III.—Sea-Shells and their Makers. By A. J. Jukes-Browne, F.R.S., F.G.S.

A shell is the hard calcareous covering of a soft-bodied animal, and the term should properly be restricted to the coverings of those soft-bodied animals which are called the Mollusca. It should not be applied to the covering of a Crab or a Shrimp, such envelopes being called *carapaces*. The Mollusca include several different classes of animals, and they construct a great variety of shells, some forming simple conical caps like Limpets, others building spiral shells such as the Whelks and Periwinkles, and others, again, protecting their sides by two separate shells or valves which are hinged together at the top as in Cockles and Mussels.

The study of shells is known as Conchology, and when combined with that of the animals which make them it is often called Malacology. Every shell is, of course, closely related to the animal which made it, reflecting as it were the structure of that animal; but there are parts of the animal which have little to do with the construction or modification of the shell. These parts may vary in different kinds of molluscs, and consequently it is necessary to observe them while the animal is alive, in order to obtain a full knowledge of the creature and its relationships to others.

Shell-bearing Mollusca are divisible into three great classes: the *Cephalopoda* or Cuttle-fish; the *Gasteropoda* or Snails, whether land, freshwater, or marine; and, lastly, the *Conchifera* or Bivalves, such as Oysters, Mussels, and Clams, most of which live in the sea, though some inhabit rivers and lakes.

I do not propose to say much about the *Cephalopoda* because very few of them construct an external shell. Many of them possess an internal one, which is sometimes horny and sometimes calcareous in composition, the one kind being known as "sea-pens," the other as "cuttle-bones," and these are often thrown up on the shore. The shell of the *Argonauta*, however, is an external and very beautiful construction, consisting of a delicate white convolute shell, which is only produced by the female and serves as a protection for the eggs, which are fixed inside the spire. The shell is clasped by two of the creature's tentacles, and it is said that when captured the Argonaut often disengages herself from the shell, leaving it to float on the surface of the water and to carry its burden of eggs till they are hatched. Another more common shell-bearing Cephalopod is the *Spirula*, which forms a small loosely coiled and chambered shell of pearly white, and this is embedded in the lower part of the animal's body, both of males and females, being of use in flotation and having nothing to do with the protection of eggs.

Lastly, there is the Nautilus, which actually lives in a shell—a large-chambered shell—the animal occupying the last and largest of the chambers, while those of the inner coils are partially filled with air or gas, giving buoyancy to the shell and enabling the animal to rise or sink at pleasure. The Nautilus usually lives on the bottom, in deep water, but is believed to come to the surface at certain seasons.

The *Gasteropoda* comprise a large number of shell-making animals, and have been divided into several orders or tribes, each including many families and genera. Their shells are always univalve, consisting of one piece, which is generally twisted into a spiral form. The animals have definite heads, which carry a pair of tentacles, a pair of eyes, and a sort of snout or proboscis which encloses the mouth. Inside the mouth there is a curious dental apparatus, not in the form of toothed jaws, but consisting of a hard and horny ribbon set with rows of minute teeth, this ribbon working backwards and forwards over a cartilaginous ridge or cushion. The dental ribbon or *radula* forms an interesting microscopic object, and is of importance to conchologists because the form and arrangement of the teeth vary in different genera, and they are found to be a useful means of classification. The teeth are siliceous, and it is by the scraping action of the teeth on the radula that the animals masticate their food.

Some of the *Gasteropoda* are vegetable feeders, browsing on the weeds which grow in such abundance on the sea-floor and in rock-pools between tide-marks. Others are carnivorous, and prey either upon their vegetarian relatives or on the bivalve mollusca; and some are carrion feeders, living upon dead fish and other creatures which die and leave their bodies on the sea-floor. No one can pick up dead shells on the sea-shore without sooner or later noticing that many of them are pierced by a small round hole, and that when the shell is thick this hole is not cut straight through, but narrows downward as if it had been made by a conical file, such as that used to sink the head of a screw. The reason of this is that the animal has been killed by one of his carnivorous fellows who has bored a hole in the shell by means of his dental ribbon, which is curved from side to side so that the central teeth come into action first and the lateral teeth are only brought to bear as the hole is deepened.

Passing now to a consideration of the shell, we may first ask, what is the use of it? The primary reason for its existence seems to be the protection of the soft parts of the animal, and especially of the delicate gill or breathing organ; it also serves as a basis of attachment for the muscles of the foot and of those by which the animal retracts itself within its shell. The scar of this attachment is clearly seen inside a limpet-shell as a mark in the shape of a horseshoe, but in spiral shells the retractor muscle is attached to the central axis or "columella" round which the shell is coiled.

Here, also, it should be mentioned that most of the spiral *Gasteropoda* have a horny or shelly plate attached to the hinder part of the foot, so arranged that when the animal withdraws itself this plate or "operculum" comes last and closes the aperture of the shell, so as to afford protection from attack in that quarter. The shape and substance of the operculum vary in different genera, and thus it becomes of assistance in classification. It is generally fully developed and very tight-fitting in the spiral vegetarians, while among the carnivorous genera, though many possess opercula, they are often too small to close the aperture completely, and in some cases they are absent altogether.

The shell itself is either conical or spiral, and the spiral form may be regarded as a twisted cone. The Limpet has the simplest form of shell; the Bonnet-shells (*Capulus* and *Crucibulum*) show how the apex of the cone becomes twisted into the beginning of a spire. The Ear-shells, again (*Haliotis*), show how this can be coiled into a flattened whorl, and from this the transition is easy to the more elongate spiral form of a turbinate shell such as the Winkle (*Littorina*) or the Top-shells (*Turbo* and *Trochus*).

Some Gasteropods have a tube or siphon, through which water is passed into the gill-chamber, and when such a siphon exists, the aperture of the shell is notched at the bottom or prolonged into a shelly canal for the protection of the siphon. This canal is formed by a prolongation of the columella and of the outer lip of the aperture, and is sometimes as long as or even longer than the spire, so that the shell is fusiform or spindle-shaped. One such shell, of which several species occur in the Indian Ocean, is called *Fusus*, which is the Latin for a "spindle"; another is known as *Fasciolaria*; *Murex* and *Turbinella* are also shells with long canals.

In other cases the whole shell is coiled up on its axis, and is then said to be convolute, the body-whorl being very large and the aperture a long narrow slit. The Cowries (*Cypræa*), so well known as ornamental shells, are an instance, but they are spiral when young, and only become convolute at a certain age. The Olive-shells (*Oliva*) are partially convolute, having a very short spire and a cylindrical body-whorl with a narrow aperture.

The mention of Cowries and Olives leads me to say a few words about the outer surface of shells, why some are smooth and even polished, others rough and ribbed, and others, again, tubercular, spiny, or frondose. The surface-layer of the shell is produced by the outer margins of the mantle or body-covering, and these margins are either smooth, rugose, or elongated into projections in accordance with the kind of surface which is produced, and which we must suppose is in some way beneficial to the animal.

In some cases the borders of the mantle are reflected over the shell, sometimes to such an extent that they cover nearly the whole of it, and in such cases the shell generally has quite a polished surface, as in *Cypræa*, *Oliva*, and *Natica*. But others produce shells with a similar natural polish, without any reflection of the mantle; such are the Auger-shells (*Terebra*), the Pheasant-shell (*Phasianella*), and *Eulima*. Again, there is at least one genus where the mantle is reflected over the shell, and yet that is rough, with a raised reticulate ornamentation; this genus is *Pirula*. Lastly, there are cases where some species of a genus are smooth and polished though the majority are ribbed or striated, such a contrast being found in two Bornean shells, *Nerita polita* and *Nerita lineata*. Hence it is clear that there is no relation between the smoothness of a shell and the reflection of its maker's mantle over its edges; it is evident that the smoothness or roughness of the shell is co-ordinated with some requirement of the animal's environment about which at present we know very little, and observations directed to the elucidation of this point are much to be desired.

If we assume that the edges of the mantle can produce a smooth surface or a sculptured one according to the animal's requirements, we may perhaps also assume that a smooth shell is the normal product, formed when there is no special reason for it to be otherwise; for it is probable that the borders of the mantle are normally smooth, and that rugosities or prolongations are special modifications evolved mainly for protective purposes. Thus the foliaceous and frondose processes of the *Murex* shell may serve this purpose by imitating the fronds of seaweeds, and preserve the animal from the eyes of predatory carnivorous fish, but observations are needed to confirm this theory.

The third great class of Mollusca are those which make their shelly covering in two pieces or valves, each one covering and protecting one side of the animal; hence they are known as the Bivalves or *Conchifera*. These animals have no definite head and no dental apparatus of any kind, but they have a sort of mouth and they feed on small animalculæ brought to this mouth by the currents set up in the gills, which are supplied with water through two tubes called siphons.

In this class the whole body is covered by a mantle in two lobes which secrete the two valves of the shell; this mantle is sometimes open below, sometimes closed, but there is always an opening for the extrusion of the foot, a soft, muscular, elongate, and extensible organ, which is used for the purpose of propulsion. Further, the hinder part of the mantle is always converted into two tubes or siphons, one being the incurrent and the other an excurrent siphon. These siphons are sometimes short and sometimes very long, but are always strong, muscular, and contractile; in some cases they are separate from one another, while in others they are partially or wholly united, and in some genera they are both enclosed in a papery kind of epidermis.

The foot varies much in shape and length, being sometimes very small and degenerate, more usually it is tongue-shaped, and sometimes it is much prolonged and curved, as in the Cockles (*Cardium*), enabling them to jump several inches at a time and to burrow quickly into soft sand. The margins of the mantle are generally smooth, but are sometimes frilled and even fringed. It is on these organs, the mantle, foot, and siphons, that observations are wanted with regard to the differences which they exhibit in different genera, for we know much less about the animals of Conchifera than about those of the Gasteropoda.

Bivalve shells should be obtained alive whenever that is possible, not only because observations on the animals are required, but because when thrown up on the beach the valves soon become detached and broken. After notes have been made about the points above mentioned, the animal can be easily removed by being placed in hot water, when the valves open and the muscles which hold the shell together can be cut. There are generally two of these "adductor" muscles, and the shell then opens more widely because the valves are pulled apart by an elastic ligament above the hinge-plate; while wet, however, they can be closed, and should be tied together with thin string or cotton. In the case of small shells this is quickly done by taking two or three turns of cotton round them and twisting the ends together between the fingers without troubling to tie a knot.

Most of the Bivalves live in sand or mud near or below low water-mark, but some attach themselves to rocks, and a few even bore holes in soft kinds of rock or in timber. Some, therefore, can be dug out at low water with a spade, and others extracted by breaking off pieces of rock or coral-reef at low water; but to obtain those from the sea-floor outside low water-mark a small dredge must be used from a sailing-boat. Occasionally some of these are torn from their hold in the sand or mud by storm-waves, and are thrown up on sandy beaches without being injured, so that such a beach is always worth searching after a storm, or after a strong wind from seaward. Most of the Conchifera are marine animals, but a few are to be found in the mud of estuaries, rivers, and lagoons.

It may perhaps be as well to mention some of the different kinds of Bivalves, for they differ much in shape and in texture of shell. Most of them have similar opposite valves, which are either smooth or sculptured, white or variously coloured; such are the ordinary Cockles (*Cardium*), scallops (*Pecten*), and Tellens (*Tellina*); others are elongate and covered with a dark-coloured epidermis, such as the various kinds of Mussels, *Mytilus*, *Modiola*, *Pinna*, and *Perna*; these are generally attached to rocks or timbers by a bundle of fibres secreted by the foot and known as a "byssus." Others, again, have a flattish shell with a scaly or platy structure, such as the Oysters, both edible and pearly (*Ostrea* and *Meleagrina*). Lastly, some species fix themselves to rocks by one valve and form thick foliaceous or spiny shells, one valve of which is smaller than the other (*Chama* and *Spondylus*).

Bivalves differ also very greatly in the way in which the two valves are hinged together. In most cases the opposing edges are furnished with a set of projections or teeth which fit in between one another, and the arrangement of these teeth affords a basis of classification into families and genera. In some there are a great number of similar small teeth, as in the Ark-shells (*Arca*); in others there are two or three median teeth with elongate lateral teeth on each side, as in the Cockles (*Cardium*) and the genera called *Mactra* and *Donax*. Others, again, have only median teeth, and a few have no teeth at all (as in *Anatina*) or only a spoon-shaped process (as in *Mya*).

Bivalves are rather more local in their distribution than Univalves, and it is quite possible that some are common on the north coast of Borneo which are rare elsewhere.

This article has been written in the hope that I may interest some of the planters, officials, and traders who live on and near the seashore in the subject of Marine Mollusca, that I may induce them to observe the animals which construct all these various kinds of shells, and to collect the shells themselves, either for their own interest and study or for exhibition in the Rajah's Museum at Sarawak. I shall be happy to correspond with any one who resides in Sarawak or other part of Borneo, and would name any shells that are sent to me through the Curator of the Museum.