellæ while the third, longitudinal layer is developed in the same way as the third, transverse layer in the typical shells. Only in the two families in which the calcitic layer is never wanting, the aragonitic part is correspondingly reduced. In the *Scalariidae* some of the members possess the normal three layers while others have only the first one, and the thin, aragonitic part of the shells of the *Janthinidae* only consists of that layer.

A calcitic layer is found in all members of the families *Janthinidae* and *Scalariidae* examined by me and in some members of the *Litorinidae, Muricidae, Purpuridae* and *Fusidae*; there has likewise been such a layer in some of the Paleozoic members of the *Capulidae*. The calcitic layer is in almost all instances very thick, the structure is always prismatic, in some cases rather regular in others more irregular.

4. Suborder: *Heteropoda*.

The shells of *Atlanta* sp. and *Carinaria mediterranea* examined by me are essentially alike; they consist of aragonite and have a homogeneous structure without any distinctly visible elements.

Schmidt (p. 177) describes the homogeneous structure of *Carinaria mediterranea*, but he finds that the shell consists mainly of calcite, as, by using the fluid of Mohr, he obtains a mainly yellow precipitate with green spots. I think it highly improbable that a shell which looks so homogeneous, can consist of two substances, and I have found no trace of calcite either by means of the fluid of Mohr, or by other ways of determination.

B. Order. Opisthobranchia.

Actaeonidae.

The shell consists of the common three layers with alternating lamellæ, those of the first layer being, as usual, transverse. The third layer may, in some instances, be very insignificant or wanting. As to the aspect of the lamellæ there is a great difference between the different genera. The Senonian form, *Actæonella gigantea*, has very regularly formed lamellæ, and the third layer is very thick here and has also the lamellæ regularly formed. *Actaeon Moulinsii* from the Miocene has still regularly formed lamellæ, but here the third layer is insignificant. Different Eocene species of *Tornatella* have irregular lamellæ but the layers are still very distinct, whereas, in several species of *Ringicula* examined by me they are merged to a great extent and only recognizable with great incertainty.

Bullidae.

The shells of this family are differently built; the lamellæ are, however, always rather irregularly formed. *Bulla sp.* (recent) has the common three layers, the third of which is divided into two sub-layers. Among the Eocene forms *Athys semistriata* and *Bulla parisiensis* have four layers, as there is an uppermost, very thin layer with longitudinal lamellæ; *Cylichna Bruguierei* also possesses this upper layer, but there is no trace here of the usual, undermost transverse layer. In *Cylichna cylindroides* and *Bulla angistoma* the uppermost layer is also wanting, and there are only two layers in all, the first one being transverse. The Miocene form, *Scaphander Grateloupi*, has the same two layers combined with the upmost longitudinal layer (as in *Cylichna Bruguierei*); the layers are more indistinct than in most *Bullae.* In *Philine* aperta and *scabra* (both recent) the layers and lamellæ are highly irregular and indistinct, the lower part of the shell possessing a perfectly complex structure.

It will be seen that the shells of the *Opistobranchia* are built up after essentially the same scheme as those of the *Ctenobranchina*, possessing, in most instances, the same three or four layers. But there is, in this small group, much more variation than in the other, large group. The layers are, in some instances, much more indistinct than in the former group; the third layer may be wanting, but it may, on the other hand, be much thicker than in any members of the *Ctenobranchina* and possessed of much more regular lamellæ.

C. Order. Pteropoda.

Cavoliniidae.

The few forms examined by me (a recent *Hyalaea sp.* and the Miocene *Vaginella* depressa) are quite alike; the shell consists of aragonite and the structure is perfectly homogeneous without any visible element.

Cayeux (p. 490) describes the shell of a *Vaginella* as consisting of three layers, of which the upper and under ones are homogeneous and are said to consist of calcite, whereas the middle one is described as being crossed lamellar; this structure is, however, said to be extremely fine and is not visible in the figure (pl. 54, fig. 2).

Hyolithidae.

The shell of *Hyolithes*, if not altered into some other substance, consists of irregularly grained calcite, and there is no doubt that it originally consisted of aragonite. In no case is there any trace of the original structure.

Appendix.

Tentaculitidae.

The shells have mostly a very uniform structure consisting of calcite which is certainly original, possessing a very regular, finely foliated structure (pl. XIII, fig. 2) with a regular, normal extinction. As the most typical examples may be mentioned *Tentaculites annulatus* from the Ordovician or *T. intermedius*, *T. ornatus* and others from the Silurian. A similar but less regular structure is found in *T. sp.* of Gothland, whereas, in *T. cfr. grandis* from the Ordovician, it has not been possible to find any distinct structure.

In the handbooks of ZITTEL the shell is said to consist of two layers, an outer, massive, and an inner, foliated layer. I have not seen any such difference in the shells examined by me.

Torellellidae.

The shell of the Cambrian *Torellella laevigata* consists of phosphorite which is, as usual, composed of alternating layers of a weakly doubly refracting and a seemingly perfectly isotropic substance. The former is positive with the axes regularly vertical. The sign of the double refraction is remarkable, as not alone most varieties of the common phosphorite, but also other phosphoritic shells, as those of the *Conularia* and of the brachiopods, are always negative. The very thin shell of *Hyolithellus micans* (Cambrian) also consists of phosphorite with a positive sign, but here no alternating layers are visible.

Conulariidae.

The shells of different species of *Conularia* were examined. In most respeets they resemble those of the foregoing family. In some instances the whole shell is isotropic, in others there are alternating layers; the sign of the double refraction is negative.

D. Order. Pulmonata.

1. Suborder. *Thalassophila.*

The only shell examined by me is that of the recent *Siphonaria Lesseni*; it consists of three alternating layers, the first one having concentrical lamellæ. The lamellæ, as usual, are rather regularly formed in the first two layers and irregular in the third one.

2. Suborder. *Basommatophora.*

Auriculidae.

The shells of the recent *Auricula myosotis* and of the Eocene *A. Douvillei* are quite alike and consist of four alternating layers the first of which is very thin and consists of longitudinal lamellæ; the lamellæ of the fourth layer are, as usual, very irregularly formed.

Limnaeidae.

The recent forms of *Limnaea* examined by me (*L. stagnalis*, *ovata*, *palustris* and *pereger*) all have their shells built up of four layers, the first of which is very insignificant and has longitudinal lamellæ. The shells of the recent *Planorbis umbilicatus* and of the Miocene forms, *P. corneus* and *pseudoammoneus*, only possess three layers, the first of which is very insignificant and has longitudinal lamellæ; the lamellæ of the third layer are very indistinct. *Physa columnaris* (Eocene) also possesses three layers the first of which has longitudinal lamellæ; this layer is, however, better developed than in the two other genera and the layers are, as a whole, more distinct, whereas, in the recent *Ancylus fluviatilis*, they are so indistinct that they can hardly be seen. The lamellæ in all members of the family are very irregularly formed.

3. Suborder. *Stylommatophora.*

Helicidae.

The shells are, as usual, built up of alternating layers but the number of these layers is, in most instances, greater than in any other shell. The recent forms, *Helix pomatia* and *nemoralis*, and the Miocene forms, *H. inflata* and *sylvana*, have five layers (pl. XIII, fig. 3) the first of which has longitudinal lamellæ, whereas, in the Eocene *H. turonica*, this layer is wanting, there being only four layers. The lamellæ of *Helix* are rather irregularly formed, especially those of the undermost layers. Five alternating layers are also found in the recent forms *Bulimus rosaceus*, *Clausilia sp.* and *Pupa uva* (pl. XIII, fig. 4), but here the lamellæ of all layers are all more irregularly formed. In the thin shells of *Succinea oblonga* and *elegans* there are only four layers, as the undermost, longitudinal one is wanting here, and in the recent *Buliminus obscurus* only the three first layers are developed, the undermost part of the shell possessing a very complicated structure.

Biedermann (p. 72 ff.) gives a thorough description of the shell of *Helix pomatia* which is said to consist of three alternating layers, the first of which has longitudinal lamels. Also Schmidt (p. 174) has described the structure of *H. pomatia.*

The shells of the *Pulmonata* are, as a whole, built up after the same scheme as those of the *Ctenobranchina*, but there seems to be a closer resemblance to the *Opistobranchia* in that there are many deviations from the main type which seems to be very rare here. The deviations, as in the *Opistobranchia*, may consist both in a reduction and in an addition of new layers. A reduction has taken place only in the genera *Ancylus* and *Buliminus*, where the normal third (concentrical) layer is not found or, at all events, very indistinct. All shells examined by me, with the exception only of those of *Siphonaria* and of *Helix turonica*, possess an upmost longitudinal layer, the character of which is exactly the same as in the *Ctenobranchia* and *Opistobranchia*, the layer being mostly very thin with very thin lamellæ. The most remarkable feature is the addition of an undermost, longitudinal layer in many members of the *Helicinae*; in some instances we may find, in the two other groups mentioned above, that the common third layer may be divided into two sub-layers but the lamellæ of both of them must still be said to be concentrical although their directions are rather deviating.

The following summary may be given of the results of the examination of the shell structure of the gastropods: The groups of the *Ctenobranchina*, the *Opistobranchia* and the *Pulmonata* are very closely related, while the *Aspidobranchina* and the *Cyclobranchina* stand rather apart from these. Still more apart are the *Heteropoda* and the *Pteropoda*, and quite isolated are such families as the *Tentaculitidae*, the *Torellellidae* and the *Conulariidae*.

V. Class. Cephalopoda.

The shells of the *Cephalopoda* are much more simply constructed than those of most other mollusks, possessing only the most primitive structures, especially the nacreous and the prismatic ones. With one exception (*Orthoceras annulatum*) the shell is what we may call unorientated, as there is no difference between the two main directions, the transverse and the longitudinal. Aragonite is the commonest element in the shell.

A. Order. Tetrabranchiata.

1. Suborder. *Nautiloidea*.

The shell of the recent *Nautilus pompilius* (pl. XIII, figs. 5 and 6) mostly consists of a beautiful nacreous substance. Above that there is a thin layer of an irregularly prismatic structure; the prisms are of a homogeneous nature with a feathery arrangement of the axes, which diverge downwards. The upmost, thin layer is irregularly grained; downwards the grains are relatively large and scattered among the prisms while, towards the upper side of the shell, they get gradually exceedingly fine and, at the same time, form a compact layer. The septa consist throughout of the nacreous substance. The Eocene *Nautilus imperialis* seems to have a similar structure which is, however, very indistinct because of an incipient alteration of the substance. The Oligocene *Aturia* (pl. XIV, fig. 1) *Basteroti* is more remarkable having upmost a thick, nacreous layer under which there is a thick, prismatic layer, while the undermost, thin layer is nacreous. The septa are built up of a thick, prismatic layer, on both sides of which there is a thin, nacreous layer. At the connection between the septum and the outer shell, the undermost nacreous layer of the latter continues into the two nacreous layers of the septum, while the prismatic layer of the septum has no connection with that of the outer shell, both being rather differently constructed. The Senonian *Eutrephoceras dekayi* seems to consist entirely of a nacreous substance. The shells of these four species, which are the only ones examined among the newer nautiles, consist of aragonite.

Appellöf (p. 69 ff.) gives a very thorough description of the structure and formation of the shell of *Nautilus umbilicalis*; the structure is, in all essentials, the same as that described above, it seems, however, that the upper part of the shell is built up in a somewhat more complicated manner. A description and a figure of the shell of *Nautilus pompilius* is given by Cayeux (p. 491). Also Schmidt (p. 178) describes the shell of a *Nautilus*.

I have examined a large number of the older, Paleozoic and Mesozoic, *Nautiloidea* and in most of them I have found that the shell consists of quite irregularly grained calcite which indicates that the structure is secondary and produced by alteration of an original aragonitic shell. Only in a few instances have I found a regularly prismatic calcite which must be original, and as it is found only in the upper part of the shell we must assume that this has consisted of an upper, calcitic, and an under, aragonitic layer, as found in several bivalves and gastropods. The most certain calcitic layers are found in the Ordovician *Lituites antiquissimus* and the Silurian *Gyroceras alatum*; the prisms are regularly formed and their extinction is also very regular, the axes being normally orientated, parallel to the prism axes. The most peculiar shell is the Silurian *Orthoceras annulatum*; the form of the prisms is not so regular as those mentioned above, but the optic axes have a very rare orientation transverse in relation to the prism axes and, at the same time, transverse to the axis of the animal. In none of the three species mentioned is there any trace of original calcite in the septa.

There may, of course, have existed a calcitic layer in other cases where it is no longer possible to detect it. Especially in such instances where all carbonate of lime has been diluted, it will be quite impossible to state anything about the original nature of the shell. Of this kind is e. g. the material which I have seen of the oldest among all Cephalopada, the Cambrian form *Volborthella*.

Of the *Rhyncholites* I have examined a few forms; they consist of a primary calcite the structure of which is very variable; sometimes it is homogeneous while in other places, it, may be spherolitic or complicated in other ways.

2. Suborder. *Ammonoidea*.

The shells of the ammonites, if preserved, consist throughout of aragonite and the structure is rather simple and uniform. In some instances the shell is nacreous throughout while, in other instances, there is a lower layer of a prismatic substance (pl. XIV, fig. 2—4); this layer is always very thin and the prisms are rather fine and inconspicuous, their extinction is normal. As we may find in some genera (f. i. *Perisphinctes*) some forms with and others without the prismatic layer, I do not think that its presence can be of any systematic value, and I shall not, of course, give a list of the forms in which I have found it. In some instances we find, under this layer a very thin nacreous one, the structure very much resembling, in that respect, that of the *Aturia* described above. There may also be found two or more thin prismatic layers.

In the septa I have never found any trace of a prismatic layer; their substance is nacreous throughout.

All Paleozoic and many Mezosoic ammonites have their shells completely altered, generally into an irregularly grained calcite (pl. XIV, fig. 5). In no instance have I found any trace of primary calcite.

Cornish and Kendall have stated that the shells of the ammonites consist of aragonite. Cayeux (p. 492) mentions an upper, prismatic layer corresponding to that of the nautiles; in his figure of *Aegoceras planicosta* (pl. 54, fig. 5) we see, besides two specimens of the shell which are nacreous throughout, a third specimen with an upper, rather coarsely prismatic layer. I think it most probable that this figure represents a shell of some lamellibranchiate.

The shells of *Aptychus* all consist of calcite; there seem to be two kinds of structures. Some of them are prismatic with rather coarse and very irregularly formed prisms (pl. XIV, fig. 6); the extinction is quite irregular. The other group was originally porous, consisting of coarse, cylindrical cells (pl. XIV, fig. 7, and pl. XV, fig. 1) the orientation of which may be normal or more or less oblique; their form is generally irregular and on the upper and under sides of the shell they grow together and pass into different compact structures. The walls of the cells are rather thin and consist of a homogeneous calcite, the axes of which are sometimes normal to the walls and sometimes more or less oblique. The interior of the cells are filled up by secondary calcite.

Cornish and Kendall have stated that the *Aptychi* consist of calcite.

B. Order. Dibranchiata.

1. Suborder. *Belemnoidea.*

Belemnitidae.

As is well known, the rostrum of the *Belemnites* normally consists, of calcite in prismatic arrangement and with larger elements than found in any other mollusk. The structure is essentially the same in all forms, there being only some difference in the regularity of the form of the prisms and the regularity of the extinction. The most irregular type with very coarse prisms I have found in *Belemnites parvus* (pl. XV, fig. 3) from the Liassic, whereas the Senonian form *Belemnitella mucronata* (pl. XV, fig. 2) shows the most regular prisms. Only the Triassic form *Aulacoceras* possesses a rostrum with a quite irregularly grained structure and we must assume that it consisted originally of aragonite.

The most peculiar structure is found in the genus *Actinocamax*; the main part of the rostrum is built up of prisms in the usual manner, but next to the alveole this structure gradually passes into one large calcite individual; by breaking the shell here we find large cleavage faces curved in a regular manner according to the form of the alveole.

Cornish and Kendall have stated that the *Belemnites* consist of calcite. A very thorough description of the structure of the shell of *Belemnitella mucronata* is given by Cesàro (Ann. Soc. Geol. de Belgique, 26, 1899, p. 73). By examining the traces of the cleavages in the vertical section he finds that the single individuals must have a regular orientation around the main axis, but I have not been able to find any such regularity. On the contrary, if we place a fragment of the shell on the goniometer, we see that the reflexions of the cleavages, which are very distinct, form a perfect ring around the main axis and that their direction is, of course, quite accidental.

Of the phragmocones I have had only a very scarce material for examination. Of the Triassic genus *Atractites* both the wall and the septa consist of irregularly grained calcite, and we must assume, therefore, that the shell has consisted of aragonite. On the other hand, in *Belemnitella mucronata* we find the wall consisting of finely prismatic calcite which must be original.

Spirulidae.

The shell (pl. XV, fig. 4) consists entirely of aragonite; the outer shell is prismatic with rather regularly formed prisms; the extinction is somewhat variable but does not deviate very much from the direction of the prisms. A very thin upper layer is perfectly homogeneous. The septa, on the contrary, are nacreous.

A very thorough description of all parts of the shell of *Spirula* has been given by Appellöf; as he has, apparently, not made use of polarized light, he has not observed the prismatic structure.

2. Suborder. *Sepioidea.*

The shell of *Sepia* consists entirely of aragonite; the different parts possess a very different structure and here I shall only point out some essential features (pl. XV, fig. 5). The external wall and the mucro possess a very fine prismatic structure, the whole arrangement being as a rule rather irregular in accordance with the mamillary surface of the shell. In the parts next the margin there is a horny plate between two calcareous ones, in the more central parts the shell is calcified throughout but it contains a large amount of organic substance. In the spongy body the lamellæ consist of an irregularly grained mass which is otherwise rarely found; the rods are perfectly homogeneous with their extinction orientated parallel to their maximal direction. As is well known, they have the form of very thin plates so that, in longitudinal sections, they may be narrow or broad according to their orientation, whereas, in cross sections, they show very characteristic meanderlike figures (pl. XV, fig. 6).

Further descriptions of the many peculiar features in the *Sepia* shell have been given by Appellöf a. o.

3. Suborder. *Octopoda.*

The shell of *Argonauta* consists of calcite and is very peculiarly built (pl. XV, fig. 7). The greater part, consisting of a thicker upper and a thinner under layer, is very finely prismatic with an extinction which is, in most instances, so perfectly parallel to the axes of the prisms that the structure is not very distinctly seen under the microscope, whereas it is more easily seen if one examines a fragment of the shell with a strong magnifying lens. Between the two above-mentioned layers there is a very thin layer of a very fine, irregularly grained calcite.

Miss Kelly was the first to determine the calcitic nature of the *Argonauta.*

LIST OF LITERATURE

Appellöf, A. K. Vet.-Akad. Handl. Stockholm. 25, Nr. 7, 1892.
Biedermann, W. Jenaische Zts. f. Naturwiss. 36, 1902.
Bournon, de. Traité complet de la Chaux carbonatée et de l'Aragonite. London, 1808.
Buch, L. v. Abh. d. Akad. d. Wiss. Berlin, 1826.
Brauns, R. Ueber das Verhältnis von Conchit zu Aragonit. Centralbl. Min. 1901.
Brewster. Bibliothèque universelle de Genève, 1836, II.
Bütschli, O. Abh. Göttinger Akad. N. F. 6, 1908.
Carpenter, W. Rep. Brit. Ass. Advance of Sci. 1844 and 1847.
Cayeux, L. Introduction à l'Étude pétrographique des Roches sédimentaires. 1916.
Cornish and Kendall. Geol. Mag. London. Dek. 3, Vol. 5, 1888.
Ehrenbaum, E. Zts. wiss. Zool. 41, 1885.
Gray. Phil. Trans. R. Soc. London, 1835.
Gümbel. Zts. d. geol. Gesell. 36, 1884.
Karny, H. Sitzber. Akad. d. Wiss. Wien. Mat.-nat. Kl. Bd. 122, 1913.
Kelly, Agnes. Beiträge zur mineralogischen Kenntnis der Kalkausscheidungen im Tierreich Inaug.-Diss. München, 1901.
Leydolt. Sitzber. Akad. d. Wiss. Wien. Bd. 19, 1856.
Necker. Ann. des Sciences naturelles. 11, 1839.
Römer, O. Zts. Wiss. Zool. 75, 1903.
Schmidt, W. J. Die Bausteine des Tierkörpers in polarisiertem Lichte. 1924.
Sorby. Quart. Journ. Geol. Soc. London. 35, 1879.
Thiem, H. Jenaische Zts. f. Naturwiss. 54. 1917.
Tullberg, T. K. Vet. Akad. Handl. Stockholm. 19, Nr. 3, 1881.

EXPLANATION OF THE PLATES

(IF NOT OTHERWISE STATED THE ENLARGEMENT IS 1: CA. 55)

PLATE I

Fig. 1. *Avicula sp.* (recent). Vertical section showing the upper, prismatic layer and the lower, nacreous one.

Fig. 2. *Avicula Münsteri* (Upper Jurassic). Vertical, concentrical section; upmost the prismatic layer, the lower one is crossed lamellar.

Fig. 3. *Pinna sp.* (recent). Horizontal section of the prismatic layer.

Fig. 4. *Pecten undulatus* (Senonian). Vertical, radial section, showing the zigzag-structure.

Fig. 5. *Pecten sp.* (recent). Vertical section. An aragonitic, prismatic layer between two lamellar, calcitic ones.

Fig. 6. *Pecten aequivalvis* (Liassic). Vertical, radial section; the double zigzag-structure is distinctly seen.

Fig. 7. *Spondylus sp.* (recent). Vertical, concentrical section; an upper, calcitic, lamellar layer, and two aragonitic layers, the uppermost is crossed lamellar, whereas the undermost is prismatic.

Fig. 1

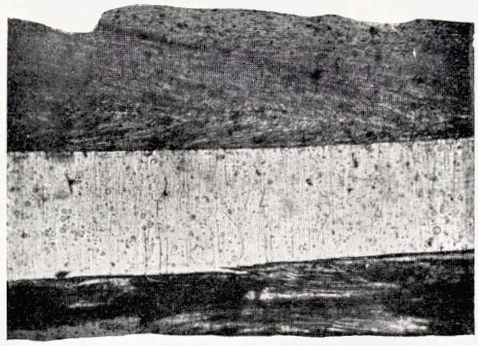


Fig. 5

Fig. 2

Fig. 6

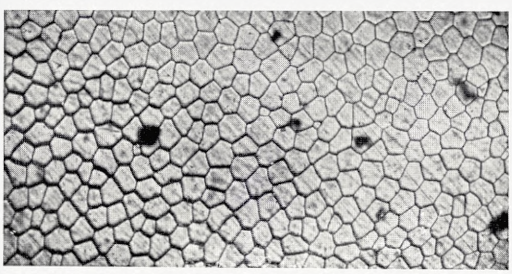


Fig. 3

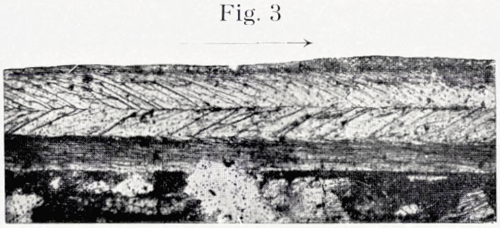


Fig. 4

Fig. 7

PLATE II

Fig. 1. *Exogyra conica* (Neocomian). Vertical section showing the typical, irregularly lamellated structure.

Fig. 2. *Ostrea edulis* (recent). Vertical section, showing alternating layers of nearly horizontal, compact lamellæ and nearly vertical, more loosely connected lamellæ.

Fig. 3. *Gryphaea vesicularis* (Senonian). Vertical section. Thinner layers of the lamellar kind alternating with others with a vesicular structure.

Fig. 4. *Gryphaea cymbium* (Liassic). Vertical, concentrical section. The crossed lamellar structure.

Fig. 5. *Nucula nitida* (recent). Vertical, radial section; an upper, composite prismatic layer and a lower one, nacreous.

Fig. 6. *Nucula similis* (Eocene). Horizontal section through the composite prismatic layer showing the feathery arrangement.

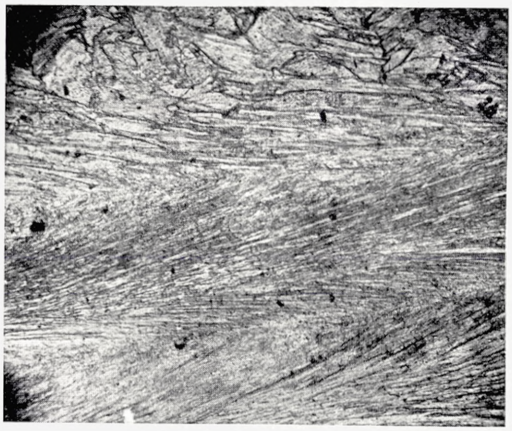


Fig. 1

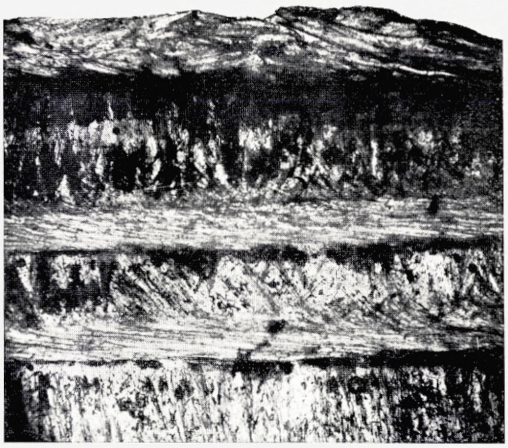


Fig. 2

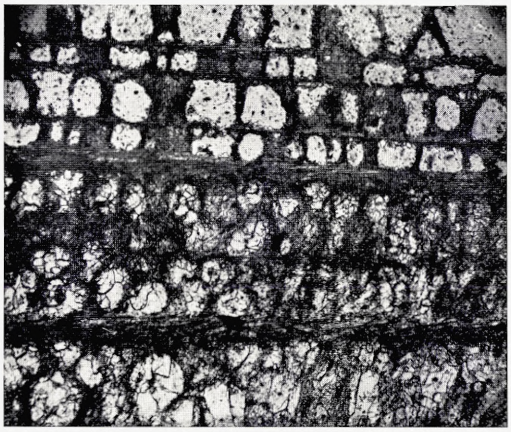


Fig. 3


Fig. 4


Fig. 5

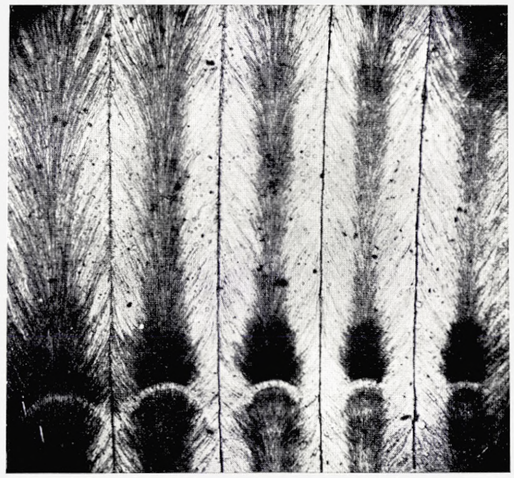


Fig. 6

PLATE III

Fig. 1. *Astarte Reimersi* (Miocene). Uppermost the crossed lamellar layer, getting more and more indistinct downwards; below, the prismatic layer.

Fig. 2. *Durga crassa* (Jurassic). Vertical section. The complex layer with thicker, prismatic and thinner, complex crossed lamellar layers.

Fig. 3. *Isocardia Forchhammeri* (Miocene). Vertical section. An upper, homogeneous, and a lower complex crossed lamellar layer with distinct prismatic arrangement.

Fig. 4. *Chama sp.* (recent). Vertical, radial section. The upper part is formed of the crossed lamellar layer with the lamellæ strongly reclined upwards. Below is seen a prismatic part of the complex layer.

Fig. 5. *Chama sp.* (recent). Vertical, concentrical section. The upper part is formed of the crossed lamellar layer. Downwards we see the complex layer with irregularly formed inclusions of a complex crossed lamellar structure in a prismatic ground mass.

Fig. 6. *Biradiolites cornu pastoris* (Middle Cretaceous). Section normal to the walls which here form a network; one of the tabulae is cut in a flat section. Enl. 1:33.

Fig. 1

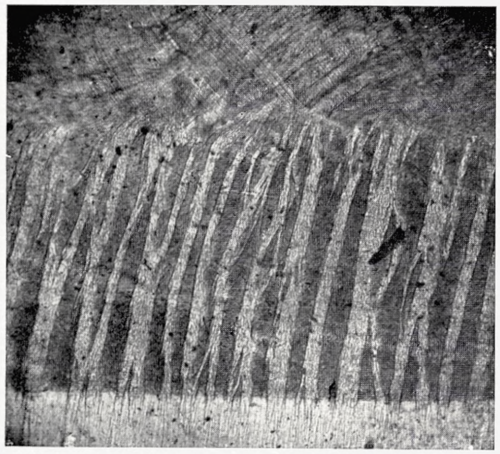


Fig. 4

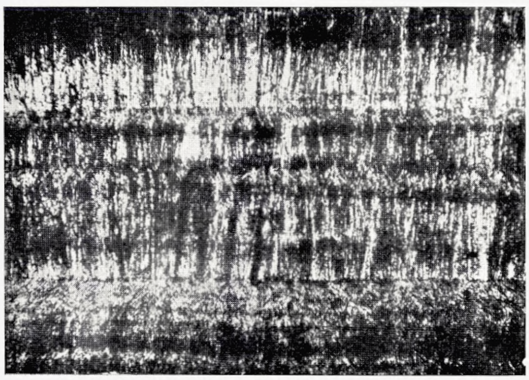


Fig. 2

Fig. 5

Fig. 3

Fig. 6

PLATE IV

(Enlargement 1: ca. 35).

Fig. 1. *Biradiolites cornu pastoris.* Section normal to the tabulae, the finely prismatic structure of which is distinctly seen.

Fig. 2. *Radiolites radiosus* (Turonian). Section normal to the tabulae and almost parallel to the walls, some of which are cut in flat section; their finely prismatic structure is seen.

Fig. 3. *Radiolites radiosus.* Section normal to the tabulae and to the walls.

Fig. 4. *Sphaerulites cylindricus* (Turonian). Section normal to the walls and almost parallel to the tabulae, one of which is seen in flat section.

Fig. 5. *Biradiolites foliace-alaeformis* (Cretaceous). Section normal to the walls, which are here badly developed, and to the thick tabulae, each of which consists of an upper, finely grained, dark, upper layer and of a lower one, finely prismatic.

Fig. 6. *Biradiolites pseudo-cornu-pastoris* (Turonian). Section normal to the walls and to the tabulae, the two layers of which are distinctly seen.

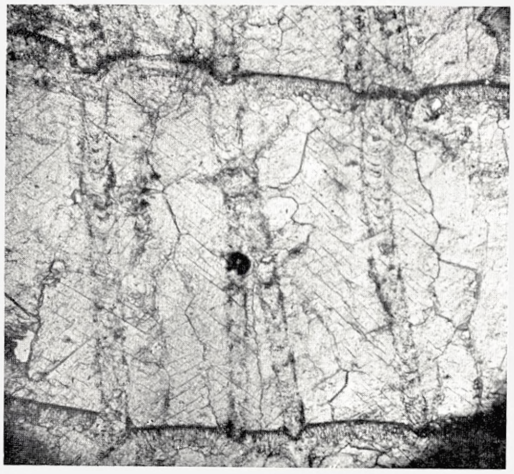


Fig. 1

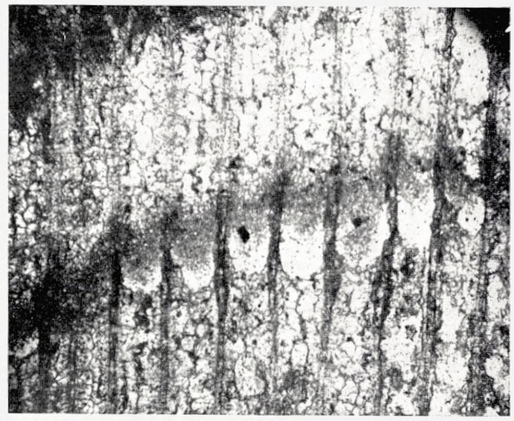


Fig. 4

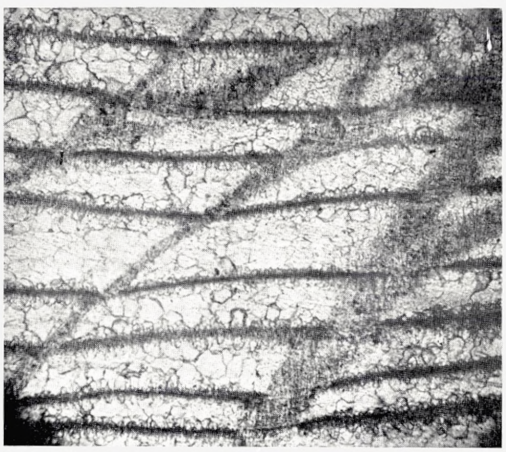


Fig. 2

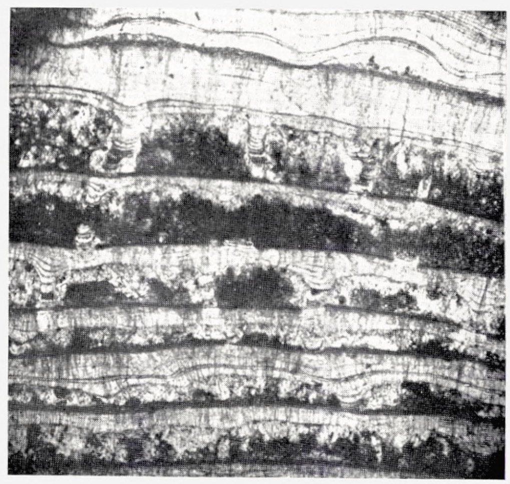


Fig. 5

Fig. 3

Fig. 6

PLATE V

Fig. 1. *Biradiolites pseudo-cornu-pastoris.* Section normal to the walls and almost parallel to the tabulae one of which is cut in a flat section; the two layers of it are seen. Enl. 1:35.

Fig. 2. *Hippurites organisans* (Senonian). Type of the compact, finely prismatic structure of this genus.

Fig. 3. *Lucina sp.* (recent). Vertical, radial section showing the upper, composite-prismatic layer and the middle one, crossed lamellar.

Fig. 4. *Lucina sp.* (recent). A horizontal section of the crossed lamellar layer showing the characteristic rhomboidal arrangement of the lamellæ. Nicols crossed.

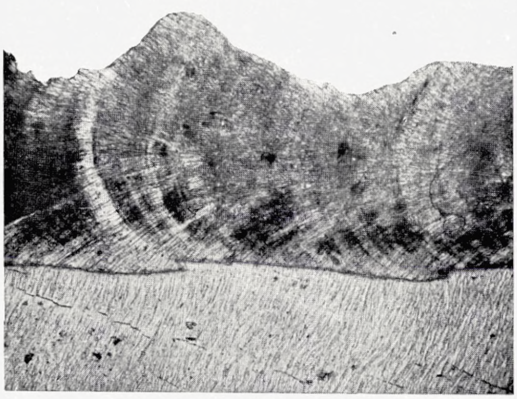
Fig. 5. *Lucina sp.* (recent). Horizontal section of a complex crossed lamellar layer showing a very irregular arrangement of the elements.

Fig. 6. *Cardium echinatum* (recent). Vertical, radial section of the crossed lamellar layer; the lamellæ are vertical downwards while upwards they become reclined and then very indistinct with a feathery arrangement.

Fig. 7. *Cardium edule* (recent). Horizontal section of the complex crossed lamellar layer showing a spherolitic structure. Crossed Nicols.

Fig. 1

Fig. 2



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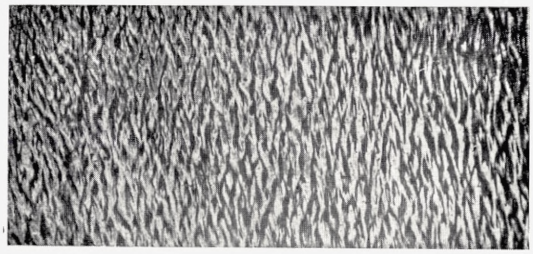


Fig. 4

Fig. 5

Fig. 6

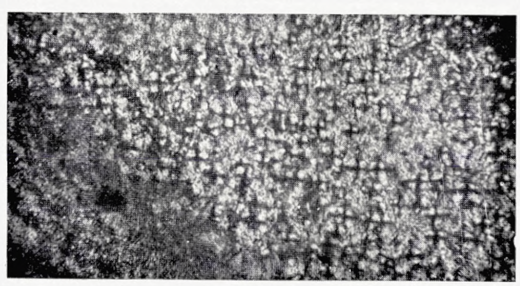


Fig. 7

PLATE VI

Fig. 1. *Tapes pullastra* (recent). Vertical, radial section; the upper layer is composite-prismatic, the lower one is homogeneous.

Fig. 2. *Cytherea incrassata* (Miocene). Vertical, radial section. The crossed lamellar layer downwards passes gradually into the homogeneous one; upwards the lamellæ become strongly reclined, then almost horizontal, and upwards reclined once more.

Fig. 3. *Cytherea sp.* (recent). Vertical, radial section. The crossed lamellar layer; the lamellæ are reclined downwards; upwards they become horizontal and at last inclined, obtaining, in this way, a feathery arrangement.

Fig. 4. *Cyrena sumatrana* (recent). Vertical, radial section. We see an upper, crossed lamellar layer, and a lower one, of the complex kind; it consists of very thin, prismatic layers and of thick, complex crossed lamellar ones, partly with a prismatic arrangement.

Fig. 5. *Tapes pullastra* (recent). Vertical, concentrical section. Undermost we see the homogeneous layer, uppermost the composite prismatic one, the prisms of which are cut, in the middle part, normally, but upwards and downwards more and more obliquely.

Fig. 6. *Donax vittatus* (recent). Vertical, radial section. The upper part is formed of a composite prismatic layer, and under that there is a thin, crossed lamellar layer and small parts of an undermost, homogeneous one.

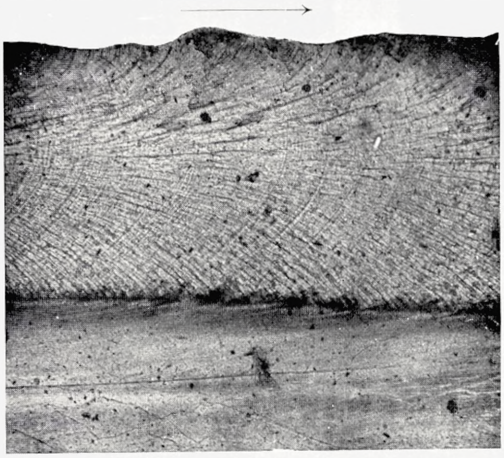


Fig. 1

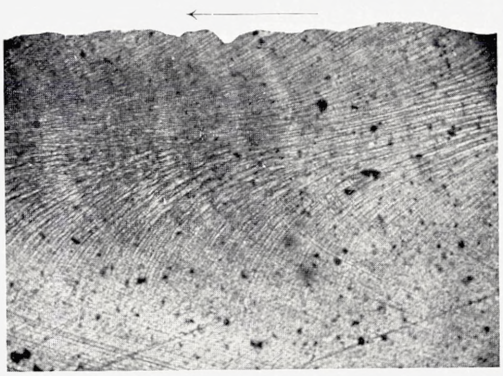


Fig. 2

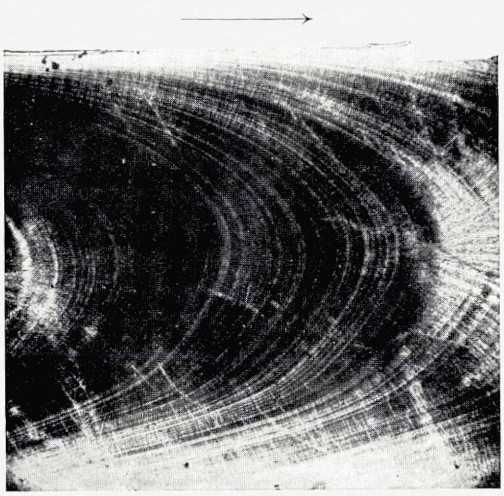
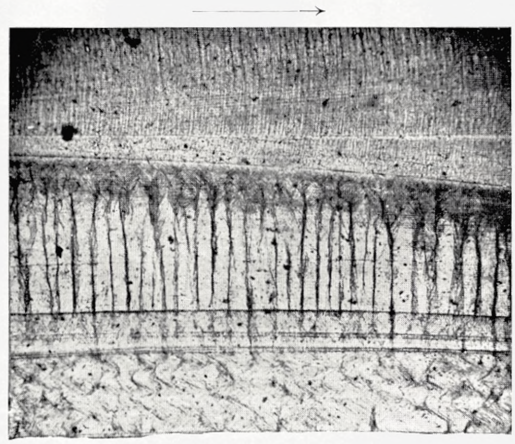


Fig. 3



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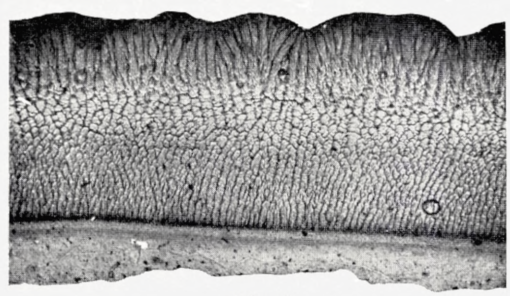


Fig. 5

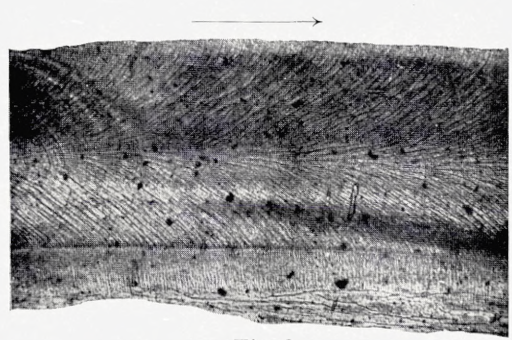


Fig. 6

PLATE VII

Fig. 1. *Donax vittatus.* Vertical, concentrical section. Above we see the cross sections of the prisms of the 1st order of the composite prismatic layer; the two lower layers are very indistinct.

Fig. 2. *Tellina calcaria* (recent). Horizontal section of the crossed lamellar layer showing a not very distinct, rhomboidal arrangement.

Fig. 3. *Tellina calcaria.* Horizontal section of the complex crossed lamellar layer, showing irregular cross sections of the prisms.

Fig. 4. *Lutraria sp.* (recent). Horizontal section of the complex crossed lamellar layer with a distinct spherolitic structure. Crossed Nicols.

Fig. 5. *Ervillia podolica* (Miocene). Horizontal section. The black parts to the left show the lower, homogeneous layer; above that we see, in the central part of the figure, the crossed lamellar layer, as usual with the lamellæ orientated in the concentrical direction. To the right we see the upper, radially prismatic layer.

Fig. 6. *Solenomya sp.* (recent). Horizontal section, showing the peculiar, cellular structure; the cell walls are gradually becoming thinner in the lower part of the figure which is, at the same time, the under layer of the shell.

Fig. 7. *Zirphaea crispata* (recent). Horizontal section of the crossed lamellar layer showing a very distinct rhomboidal arrangement.

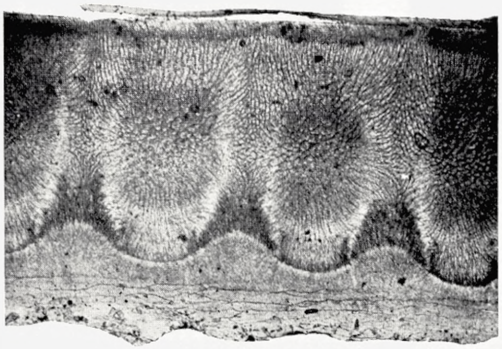


Fig. 1

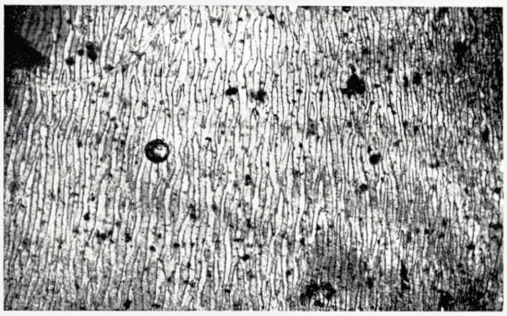


Fig. 2

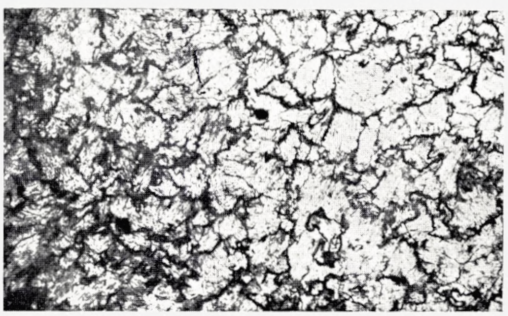


Fig. 3

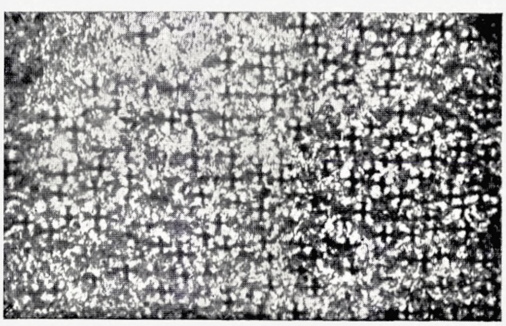


Fig. 4

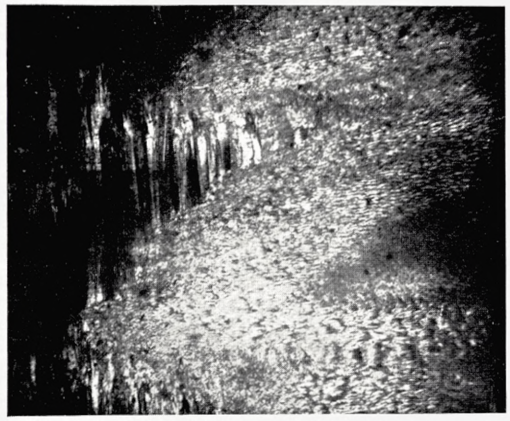


Fig. 5

Fig. 6

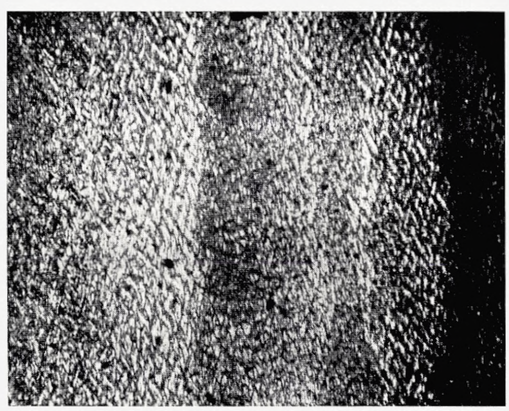


Fig. 7

PLATE VIII

Fig. 1. *Dentalium Bouei* (Miocene). Vertical, transverse section. Between upper and lower sub-layers we see, in the main part of the shell, the crossed lamellæ.

Fig. 2. *Dentalium Bouei.* Vertical, longitudinal section. Here the lamellæ of the 1st order are seen in transverse sections.

Fig. 3. *Dentalium Bouei.* Horizontal section of the main layer. The lamellæ of the 1st order here show rhomboidal figures, otherwise characteristic of the bivalves.

Fig. 4. *Chiton sp.* (recent). Vertical, transverse section (in relation to the animal), showing the two layers designated as a and c in the text (p. 67); the intermediate layer, b, is not developed in this place.

Fig. 5. *Chiton sp.* (the same as fig. 4). Horizontal section of the crossed lamellar layer showing the very fine and regular lamellæ specific to the Amphineura.

Fig. 6. *Bellerophon sp.* Vertical section. This single species, from the Ordovician of Bornholm, is divergent from other species of B. and from almost all other shells in that it consists of regularly lamellated calcite.

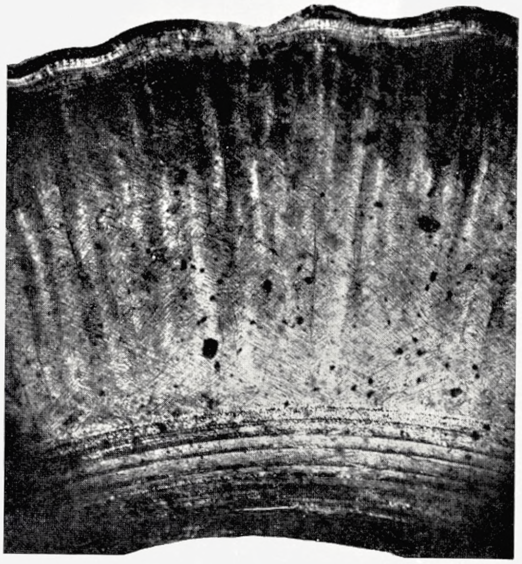


Fig. 1

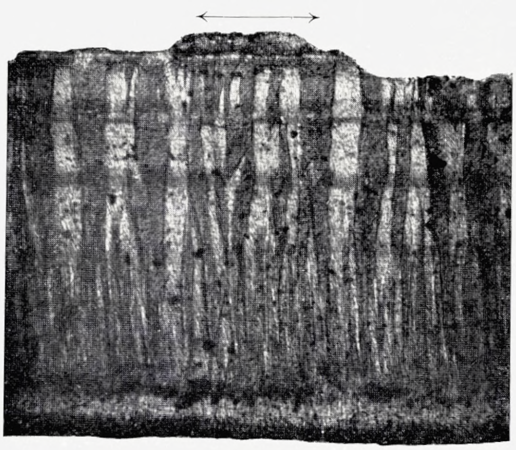


Fig. 2

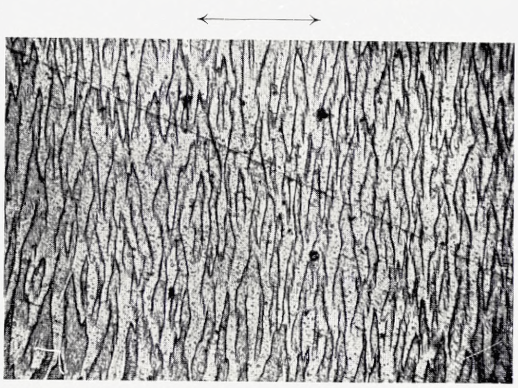


Fig. 3

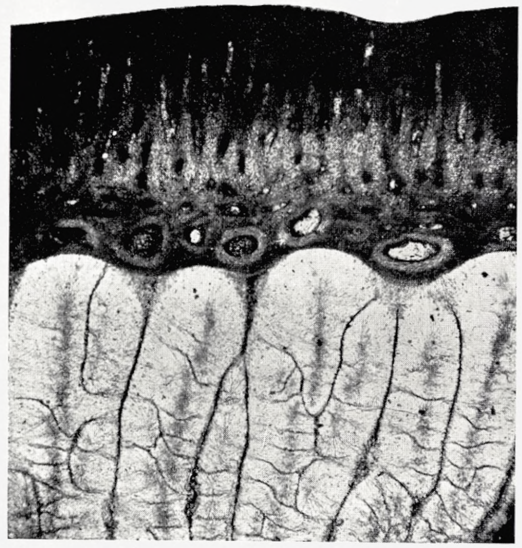


Fig. 4

Fig. 5

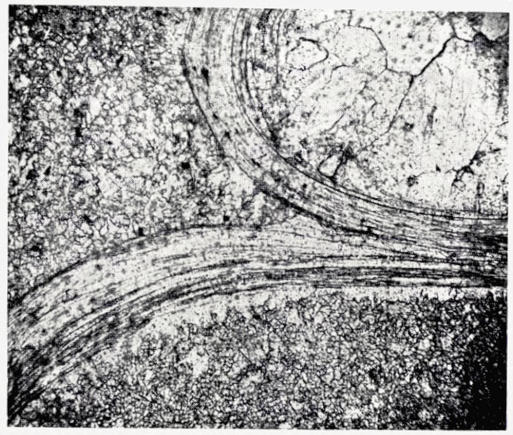


Fig. 6

PLATE IX

Fig. 1. *Subemarginula sp.* (recent). Vertical, transverse section. Shows transitions from the crossed lamellar structure to a more regularly lamellated one.

Fig. 2. *Haliotis sp.* (recent). Vertical, longitudinal section. The upper, homogeneously grained layer is here quite intransparent; the lower layer is the nacreous one.

Fig. 3. *Haliotis sp.* (recent). Vertical, longitudinal section, between the two, aragonitic layers a prismatic, calcitic layer is seen.

Fig. 4. *Turbo tuber* (recent). Vertical, longitudinal section. The upper, dark layer is homogeneous and at the same time grained and prismatic; the lower layer is nacreous.

Fig. 5. *Phasianella bullinoides* (recent). Vertical, longitudinal section. The upper layer is complex prismatic, the middle one is crossed lamellar with peculiar zigzag figures; the lower layer is finely prismatic.

Fig. 6. *Phorus agglutinans* (recent). Horizontal section showing rather regular lamellæ of the crossed lamellar structure.

Fig. 7. *Neritina concava* (recent). Vertical, longitudinal section. An upper, very thin, calcitic layer, and a lower one, aragonitic, crossed lamellar.

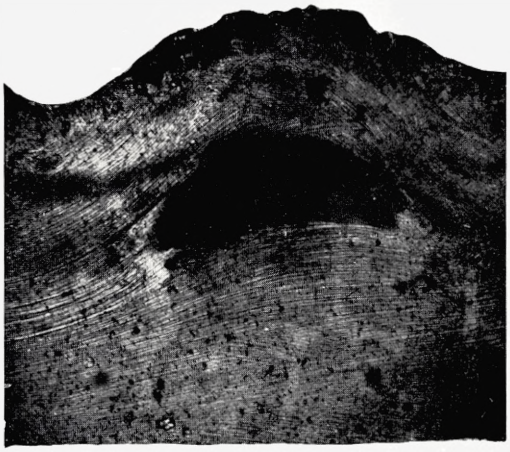


Fig. 1

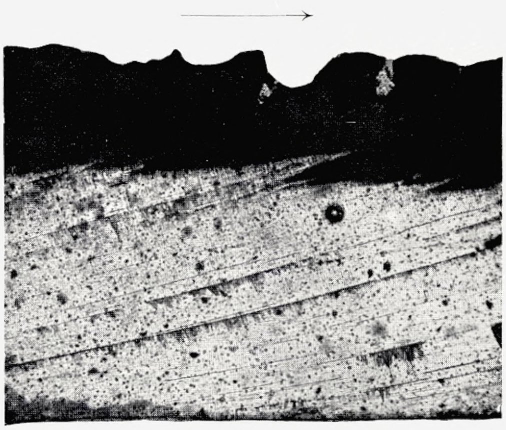


Fig. 2

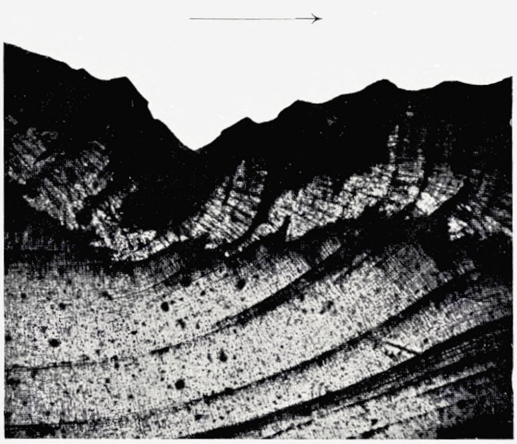


Fig. 3

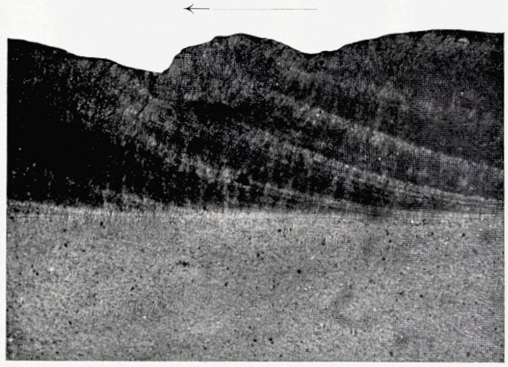


Fig. 4

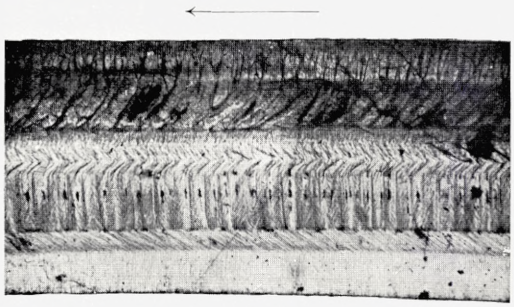


Fig. 5

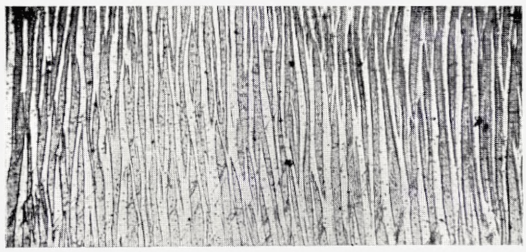


Fig. 6

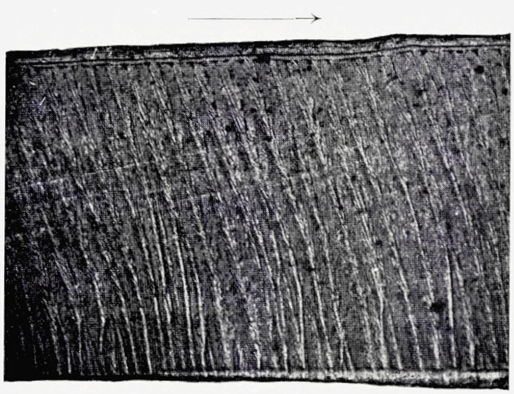


Fig. 7

PLATE X

Fig. 1. *Nerita polita* (recent). Vertical, longitudinal section. The upper layer is calcitic, prismatic, the middle one is aragonitic, crossed lamellar, with dark lines of growth. The lower layer is aragonitic, complex crossed lamellar.

Fig. 2. *Patella fluctuosa* (recent). Vertical, radial section. Upwards, to the left, is seen the calcitic, foliated layer, downwards, to the right, there is a complex crossed lamellar, aragonitic layer.

Fig. 3. *Acmaea virginea* (recent). Vertical, radial section. An upper, exceedingly thin, calcitic layer. Of the two aragonitic layers the upper one is prismatic, the lower one is crossed lamellar.

Fig. 4. *Patella bavia* (recent). Vertical, concentrical section. An upper, calcitic, crossed lamellar layer with concentrical lamellæ; next is seen an aragonitic, crossed lamellar layer with radial lamellæ. The undermost layer is prismatic and aragonitic.

Fig. 5. *Patella bavia*. Vertical, radial section. The same three layers as described above are seen.

Fig. 6. *Litorina litorea* (recent). Vertical, longitudinal section. The upper layer is calcitic, prismatic. Of the aragonitic, crossed lamellar layers are seen the 1st, which is transversely lamellated, and the 2nd, longitudinally lamellated.

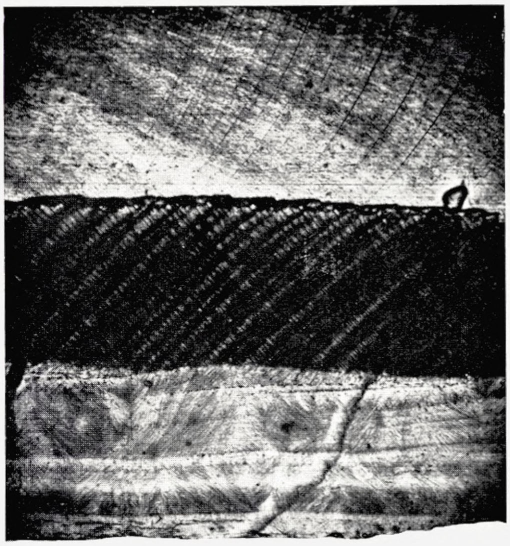


Fig. 1

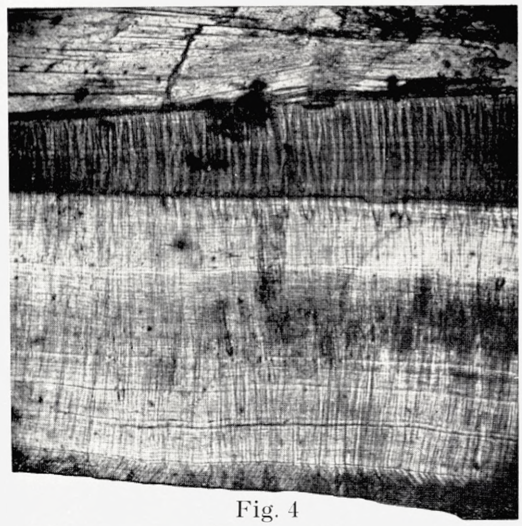


Fig. 4

Fig. 2

Fig. 5

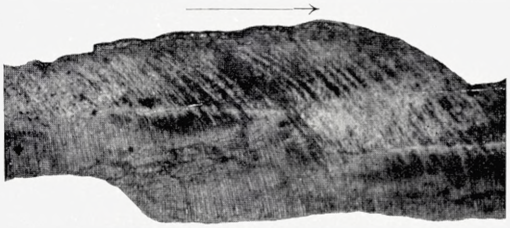


Fig. 3

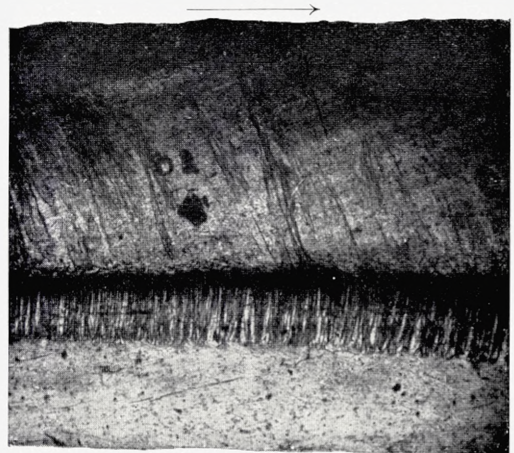


Fig. 6

PLATE XI

Fig. 1. *Pileopsis cornu-copiae* (recent). Horizontal section. The 2nd, concentrically lamellated layer, and the 3rd one, radially lamellated are seen. Crossed Nicols.

Fig. 2. *Natica sp.* (recent). Horizontal section. To the left is seen the 1st, transverse layer, and to the right the 2nd, longitudinal.

Fig. 3. *Ampullaria sp.* (recent). Horizontal section. The same two layers are seen. Crossed Nicols.

Fig. 4. *Paludina sp.* (recent). Horizontal section. All three layers are seen; the two undermost, in the middle and to the right, have orientations which deviate from the normal ones. Crossed Nicols.

Fig. 5. *Janthina sp.* (recent). Vertical, longitudinal section. The upper layer is irregularly grained, calcitic, the lower one is aragonitic, crossed lamellar, with transverse lamellæ.

Fig. 6. *Scalaria sp.* (recent). Vertical, transverse section. The same layers as in Janthina; the calcitic layer is irregularly prismatic.

Fig. 7. *Aporrhais speciosa* (Oligocene and Miocene). Horizontal section of the three layers.

Fig. 8. *Aporrhais speciosa.* Horizontal section of a part of the shell a little to the right of that shown in fig. 7. The third layer is divided into two sub-layers.

Fig. 9. *Cassis sp.* (recent). Vertical, longitudinal section, showing the very regular lamellæ of the 1st transverse, and the 2nd, longitudinal layer.

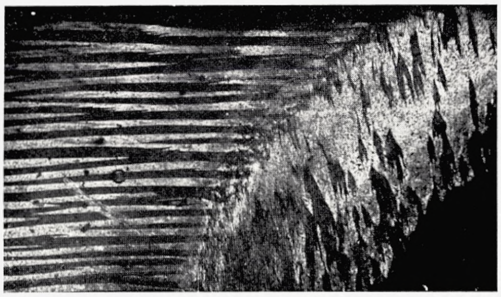


Fig. 1

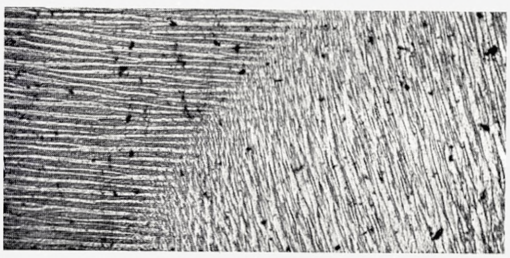


Fig. 2

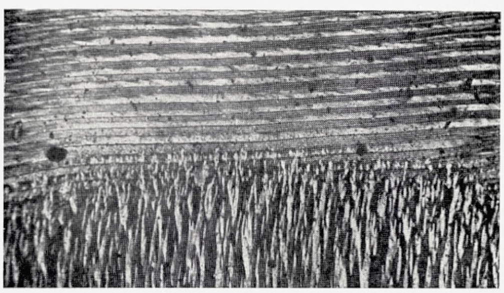


Fig. 3

Fig. 4

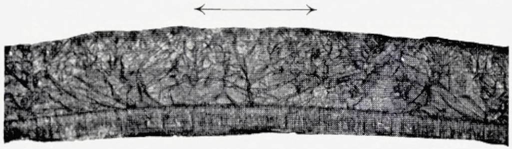


Fig. 5

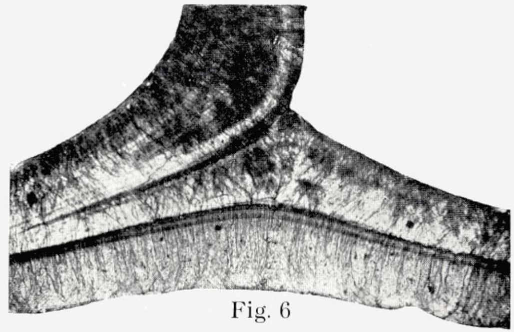


Fig. 6

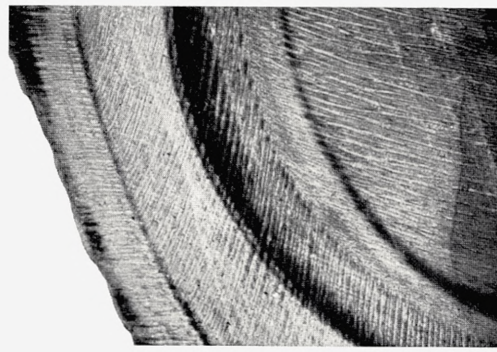


Fig. 7

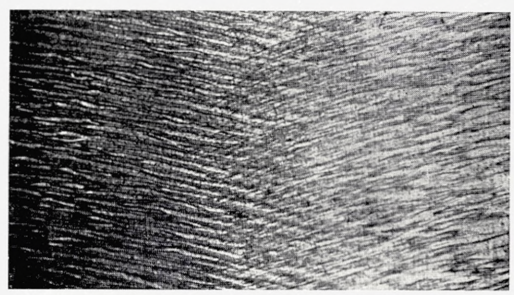


Fig. 8

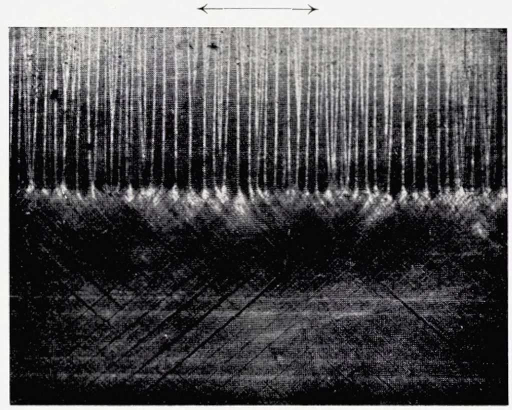


Fig. 9

PLATE XII

Fig. 1. *Cassis sp.* (recent). Horizontal section of the 1st layer. Crossed Nicols.

Fig. 2. *Cassidaria nodosa* (Oligocene). Vertical, transverse section, showing the three layers.

Fig. 3. *Buccinum undatum* (recent). Vertical, longitudinal section. The upper layer is irregularly prismatic; below this are seen the 1st and the 2nd of the ordinary, crossed lamellar layers.

Fig. 4. *Nassa sp.* (Eocene). Horizontal section showing the ordinary three layers with a very regular orientation. Crossed Nicols.

Fig. 5. *Purpura recta* (recent). Horizontal section. The lamellæ of the third layer have a very abnormal orientation. Crossed Nicols.

Fig. 6. *Purpura lapillus* (recent). Vertical, transverse section. The upper layer is irregularly prismatic, calcitic. At the under side is seen the first, crossed lamellar, aragonitic layer.

Fig. 7. *Murex sp.* (recent). Vertical, transverse section. Four layers are seen, the 1st one with longitudinal lamellæ.

Fig. 8. *Voluta sp.* (recent). Horizontal section. The ordinary three layers the 3rd of which is composed of two sub-layers. Crossed Nicols.

Fig. 1

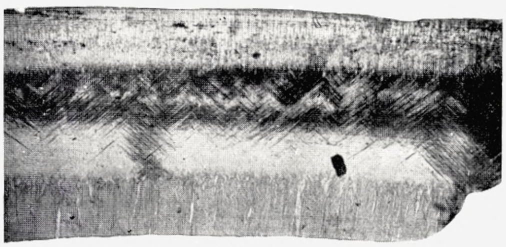


Fig. 2

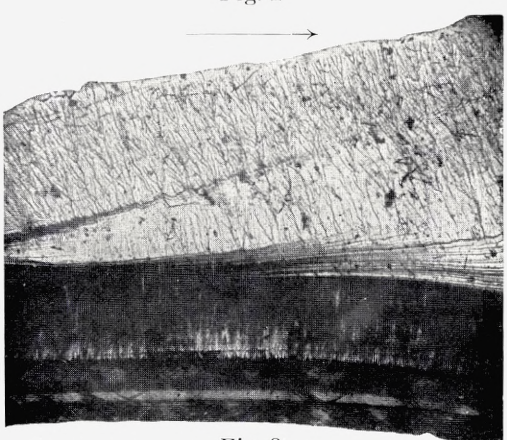
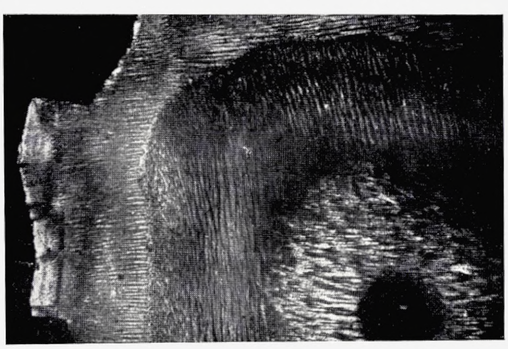


Fig. 3



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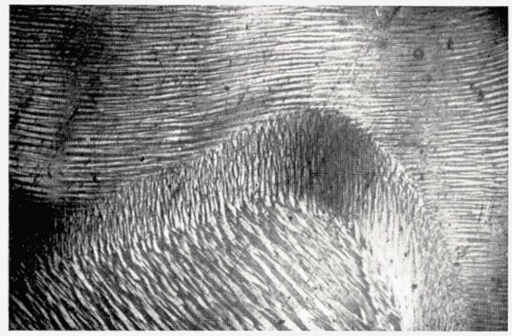

Fig 5.

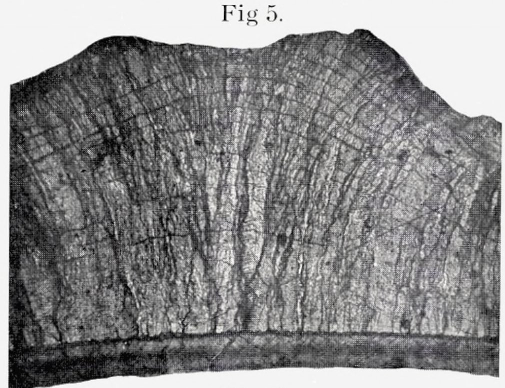

Fig. 6

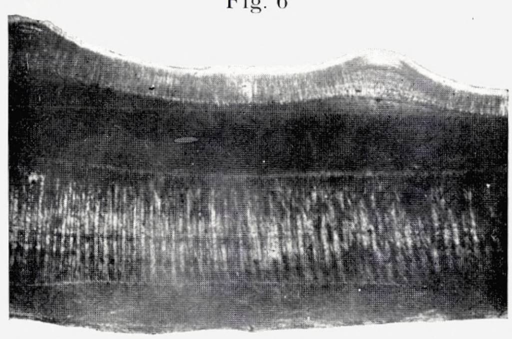

Fig. 7

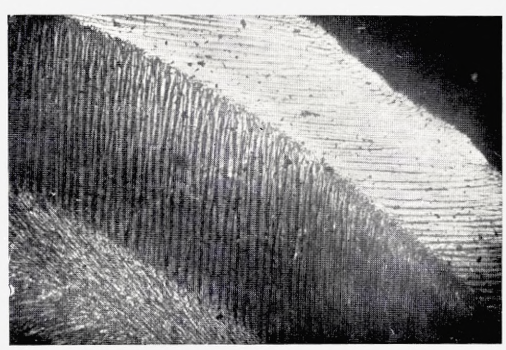

Fig. 8

PLATE XIII

Fig. 1. *Harpa sp.* (recent). Horizontal section. The ordinary three alternating layers the 3rd of which is divided into two sub-layers. Crossed Nicols.

Fig. 2. *Tentaculites sp.* (Silurian). Longitudinal section of two individuals, showing, rather indistinctly, the foliated, calcitic structure.

Fig. 3. *Helix nemoralis* (recent). Horizontal section showing the five alternating layers with rather irregular orientations; the first one, which is rather indistinct in the figure, has longitudinal lamellæ. Crossed Nicols.

Fig. 4. *Pupa uva* (recent). Horizontal section. The same five layers; the 1st, longitudinal one is also rather indistinct here. Crossed Nicols.

Fig. 5. *Nautilus pompilius* (recent). Vertical section. The upper, black layer has a grained consistency; thereafter follows a thin, complex prismatic layer, and the broad, undermost layer is nacreous.

Fig. 6. *Nautilus pompilius*. Horizontal section. Upmost is seen the grained layer gradually passing into the prismatic one; the lower part is the nacreous layer.

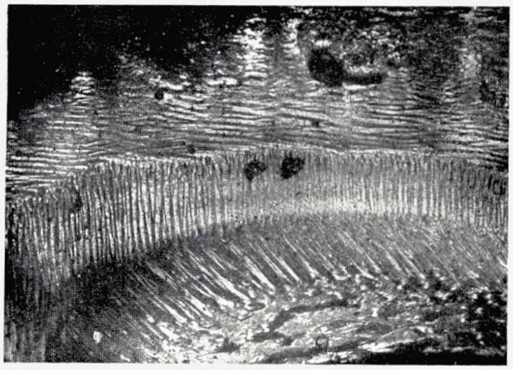

Fig. 1

Fig. 2

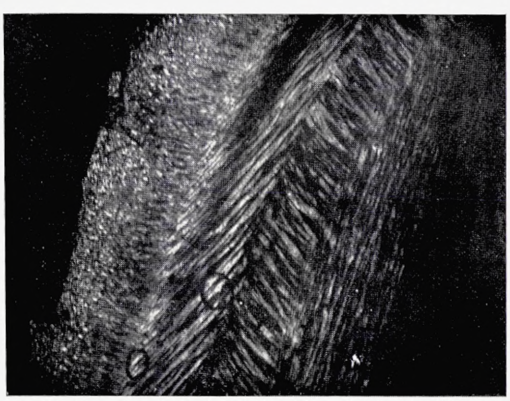

Fig. 3

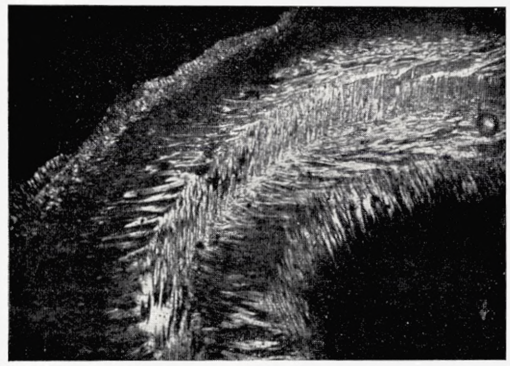

Fig. 4

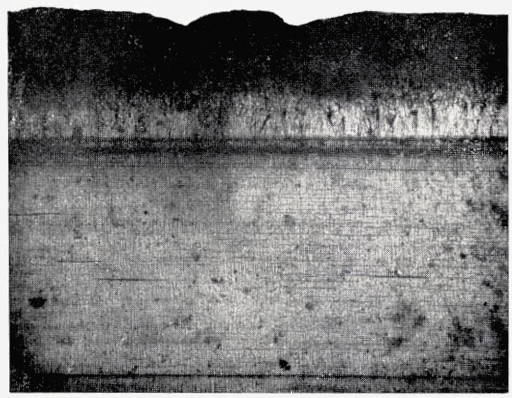

Fig. 5

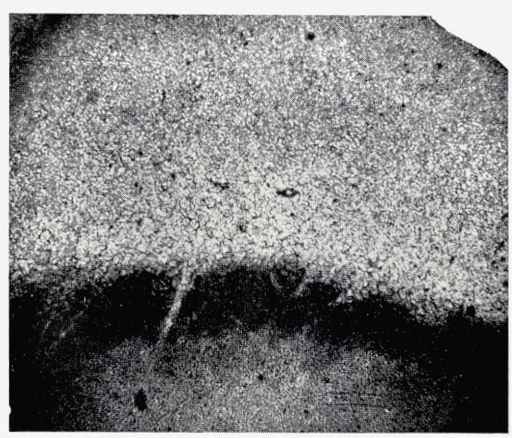

Fig. 6

PLATE XIV

Fig. 1. *Aturia Basteroti* (Oligocene). Vertical section. The upper layer is nacreous, with inclusions of pyrite; under that is seen a prismatic layer and, under that, part of a thin, nacreous layer.

Fig. 2. *Harpoceras opalinum* (Middle Jurassic). Vertical section. The upper, dark layer is nacreous, the lower, very thin one is prismatic.

Fig. 3. *Cadoceras Elatmae* (Middle Jurassic). Vertical section showing the same two layers; the septum consists throughout of a nacreous substance.

Fig. 4. *Cadoceras Elatmae*. Vertical section. Here are seen several, thin, prismatic layers.

Fig. 5. *Cladiscites tornatus* (Triassic). Vertical section. The shell is totally altered into calcite, and the structure is the typical secondary one showing twin-lamellæ which are never seen in the primary shell substance. Crossed Nicols.

Fig. 6. *Aptychus sp.* (Senonian). Vertical section. Type of the compact, irregularly prismatic structure. Crossed Nicols.

Fig. 7. *Aptychus sp.* (Cretaceous). Vertical section. Type of the cellular structure.

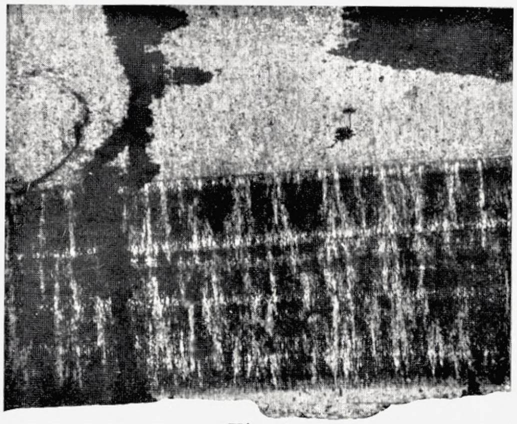

Fig. 1

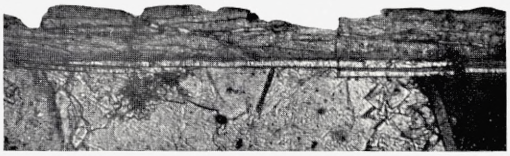

Fig. 2

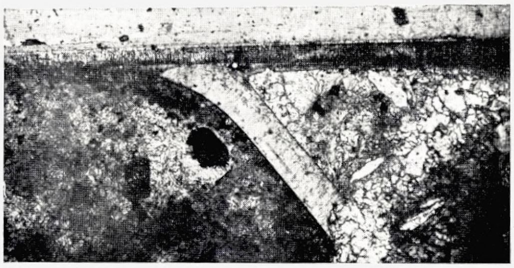

Fig. 3

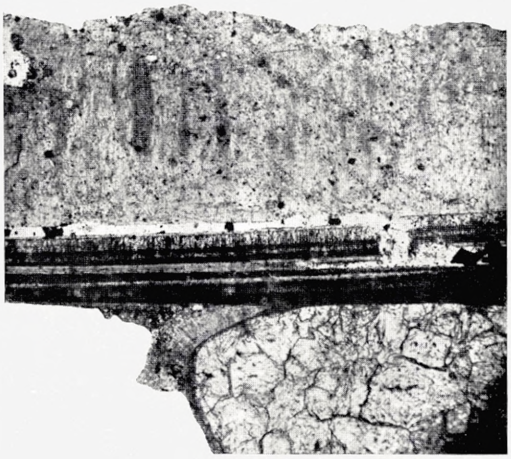

Fig. 4

Fig. 5

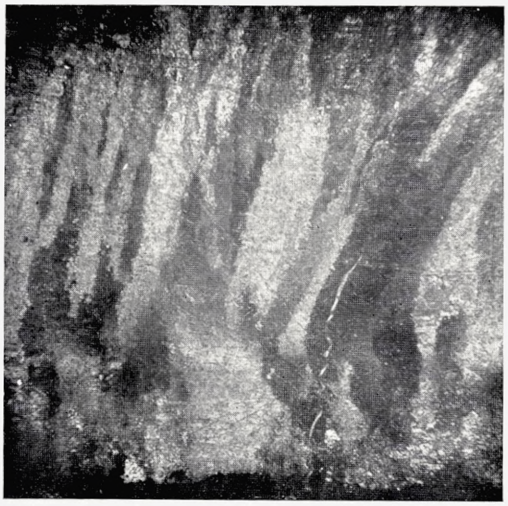

Fig. 6

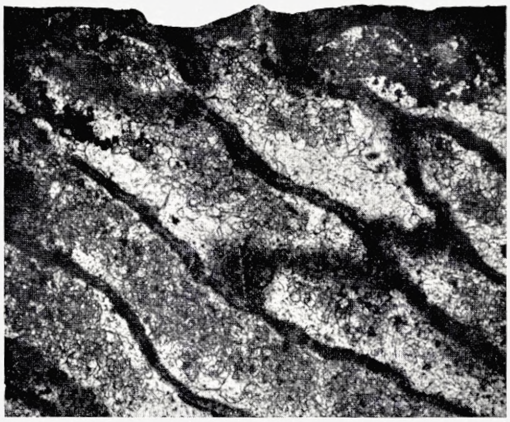

Fig. 7

PLATE XV

Fig. 1. *Aptychus sp.* (the same as shown in pl. XIV, fig. 6). Horizontal section.

Fig. 2. *Belemnitella mucronata* (Senonian). Cross section of rostrum. Type of a very regular prismatic structure with regular extinction. Crossed Nicols. Enlargement 1:19.

Fig. 3. *Belemnites parvus* (Liassic). Cross section of rostrum. Type of irregular prisms with irregular extinction. Crossed Nicols. Enlargement 1:19.

Fig. 4. *Spirula sp.* (recent). Vertical section. The outer shell is prismatic, the septum is nacreous.

Fig. 5. *Sepia sp.* (recent). Section through the external wall, showing an irregular, prismatic structure, and through part of the spongy body. Two of the lamellæ are cut, and some of the rods, showing a characteristic transverse striation, due to foldings of the leaves.

Fig. 6. *Sepia sp.* (recent). Section of the spongy body nearly parallel to the lamellæ one of which is cut in a flat section in the lower part of the figure. The meanderlike figures of the rods are seen.

Fig. 7. *Argonauta argo* (recent). Vertical section of the external shell showing a thin, grained layer between two prismatic ones.

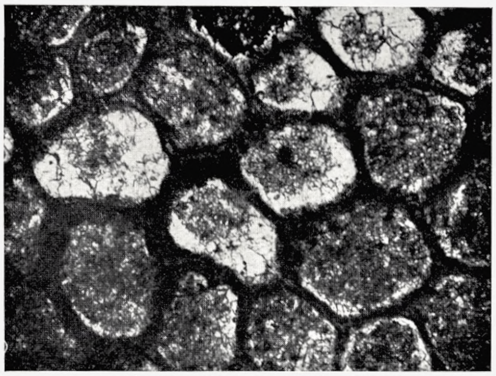

Fig. 1

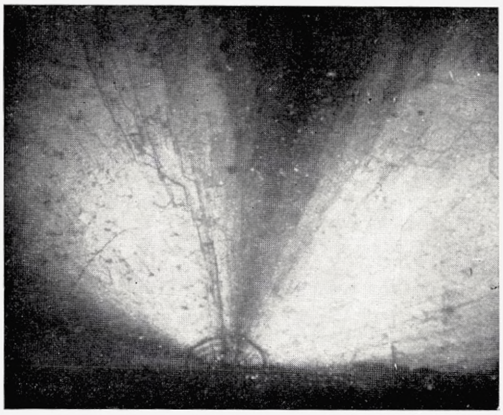

Fig. 2

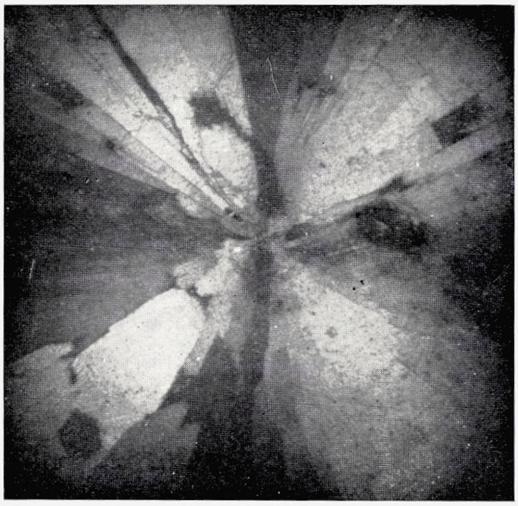

Fig. 3

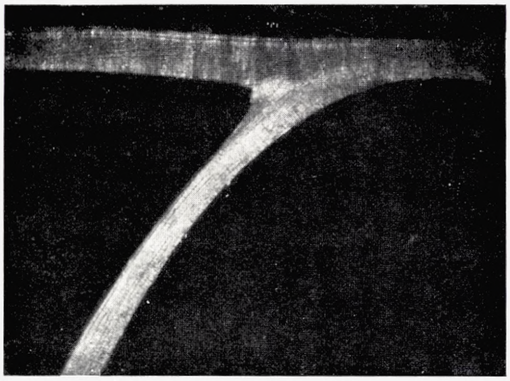

Fig. 4

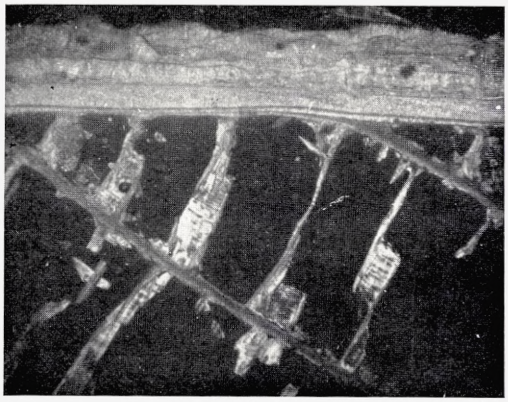

Fig. 5

Fig. 6

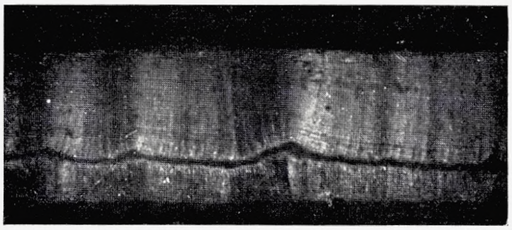

Fig. 7

Det Kgl. Danske Videnskabernes Selskabs Skrifter.

Naturvidenskabelig og mathematisk Afdeling,

8de Række.

		Kr.	Øre
	I, 1915—1917	10.	75.
1.	**Prytz, K.** og **J. N. Nielsen:** Undersøgelser til Fremstilling af Normaler i Metersystemet, grundet paa Sammenligning med de danske Rigsprototyper for Kilogrammet og Meteren. 1915	1.	55.
2.	**Rasmussen, Hans Baggesgaard:** Om Bestemmelse af Nikotin i Tobak og Tobaksextrakter. En kritisk Undersøgelse. 1916	1.	75.
3.	**Christiansen, M.:** Bakterier af Tyfus-Coligruppen, forekommende i Tarmen hos sunde Spædkalve og ved disses Tarminfektioner. Sammenlignende Undersøgelser. 1916	2.	25.
4.	**Juel, C.:** Die elementare Ringfläche vierter Ordnung. 1916	»	60.
5.	**Zeuthen, H. G.:** Hvorledes Mathematiken i Tiden fra Platon til Euklid blev en rationel Videnskab. Avec un résumé en français. 1917	8.	00.
	II, med 4 Tavler, 1916—1918	11.	50.
1.	**Jørgensen, S. M.:** Det kemiske Syrebegrebs Udviklingshistorie indtil 1830. Efterladt Manuskript, udgivet af *Ove Jørgensen* og *S. P. L. Sørensen*. 1916	3.	45.
2.	**Hansen-Ostenfeld, Carl:** De danske Farvandes Plankton i Aarene 1898—1901. Phytoplankton og Protozoer. 2. Protozoer; Organismer med usikker Stilling; Parasiter i Phytoplanktonter. Med 4 Figurgrupper og 7 Tabeller i Teksten. Avec un résumé en français. 1916	2.	75.
3.	**Jensen, J. L. W. V.:** Undersøgelser over en Klasse fundamentale Uligheder i de analytiske Funktioners Theori. I. 1916	»	90.
4.	**Pedersen, P. O.:** Om Poulsen-Buen og dens Teori. En Experimentalundersøgelse. Med 4 Tavler. 1917	2.	90.
5.	**Juel, C.:** Die gewundenen Kurven vom Maximalindex auf einer Regelfläche zweiter Ordnung. 1917	»	75.
6.	**Warming, Eug.:** Om Jordudløbere. With a Résumé in English. 1918	3.	65.
	III, med 14 Kort og 12 Tavler, 1917—1919	26.	00.
1.	**Wesenberg-Lund, C.:** Furesøstudier. En bathymetrisk Undersøgelse af Mølleaaens Søer. Under Medvirkning af Oberst *M. J. Sand*, Mag. *J. Boye Petersen*, Fru *A. Seidelin Raunkiær* og Mag. sc. *C. M. Steenberg*. Med 7 bathymetriske Kort, 7 Vegetationskort, 8 Tavler og ca. 50 i Texten trykte Figurer. Avec un résumé en français. 1917	22.	00.
2.	**Lehmann, Alfr.:** Stofskifte ved sjælelig Virksomhed. With a Résumé in English. 1918	3.	15.
3.	**Kramers, H. A.:** Intensities of Spectral Lines. On the application of the Quantum Theory to the problem of the relative intensities of the components of the fine structure and of the stark effect of the lines of the hydrogen spectrum. With 4 plates. 1919	9.	50.
	IV, med 15 Tavler og 1 Kort	28.	50.
1.	**Bohr, N.:** On the Quantum Theory of Line-Spectra. Part I. 1918	2.	25.
	— Samme. Part II. 1918	4.	00.
	— — — III. 1922	1.	25.
2.	**Warming, Eug.:** Økologiens Grundformer. Udkast til en systematisk Ordning. 1923	4.	50.
3.	**Wesenberg-Lund, C.:** Contributions to the Biology of the Danish Rotifera. With 15 Plates and 18 Textfigures. 1923	21.	25.
4.	**Hertzsprung, Ejnar:** Effective Wavelengths of Stars in the Pleiades from plates taken at Mount Wilson. With 4 Figures and 1 Map. 1923	4.	75
	V, med 57 Tavler	46.	90.
1.	**Bjerrum, Niels** und **Kirschner, Aage:** Die Rhonadide des Goldes und das freie Rhodan. Mit einem Anhang über das Goldchlorid. 1918	3.	50.
2.	**Orla-Jensen, S.:** The lactic acid Bacteria. With 51 Plates. 1919	46.	00.
3.	**Brünnich Nielsen, K.:** Zoantharia from Senone and Paleocene Deposits in Denmark and Skaane. With 4 Plates. 1922	5.	25.
4.	**Petersen, Axel:** Bidrag til de danske Simuliers Naturhistorie. Med 2 Tavler, 53 Figurer og 1 Kort i Texten. 1924	7.	75.

		Kr.	Øre
	VI, med 12 Tavler	25.	70.
1.	**Christensen, Carl:** A Monograph of the genus Dryopteris. Part II. 1920	8.	25.
2.	**Lundblad, O.:** Süsswasseracarinen aus Dänemark. Mit 15 Tafeln und 34 Figuren im Text. 1920.	18.	50.
3.	**Børgesen, F.:** Contributions to the knowledge of the Vegetation of the Canary Islands (Teneriffe and Gran Canaria). With an appendix: Lichenes Teneriffenses, scripsit Edv. A. Wainio. 1924	7.	50.
	VII, med 29 Tavler	37.	50.
1.	**Wesenberg-Lund, C.:** Contributions to the Biology of the Danish Culicidæ. With 21 Plates and 19 Figures in the text. 1920—21	29.	00.
2.	**Nørlund, N. E.:** Stirlings Interpolationsrække. 1924	4.	50.
3.	**Levinsen, G. M. R.:** Undersøgelser over Bryozoerne i den danske Kridtformation. Efter Forfatterens Død udgivet af Dr. K. Brünnich Nielsen og Dr. Th. Mortensen. Med 8 Tavler. 1925	16.	50.
	VIII.		
	Jessen, Knud og **Jens Lind:** Det danske Markukrudts Historie. Med 1 Oversigtsskema. 1922—23.	24.	50.
	IX, med 5 Tavler.		
	Thoroddsen, Th.: Die Geschichte der isländischen Vulkane (nach einem hinterlassenen Manuskript). Mit 5 Tafeln. 1925	25.	15.
	X, med 30 Tavler og 2 Kort	38.	10.
1.	**Wesenberg-Lund, C.:** Contributions to the Biology of Zoothamnium Geniculatum Ayrton. With 14 Plates. 1925	14.	00.
2.	**Micoletzky, H.:** Die freilebenden Süsswasser- und Moornematoden Dänemarks nebst Anhang über Amöbosporidien und andere Parasiten bei freilebenden Nematoden. Mit 13 Tafeln und einer Textfigur sowie mehreren Tabellen. 1925	25.	75.
3.	**Gram, J. P.:** Tafeln für die Riemannsche Zetafunktion. Herausgegeben von N. E. Nörlund. 1925	1.	00.
4.	**Johs. Schmidt:** On the distribution of the Fresh-Water Eels *(anguilla)* throughout the world. II. Indo-pacific region. A bio-geographical investigation. With two charts and ten text-figures. 1925.	5.	00.
5.	**Jul. Hartmann:** A Comparison between the Flow of Water and Mercury in Pipes with a view to testing the Osborne Reynolds' Law of Similarity. With 3 Plates and 18 Figures in the text. 1926	5.	00.
	XI, med 14 Tavler	27.	15.
1.	**Luplau Janssen, C.:** La Surface de la Planète Jupiter 1919—1924. Avec 7 planches. 1926	10.	00.
2.	**Wesenberg-Lund, C.:** Contributions to the Biology and Morphology of the Genus Daphnia with some Remarks on Heredity. With 2 Plates and 21 Textfigures. 1926	13.	20.
3.	**Braae, Johannes:** Eine Reihe differentieller Beobachtungen am Meridiankreis der Kopenhagener Universitätssternwarte. 1927	5.	00.
4.	**Ravn, J. P. J.:** De irregulære Echinider i Danmarks Kridtaflejringer. Med 5 Tavler. 1927	6.	00.
5.	**Mortensen, Th.:** On the Postlarval Development of some Cidarids. 1927	2.	00.
	XII,	20.	70.
1.	**Kramp. P. L.:** The Hydromedusæ of the Danish Waters. 1927	16.	50.
2.	**van den Bos, W. H.:** The Multiple System ξ Ursae Majoris. 1928	2.	50.
3.	**Bohr, Harald** og **Jessen, Børge:** Om Sandsynlighedsfordelinger ved Addition af konvekse Kurver. Med 34 Figurer. 1929	8.	60.

9de Række.

		Kr.	Øre
	I, med 35 Tavler	30.	50.
1.	**Ravn, J. P. J.:** De regulære Echinider i Danmarks Kridtaflejringer. Med 6 Tavler. 1928	7.	00.
2.	**Clausen, Hans:** On the Crystal Structure of Cryolithionite. With 4 Figures in the text. 1928	2.	25.
3.	**Boas, J. E. V.:** Biologisch-anatomische Studien über den Hals der Vögel. Mit 23 Tafeln und 20 Figuren im Text. 1929	20.	00.
4.	**Berg, Kaj** and **Gunnar Nygaard:** Studies on the Plankton in the Lake of Frederiksborg Castle. With 6 Plates and 27 Figures in the text. 1929	11.	50.
	II, med 30 Tavler og 8 Skemaer	23.	25.
1.	**Wesenberg-Lund, C.:** Contributions to the Biology of the Rotifera. Part II. The Periodicity and Sexual Periods. With 15 Plates and 8 Schemata. 1930	20.	00.
2.	**Bøggild, O. B.:** The Shell Structure of the Mollusks. With 15 Plates and 10 Figures in the text. 1930	11.	00.