XXX. *Some Observations on the Economy of Molluscous Animals, and on the Structure of their Shells.* By JOHN EDWARD GRAY, *Esq., F.R.S., &c.*

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1. *First Formation of Shells.*

THE shells of Mollusca appear to be coeval with the first formation of the animal: they may be observed covering the embryo on its first development in the egg, even before it has acquired its proper shape or any of its internal organs. The accurate SWAMMERDAM observed them in the eggs of several of the garden and pond snails. His observations have been recently verified and extended by PFEIFFER, on many species of land and fresh-water Mollusca; and I have myself observed the same fact in the eggs of several animals belonging to the different orders of marine shells: there is reason, therefore, to believe that this circumstance is general throughout the class. These observations are most easily made on the embryo of the fresh-water shells, such as the *Lymnææ*, *Physæ*, *Ancyli*, and *Bithyniæ*, the eggs of these animals being covered with a transparent coat; while the viviparous Mollusca, and especially the *Littorinæ*, *Paludinæ*, and *Cyclades* *, offer the additional advantage of exhibiting the embryos of their animals in all the different states of development at the same time.

The cephalopodous Mollusca form no exception; their bone, composed of

* Between the laminæ of the branchiæ of the *Anodontes* and *Uniones* are found small cordate, bivalve bodies, which have been considered as their young; but they differ so much in external form and internal structure from the adults, that many excellent naturalists, and especially Professor JACOBSON, of Copenhagen, have considered them as parasites. It is, however, remarkable that they are found in abundance in almost every specimen, and PFEIFFER has apparently proved that they are the young, he having found them constituting the umbones of very minute *Uniones*. I have searched for them in vain in this situation; perhaps because I have never been so fortunate as to discover specimens of the young shell so small as those figured by this author. If PFEIFFER should prove to be correct, this remarkable change of form and structure will be the only approach towards a metamorphosis that has been hitherto observed in this class of animals.

two or three calcareous plates, being found fully developed in the egg of the Cuttle-fish some time before the young animal is hatched.

These observations are directly at variance with the theory maintained by the late Sir EVERARD HOME*, viz., that the shell of the Vermes Testacea is formed after the animal has quited the egg; and as regards the Cuttle-fish, they are opposed to the remark, made by the Baron CUVIER, that the young Cuttle-fish, when first hatched, has only a cartilaginous plate like the *Loligo*.

The shell when first observed on the embryo (even of the animals of spiral shells) forms a short, blunt, more or less curved, subcylindrical cone, covering the hinder part of its body: as the organization of the embryo becomes developed, and the hinder part of the body extended, the shell increases in size, till the body and shell together occupy nearly the whole of the egg. While inclosed in the egg, the embryo shells are generally of a pale horn colour, and destitute of markings: when, therefore, they remain attached to the apex of the spire of adult shells, they may be easily distinguished by their appearance from the part formed after their exclusion; and as, in such cases, they offer some characters of importance, it has been proposed to designate them by the name of the Nucleus of the shell.

The effect of the atmosphere on the shell is almost instantaneous: in some young *Helices* and in a species of *Voluta* in my collection, the very first line of calcareous matter deposited after their exclusion from the egg is marked nearly as the adult shells of the species.

The nucleus may be generally distinguished from the perfect shell, by the rapid enlargement of its whorls, by its extreme tenuity, by its want of colour, and by the great obtuseness of that part which is earliest formed and constitutes the extremity of its first volution. It is necessary to pay attention to these particulars, inasmuch as the nuclei of some large species have been mistaken for full-grown shells, and vice versâ. Thus the *Murex decollatus* of PENNANT is the just-hatched shell of the *Fusus despectus*; RISSO's genus *Orbitina* is established on the nuclei of two land shells; and the genus *Vitrina* was regarded by MONTAGU as the nucleus of the Common Snail. In some instances the first half-whorl of the nucleus, (the part first formed on the embryo,) instead of being regularly curved, is bent across the tip of the other

* Philosophical Transactions, 1817, p. 229.

whorls, as in the *Pyramidellæ*, or placed in an oblique position with regard to the succeeding one, as in *Voluta papillosa* and some other species.

The nuclei of many shells of different genera have not the same characters as their parent shells; thus the nucleus of the Tritons has a short anterior nick, instead of an elongated canal, and is very like a minute Buccinum. Some retain the generic but not the specific character of the group to which they belong; thus the nuclei of the Volutes in general have the pillar slightly plaited, but the young of *Voluta musica* has only two or three plaits on its pillar, while the adult has many.

The nucleus forms the original apex of the valves of all shells whatever may be their form, and frequently remains attached to them during all their periods of growth; this is particularly the case with the Volutes, in which, from its large size and rounded shape, it has been called the Nipple. It is also conspicuous on most of the species of *Dolium* and on some *Fusi*, among the univalves; and on the apices of the valves of the *Cyclades*, and *Chamæ*, among the bivalves.

This part of the shell has not received the attention that it deserves. It is largest in those shells the animals of which are viviparous; and is consequently very distinct in the *Volutæ*, *Paludinæ* and *Cyclades*. In the oviparous species it agrees in size with the egg of the animal; thus *Achatina octona*, which has an egg nearly equal in dimensions to the mouth of the shell, and *Bulimus ovatus* and *B. bicarinatus*, which have large eggs, have large nuclei, the magnitude of the nucleus in general rendering the top of the spire blunt. Some shells on the contrary, those, for instance, of the genus *Stylina* generally, and of the *Pupa purpurea*, have a very long, slender, acute, turreted nucleus, but the form and size of the eggs are in these cases unknown.

The nucleus is found on examination to consist of two very distinct parts or coats, the outer of which is membranaceous or horny, and called the Periostracum, and the inner hard and calcareous, and constitutes the Shell.

These two coats may be observed in all the stages of the shell: they are generally very thin in the nucleus, and the outer one is rarely distinctly visible in that state; but it is to be clearly seen (covered with five or more bands of hair-like processes) in the very young *Paludinæ*. In such shells as are enveloped in the mantles of their animals, as the *Dolabellæ*, *Aplysiæ* and *Bullææ*, the outer coat or periostracum is very thin; it is, however, to be found in all shells, and may also be observed on the shelly plates of the Cirrhipedes. In some instances, as in the Cowries and Melons, the outer coat of the shell is covered in the adult age with a deposition of shelly matter, which entirely conceals it from view. A few shells, as for example those of *Loligo* and *Aplysia*, contain so little calcareous matter, as to appear to be formed entirely of periostracum.

2. *The external Form of Shells, and their Variations.*

Each valve of a shell, according to the manner in which it is first formed and subsequently increases, is a more or less depressed or lengthened cone. The apex of this cone is always oblique: in all the shells with which I am acquainted, it is excentric; and in most of the univalve shells, whether they be simply conical, involute or spiral, it is directed from the head of the animal towards the hinder part. The only exception, as far as I know, to this rule, occurs in the genera *Patella* and *Lottia*, in which the apex is directed from the hinder part towards the head; and this is the more remarkable, as in the Chitons, the animal of which so much resembles that of *Patella*, each of the valves takes the usual direction. The similarity of direction in the two genera above named is still more curious, as their animals bear scarcely any resemblance to each other.

The nucleus of the bone of the Cuttle-fish and of the *Loligo*, is placed in the same direction; for it is the conical process at the end of the bone of the Cuttle-fish (called *Beloptera*, when found in the fossil state,) which must be regarded as the nucleus of these shells. If, however, the relative position of the animal of the Nautilus, the anatomy of which has been admirably described by Mr. Owen, be correctly assigned by that author, with respect to its shell, it must offer a similar anomaly with the genera *Patella* and *Lottia*. The shells of the Pteropodes, as for example *Hyalœa*, *Cleodora* and *Vaginella*, take the same direction as the other univalves; and it was this circumstance that gave rise to the supposition that M. de Blainville, in his figure of the animal of *Cymbulia*, had placed it in the shell in the wrong position. The numerous specimens which are now in European cabinets have proved the accuracy of this supposition.

In bivalve shells the apex of each valve is always placed on or near the dorsal or hinge margin, varying its position on this part in the different groups.

Thus, in the *Pectines* and other suborbicular shells, which having a very large subcentral posterior adductor muscle, were called by LAMARCK *Monomyaires*, the apex is generally in or near the centre; while in most of the other genera it is placed more or less towards the anterior extremity of this margin, and is sometimes incurved. In some of these shells the apex is spirally twisted, and the spire becomes more developed as they increase in size. Now this could not take place if the valves remained inseparably united together at the same part of the dorsal margin; but it is provided for by the hinge of the shell being gradually moved backwards on the edge of the valves, the ligament separating in front of the hinge into two parts, one of which diverges along each of the umbones, and forms a spiral groove down the suture of the whorls. In *Isocardia* the umbones seldom make more than half a turn, but in one specimen of *Chama* in my collection they have made an entire revolution, and in another a revolution and a half. The valves of these shells being unequal, the spiral part of the lower or attached valve is produced into an elongated cone, while in the other it is depressed, and simply marked with a spiral groove, like that of an operculum.

In most bivalves the hinge margin, which is deposited by a part of the mantle extended behind and between the teeth, increases in size much more slowly than the other margins of the shell; but in some free shells, such as the *Arcæ*, this part increases nearly as rapidly as the rest, and the umbones thus become separated from each other by a lozenge-shaped disk. In others which attach themselves to foreign bodies, as the *Spondyli* and *Ostreæ*, the hinge margin of the attached valve only enlarges, forming a triangular flat-topped process, while that of the upper valve is scarcely increased in size. Thus the cavity of the shell, as the growth proceeds, gradually retreats from the part by which the attachment first took place.

The direction followed by the whorls in passing down the axis derives its origin from that which the shell takes in the egg; and is probably dependent upon the direction in which the embryo rotated whilst inclosed therein. In most shells they turn from left to right, and the mouth is on the right side of the axis, when the shell is in its natural position; but in others, which are called sinistral or reversed, the whorls are twisted in the contrary direction. The sinistral direction appears to be constant in many species, especially among the air-breathing Mollusca; in all belonging to the genus *Clausilia,* among the land ones; and in all the *Physæ, Planorbes* and *Ancyli,* among those which inhabit fresh water. But besides these entire genera, the shells of which are invariably sinistral, there are numerous species of *Bulimus, Partula, Pupa,* and *Chondrus,* that are uniformly so twisted; and there are even some that are sometimes twisted in one direction and sometimes in the other, as *Bulimus Lyonettianus, B. aureus,* &c. Among the marine shells the sinistral direction is much more rare, although there are a few species, such as *Fusus sinistrorsus* of DESHAYES, *F. contrarius* and *F. sinistratus* of LAMARCK, and some species of *Cerithia,* which are constantly so contorted. The *Pyrula perversa* is as often found twisted in one direction as in the other, and its shells have even been considered as different species according to the direction of their whorls. Of other marine species liable to the same variation, I have observed *Buccinum undatum,* which is not uncommonly found reversed; *Turbinella napus,* the reversed variety of which is much sought after by the Chinese; *Oliva oryza, Nassa reticulata* and *N. Thersites*; but there are some genera in which I do not recollect to have noticed its occurrence, as, for example, the *Cypræœ* and *Ovulæ.*

A bivalve shell is composed of a dextral and a sinistral valve, united together by a ligament. When the two valves are separated, and spread out on a table with the umbones above, and the front end towards the observer, the valve to the right (the left when on the animal and in its usual walking position,) resembles a dextral, and that to the left a sinistral, very depressed spiral shell. This is well illustrated by comparing the left valve of an *Isocardia* with a *Concholepas.* In some very rare instances these shells also are reversed, but the fact is not easily observed, except in the unequal-valved kinds. There were formerly in the TANKERVILLE collection two specimens of *Lucina Childreni,* in one of which the right valve was a dextral shell, in opposition to the general structure. A much more remarkable variation is to be observed in some of those bivalve shells, whose under valve is attached to foreign bodies; thus, for example, most of the *Chamæ* are attached by their left valve, but some species, such as *Chama Lazarus,* are frequently attached by their right valve, under which circumstance the teeth proper to the left and usually attached valve are transferred to the right, and vice versâ.

The equality or inequality of the valves of bivalves appears to be dependent on the habitual position of the animal. Thus all the genera whose animals bore perpendicular holes in rocks, like the *Pholades*; or bury themselves in the mud of rivers, as the *Uniones*; or in the sand of the sea-coast, as the *Cardia*; or walk freely about on the shores, as the *Veneres*; or are attached by a byssus which passes out of a gape formed by the inflection of the margins of both valves, as the *Tridacnæ*, *Saxicavæ* and some *Arcæ*, have equivalve shells: whilst on the other hand, all those Mollusca whose shells are immediately attached by the outside of one of their valves, as the *Etheriæ*, *Ostreæ*, *Spondyli*, *Hinnites* and *Chamæ*; or of which the animals are attached by a byssus passing through a groove near the umbo of one of the valves only, as the *Pectines*, *Aviculæ*, *Peda* and *Anomiæ*; or which lie free on the surface of one of their valves, as the *Ostreæ*, *Anatinæ*, and some of the *Arcæ*, are more or less inequivalve. In those inequivalve shells which are attached by the intervention of a byssus, this substance passes out through a groove in the right valve, which is the smallest; whilst, on the other hand, in those that are immediately attached by the outside of the shell, the right valve is affixed, and the left is the smallest, sometimes indeed so disproportionately as to appear like a lid to the other. It is only in the families *Ostreidæ* and *Anatinidæ*, which have unequal valves, that there are found some genera entirely free, and others which are immediately attached. The free inequivalve shells offer some curious anomalies in the relative size of their valves; nearly all the *Anatinidæ*, as *Anatina*, *Periploma* and *Magdala*, having the left valve the smaller, as have also the genera *Corbula* and *Sphænia* of the family *Myidæ*; whilst the other two genera of that family, *Mya* and *Pandora*, and *Lyonia* among the *Anatinidæ*, have the right valve the smallest.

In the *Terebratulæ* and Brachiopodous Mollusca in general, the valves being applied to the dorsal and ventral, instead of the lateral, surfaces of the animal, their lateral halves are analogous in situation to the right and left valves of other bivalves, and the byssus by which the animals are attached passing through a hole in the centre of the dorsal valve, the sides of the shell are equal. The dorsal or perforated valve is superior and convex in all the genera of this order, with the exception of *Discina*, in which, the usual position of the animal being reversed, it is inferior and flattened.

In all shells, the young of which I have had an opportunity of observing, the nucleus or shell of the animal when first hatched is regular. The irregularity in the form of adult shells appears to depend on their becoming attached to foreign substances, for it is only among attached shells that any irregularity of form is found, and even these are perfectly regular so long as they continue free. This explains why irregular shells are more rare among the univalves than among the bivalves, as not more than three or four genera of the former ever become attached. Good examples of shells which are irregular when full grown, although regular in their very young state, may be seen in the genera *Ostrea, Chama, Hinnites, Magilus*, and *Vermetus*. The very young shell of *Chama arcinella*, which closely resembles in form a minute *Petricola*, is frequently found persistent and constituting the apex of the umbones of adult specimens; and so regular is its form, that I have little doubt, were a conchologist to meet with a very young free specimen among the sand of the West Indian coasts, that he would refer it either to the latter genus, or to the genus *Cardita*. In like manner the very young shell of *Hinnites pusio*, when persistent in the umbones of the adult, cannot be distinguished from a free regular *Pecten*.

Many univalves exhibit the same phenomenon: the young *Spiroglyphus* and *Magilus*, as will hereafter be described, are quite regular so long as they remain free; and the apices of all the *Vermeti* and *Siliquariæ* show that they also are regular in their youth. The apex of the former has indeed been mistaken for a regular spiral shell, and described as a *Turritella* by LAMARCK and by Dr. TURTON.

Some land shells (for it is only in such shells that I have observed it,) offer a very curious anomaly in their form: they are quite regular in their young state, but change the direction of their last whorls as they approach maturity, and in some cases even reverse the position of the mouth. A remarkable instance of this change of direction occurs in a rather common Brazilian snail, which is transversely striated in its young state, and exactly resembles a common umbilicated snail; but acquires when adult a smooth last whorl much larger than the others, and pressed towards the side next the mouth, by which means the axis is bent out of the line, and the umbilicus is compressed and closed. This obliquity in the form of its whorls gives the shell the appearance of having been slightly crushed, from which circumstance it has been called by Baron Férussac *Helix contusa*. A similar departure from the regular form is found, in even a greater degree of development, in a minute species from the same country, named *Helix deformis* (Wood's Supplement, tab. 7. fig. 40.); and may also be seen in a slight degree in the *Helix concamerata* of Wood's Supplement, tab. 7. fig. 21. The last whorl of *Bulimus Lyonettianus* is compressed on the side opposite to the mouth, and produced into an acute angle, which gives the shell a very anomalous appearance. A somewhat analogous deformity, but not so much developed, may also be observed in *Helix Auris Leporis*. This kind of variation is, however, not confined to the inoperculated land shells, for the *Cyclostoma compressum*, figured by Mr. Wood in his Supplement, tab. 6. fig. 42, differs from all others of the genus in its last whorl being compressed, although not in so great a degree as in the *Bulimus Lyonettianus*; and in the *Cyclostoma tortum* (*Turbo tortus* of Wood's Supplement, tab. 6. fig. 32.) the last whorl is slightly pressed on one side like that of *Helix contusa*, the mouth being produced in front, and nearly in a line with the axis.

But the most remarkable of these anomalies occurs in the genus *Anastomus*, where the mouth of the young shell occupies its ordinary situation in front of the whorls, the animal in this early stage doubtless crawling in the usual manner, with the spire of the shell uppermost; but as it approaches maturity, the end of the last whorl is curved upwards, and the mouth of the perfect shell is applied to the upper edge of the last whorl but one, with the opening directed towards the tip of the spire, in such a manner that, in walking, the animal must crawl with the tip of the spire downwards, and thus completely reverse the position of its shell. A similarly formed shell has been discovered in the fossil state, and named *Strophostoma*, and this, from the roundness of its mouth, has been supposed to belong to the family of *Cyclostomidæ*.

The axis of most spiral shells is perfectly straight, but the species of some few genera, such as *Eulima* and *Stylifer*, are very liable to have it more or less curved or twisted. And this is not the only point of resemblance between these two genera, both having the same polished surface and similar varices on the spire; but they differ in the degree of solidity of their shells. The *Styliferi* live buried in the substance of Star-fish, which may perhaps account for their inflections: the habits of the *Eulimæ* are unknown.

The growth of other spiral univalve shells appears never to be thrown out of its proper course, except by some accident, such as the interruption caused by the occasional attachment of a foreign body, or by a fracture. I have a *Fusus virgo* and a *F. colosseus*, which are thus bent; and there are two specimens of the common Whelk in the British Museum, the spires of which are very much elongated, the elongation having evidently been caused by a fracture in their very young state. One of the latter has been described as a distinct species, under the name of *Buccinum acuminatum*. Sometimes, after the occurrence of such an accident to a spiral shell, the form or sculpture of the whorls is entirely altered: they often become ventricose and smooth, instead of remaining thick and ribbed, as in the common state of the shell; and this change of form has even occasioned shells under such circumstances to be regarded as distinct species. As an instance of this I may refer to *Cingula alba* of Dr. FLEMING, founded on specimens of *Turbo parvus* of MONTAGU, which had been injured in their growth. In Mr. TURNER's collection there is a specimen of *Terebra maculata*, which had sustained an injury when about an inch and a half in length: the whorls beyond this injury are rounded and elevated near the suture, and are destitute of the posterior groove. In this specimen the colouring also is altered, for instead of being spotted, the irregular volutions are marked only with two narrow posterior spiral bands.

A distortion or change of form, caused by a fracture or other accident, is sometimes overcome, as the animal increases in size and recovers its strength. Thus a specimen of *Strombus bituberculatus* in my collection, which had met with an accident in its young state, has the five upper whorls sharply keeled and nodulous, as in the ordinary state of the shell, but the volutions formed after the accident turn more obliquely down the axis, and thus their anterior part becomes more exposed, leaving a deep narrow groove on the suture. The first half-whorl that succeeds the fracture is rounded and distinctly tubercular; after which the shell continues rounded, but quite smooth for a whorl and a half; when it again becomes slightly tubercular, and at length keeled and tubercular, the last whorl exactly resembling the last whorl of the normal shell. The collection of Mr. LINCOLNE of Highbury contains a specimen of *Cassis rufa* in a very similar state.

The shape of attached shells depends greatly on the form of the bodies to which they are applied; and this is a circumstance that has been generally overlooked by conchologists. It strongly affects most shells that are immediately and permanently attached, such as the *Chamæ* and *Ostreæ*, which completely assume the form of the substances on which they grow. Thus the *Chamæ* and *Spondyli* attached to the plane surface of mother-of-pearl shells have always a flat side, whilst those which are adherent to coral and to other uneven surfaces are variously and irregularly shaped. The Oysters which are attached to the branches of mangrove trees have a central convex rib, modelled on the shape of the branch, from which the plaits of the shell radiate; while the specimens of the same species fixed to the trunk are destitute of any such peculiarity. In the collection of Mr. ADAMSON of Newcastle there is a curious specimen of a common Oyster found in the Frith of Forth attached to a species of *Pecten*; on the latter there also grew three corallines, surrounding the Oyster, which have formed in its circumference three deep notches, giving it the form of an ace of clubs. The same changes may be observed to take place in the *Anomiæ*, which are attached by the intervention of a ligamentous band; thus the species called *Anomia squamula* is founded on young shells of the common *A. ephippium* attached to flat surfaces; whilst *A. cymbiformis* is characterized from small specimens of the same shell attached to the cylindrical spines of sea eggs, or to the stems of sea weeds.

A similar influence is also observable in such free univalve shells as have a widely expanded mouth, and an animal provided with a large foot, by means of which they remain for a considerable length of time adherent in the same situation. When a *Patella* or a *Crepidula* has attached itself to the flat surface of a rock or the leaf of a large *Fucus*, the base of its shell is flat, and its mouth roundish; when it adheres to a concave surface, such as the cavity of an old shell, the base becomes flattened, and convex internally; and when it fixes itself on the rounded stalk of a *Fucus*, the sides become compressed so as in some measure to clasp the stem, and the lateral portions of the base project beyond the front and hinder parts, to such an extent that when placed on a flat surface it rocks backwards and forwards. Several nominal species of these and allied genera depend on variations in the shape of the shell caused by the adhesion of the animal to surfaces of different forms; thus the *Patella pellucida* of MONTAGU is synonymous with the *P. cœrulea* of the same author, the former having been founded on specimens taken from the stalk, and the latter on individuals obtained from the flattened frond of the *Fucus* on which the species usually takes up its abode: it is indeed by no means rare to find specimens in which the animal has moved from one of these positions to the other, and in such cases the apex of the shell represents *P. cœrulea* and the base *P. pellucida*, or vice versâ. The same change takes place with regard to *P. miniata* and *P. compressa*. I have in my collection a specimen of this latter shell which is *P. miniata* at the top, it having in its youth lived on the frond of a large Cape *Fucus*: it afterwards removed to the stem, and became compressed, and consequently is in this part the *P. compressa*; but by some accident it was again induced to change its situation, and, removing to a flat surface, the edge of the mouth expanded, and it became a second time *P. miniata*, or perhaps what may be called by some authors *P. saccharina*, as this also appears to be a conical variety of the same species. LAMARCK has described a similar specimen; and Mr. SOWERBY, in his Genera of Shells, has figured an example of this species, showing the two states. In like manner the *Crepidula porcellana*, when applied to a flat surface, has an expanded base and a flattened inner lip; but when adherent to a convex body, such as the stem of a sea-weed, or (as frequently happens) to the back of another shell of the same species, the animal being pressed into the cavity, the inner lip becomes concave, and the sides of the aperture are contracted: in this state the shell is called by most authors *C. fornicata*.

When the shells of this family are adherent to irregular surfaces, they adapt their margins to the inequalities with which they meet. I have several specimens from the coast of Devonshire, having one or more processes on their sides, which fitted into holes in the rock to which I found them attached; and such changes are the more remarkable, as some specimens are seen constantly moving from place to place, whilst others appear to remain for a long time fixed in one spot, and even those that are thus stationary in the young state constantly elevate the margins of their shells when the tide is low. I have also a specimen of *Siphonaria gigas* exhibiting in a great degree a similar adaptation of its edges to the form of the rock on which it grew.

The substances to which attached shells become adherent, besides altering their general form, often change the character of their surfaces; thus, when fixed to ribbed shells, like the *Pectines, Cardia,* &c., they are frequently variously ribbed, a circumstance which often takes place in the common *Anomiæ*; and if attached to a *Dolium*, as in a specimen in the collection belonging to Mrs. MAUGER, they even exhibit on their own surface the alternate broad and narrow ribs of that shell. In specimens of *Crepidula adunca* attached to *Trochus doliarius*, (and inhabiting the same locality, they are not unfrequently so attached,) the convex part of the former is marked with the ribs of the latter. Shells which are ribbed from this cause are, however, easily distinguishable from those which are naturally ribbed, the ribs in the former generally extending across or along the shell, and not radiating from its apex or nucleus, as in all shells the natural character of which is to be ribbed. In those which adhere to ribbed shells by the foot of their animal (as in most of the univalves), and are therefore capable of being moved from place to place, the young animal may have lived on a smooth surface, and have had a smooth shell; and may have moved, during its growth, to a ribbed body, producing ribs on the later formed part of its shell, or vice versâ. In a specimen of *Crepidula adunca*, for example, in the British Museum, the upper half of the shell is smooth, and the lower half ribbed; and I have seen specimens, on the contrary, in which the apex was ribbed and the base smooth.. This change of form has, however, misled some conchologists, for Dr. BRONN, of Heidelberg, has founded a genus under the name of *Brocchia*, on a specimen of *Capulus*, which had acquired a ribbed surface in consequence of having been attached to a *Pecten* or to some other radiated shell.

These alterations of form and surface are always most distinct in univalves and in the upper valve of bivalves. In the latter case, the edges of the upper valve being produced beyond those of the under, they are immediately moulded on the surface of the substance to which the shell is attached, whilst the under valve simply covers it over. This is well illustrated in the unique specimen of *Hinnites gigantea* in the collection of the British Museum, which must have been attached to some marine body having a *Serpula* growing upon it. There is merely an irregular convexity in the inner part of the under valve, but on the outer surface of the free valve is to be observed a representation of the whole form, and of almost the entire surface of the *Serpula*, in consequence of the edge of that valve, during each deposition of shelly matter, having rested on the worm-shell. In the collection of Mr. LINCOLNE is a specimen of an

Oyster which, having been attached to a plank covered by a number of *Balani* and *Serpulæ*, has the upper valve marked with prominences, exactly agreeing in shape with the substances concealed beneath the under one. The edges of the valves of Barnacles being very closely affixed to the surface of the substances to which they are attached, it appears that they not only assume the form of the larger prominences, such as the ribs and spines of a shell, but also the most minute differences of its surface. A Barnacle in my collection, which had been fixed to a Scollop (*Pecten suborbicularis*), has not only the ribs of the latter marked across its valves, but the whole surface of the prominent part of the valves is covered in addition with minute rugosities, produced by the small projecting scales which cover the surface of the ribs of the *Pecten*, whilst the articulating portion of the valves is smooth, as in the common state of the species. In another similarly ribbed specimen the articulating portions are also ribbed like the rest of the valves; and in a third, which was found on a piece of roughly planed and loosely textured wood, the surface of the valves bears an exact resemblance to the grain of the wood on which the specimen was attached.

The thickness, the roughness, and the smoothness of the surfaces of shells appear to depend, in a great measure, on the stillness or agitated state of the water which they inhabit. The species of our own coast afford abundant instances of this: the shells of *Buccinum undatum* and *B. striatum* of Pennant have no other difference than that the one has been formed in rough water, and is consequently thick, solid and heavy; and the other in the still water of harbours, where it becomes light, smooth, and often coloured. In the same way the specimens of *Purpura Lapillus*, which inhabit sheltered situations, are covered with small arched scales, whilst those found in exposed places are thick and rugose. Lamarck, not being aware of this circumstance, considered the specimens in the first state as a distinct species, which he named *Purpura imbricata*. The English shells of the genus *Pinna* (and doubtless the foreign ones also,) offer the same variations, which have given rise to similar subdivisions of species. Shells which have branching or expanded varices, like the *Murices*, are also much influenced by these circumstances; and hence many mere varieties, arising from local causes, have been considered as distinct species. Thus *Murex angulifer* is merely a *Murex ramosus* with simple varices; and *Murex erinaceus, M. torosus, M. subcarinatus, M. cinguliferus, M. Tarentinus* and *M. polygonus,* are all varieties of one species. *Murex Magellanicus,* when found in smooth water, is covered with large acute foliaceous expansions; but the same shell living in rough seas is without any such expansions, and only cancellately ribbed. In such situations it seldom grows to a large size; but when it does so, it becomes very solid, and loses almost all appearance of cancellation. *Triton maculosus* is very widely spread over the ocean in different temperatures and different kinds of seas; it consequently offers a multitude of varieties both in size and surface, all gradually passing into each other, and most probably produced by the operation of the foregoing causes. Indeed, a vast number of merely nominal species have been formed from the habit, too prevalent among conchologists, of describing from single specimens, or even from several individuals brought from the same locality, which would never have been considered as distinct had collectors kept in their cabinets a series of specimens found under different circumstances, and studied, on the coasts where they are found, the variations which shells undergo.

Those shells which are attached to rocks, either immediately by their outer surface, or by the intervention of a beard, are most acted on by these causes: thus the *Anomiæ* found in protected places are thin and transparent, while those which inhabit exposed situations are thick and nearly as opake as the shell of an oyster; and the under valves of the *Craniæ* which are affixed to the branches of coral are very thick and solid, while those that adhere to the *Pinnæ* and other flat shells are so thin as to have been overlooked by conchologists, who have repeatedly described their upper valve as a species of *Patella.*

Boring shells are greatly influenced in regard to their size, thickness and form by the hardness or softness of the rock in which they are found: thus the specimens of *Pholas dactylus* found in the soft rock of Salcombe, are large and thin, and are covered with beautiful, regular, arched scales; while those found in the hard rock are small, irregular, thick, with a very wide anterior gape and large dorsal valves, and closely wrinkled externally, but almost or entirely destitute of scales: and the *Saxicavæ,* found in hard limestone, are often curved and otherwise distorted, in order to avoid the harder parts of the rock during the process of boring.

Land shells are much influenced, as regards their size, by the temperature, altitude, and abundance of food, of the country in which they are found. Specimens of *Helix arbustorum* from the Swiss Alps, are not one half the size of those of the neighbourhood of London; the shells of *Helix nemoralis* and *H. hortensis*, found in the last-named locality, are not above two thirds the size of those which occur in Portugal and in the South of France; and there is so much difference in size between individuals of *Bulimus rosaceus* found on the coast and on the mountains of Chili, that the latter have been described as a distinct species under the name of *Bulimus Chilensis*. There would be no difficulty in multiplying examples of the same kind.

It is not so easy to determine the influence of climate on marine shells, although there is little doubt, from the great differences of size observable between specimens of the same species, brought from different localities, that it actually exerts considerable power. Indeed, I have been enabled to mark this difference in some of the shells found on our own coast. The specimens of *Littorina petræa* found on rocks with a southern exposure near Torquay, are larger than almost any others which I have met with in England; but the largest of this species that I have seen, occur on the part of the Breakwater at Plymouth next the sea, where they are much exposed to the sun. The latter are twice the size of any that I found on the northern face of that magnificent structure.

The colouring of many shells evidently depends on the degree of exposure to light, air, heat, and the action of the waves to which they may have been subjected. Thus, among the *Patellæ* and *Crepidulæ*, those which are attached to the stems of *Fuci* or other round bodies, and are thus exposed on all sides, are of a dull colour, or nearly colourless. This is well exhibited in the specimen of *Patella miniata* before referred to, which had changed its place of attachment twice during its growth; the two portions of the shell formed while the animal was affixed to a flat substance being white, beautifully varied with bright red, (the general colour of *P. miniata*), whilst the central portion of the shell is of a dirty yellow, with a few indistinct, reddish dots, like the ordinary specimens of *P. compressa* *. In like manner *P. pellucida* when obtained from the stems

* Such exposed shells are very rarely brightly coloured; but a specimen of *Patella compressa* formerly in the collection of the late Earl of Tankerville, but now in that of Mr. Lincolne, is coloured nearly as brightly as *P. miniata*.

of *Fuci* is of a pale horn colour, whilst the same shell, on the leaves, is of a beautiful purple with longitudinal pale blue lines. The thinnest specimens of a species are generally the best coloured. The light certainly exerts considerable influence on the strength of colour, even in marine shells; and it appears to be owing to its modifying power that many *Nassæ, Buccina, Naticæ, Cypræœ,* and other littoral shells, have the back part much darker than the rest. This is particularly the case with *Nassa glans, Natica castanea,* and several Cowries, as *Cypræa stolida, C. errones,* and *C. caurica,* which have always an irregular bright red spot on the back of the body volution.

The colour of shells is generally disposed in rays, streaks, or bands, arising from the nucleus and extending to the circumference; in the spiral shells the lines of colouring consequently follow the direction of the whorls. The rays vary greatly in size; they are sometimes interrupted, and they generally become wider as the shell grows larger.

These coloured bands are evidently deposited by glands placed on the margin of the mantle. Sometimes the action of the glands is interrupted, and the bands are broken. In a few shells this suspension of the action of the glands takes place at regular and very short intervals, in which case there is formed a chain-like band, as in *Marginella catenata,* certain Cones, and some other shells. In the *Volutæ, Olivæ, Coni* and some *Cassides,* the colouring often forms angular lines, so disposed, that the glands which deposit it seem to have receded from each other, and then again contracted together. Sometimes, as in *Oliva tessellata,* for example, these lines are broken into spots; but even in this species some specimens exhibit the spots united into angular lines.

In general the colour is situated on the outer coat of the shell. It is often deposited on the inner side of the outer layer, as in *Strombus bituberculatus,* and sometimes extends a little into the outer part of the middle layer; but I do not recollect to have ever seen it pervade the whole thickness of this coat. This circumstance leads me to believe that the colouring matter is generally deposited by the glands immediately after the deposition of the calcareous particles on the periostracum, and during the formation of the outer coat which, as will be seen hereafter, is always deposited before the two inner ones.

This situation of the colouring matter explains the reason why many shells, such as the Olives and Cones, are darker when their outer coat is removed; as is particularly the case with *Oliva utriculus*, which is often sold in that state as a different shell. There is reason to believe that LAMARCK was deceived by a specimen which had been so mutilated, and which he described as a distinct species, under the name of *O. harpiformis*.

The belts across the whorls of the *Olivæ* and *Ancillariæ* have the coloured matter deposited on their inner surface. In a few shells, the *Oliva porphyria* for example, some of the more distinct coloured lines even form raised ridges on the outer surface; and in some others the inner layer is darker than the outer. Thus in *Oliva tessellata* and *O. lineolata*, and in some Cowries, the inner layer is purple; in *O. ispidula*, brown; in *Turbo chrysostomus* and *T. Nicobaricus*, bright golden; in *Capulus Hungaricus*, in *Strombus gigas*, and in many others, pink: but it is generally much paler, and in the greater number of shells white or colourless.

Some brown shells, such as the Volutes, become white when touched with a hot iron: there was formerly in the Museum at Paris a specimen of a Melon, marked in this manner with close series of white spots. The purple colour of some shells is also changed under a similar treatment to dusky red; and it is by this process that the red spots are formed on the polished muscle-shells and uncoated Nutmeg Cowries, which are so abundant in the shops. A very curious effect is produced by ink on some purple shells, which I have seen only in individuals of that colour. On the receipt of the CRACHERODE collection of shells at the British Museum, my uncle, Dr. GRAY, wrote on each of them with a pen and ink the number of the catalogue and the name of the species. In many instances, although the ink has been washed off, the name and number are still distinctly visible, forming an evenly raised letter as broad as the ink line, and slightly interrupted, as if by bubbles, in a few places. This is particularly visible in the specimen of *Solen diphos*, No. 186. in that collection. The effect, however, is not produced in all shells of this colour, nor even in some of the same natural genus which were written upon at the same time; but as I have observed it in a few other purple shells, and as I have not met with it in any of a different colour, I am inclined to think that the nature of the colouring matter may have some share in its production.

3. *The Structure of Shells.*

Shells exhibit, when examined, two very distinct kinds of structure: in the one case the calcareous particles of which they are formed are crystallized, in the other they are granular. These differences in structure correspond with differences in their chemical character, the shells in which the lime is crystallized appearing to contain less animal matter than the others. The primary division of shells according to their structure consequently agrees with the division proposed by Mr. Hatchett, in his paper on their chemical composition; the porcellaneous shells of that distinguished chemist being crystalline, and the nacreous granular.

Shells of the crystalline structure are themselves of two very distinct kinds; the crystals being rhombic in some, and prismatic in others.

Those of the rhombic crystalline structure exhibit, when broken, three distinct layers of calcareous matter. On examining fragments of most of the spiral univalves, there will be observed on two of the fractured sides of the cubic pieces into which they generally break, flat surfaces on the inner and outer edges, separated from each other by a shelving portion in the centre; and on the two intermediate broken sides shelving external and internal edges, connected by a flat central portion; these differences of surface being produced by the different position of the crystals of the different layers.

Each of the three layers thus rendered obvious is composed of very thin laminæ, placed side by side, as high as the thickness of the plate and perpendicular to its surface. When these laminæ are minutely examined, they will be found marked with obscure oblique lines; in the direction of which they separate, when broken, into long narrow rhombic crystals. The lines of cleavage in the succeeding laminæ are placed in contrary directions, so that when two of these plates united are examined under the microscope, the lines of cleavage appear to cross each other at right angles, whilst those of the alternate laminæ follow the same direction.

The laminæ of the outer and inner plates are always directed from the apex of the cone of which the shell is formed towards its mouth; in the spiral shells they consequently follow the direction of the spire. On the contrary, the laminæ of the plate situated between the other two, form concentric rings round the cone parallel with its base, and cross at right angles those of the inner and outer layer. This decussation of the laminæ of the plates, and of the crystals of the laminæ themselves, adds considerably to the strength of the shell, and accounts for the great difficulty that is found in breaking many shells of this structure, more especially the Cones and Olives, in which, however, nearly the whole of the strength resides in the outer whorl and in the spire.

A good illustration of this structure may be obtained by examining with a pocket-glass the fractured edge of a Cone, Olive, or other spiral shell, in which the *extremities* of the laminæ of the outer and inner plates, and the *sides* of those of the central layer, or the converse, will be observed, according to the direction of the fracture; the extremities of the laminæ showing the angles of the crystals, while their sides, when closely examined, will often exhibit the crystalline flakes. In order to observe the lines of cleavage, the best mode of proceeding is to bruise part of a shell with a hammer, and to examine the fragments moistened under a microscope, until one is discovered which exhibits two laminæ in conjunction. The plates and their structure are also well seen in the polished surfaces of shells which have been slit or ground down to exhibit the internal structure of their cavity. The relative thickness of the three plates varies in different species; but as far as I have yet examined, the central plate is generally rather the thickest, and the outer one the thinnest. The Italian cameo cutters appear to be aware of this circumstance, and avail themselves of it in cutting the cameos, the ground being always formed of the innermost layer of the three, which is also generally the most transparent.

The layers increase in thickness from their inner to their outer edge, each of them being formed by successive depositions of thin coats of animal and calcareous matter on its inner surface until it acquires the proper thickness for the shell, the outermost edge of which is very thin, and has during the progress of the growth little calcareous matter, but gradually passes into the periostracum.

This *accumulation* of calcareous particles, deposited at various times and nevertheless forming the same crystals, is well illustrated in the prismatic crystalline shells. These are also evidently formed of several layers, which in some instances, as in the *Pinnæ*, are distinctly separate from each other: if, however, the shell be cracked transversely to its layers, the crystals will be found continued across the line which separates them. An analogous structure exists in some minerals, the Hæmatite for instance, the balls of which appear to be formed of separate concentric coats, but nevertheless when they are broken exhibit the crystals radiating from the centre to the circumference without interruption.

The plates of which the rhombic crystalline shells are formed are deposited in succession, each gradually increasing in thickness as the shell enlarges, and undergoing no variation in this respect after the deposition of the succeeding coat has commenced. That the coats are deposited in regular succession, may be seen by examining the lip of any shell which has been taken whilst the animal was increasing its size. At this period the lip will be found gradually shelving and becoming thinner from the inner to the outer edge, the innermost part being formed of three, the next of two, and the outer and thinnest part, which is always the first formed, of only a single layer. This is best seen by making a section of the lip of a Strombus or a Cone along one of the spiral grooves, in which, if the polished edges be examined, the layers will be distinctly seen. When the animal is about to make its periodical stoppage of growth, the second, and afterwards the innermost layer is deposited up to the edge of the mouth, which is thus completed.

In the *Olivæ, Ancillariæ,* and some *Volutæ,* which have, at all periods of their growth, a polished surface, (now known to be caused by their shell being more or less immersed in the large foot of the animal,) the outer layer, although equally crystalline, is very thin. It is harder and much more compact than the others, and between it and the central layer is deposited an opake, white, powdery film, which often causes it to break off in splintery flakes, while the rest of the shell separates into fragments, generally more or less cubical, their shape depending, doubtless, on the rectangular disposition of the laminæ of which the plates are formed.

Some Olives, as *Oliva utriculus, O. undatella,* and *O. acuminata,* have an additional band, in structure and hardness resembling the outer coat, forming a belt over the latter, across the front of the whorls; and some *Ancillariæ,* as *Ancillaria marginata,* have also a similar belt placed on the back of the volutions.

When the animals of many of the shells of this structure arrive at their full size, or when they form the successive mouths of their shells at their periodical stoppages of growth, they deposit a considerable number of layers of shelly matter, either on the lip or on the pillar: these layers are formed of laminæ disposed in the same manner as those of the inner layer of the body of the shell, and, indeed, may be considered as repetitions of this part.

The animals of some genera, as for instance *Cypræa, Ovula, Erato,* and *Marginella,* deposit, at the same period, on the outside of their shells an additional coat covering the lip and back, which may also be considered as a continuation of the inner layer, since it agrees with this layer in the position of the laminæ: it changes its character, however, on becoming external, being harder, more compact, and often differently coloured. In all these cases the sides of the mantle of the adult animal are expanded into wing-like processes, which are reflected over the shell, and deposit the additional layer. In the *Cypræœ, Erato,* and *Ovula,* in which the lobes of the mantle are large and nearly meet, there is left a differently coloured line at the place of their junction, which, on account of the left lobe of the mantle being usually the largest, is generally situated on the right side of the back, and is called the dorsal line: this line is not observed on the *Marginellæ,* the lobes of the mantle being in them less developed, and leaving a broad uncovered space on the back.

It is probable that the polished coat of the *Struthiolaria oblita* is formed in the same manner, but the animal of this shell has not been examined. From the reflected form of the lip, however, in other species of that genus, and from the edges of the mantle in the other genera of the family of *Strombidæ* (to which *Struthiolaria* evidently belongs,) becoming developed when the animal attains its full growth, as is proved by the expansion of the lips of the *Strombi* and the lobed form of those of the *Pterocerœ* and *Rostellariœ,* it is easy to suppose that its lobes may even become completely reflected.

The species of *Cymbium,* when fully grown, or under particular circumstances, are often covered externally with an additional glazed coat, which is apparently deposited by the foot, as the animals of these shells do not appear to be provided with large lobes to their mantle. This coat being deposited over the periostracum, is liable to be broken off.

There is deposited on the sides, and more especially in the posterior part, of the cavities of the upper whorls of many of the spiral univalves, a transparent calcareous concretion, which lines, and more or less fills up the cavity. This deposit may be observed lining the cavity of the upper whorls of *Mitra episcopalis, Triton pileare, Cassis glauca, Voluta hebræa*, and several other shells. In some, which have an elongated acute spire, as in the various species of *Fasciolaria*, and in the turreted shells, such as the *Terebræ, Cerithia* and *Turritellæ*, it entirely fills the cavity of the tips, which, from their small size and original thinness, would otherwise have been liable to be broken. Its deposition is not confined to adult shells, for I have observed it filling the cavity of the upper volutions, and lining the succeeding ones, in a slit specimen of a young *Strombus gigas* in the possession of Mrs. J. P. Atkins, to whom I take this opportunity of expressing my thanks for her kindness and liberality in allowing me to examine the numerous dissected shells in her collection.

In those Volutes which retain the nucleus (or that form which the shell has when first hatched,) that part, which was originally very thin and brittle, is speedily filled up with the deposit in question. In fact, all shells whose spires are exposed, and, being thin in their young state, would be liable to be broken off by the action of the sea, have that part strengthened by the internal deposition of calcareous matter.

The distinction between these and the decollated shells, such as *Bulimus decollatus, Cerithium decollatum*, &c., is, that in the latter, the animal, instead of lining the upper whorls with an internal coat, suddenly withdraws its body from them and forms behind its extremity a concave septum; and the vital communication between the body and the apex of the shell being thus cut off, the latter part decays, in the manner of a dead shell, and falls off in particles*.

The greatest development of the deposit mentioned above is to be observed in the genus *Magilus*, in which the young shell is very thin, shaped like a *Purpura* and of a crystalline texture; but when the animal has attained its full size, and has formed for itself a lodgement in a coral, the greater part of the cavity of its shell is filled with a glassy substance, leaving only a small conical space for the reception of its body: layer after layer of this substance are then deposited in rapid succession, in order to keep the body of the animal on a

* M. de Blainville refers the decollation of the spire to the inner surface of the cavity of the shell becoming filled with a very brittle glassy deposit.

level with the top of the growing coral in which it is buried, until its shell is almost lost in the quantity of glassy matter subsequently formed.

The shells of the prismatic crystalline structure exhibit, when broken, a quantity of short fibres perpendicular to the surface: when examined, these are found to be mostly hexagonal prisms, with a few smaller polyhedral prisms interposed. This structure, which has been repeatedly described, is to be observed in the tube of the large *Teredo* from Sumatra, in the vitreous deposit of *Magilus*, and in many bivalves, especially those which belong to the families of *Mytilidæ* and *Aviculidæ*, as the *Pinnæ*, Mother-of-pearl shells, &c.; and it may likewise often be seen in fossil shells, such as the *Inoceramus*, fragments of which, exhibiting this structure, are frequently found imbedded in flints.

On the other hand, shells of the concretionary structure exhibit, when broken, a nearly uniform texture: they separate, when heated, into numerous thicker or thinner laminæ; and when digested in weak muriatic acid, the lime is dissolved, leaving a great number of thin plates of animal matter, which retain the original shape of the shell. In general, the plates of which these shells are composed are very thin, and closely applied to each other, forming by their union a hard and compact texture.

The pearly or iridescent lustre appears to be confined to shells of this texture, in which it is very general; a circumstance which induces me to believe that this lustre depends in a great measure on the thinness and number of the laminæ of which the shell is formed *.

This variety of structure is found to constitute the whole shell of the *Anomiæ* and *Placunæ*; and to form the inner coat of those shells which have pearly insides, as the *Turbines*, *Haliotides*, *Uniones*, &c., as well as the laminar portion of the *Pinnæ* and Mother-of-pearl shells.

When such shells disintegrate, they separate into very numerous thin lamellar scales of a pearly grey colour and silvery lustre. The Chinese are aware of this circumstance, and use the particles of the disintegrated *Placunæ* as silver in their water-colour drawings. I have myself used some of this silvery powder, brought to England by Mr. Reeves, for the same purpose, in colouring the figures of fish, with good effect: it is not quite so brilliant as the

* The iridescence of the *Turbinella prismatica* and of *Bulimus cactivorus* appears to depend upon the texture of the periostracum.

powdered leaf metal, but it has the advantage of not changing colour by exposure.

In some shells of this structure the layers are thicker, and the animal matter is deposited in larger quantities, giving the shell a foliaceous appearance. In these the calcareous particles are large, opake, white, and earthy, like chalk. This is well exhibited in the common Oyster; and is also found, not so distinctly developed, in the *Pectines,* and on the outer surface of those shells which are internally pearly, such as the *Haliotides, Turbines,* &c. The animal matter between the laminæ is sometimes very unequally deposited: it is found forming large brown spots in the pearly coat of many of the *Haliotides,* especially in the *Haliotis Midæ,* and *H. splendens,* in which these spots produce beautiful variations in the colouring and pearliness of the shell.

In many of the fresh-water bivalves there is deposited between the layers of the shell a lamina of animal matter, similar to the periostracum. In the genera *Etheria* and *Mulleria,* such a coat is deposited between nearly all the layers, giving them a very peculiar olive-green colour, and having minute dots on its surface. The shells in question appear to be extremely liable to be eroded by the water, and these successive depositions of animal matter enable them to offer a new layer of periostracum to protect each succeeding plate, as the one above it gives way to the destructive influence of the medium in which they reside. A similar deposit of animal matter is also often found forming green stains in the pearly inner coat of the various species of *Uniones,* and it sometimes protects from the action of the water the inner part of the umbones of shells which have been eroded. In the upper valve of *Ostrea cornucopiæ,* I have observed the thick inner layer to be rather prismatic, and the outer part of the laminæ to be separated by layers of periostracum.

In some shells of this kind, there are left between the plates larger or smaller spaces, which are generally found filled with water. These spaces are sometimes met with in the common Oyster, and they occur not unfrequently in a large *Spondylus,* which is known to the dealers, on this account, by the name of the *Water Spondylus.* In the latter shell it is not unusual to find these cavities, which are sometimes of a large size, in both the valves, recurring one on the top of another, and giving the valve, when cut through, the appearance of a chambered shell; but having no siphon passing from one septum to the other. There can be little doubt that these laminæ, the concave plates at the end of turreted shells, and the septa of the regularly chambered shells, are all deposited in the same manner, the body representing the model on which they are formed. But it is not so easy to understand why such cavities should be left in these shells, especially in the upper valves, as it is to account for the existence of the analogous structure in turreted and chambered shells, the flat form of their valves enabling the animals of the former, as we might suppose, to extend the diameter of the existing cavity, when larger space was required for their accommodation, without constructing one altogether new. In the *Etheriæ*, cavities in the form of small vesicles, or very thin bladders, are also left between the plates. The cavities in the *Ostreæ*, *Spondyli* and *Etheriæ* are, I have reason to believe, filled with water when the animals are alive; and this also appears to be the case, from Mr. George Bennett's account, with the chambers of the Nautilus; but the water soon evaporates through the pores of the shell, if kept in a dry place. I have never observed this peculiarity except in those bivalve shells which are immediately attached by their outer surface to other bodies.

Many shells are composed entirely either of the rhombic crystalline or of the concretionary structure; but I know only of a single instance (and that occurs in the tube of a shell,) in which the whole mass affects the prismatic crystalline structure. In all other shells of this latter texture, the inner and front part, which is occupied by the body of the animal, is always covered with a coat of the laminar concretionary texture.

4. *On the Power possessed by Mollusca of dissolving Shells, Rocks, &c.*

It has been generally believed, and indeed sometimes most positively asserted, that Molluscous animals do not possess the power of reabsorbing the matter of their shells when once deposited. The following observations, I think, will distinctly prove that this theory is quite unsupported by fact.

If a Cone, an Olive, or any shell whose last whorl almost completely envelopes and protects the rest, and whose cavity is much compressed, allowing only a small space for the convolutions of the body of the animal, be slit down, either from the apex to the front of the axis, or across the body volution, at a little distance before the suture, it will be observed that all the septa between the different whorls are extremely thin and transparent; and when these septa are minutely examined, they will be found to consist of only a single one of the three plates of which all such shells are originally composed, which plate will be seen to agree in structure with the inner one of the three. On tracing these septa to the outer whorl, it will be observed that every part of them, during the various stages of growth of the shell, has been once a part of the outer whorl; and since we know from experience that the outer whorls of the young Olive and young Cone are as thick in proportion to their size as those of the adult, there is little reason to doubt that each of these septa was originally formed of three plates, in the same manner as the other parts of the shell. That this was actually the case, and that the part remaining is the continuation of the inner plate, the other two plates having been removed by absorption, may be proved by the fact that the other two layers of the same volutions are distinctly visible on the exposed part of the spire, and on the front part near the pillar, while they are deficient only on the thin part of the septa; and if the outer half of the penultimate whorl, or rather the half-whorl just within the mouth, be examined, the two outer layers will be found to be there only in part absorbed, leaving a shelving edge directed towards the cavity of the shell*.

A still stronger instance of the absorption of the septum may be observed in the shells formed by some of those Mollusca whose respiration is effected by means of lungs, as, for instance, the *Auriculidæ*. In the young shells of this family the septa which separate the whorls are incomplete, and twine nearly parallel to each other. As the shells increase in size, the later formed septa become much more oblique and broader, and at length completely separate the cavities of the whorls. When, however, the animals of many of the species, especially those of the *Melampi*, approach maturity, the whole of the septa, except the outer half of the penultimate volution, are absorbed, leaving a simple cavity in the upper part of the shell. On further examining the remains of the septum, it will be found that the absorption has taken place on the outer

* It is probable that some Bernard Crabs have also the faculty of dissolving shell, for it is not unusual to find the long fusiform shells, (such as *Fusus*, *Fasciolaria* and *Turbinella*,) which are inhabited by these animals, with the inner lip and great part of the pillar on the inside of the mouth destroyed, so as to render the aperture much larger than usual. I have never seen this erosion except in dead shells which had been inhabited by Hermit Crabs; but it does not occur in all that are so tenanted, for I have also observed these animals occupying the shells of *Fusi*, &c. in which the lip was in its usual state.

side, as is proved by the surface shelving down to form an acute edge on its inner side.

A similar absorption may be observed in the inner whorls of the *Harpa articulata*; but it is in this case confined to the central part of the septa, and all the coats are partially dissolved, so as to leave a slit between the cavities of the different whorls. An absorption of the upper septum also takes place in some of the *Neritinæ*, as the *Neritina fluviatilis*; and it was on a character derived from this circumstance that De Montfort established the latter shell as a genus under the name of *Theodoxus*.

These facts distinctly show, that as the animal enlarges the mouth of its shell, it absorbs in a greater or less degree the substance of the inner whorls. This process of absorption, besides furnishing the animal with calcareous matter towards the enlargement of its shell, gives more space for the lodgement of the body, and renders the shell far lighter to carry; and these advantages are gained without in the slightest degree detracting from its strength, as the outer whorl and spire, which are alone exposed in shells of this form, remain at least as thick as in most other shells.

In many other univalves, the animal, before depositing the laminæ which form the inner part of the mouth, absorbs the outer layer of the penultimate whorl, as is evidenced by the ridge with which that part is often surrounded. This is particularly the case in the various species of *Turbines*, as in *Turbo coronatus*, *T. smaragdus*, *T. sarmaticus*, and in some *Fusi*, as *Fusus despectus*. But it is most distinct in the *Purpuræ*, where the Lamarckian character of the genus depends upon this absorption, which causes the concave flatness of the inner lip. In the *Murices*, and other shells which have spines or branching appendages on the front of the whorls, the site of which appendages the succeeding whorls must overlap, these processes are generally absorbed by the animal before it produces the inner lip over their base, as their length would otherwise offer an obstacle to the regular progress of the shell. This absorption of the outer part of the last whorl but one, and of the spines, is evidently effected by the edge of the mantle. In specimens taken while the process is going on, there may be observed a notch, formed by this means, in the base of the spines or processes, the completion of which causes them eventually to separate from the shell. A similar effect is produced on a new species of Sun Trochus, *Imperator*

Guilfordiæ, where the keels of the whorls are furnished with a central series of spines, which are removed before the mouth of the shell is continued.

In some shells, however, which have only short processes, as in the variety of the *Pyrula bucephala* with two rows of spines, the front rows are not absorbed, the inner lip being deposited of such a thickness as to cover them. A similar circumstance may be observed in a monstrous variety of *Strombus pugilis,* with two rows of spines, of which there is a specimen in the British Museum.

In the young state of the *Fissurellæ,* the hole by which the fæces pass out of the shell is placed a little in front of its recurved and spiral apex: in this state it has been formed into a genus under the names of *Rimula* and *Puncturella.* But as the animal grows, the hole enlarges in size backwards, and the true apex being absorbed, the hole appears in the adult shell to be placed on the tip, and in some species even to extend behind it.

The animals of many species absorb parts of their shell at regular periods: thus the Tritons, which at each of the periodical interruptions of their growth form a thickened edge to their lips, when they again commence enlarging their shells, generally absorb this thickening both as regards that part which had been deposited on the pillar and that which formed the ribs and teeth of the outer lip; for on examining the cavity of any of these shells, it will be found quite smooth and free from interruption. Such an absorption does not, however, take place in some of the larger *Cassides,* and in the genus *Persona,* in which the thickening of the former lips remains after the shell has enlarged in size, and forms prominent bands on the parietes of its cavity. But a similar periodical deposition and absorption of the thickening of the outer lip takes place in many of the land shells, as the *Helices* and *Bulimi*; in most of which there is formed, at every interruption of their growth, an internal rib, just within the edge of the mouth, which is removed when the animal again begins to increase its shell. This is particularly visible in the genus *Scarabus,* where the interruptions are regularly periodical, each period of growth occupying half a whorl, as in the *Ranellæ.*

Mollusca not only have the power of absorbing their own shells, but they also possess the faculty of forming cavities in those of other animals. When a specimen of *Pileopsis* attaches itself to the surface of a shell, it generally leaves in the place of its attachment a depression of its own size, and furnished with a horse-shoe-shaped ridge: such cavities are sometimes formed even in other specimens of the same species. It appears moreover to be of little importance how great may be the hardness, or what may be the structure, of the shell on which they fix; all yielding with equal readiness to their absorbing powers. It is not unusual to find holes thus produced nearly a quarter of an inch in depth in the very hard external coat of the larger *Turbines*; and similar depressions are found in *Purpuræ, Strombi, Fissurellæ, Chitones, Patellæ,* &c.

The animals of *Siphonaria, Patella,* and an allied genus* (*Lottia*), which appears to be peculiar to the coast of South America, have the same faculty, but in a less degree, and the cavities formed by them are destitute of the horse-shoe-shaped ridge. The depressions produced by the *Siphonaria* and the *Chitones* have, however, an unequal groove round their margin, which is largest and deepest on one side, occasioned probably by the shell being generally raised on the opposite side to admit of the access of air to the branchiæ. The *Patella cochlea* is often found at the Cape of Good Hope, where it lives almost exclusively, attached to a large species of the same genus, on the surface of which it forms a flat disk, exactly the size of its mouth. To form these flat disks, (of which there are so generally two, one on each side of the apex of the larger *Patella*, as almost to form a character of the species,) and to assist in the increase of its size, the animal appears also to absorb the coralline or other similar substances with which the larger shells are abundantly covered. The common *Patella* of our own coast, when long adherent to another shell of its own species, to chalk, or to old red sandstone or limestone, also forms for itself a deep cavity of the same form as its shell, and evidently produced by the dissolution of the surface to which it is affixed.

The animals of the several species of *Vermetus*, especially of that called by Daudin *Spiroglyphus*, have the faculty of producing by absorption a groove in the surface of many very hard shells, such as the *Trochi, Haliotides,* and *Fissu-*

* This genus must be extremely perplexing to those systematists who attend only to the form of the shell without paying any regard to its animal inhabitant. The shells of *Patella* and *Lottia* do not in the least differ in external form, and yet their animals belong to very different orders, the one having the branchiæ placed round the foot, as in the Chitons, and the other having them placed on the side of the neck, like the *Fissurellæ*, from which indeed it chiefly differs in having only one branchia.

rellæ; which groove they cover with a calcareous deposit, and thus form it into a tube. The history of *Spiroglyphus* is altogether peculiar: the young animal, when first hatched, is covered with an ovate regular spiral shell, consisting of a whorl and a half, and in appearance very like the young shell of *Magilus,* with which, indeed, its affinity is very striking; it soon attaches itself to the surface of a shell, in which it commences the formation of a canal, narrow and shallow in the first instance, but becoming deeper and wider as the animal increases in size. Both the canal and its shelly covering retain for some time the regular discoidal spiral form, and the whorls are sometimes so closely impressed on each other, that the animal actually absorbs part of the tube which it had previously deposited, in order to make room for its new whorl. In one instance which has fallen under my observation, it had left only a very thin transparent plate between itself and the cavity of the tube. When, however, the animal has nearly attained its full size, the shell assumes an irregular form, and is sometimes extended into a straight line, and at others closely twisted over its former shell, which, under such circumstances, it often absorbs. It is not uncommon to find several young animals of this genus burying themselves in the tube of an adult shell.

These unequivocal instances of the power of the Mollusca to dissolve their own shells, and to make holes in the shells of other animals without the exertion of any mechanical force, but by simply applying their foot to the part to be dissolved, afford strong grounds for believing that the holes formed by the regular boring Mollusca, such as the *Pholades, Petricolæ, Venerupes,* and *Lithodomi,* in shells and calcareous rock, are produced in a similar manner; and this belief is strengthened by the following considerations:

1st. That the animals of most of the boring shells are furnished, like those of which I have just been speaking, with a large foot, more or less expanded at the end.

2ndly. That the holes bored by some of the *Petricolæ* and *Gastrochænæ* are compressed, and so exactly fit the shell, that it would be impossible for the latter to rotate on its axis in such a manner as to use the asperities of its surface for the purpose of rasping, as some conchologists have supposed. I have also seen specimens of *Pholas pusillus,* the back valves of which were so much distorted, as to demonstrate the impracticability of such a process, a projecting part of the back having evidently been fitted into a cavity on one side of their cell; yet these *Pholades* appeared to have enlarged subsequently to the distortion having taken place. Those of the Barnacles which bore, such as the genera *Conchotrya* and *Brismeus* (and probably *Lithotrya*), form an oblong compressed hole, of the exact size of their shells. Specimens of *Brismeus*, in my collection, are attached to the side of an oyster-shell, in which they have destroyed part of two or three plates to form such a cavity; but although the shells of these boring Cirrhipedes are furnished with raised lamellæ, the projections are placed across the valves in such a manner that no motion that could be given to them would enable them to rasp a hole.

3rdly. That all the boring shells are covered with a periostracum, which is thin in the *Teredines, Pholades, Laseæ*, &c., and thick in the *Lithodomi*, and which, if the animals used the outer surface of the shell as a means of boring, must be very speedily rubbed off. Such a fact would be readily observed, as this part is never renewed after having been once destroyed; which is easily understood when we consider, that it can only be formed on the edge of the shell before the deposition of the shelly matter has advanced beyond it.

4thly. That although the shells of *Teredines, Pholades*, some *Petricolæ*, &c., are covered with short spines and striæ by means of which they might be supposed capable of rasping stones, other boring shells, such as the *Laseæ* and *Lithophagi*, are smooth.

5thly. That I have not observed shells of this kind to bore into any other substances (wood excepted,) than shells, calcareous rocks, clay, marl, chalk, limestone, and sandstone united by a calcareous cement; nor do such shells, as far I have seen on the coast of Devon, attack the latter rock, except when it has lain a long time under the sea, and become as soft as clay. Colonel MONTAGU states that he has seen specimens of *Gastrochæna* which had bored into fluorspar and granite; but an examination of his specimens in the British Museum proves that what he regarded as fluorspar are merely crystals of carbonate of lime; and although the shell is not uncommon on the coast of Cornwall and Guernsey, I have never seen it produce the slightest impression on the granite rock, even in its disintegrated state. Instead of attempting this, the animal changes its habits, and generally chooses a slight crack in the granite rock, in which it forms for itself, like some of the fossil species of the genus called

Fistulana by LAMARCK, a calcareous case, partly constructed of such fragments of shells or stones as may be thrown within its reach. The granite, indeed, appears completely to resist all the dissolving powers of the Mollusca. Thus in some structures, as the Plymouth Breakwater, for instance, in which limestone and granite are employed together, and placed side by side, the *Patellæ* form their rounded holes in the former; while they do not in the slightest degree alter the surface of the latter, except in general by clearing from off it any calcareous substance which may have previously grown upon it. I have one specimen beautifully illustrating this latter fact, a young *Patella* having affixed itself to the shelly base remaining from a Barnacle, in which it has dissolved only the part beneath its foot, leaving the rest forming a ring around its shell.

Many of the boring Mollusca, especially the *Lithodomi* and *Petricolæ*, cover the hinder part of their shells with a calcareous coat, which is often of a spongy texture, and differs from the shell in internal structure. This is probably the dissolved part of the rock again deposited. Many also of these animals, as the *Gastrochænæ*, *Clavagellæ*, and *Teredines*, secrete constantly, and others, as the *Lithodomi*, under particular circumstances, a calcareous deposition, with which they line the inner surface of their holes.

The determination of the existence of this power of dissolving shell and calcareous matter does not, however, remove the difficulty with regard to those shells which bore into wood; although it is not impossible that this substance may also be dissolved by the same means. And this appears to me the more probable, as, although there are some species of *Pholades*, such as *Pholas pusillus* and *P. rudis*, which I have never seen in any other substance, I have found others, such as *P. dactylus* and *P. candida*, indiscriminately in chalk, marl, limestone, red sandstone, and wood; and it is difficult to suppose that these species adopt different means of boring when employed in penetrating the latter substance.

Possessing this power of absorbing their own shells, the shells of other Mollusca, and calcareous rocks, it is remarkable that these animals do not exert it for the purpose of removing extraneous obstacles which may oppose their progress in the formation of their shells. In the collection of the British Museum is a specimen of *Pyrula bezoar* that appears to have grown with perfect regularity until the formation of its last half-whorl, which is thrown considerably more than half an inch out of its proper position by a group of Barnacles. These shells had probably attached themselves to the back of the *Pyrula* at an earlier stage, and, as the latter increased in size, at length filled the place that should have been occupied by the inner lip, which, on meeting with this interruption, diverged from its course, and was thrown over the Barnacles. Had the shell not been taken until a later period, there can be little doubt that the animal would have at length destroyed the Barnacles, and completely hidden them from view, by continuing the whorl entirely over them; although it would appear that it had not the power to remove them by absorption while they retained their vitality. In the same collection there is also a specimen of *Strombus luhuanus* the spire of which has been much distorted in consequence of the temporary attachment of some parasitic shell, which subsequently became loose and has been detached.

In the collection of my friend Mrs. Mauger is a specimen of *Helix aspersa*, showing a similar deformity arising from the same cause; but in this case the obstruction has been produced by a young shell of the same species. The young specimen is attached to the spire, to which it had doubtless fixed itself during the dry season; and not awaking from its torpor so early as its older companion, the latter, when it commenced increasing the size of its shell, threw its new whorl partly over the smaller individual, which was thus inclosed in a prison formed by its own shell. In this instance, the form of the larger specimen is not much altered; but about one half of the young shell projects above the spire.

In like manner, the Cowries, and other shells which have an additional coat deposited on their back by the enlarged lobes of the mantle, on arriving at the adult age, cover in with this coat any body which may be accidentally attached to their surface. There are two specimens of *Cypræa rattus* in the collection of Mr. Gaskoin, on one of which a *Crepidula*, and on the other a Barnacle, is evidently so inclosed; and Humphreys, in the Portland Catalogue, described two specimens of the same shell in which he had observed a similar occurrence. Such accidents appear, however, to be rare, the extension of the mantle having in itself a strong tendency to prevent other animals from adhering to the surface of these shells.

A similar occurrence may frequently be observed in the shells of the genus

Cymbium, the glazed coat of which often includes *Balani* and particles of sand. The presence of such bodies under the glazed coat in these shells is so constant, that I am inclined to believe that the animal deposits this coat with the view of ridding itself of the irritation caused by the adherent sand and Barnacles rubbing against its foot, as the animal of the Chinese Pond Muscle (*Dipsas plicata*) deposits its pearls over buttons or spines which are artificially introduced into its shell.

5. *On the Deposition of Shelly Matter by the Foot.*

It has been very generally supposed, that the calcareous matter of which shells are formed is secreted only by the mantle of the animal; and it has consequently been taken for granted, that the expanded base of the *Cassides* and *Personæ,* the broad inner lip and the closed back of the *Cymbia,* and the polished coat on the outer surface of an *Oliva* or an *Ancillaria,* were each and all deposited by some expansion of the mantle.

I have lately, however, had an opportunity of observing the animals of all these, and of many other genera, in the Museum of the Jardin du Roi at Paris, where my excellent friend Professor De Blainville, who was at that time keeper of this part of the collection, kindly allowed me to examine at my leisure all the stores of Mollusca collected together for a long series of years by the late Baron Cuvier, as well as those brought home by MM. Quoy, Gaimard, and Lesson, from the recent voyages of discovery in which those naturalists took part. At the same time I was allowed, by the kindness of M. Quoy, to consult and copy the numerous drawings made by him, during his voyage, from the animals whilst alive and walking about. From this examination I am enabled to state, that in all the shells just named the shelly matter in question is deposited, and most probably secreted, by the upper surface of the foot, which is very large, and not by the mantle, which, on the contrary, is small, and not expanded beyond the edge of the mouth. This is most obviously the case in the *Cymbia, Olivæ* and *Ancillariæ,* which have so large a foot that the shell appears to be actually immersed in it. Animals of these genera, drawn from life, are figured by Adanson in his Voyage to Senegal, and by Forskahl in his Fauna Arabica. The *Murex anus* of Linnæus, which has been referred by Lamarck to his genus *Triton,* differs in this particular from all the other animals placed by him in that group, and agrees with the genus *Cassis*, the expanded base round the mouth being produced by the very widely expanded foot: it forms the genus *Persona* of DE MONTFORT.

It is remarkable that this fact should not have been before observed, more especially as the operculum of all molluscous animals which are furnished with such a protection is secreted by the back of the hinder part of the foot, where there is no extension of the mantle.

6. *On the Operculum.*

The part usually called Operculum is a horny or shelly plate, adherent to the back of the hinder part of the foot of many Gasteropodous Mollusca. It is always (except perhaps in *Navicella,*) attached to the free end of the large muscle by which the animal is affixed to its shell; by the contraction of which the operculum is brought into such a situation as more or less completely to close the mouth of the shell when the animal is drawn into its cavity. It has hitherto been observed only in those Mollusca which have pectinate branchiæ, and in two genera (*Cyclostoma* and *Helicina*) amongst the pneumonobranchous land shells.

The muscle by which the animal is attached to its shell is generally affixed to the hinder part of the cavity, a little within the mouth: in the long spiral shells, which have a small or moderately sized mouth, it is simple, and forms a single scar on the pillar; but in those which have a large mouth and a slightly developed spire, as *Neritina* and *Nerita,* it is divided into two portions, one attached at each end of the pillar lip; and in those which have the mouth almost as large as the cavity of the shell, such as *Capulus,* it is divided into two nearly equal parts, which extend along each side of the cavity, and form what is generally called a horse-shoe-shaped muscular scar. The insertion of the muscle forms similar scars on the inner side of the operculum. Thus in most opercula there is only a single scar: in those of *Nerita* and *Neritina* there are two scars, one at each end; and in *Capulus* the operculum has a horse-shoe-shaped impression. The only exception, as far as I am aware, to this rule, is in the genus *Concholepas,* where the muscle forms a continuous band nearly round the cavity of the shell, while the operculum, which is very small, is marked only with a single subcentral ovate scar.

By far the greater number of these bodies are formed of a more or less condensed cartilaginous matter, similar to the periostracum; and they are often strengthened by a deposit of calcareous shelly matter on their outer side, or more rarely by a similar deposit of greater or less thickness on their inner surface, in some few instances extending to both. The deposit on the inside may be compared to the glassy enamelled coat which is found in the cavities of certain shells, and that on the outer surface may be considered analogous to the hard enamelled coat covering the backs of the Cowries. A few opercula, such as those of the genus *Neritina*, appear to be truly shelly.

The opercula agree with the valves of shells in being developed on the embryo while included in the egg, and in increasing in size by the addition of new matter round the circumference of the base of the cone of which they are formed: they also agree in the cone being sometimes simple and straight, and sometimes curved into a spiral form. That ADANSON regarded them as analogous to the valves is evident from his calling the shells which are provided with these lids on their mouths *Sub-Bivalves*. The principal difference, indeed, between the operculum and the valve of a shell consists in the former having no cavity, the cone of which it is formed being either very much depressed, so as to become nearly flat, or even concave, as in the annular or some subannular opercula, or very much compressed, forming only a spiral ribband, as in the spiral ones. Opercula are never attached to their shells by ligaments or by any other means than that of the adductor muscle; and they are always free, except in the genus *Capulus*, which offers a remarkable anomaly in this part being immediately attached by its outer surface to other marine bodies.

It is proper to observe, that in describing the operculum I have called that the anterior margin, which is nearest to the pillar of the shell, as when the animal is walking this part is directed towards its head; and the right and left extremity are the parts corresponding with the right and left sides of the body. When the operculum is placed in this position, the left end is that which fits into the front, and the right that which corresponds to the hinder part, of the mouth. This distinction of parts may, at first sight, be thought trifling; but to the practical zoologist its importance is very great. The position of the nucleus of the operculum is, for example, almost the only conchological character by which four distinct genera of shells can be divided into groups, although their animals differ both in external form and in internal anatomy. In the genera *Bithynia* and *Paludina*, which have the nucleus of the operculum nearly central, the animal has short tentacles and no air bag; whilst in *Ampullaria* and *Ceratodes*, which have the nucleus of the operculum on its anterior side, the animals have very long tentacles, and a large air pouch by the side of the branchiæ.

Opercula may be divided into three very distinct kinds, according to their form and manner of growth, and these may be again subdivided according to the mode in which they are covered with various deposits.

The annular operculum may be considered the most simple, the very depressed cone of which it is formed being nearly regular, with the apex more or less central, and the coat of new matter, by which it is increased in size, forming complete rings round its circumference; in which particulars it may be compared to the simple conical shells of the genera *Patella, Fissurella, &c.* This kind of operculum does not alter its place in the mouth, and the muscle of attachment only moves nearer towards its anterior edge as the addition of new matter on that side renders such a displacement necessary in order to keep the muscle in its proper situation with regard to the pillar of the shell.

The subannular opercula may be regarded as intermediate between the annular and spiral forms, partially combining the characters of each; but I think it better to consider them apart from the others, inasmuch as they are peculiar to those animals of the Ctenobranchous Mollusca, which are provided with a siphon in front of the mantle for conducting the water to their branchiæ, such as the *Murices, Buccina, Strombi, Melaniœ, Melanopsides, Aulodi,* and the anomalous genus *Phorus*. They are all of a horny texture, and are characterized by their very depressed cone being somewhat oblique, with its nucleus placed at or near the left end, and the lines of growth forming more or less complete rings around it, but always becoming wider apart from each other as they approach the right side. The left end, towards which the nucleus is placed, is generally acute, and the opposite extremity rounded, which is just the reverse of what takes place in the annular opercula, where the right end is acute and furnished with a fold proceeding from the nucleus, and the left side is rounded and broad. In most of the opercula of this division the muscular scar occupies the greater part of the internal surface; is marked with more or less regular concentric rings; and is surrounded by a thickened callous deposit, which is broadest on the outer side. This scar appears gradually to approximate towards the right side of the operculum, the part left free, as the scar advances, becoming covered by the callous deposit. The lines on the scar appear to be very constant in the various species, but they are sometimes distorted, and form several centres instead of one. They have no relation to the rings of growth on the outer surface, but have generally a centre of their own placed at some distance from the left end of the operculum; and they appear to be formed by the successive additions made to the edge of the adductor muscle, which is marked with lines resembling those on the scar. The greater number of these opercula do not alter their relative position in the mouth of the shell; but a few, like those of *Fusus fornicatus*, in which the end of the cone is slightly curved, move during their lives perhaps to the extent of a quarter or half a turn on the end of the muscle. In some instances, as in the operculum of *Strombus*, where the foot of the animal is very small, the apex or left extremity is obliquely elevated and free: as the rings of growth are added, this extremity elongates, and acquires such a resemblance in form to the claw of an animal, as to have induced the ancients to call such opercula *Elks' hoofs*. The scar of attachment is small in comparison with the size of the operculum, and is situated on its right side: it is cordate and marked with oblique rugose grooves, and with a strong central ridge, which is continued in the form of a rib down the middle of the under side of the free part of the operculum. In some species the posterior edge of the operculum is serrated. In both the annular and subannular divisions, the disk to which the operculum adheres is formed entirely of the muscle of attachment, and of a membranaceous fringe by which its edge is surrounded. This fringe is free from the back of the foot and is widest posteriorly: it doubtless secretes the coat of the layer of growth, and the deposit which borders the edge of the scar, whilst the muscle itself is provided with the means of secreting the proper coat of the scar.

The spiral opercula are so called because the elongated, cartilaginous or shelly, compressed, ribband-shaped cone of which they are formed is twisted into a spire of few or many whorls. In these, the new matter by which they increase in size is deposited only on the extremity of the last whorl, which in spiral opercula may be regarded as analogous to the mouth of spiral shells, as the entire circumference of the annular opercula, with their subcentral apex, is analogous to the edge of the base of a *Patella*. The lines of growth are marked by curved concentric lines extending transversely across the whorls. Opercula of this character vary much in the number of their whorls: when the whorls are few in number, the cone increases rapidly in size, and the operculum is of an ovate shape, with the nucleus approximated to the left extremity; when the whorls are more numerous, the cone increases in size more gradually, the nucleus is central, and the operculum is more orbicular. In all these cases the edge of the extremity of the last whorl is constantly anterior, that is to say, when the operculum is in the mouth of the shell, this part of it is directed towards the inner lip: when the operculum is ovate and of few whorls, it generally occupies the whole length of that lip; but in the orbicular and many-whorled opercula, it is directed towards the hinder part of the inner lip, near the angle formed by its junction with the outer. Now every time that the animal adds a new layer on the end of the last whorl, the operculum, to allow of this part continuing to occupy the same position, must make a slight turn backwards on its centre, which is the nucleus of the spire, whether the spire be placed towards one end or in the centre of the operculum. This rotation on the adductor muscle, although it may at first sight appear improbable, bears a striking analogy to several other phenomena of the same kind which are continually taking place in the animal economy: I need only instance two well known and apposite examples;—1stly, the gradual change of situation of the adductor muscle as it passes down the pillar of spiral shells, which in some of the long turreted species, such as *Turritella Archimedes*, where there are as many as thirty whorls, must have been carried to the extent of thirty complete revolutions on this part;—and 2ndly, the change of place of the adductor muscle in bivalve shells. In the opercula of the *Littorinæ* and *Naticæ*, which consist of a few very rapidly enlarging whorls, the motion and consequent alteration of position of the place of attachment is very gradual and slow; but in those orbicular opercula which are composed of many gradually enlarging whorls, as in the *Trochi* and *Monodontæ*, the place of attachment must be continually changing, as many complete revolutions being made as there are whorls in the operculum. These are sometimes extremely numerous: in a small specimen of *Turbo pica* now before me, there are seventeen or eighteen, and in some *Trochi*

I have counted still more. In the spiral opercula, which thus rotate on their axis, the nucleus, which is the centre of motion, is always included in the scar, and adherent to the muscle of attachment: it is often furnished internally with a small spiral process, buried in the muscle and resembling the end of a screw. On the contrary, in the annular and subannular opercula, which have no rotatory motion, the nucleus is often removed from the point of attachment, as is well illustrated in those of the *Strombi*.

In many of those ovate or suborbicular spiral opercula which are formed of a few rapidly enlarging whorls, as, for example, those of the genus *Littorina*, the inner surface exhibits the lines of growth as well as the outer, there being in these cases no internal deposit. In these opercula, the adductor muscle is anterior, and occupies more than half the disk to which they are attached, the remainder being formed by a membranaceous flap attached to the hinder edge of the muscle. Along the whole anterior edge of the muscle is a ridge, separated from it by a deep groove, which evidently secretes the additions to the operculum: in one specimen I thought that I could observe the edge of this part attached to the ridge, in like manner as the edge of the periostracum is adherent to the mantle of many bivalve shells.

The operculum of the *Naticæ* is formed on the plan just described; but its inner surface is covered in addition with a smooth pellucid coat, resembling the inner coat of the subannular opercula, and forming a curved tubercle over the nucleus. This coat is marked with two muscular scars, the one lanceolate and central, and the other anterior, linear, and only separated from the first by a narrow polished band; the latter is extended to the back of the tubercle, where it forms a deep oval impression. The adductor muscle occupies the anterior half of the disk, its middle part, which produces the central scar, being of a dark colour, while its front edge, giving rise to the anterior, is white: it is furnished with a thin membranaceous band posteriorly, which is broadest on the right side; and the remainder of the disk is formed of a thick semioval elevated fleshy flap, quite distinct from the back of the foot.

The opercula of some shells which have plaits on their pillar, are very thin, and are furnished with a moveable flap on the left side of their anterior margin, which passes over the plaits. I first observed this in the common *Tornatella*, and afterwards in *Turbo pallidus* of MONTAGU, (the genus *Odostomia* of Dr. FLE-

MING,) and have since verified it in *Pyramidella*. The subannular operculum of *Turbinella cornigera* has a notch on the middle of its anterior margin, and a plait running from the nucleus; but in this case the flap is not moveable.

The opercula of the genus *Neritina* agree with those just described, in their ovate form, and in being composed of few and rapidly enlarging whorls; but they appear to be entirely formed of shelly matter, and are marked both externally and internally with very minute concentric lines of growth. Like the operculum of *Littorina*, they are not covered with any internal or external deposit; but they have several peculiarities. The outer edge of their whorls is furnished with a broad flexible margin; and on the inner side, below the spire, are two diverging processes, the longer of which is curved and forms a tooth, placed near the left end of the anterior edge, which some have supposed to act as a kind of hinge on the sharp inner lip of the shell. The adductor muscle of this genus is divided into two portions, one placed at each end of the pillar: of these the hinder is the largest, and forms a submarginal scar along the end of the last whorl of the operculum, while the anterior is smaller, and forms an ovate scar behind the two processes. The disk to which these opercula are fixed is like that of *Littorina*, and there is a slight ridge extending the whole length of the front edge of the muscle, a little anterior to it, which probably secretes the shelly matter of the operculum: in this office it may perhaps be assisted by the edge of the hinder part of the mantle, situated just before it.

I might have been inclined to regard the operculum of *Navicella* as anomalous, had I not had an opportunity of comparing it with its ally *Neritina*, which has enabled me to explain its structure. In this genus, as in *Concholepas* and *Cryptostoma*, the mouth occupies so large a share of the cavity of the shell, and the hinder part of the foot of the animal is so short, that the operculum cannot be folded over in such a manner as to close the aperture. But instead of being very small, as in the two latter genera, the operculum is rather large in comparison with the size of the animal, and appears to serve a new purpose, viz. to separate the viscera from the upper surface of the foot, as the shelly plate does in the genus *Crepidula*. The part which projects externally is very small, and can only be compared to the flexible cartilaginous fringe on the edge of the outer whorls of the operculum of *Neritina*; whilst the shelly part which is included in the body of the animal is four times the size of the external portion, and appears to represent the anterior margin and the two processes of the operculum of that genus, greatly developed. The anterior process, which appears to be analogous to the curved projection in *Neritina*, is produced into a straight lanceolate ridge, and the posterior into a rounded strongly serrated edge; the straightness of these processes evincing that this operculum does not revolve on its axis.

Other ovate spiral opercula of few volutions have a concentrically ridged inner surface, and their outer surface covered with a shelly coat, which varies in thickness in the different genera, being thin in *Nacca, Phasianella* and some *Cyclostomata*, and very thick and convex in the genera *Turbo* and *Imperator*. The disk to which these opercula are attached is like that of *Littorina*; but anterior to the muscle there is a very deep groove, into which the operculum can be pushed, and which probably covers the front part of it like a hood, when the animal is living. I have little doubt that this hood secretes the thick external shelly coat, which is quite out of the reach of the disk, and which increases in size, like the rest of the operculum, by the addition of shelly matter to the edge of its last whorls. That this is really the mode of growth of that part is proved by its being in many cases marked with spiral grooves; while in others the front part of the last whorl is of a different colour from the rest of the operculum, as though it had been covered from the light. It has been sometimes thought that such shelly opercula are attached to the animals by their convex sides; but this is not the case in any of the many specimens that I have examined, in which the opercula were naturally attached to the back of the animal. Some of them have the outer edge of their whorls dilated and free, and occasionally even elevated in such a manner as to form a spiral ridge on the outer side: a structure which may be seen fully developed in the very beautiful operculum of a West Indian Cyclostoma (*Cyclostoma mirabile*, of Wood's Supplement, t. 7. f. 22.).

The operculum of *Nerita* agrees in form with that of *Neritina*; but differs in having no cartilage on its edge, which is furnished, instead, with a groove; in its outer surface being covered with a thick variously formed shelly deposit, as in the genus *Turbo*; and in its inner surface being lined with a thick, callous, polished coat. Between the outer and inner coats there exists a very distinct concentrically striated horny layer, like the operculum of *Littorina*; and the left muscular scar is deeply grooved, like that of the subannular opercula. This difference in the structure of their opercula forms an excellent distinctive character between these two genera; as do also the differences in the outer surface of those belonging to the genus *Nerita* between various species of that genus. Thus, for instance, the operculum of *N. polita* is smooth, with a transversely grooved marginal band; those of *N. exuvia*, *N. ornata* and *N. chlorostoma* are granular; and that of *N. peloronta* is smooth, with a broad convex marginal rib.

In the orbicular many-whorled opercula of the *Trochi*, the outside, which is generally concave, exhibits the volutions; and the inside is covered with a thick polished coat, marked with curved lines, produced by the successive enlargements of the muscular scar, radiating from the centre to the circumference.

An examination of the animal and operculum of *Trochus Pica* (which from its large size offers a good illustrative example of this form,) having enabled me to understand in what manner those opercula which appear to be the most complicated in their structure increase in size and thickness, I shall proceed to describe its mode of growth. A comparison with those of the other *Trochi* leaves little doubt that they are all formed and increase in size on the same principle.

The disk on the back of the foot of the animal to which the operculum is attached, shows three very distinct parts, viz. 1st, the muscle by which the operculum is affixed, which is semilunar, and occupies nearly the whole of the anterior half of the disk, having its hinder edge thin and membranaceous; 2ndly, an elongated triangular fleshy band, on the right side of its anterior part, which is separated from the muscle by a deep groove; and 3rdly, the back part of the foot, which is raised to the level of the muscle by an elevated border, attached in front to the membranes placed along the sides of the body of the animal, and is marked with minute concentric wrinkles, originating round a longitudinal fissure on its hinder edge, and becoming more and more transverse as they approach nearer to the muscle. This part of the disk merely forms a bed for the operculum to lie upon, without any attachment; it is semicircular, and is prolonged into a narrow process extending up the right side of the triangular fleshy band. If the inner side of the operculum be examined, it will also be found to exhibit three parts, differing from each other in colour and surface, but agreeing exactly in form with the three parts described as found in the disk: 1st, the scar of the muscle, which is green, and occupies nearly the anterior half of the operculum: 2ndly, on the left of the scar (that is, when the operculum is turned with its inner side towards the observer,) a triangular pale brown spot, occupying the margin of the extremity, and a triangular portion of the last volution: and 3rdly, a black and polished posterior portion.

There can be no doubt, as these divisions of the operculum agree in shape with the three parts observed in the disk, that they are severally deposited by them; and on further examination it appears that the volutions are in fact formed of three coats, each deposited by one of these parts. The new layers are first added to the extremity of the whorls by the small triangular fleshy band placed on the right side of the muscle. Afterwards, as the operculum is moved round in order to present a new end to the influence of the fleshy band, the newly formed part is covered by a black coat, secreted by the process of the back of the foot which extends up the right side of the band. Both these layers are eventually covered by a green coat, which is deposited by the surface of the muscle, and the part of this latter coat which is left exposed as the operculum turns round on its axis, is again covered by a second thin black shining coat, deposited by the posterior part of the disk, or that which is formed of the elevated portion of the back of the foot.

That the spiral opercula actually revolve upon their axes is proved by the manner in which these coats are deposited, as well as by the circumstance that the front edge of the last volution is always directed towards the hinder part of the inner lip of the mouth of the shell,—a position which it could not constantly retain, in conformity with the manner in which these opercula enlarge, without undergoing this revolving motion. A convincing proof that the green coat of the muscular scar which occupies the outer edge of the front part of the penultimate, and the hinder part of the last whorl, has covered all parts of the operculum, except the front half of the last whorl, which in turning has not yet been brought under its influence, may be readily obtained by scratching off the thin black coat, when the green will be found beneath it in all parts except that last referred to. The surface of the scar itself also demonstrates the fact of the revolution, its hinder edge being raised and definite; while its front edge, which is progressive, is double, the posterior of the two portions being elevated, and the anterior, to which the muscle is just becoming attached, being thin and ill defined.

It has been often supposed that shells which have a toothed mouth never have any distinct operculum; but the exceptions as regards annular or spiral opercula are numerous; thus *Helicina aureola* and *H. depressa*, and all the *Polyodonta*, as *P. clangulus*, &c., have large and regular opercula.

The genus *Vermetus* has an orbicular horny concave operculum, like that of a *Trochus*, but differing in having a large, orbicular, irregularly grooved, muscular scar, placed in the centre instead of on the anterior side. The outer surface in some of the smaller species, as in *V. dentifer** and *V. Adansoni*, is furnished with very close spiral elevated laminæ; but in the large species, as *V. maximus*†, it is homogeneous and horny, and does not exhibit any of the volutions. I have no means of ascertaining whether these opercula revolve, but I am inclined to believe that the spiral ones most probably do.

To these, which every zoologist has been in the habit of regarding as opercula, but the structure of which has not previously been examined in detail, I am inclined to add two other bodies belonging to Ctenobranchous Molluscous animals, which have hitherto been generally regarded as anomalous. The first of these is the support, as it was called by its discoverer M. DE FRANCE, or under valve, as it has since been regarded by some English conchologists, of the genera *Capulus* and *Hipponyx*. I am induced to regard this body as analogous to the opercula of other spiral shells, because, on an attentive examination of the animals, I find that it is attached in the same situation, and not on the under side of the foot, as most conchologists have supposed; the foot being folded on itself, and the walking disk of other Gasteropodes being in these animals (which never move from the place of their first attachment, and consequently require no such expansion,) represented by a few crumpled folds, placed between the part to which the shelly plate is attached and the head. In this idea I am further confirmed by a somewhat similar structure of the foot in the genus *Vermetus*, where the back of that organ represents a truncated cylinder, filling

* SOWERBY, Genera of Shells, Serpula, fig. 6.

† GRAY, Spicilegia Zoologica, tab. 5. fig. 3, *a*.

up and closing the mouth of the tubular shell. This foot is crowned by a horny operculum, and the walking disk is reduced to a narrow flat band, passing along the front of the cylinder, which band is in some species terminated by two conical processes, situated between that part and the base of the head: the processes have been described as tentacula, which they resemble in form. The shelly plate or operculum of *Capulus* is formed of concentric shelly laminæ, with a nearly central nucleus, and differs from all other opercula at present known, in being immediately attached, by its outer surface, to other marine bodies, like the lower valves of the Oyster and of *Crania,* and thus forming the medium by which the animal is retained in its place. The mouth of the shell being nearly as large as the cavity, the adductor muscle, as in other shells of this form, is divided into two broad bands, forming a horseshoe-shaped, posterior, submarginal muscular scar, and the operculum is marked with a similar impression.

The second body to which I refer is the vesicular appendage, placed on the back of the hinder part of the foot of the animals belonging to the genus *Ianthina* *, which appears to assist in floating the animal on the surface of the sea, and probably also in supporting the eggs after the death of the parent. This float, as it has been called, I am inclined, from its being situated in the same position as other opercula, to regard as analogous to those bodies in the neighbouring genera.

In the Medical Repository for 1821, I first called the attention of conchologists to the importance of the characters furnished by the operculum for the distinction of genera and families; and this subject, although almost neglected in this country, has since been pursued with great assiduity by M. de Blainville and other French conchologists. I have fortunately had an opportunity of examining, either in the cabinet of the British Museum or in the Continental collections which I have visited, the animals of the greater number of genera of shells, and have been thereby enabled to determine that the form and structure

* Cuvier at the time of publishing his Anatomy of Mollusca appears to have entertained the same theory, for he there properly describes this body as attached to the hinder part of the foot, a little below the usual place of the operculum; but in his Animal Kingdom he seems to have abandoned it, and describes the animal as having no operculum, but having a vesicular organ under its foot.—Règne Animal, ed. 2. tom. iii. p. 84.

of their opercula offer some of the most constant characters for the distinction and arrangement of families and genera; while, on the other hand, I have convinced myself that systematists have been in the habit of placing too much reliance on the mere fact of their presence or absence as a family character, inasmuch as that circumstance alone will scarcely prove of generic importance. Thus in the genus *Voluta,* the animals of the eight or nine species which I have examined are all destitute of opercula, except *Voluta musica,* which has an operculum of moderate size. The Olives and Mitres are in the same predicament, most of the large species being destitute of opercula, while the smaller species of both genera are furnished with rather large ones, as may be easily seen in specimens of *Oliva eburnea, O. zonalis,* or *Mitra striatula,* in which the animals have been dried; and shells in this state are not uncommon in collections. The species of Cones offer in this respect the same variations. These observations will explain the apparent contradictions of describers, and the frequent controversies that have taken place as to whether these and some other genera have or have not opercula. That their presence or absence is not a family character may be inferred from all the genera of *Buccinidæ* being provided with them except *Harpa* and *Dolium.* And this leads me to remark, that many genera and species which have very large mouths, in comparison with others of the family to which they belong, are destitute of, or have very small, opercula, whilst the others have moderate sized or even large ones. Thus the wide-mouthed Cones, as, for example, *Conus geographicus,* have no operculum, whilst the other species have a distinct one: and the genera *Cryptostoma* and *Concholepas* have very small opercula, in comparison with the size of their mouths, whilst the other genera allied to them have their opercula nearly as large as the mouths of their shells. The genus *Vermetus* is in this respect very remarkable: most of the species have the operculum as large as the mouth of the shell; but there is one in the British Museum which has an operculum very small in comparison to the size of the body of the animal, and not one fourth part of the diameter of the tube of shell. Some species of this genus, indeed, are described as having no operculum; and the observation of the above fact induces me to give credit to the description which I was at first inclined to doubt.

But of all the variations in this particular, those of *Capulus* and *Hipponyx* are the most remarkable: some species appear always to have an operculum, which, like the under valve of *Crania*, differs in thickness according to the form and degree of exposure of the substance to which it is attached:—others, as the common *Capulus Hungaricus*, are generally without operculum, although, according to the observations of Dr. Turton, the last-named species sometimes forms a thin support;—and there are others which, instead of forming an operculum, make for themselves (as has been already alluded to in this paper,) a cavity in the substance of the shell to which they are affixed, which is marked with a lunate ridge, corresponding with the muscular scar of the operculum, and doubtless occasioned by the attachment of the adductor muscle to that part of the shell, which is thus protected from the dissolving power of the mantle.