A NATURAL HISTORY
OF
INHACA ISLAND, MOÇAMBIQUE

EDITED BY

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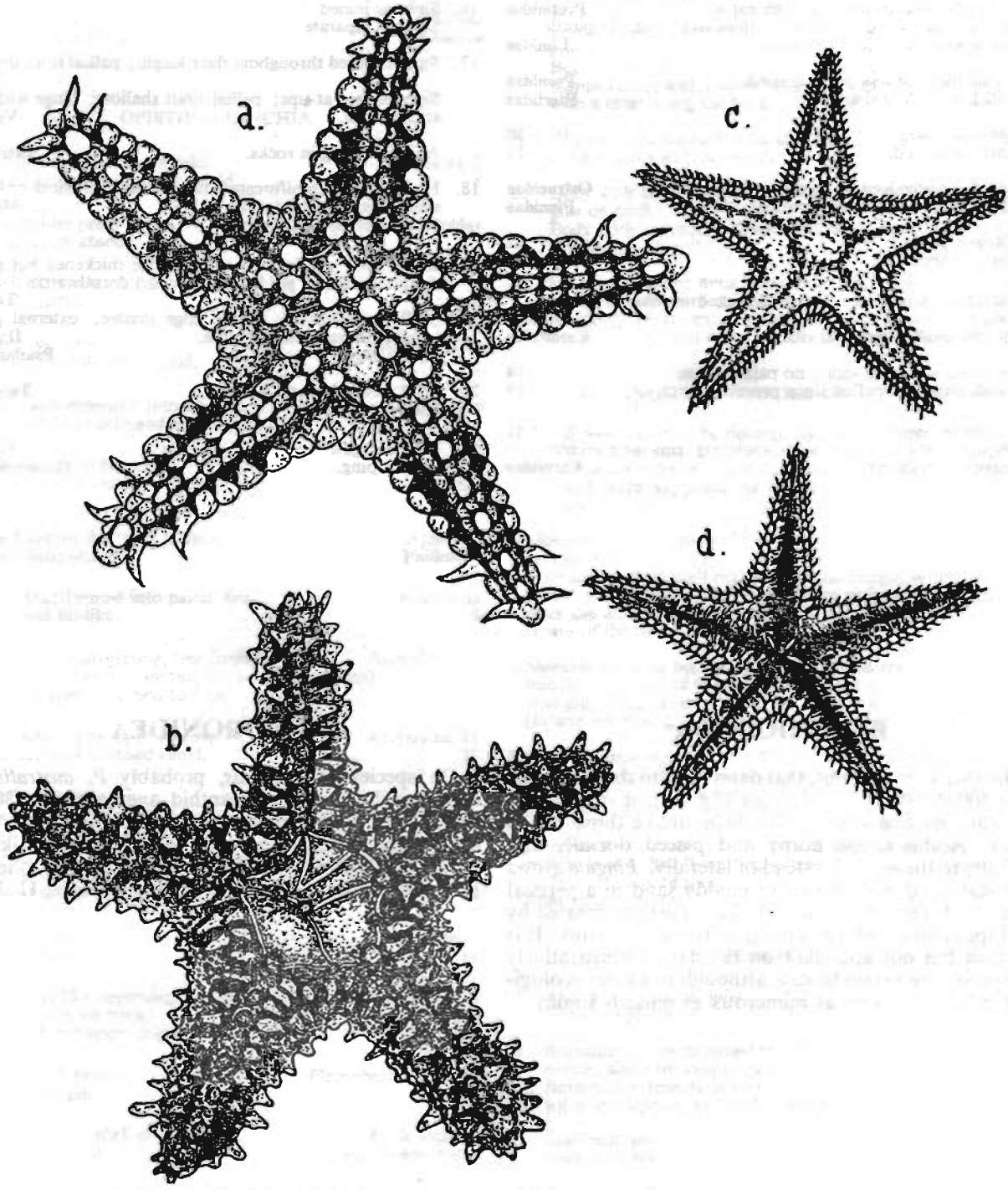


FIGURE 24
Some common echinoderms: (*a*) The starfish, *Protoreaster lincki*; (*b*) the starfish, *Pentaceraster mammillatus*; (*c*) aboral view and (*d*) oral view of the sand starfish *Asteropecten granulatus*.

THE ECHINODERMS*

Classes: Crinoidea, sea lilies,
Asteroidea, starfishes,
Ophiuroidea, brittle stars,
Echinoidea, sea urchins,
Holothuroidea, sea cucumbers.

Echinoderms are a prominent constituent of the littoral and infralittoral fauna on Inhaca Island. Echinoderms are characterized by their radial symmetry, more or less well developed calcareous external skeleton, and the presence of tube feet. The radial symmetry is most obvious in sea lilies, starfish and brittle stars, where it is manifested by the presence of a number of 'arms' arranged around the circumference of a central disc. In the sea urchins the radial symmetry is shown in the arrangement of the skeletal plates constituting the shell (test) and of the 5 double rows of tube feet. The sea cucumbers having a vermiform body, usually crawl on one side (the ventral), and the other (dorsal) side is permanently upwards. The radial symmetry manifests itself, however, in the arrangement of the circumoral tentacles and in details of internal anatomy.

The calcareous dermal skeleton makes most echinoderms hard to the touch, but it is reduced to spicules in sea cucumbers so that these are more or less soft bodied. The tube feet are best developed (that is, have adhesive discs at their tips) and serve for locomotion in starfish, sea urchins and some sea cucumbers. In other sea cucumbers, in the brittle stars and in sea lilies the tube feet are reduced and have no suckers.

The members of the five orders of echinoderms are easily distinguished. The sea lilies possess 5 arms each bifurcating right at the base so that the animal seems to have 10 arms. Each arm appears to be a feathery structure due to the presence of secondary branches—hence they are sometimes known as feather stars. Only one species of sea lily is common on Inhaca, *Tropriometra carinata*. Typical asteroids and ophiuroids are known as sea stars because they have in common the possession of distinct arms (usually 5 in number) which are not branched (except for representatives of the family Gorgonocephalidae, ophiuroids with branching arms—see further p. 99). In the order Asteroidea the arms are fairly thick and not very flexible, whilst in the order Ophiuroidea the arms are long and thin, and are capable of moving rapidly by lateral flexions which give them a somewhat snake-like appearance. The sea urchins have no arms and the body has the form of a slightly flattened sphere, however, in the suborder Spatangoidea the body is ovoid, and it is quite flat in the suborder Clypeastroidea (the sand-dollars or pansy shells). The body of sea urchins is covered with spines attached at their bases to tubercles on the surface of the test. The spines are hard and prominent in Regularia, but thinner and softer in Spatangoidea, and in Clypeastroidea very short and fine so that these have a velvety appearance. Due to the worm-like or cucumber-like shape of the body, the Holothuroidea cannot be confused with other echinoderms. Some may perhaps be confused with worms from which they may be distinguished by their usually coarse skin and large size.

Apart from many ophiuroids, echinoderms are fairly large, some are brightly coloured, and easily attract attention from laymen as well as zoologists.

All echinoderms are marine, and cannot suffer being left out of the water except for a short time. They are found therefore at levels in the littoral which are never exposed to air even during the lowest tides, or only exposed for relatively short periods. The easiest way to collect them is to wade in shallow water during a very low tide when large numbers of sea urchins, starfish and sea cucumbers can be seen crawling on the sandy or muddy bottom or sheltering between and under rocks and blocks of dead coral.

The Cymodocea beds, especially in parts of the beach with scattered coral growth, contain numbers of the most beautiful and conspicuous representatives of the phylum. In such places the asteroids are represented by the very large *Protoreaster lincki* and the many coloured *Pentaceraster mammillatus* (fig. 24*b*); the sea urchins—by several common species: *Prionocidaris baculosa* (fig. 26*b*), *Tripneustes gratilla*, *Salmacis bicolor*, *Temnopleurus toreumaticus*, *Diadema setosa* and *Echinothrix calamaris*. The large brown sea urchin *Tripneustes gratilla* is sometimes difficult to notice as it has a habit of covering itself with dead leaves of Cymodocea which stick on its needles and thus conceal the animal. This habit is common among tropical and sub-tropical echinoids and

*by Professor B. I. Balinsky

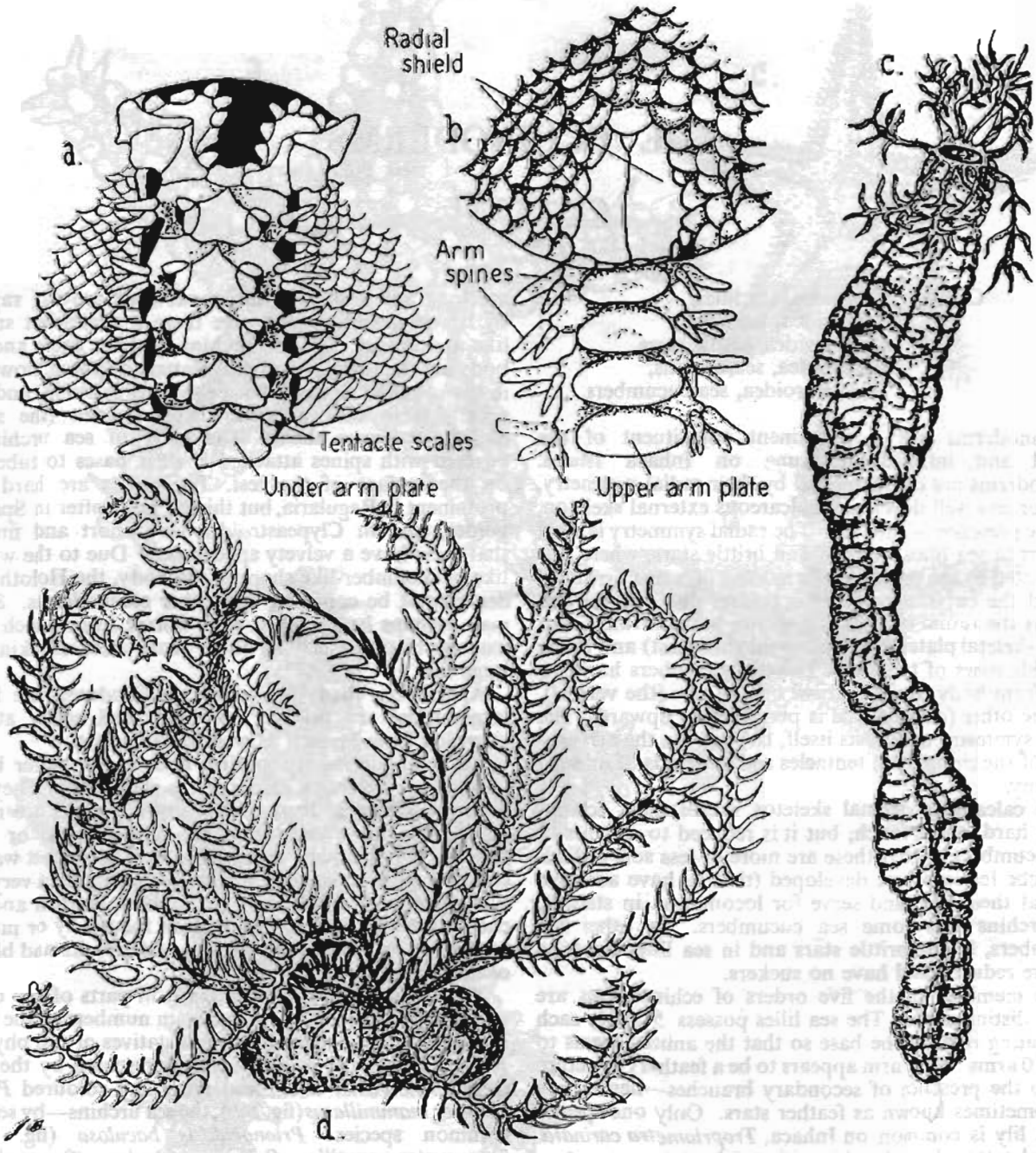


FIGURE 25

More common echinoderms: (*a*) a brittle star, *Amphioplus integer*, part of the disc from the oral side (after Mortensen); (*b*) aboral view of part of the disc and an arm; (*c*) a sea-cucumber, *Opheodesoma* sp. and (*d*) a feather star.

serves to give some shade from the sun. The holothuroids are represented by large numbers of two common and very large species: the black *Holothuria atra* and the mottled grey *Holothuria scabra*. Occasional strange species are found such as the large cushion-like, orange starfish with a pentagonal body and practically no arms, *Culcita schmideliana;* the pink-coloured sea urchin *Toxopneustes pileolus;* and very long (over 1 m.) snake-like holothurians of the genus *Synapta*. These are more common in warmer backwaters and bays.

A completely different fauna is to be encountered in the rock pools of the open coast of the Island, as at the Cabo Inhaca. The two main species of sea urchins here are *Stomopneustes variolaris* and *Echinometra mathaei*. Whilst the sea urchins on the Cymodocea beds crawl freely about, the urchins on the rock pools always hide in little hollows and depressions in the rock into which they fit quite closely, so that it would appear that the urchins excavate suitable hollows for themselves. It is often impossible to extract the urchins from their holes, for not only do they fit closely but also keep in their places very firmly, attaching themselves to the rock by their tube feet—an adaptation to life in localities exposed to heavy surf. With the urchins is associated here a pretty greenish brittle star *Ophiothrix echinotecta*, one or two specimens of which may be found concealing themselves beneath the sea urchin. Starfish have very rarely been found on exposed rocks or in the rocky pools; only members of the genus *Asterina*, rather small strongly flattened animals (under 4 cm. in diameter) with relatively short arms appear to occur here. These are most often found in masses of worm tubes. The holothuroids are represented by two large species, *Holothuria cinerascens* and *Actinopyga mauritiana*.

Masses of broken coral scattered on western shores of the Island shelter their own characteristic fauna. Underneath will be found numerous starfish with thin arms, *Linckia multifora* (fig. 29*g*). The sea urchins, *Echinometra mathaei* already mentioned as inhabiting rock pools, are also found here. But the most numerous echinoderms on dead coral are ophiuroids, represented in large numbers mainly by three species: the larger *Macrophiothrix hirsuta* (fig. 27*b*) and *M. aspidota*, and the small greenish *Ophiactis savignyi*. The holothuroids are represented by the pale brown smallish *Holothuria hilla* which is often found embedded in crevices of the dead coral, and the chocolate brown *Thyone sacellus* lying more openly. The latter shows a preference for large masses of rock, and is also found in abundance on rocky sections of the western coast of the Island, as at Ponta Rasa.

Coral reefs whilst supporting and sheltering various forms of life, do not have so rich an echinoderm fauna as might perhaps be expected. Sea urchins are hardly ever found amongst living corals, and starfish are scarce, although they may be abundant in the immediate vicinity of the reefs. Some rarer species have been found here, however, as the large grey-blue or orange *Linckia laevigata* and the enormous blood red *Leiaster leachi*, found at the foot of the main coral reef. The coral reefs are, however, the typical habitat of the sea lily, *Tropriometra carinata*, several specimens of which may be found wedged between the branches of a dead piece of coral (living corals appear to be avoided). On the coral reefs, again on dead rather than on living coral, is to be found the relatively very large and pretty brittle star, *Ophiocoma erinaceus*, remarkable apart from its size by its very striking coloration—jet-black general colour with orange-red tentacles. At the foot of the main coral reef are to be found also one of the most remarkable of ophiuroids, *Astroboa nuda* var. *nigra* (fig. 28), representative of the family Gorgonocephalidae. These ophiuroids have branched arms and the disc alone may be up to 10 cm. in diameter. Most representatives of this family live in fairly deep water and do not belong to the littoral fauna. These ophiuroids (and the starfish *Leiaster leachi*) were discovered by skin divers. A collector wading at low tide along the beach has no chance of finding them.

Open stretches of sand would appear to be unfavourable places for collecting echinoderms. Several are, however, present. There are sand-dollars, of which there are two species at Inhaca, *Echinodiscus auritus* (fig. 26*a*) and *E. bisperforatus*. In the same localities are starfish of the genus *Astropecten*, the common species being *Astropecten granulatus* (fig. 24*d*).

These animals are normally concealed under a layer of sand but the sand tends to be raised slightly over the bodies of the animals, so that the outline (a distinct star in the case of *Astropecten*, a circle in the case of sand-dollars) can sometimes be readily seen. The sand-dollars of the genus *Echinodiscus* show an interesting case of commensalism: on the under side of most specimens may be found specimens of a small whitish brittle star, *Amphylicus androphorus*. The larger specimens of these are females, the males are smaller and spend their life sitting on the oral side of the disc of the larger female, whilst the female in her turn, attaches herself to the underside of an *Echinodiscus!* The heart-urchins (the Spatangoids) are also sand-dwellers. They are rather rare on Inhaca, but a few specimens of *Echinocardium cordatum* (fig. 26*c, d, e*) have been found crawling on the surface of the sand exposed at very low tides. Normally these sea urchins spend most of their time in self-excavated burrows in the sand, depending for their food on particles of organic matter swept into their burrows by a current of water created by movements of their spines. The large starfish *Luidia maculata* and its sister species *L. savignyi*, which differ from other starfish of Inhaca by having 7 arms instead of the usual 5, are also to be found lying on the sand at low tides. Amongst the sea cucumbers two species burrow in the sand, *Holothuria hilla* already mentioned, and *Holothuria pervicax*, easily recognizable by the presence of large dark brown spots on its light yellowish coloured body.

It has already been mentioned that the sea cucumber *Thyone sacellus* is often found on the rocks on the eastern side of the Island, where it wedges itself in crevices and small cavities, and apparently never moves from such a retreat, thus becoming a sedentary animal. At very low tides these holothuroids may be exposed to air for short periods, and they then retract their tentacles and even their bodies into the crevice each inhabits, but when covered with water they expand the tentacles again. The tentacles in this species are long and finely branched, so that when spreading in the water from under a stone they give the impression of a bunch of seaweed. Another echinoderm which inhabits crevices in rock ledges is the brittle star, *Ophiocoma scolopendrina*. At very low tides

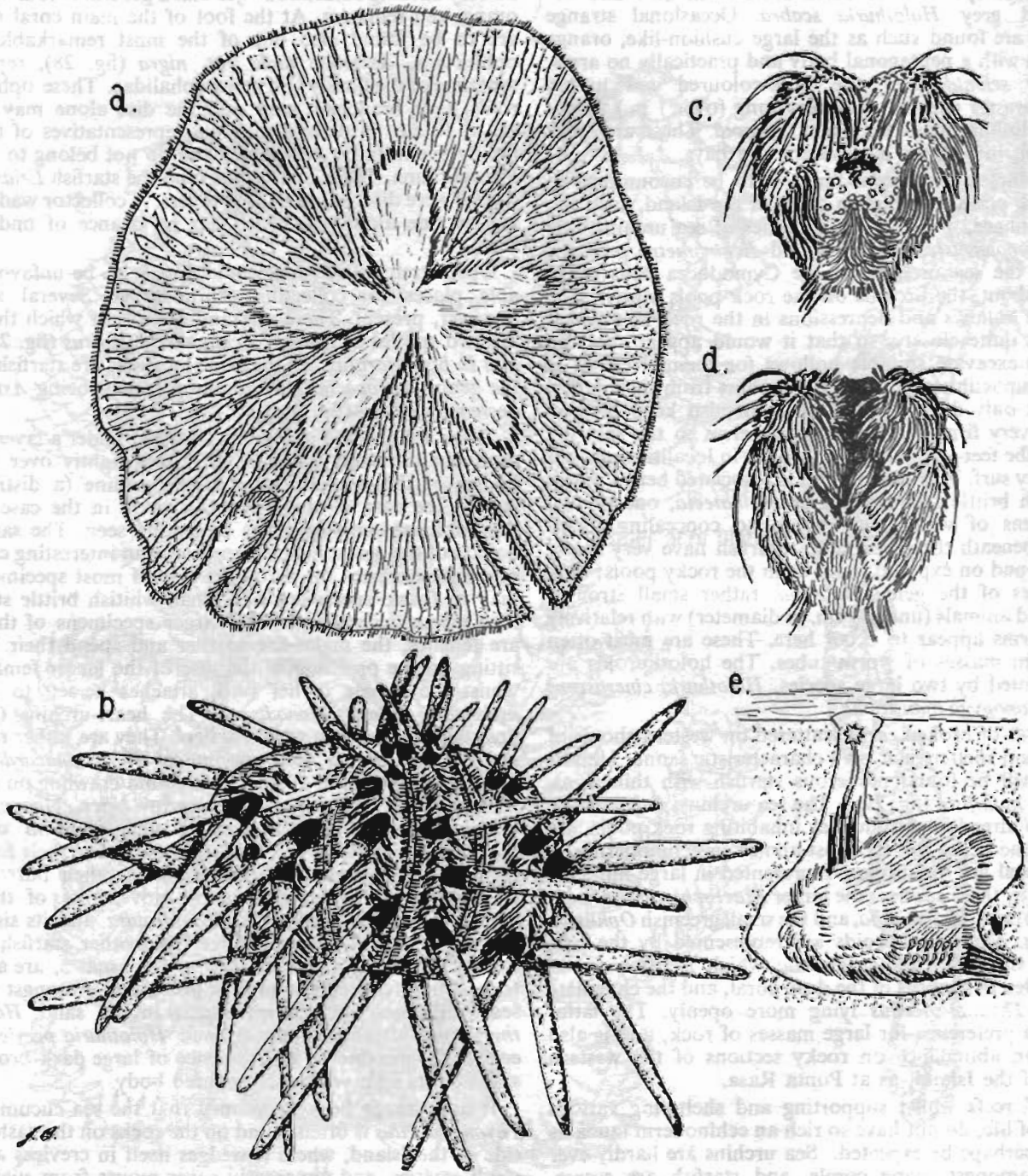


FIGURE 26

Some common echinoids: (*a*) The sand dollar, *Echinodiscus auritus*; (*b*) the slate-pencil urchin, *Prionocidaris baculosa*; (*c*) oral and (*d*) aboral views of the heart urchin, *Echinocardium cordatum*; (*e*) *E. cordatum* in its burrow (after v. Uexkul).

the animals withdraw into the depth of the crevice, but when the rock is covered with water they protrude three of their five arms and move them about in search of any food which they may capture, or perhaps also for respiration whilst the body and the remaining two arms remain concealed. The collector will find it very difficult to get these brittle stars out of their retreat; if the protruding arms are touched, they are immediately withdrawn. Even if the collector succeeds in getting hold of one or more of the protruding arms, and tries to pull the animal out, he will usually end by tearing the arms off whilst the body of the animal is held fast in the crevice by the remaining arms. This species is also to be found on flats of Cymodocea. Here it avails itself of any shelter—a piece of broken rock, an empty shell, a clump of algae. At low tide they are bunched up within their retreat. As the tide flows over them the three searching arms emerge and wave around in the water, the disc and the other two arms remaining hidden. A related species *Ophiocoma valenciae*, has a similar mode of life, but has not been found very often at Inhaca.

Echinoderms are absent from the mangrove swamps except for one sea cucumber, *Holothuria parva*, which was found amongst the roots of mangrove trees growing along the edges of the main canals of the mangroves. The bluish-grey mud of the Saco on the other hand provides a habitat for two species of ophuiroids, *Ophionephthys africana* and *Ophiophragmus sacensis*. Both these have a burrowing habit and live in vertical burrows in the mud. *Ophiophragmus sacensis* (fig. 27*a*) has a soft body, so that it can be stretched to fit into the narrow cavity in which it lives. Of the five arms three are extended in one direction, two in the other.

The numbers of echinoderms found in the littoral and infralittoral of Inhaca vary greatly from biotope to biotope, but even in what would seem to be the same type of environment, the animals may be crowded in some places and sparse in others. Perhaps the most impressive aggregations of echinoderms are the masses of sea urchins (*Prionocidaris baculosa* and *Tripneustes gratilla*) found in some years on the Cymodocea beds along the channel separating the main Island from the Ilha dos Portugueses. Breaking up masses of dead coral often reveals great numbers of ophiuroids (especially *Macrophiothrix hirsuta* and *Macrophiothrix aspidota*). In randomly chosen areas of 25 cm. square on the flat in front of the station, composed of loam and old broken coral there were found 3-4 small specimens of *Ophiactis savignyi* per square, constituting about 0·2% by weight of all animals present.

The holothurians are mainly mud and detritus feeders. This can easily be confirmed by studying their gut contents. Forms such as *Holothuria atra* and *Holothuria scabra* pass large quantities of sand and mud through the alimentary canal, the organic substances being digested and the undigestible parts defaecated. Sea urchins feed mainly on vegetable matter which they collect on the sea bottom using their teeth to scrape such matter off the rocks. They do not feed on living microphytes, however. The starfish and brittle stars are carnivorous animals. The feeding of the starfish is very peculiar: the main food is bivalve molluscs, and the digestion of the food is carried out largely outside the body of the starfish. When consuming its prey, the starfish everts its stomach, passes it between the valves of the shell, envelops the soft parts of the mollusc and digests them *in situ*, after which the liquified food is sucked into the body of the starfish and the stomach withdrawn. It is sometimes possible to find starfishes in the process of feeding, with stomachs everted, consuming a bivalve mollusc. Ophiuroids feed on any small animals which

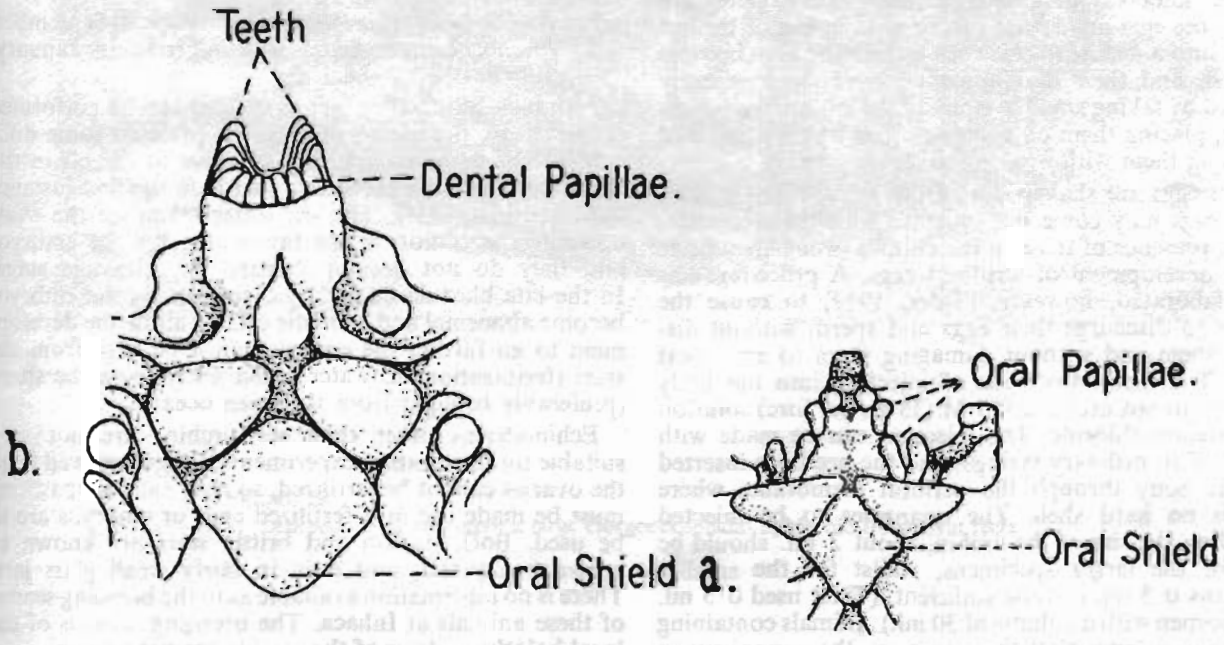


FIGURE 27

(*a*) Jaw of *Ophiophragmus sacensis* (after J. Balinsky), and (*b*) jaw of *Macrophiothrix hirsuta*.

they can capture and eat, using the teeth surrounding their mouths. The sea lilies are plankton feeders.

Some species of echinoderms show a remarkable variability of coloration. A good example of this is the common large starfish *Pentaceraster mammillatus*. In this animal the ground colour as well as the colour of the superimposed pattern (based on the spines and ridges on the surface of the body) may vary independently. The ground colour may be yellow, green, brown, or in different shades of red, and the pattern brownish or reddish against a differently coloured background, or conforming with the ground colour. These colour variations do not seem to bear any relationship either to the size (age) of the animals or to the locality which they frequent. Contrary to this diversity of colours, the nearly related species, *Pentaceraster lincki* shows very little colour variation; the ground colour is always greyish-brown and the pattern red. Another species showing a considerable colour variability is the brittle star *Placophiothrix foveolata*, found in numbers on the coral reefs and in Cymodocea beds. Different specimens of this brittle star show the same pattern of darker lines on a pale, whitish background, but the colour may vary from deep violet, through different shades of red (the usual colour) to orange and light brown. In one form the disc is uniformly bright scarlet, whilst the arms are dark red. (J. B. Balinsky, 1957).

Sea urchins are very favourable for the experimental study of fertilization and early embryology. The eggs and sperm become ripe in the gonads and are then discharged into the surrounding water, where fertilization takes place, and the eggs develop into pelagic larvae. The sea urchin larva is known as the pluteus (or echinopluteus). The larvae live as planktonic organisms for several weeks, then metamorphose and the newly formed tiny sea urchin falls to the bottom and starts a mode of life similar to that of the adult.

If the adult sea urchins containing ripe gametes are opened, the eggs and sperm can be shaken out of the cut gonads into a dish with clean sea water. The eggs become fertilized, and their development may be conveniently observed by taking small samples of the culture from time to time, placing them on a slide or in a watch glass, and examining them with a microscope.

When eggs are shaken out of the gonads into a dish, unripe eggs may come out together with the ripe ones, and the presence of these in the culture is not favourable for the development of fertilized eggs. A procedure has been elaborated, however, (Tyler, 1949) to cause the animals to discharge their eggs and sperm without dissecting them and without damaging them to any great extent. The method consists of injecting into the body cavity of the sea urchin a 0.5 M (35 gr. per litre) solution of potassium chloride. The injection can be made with the aid of an ordinary syringe, and the needle is inserted into the body through the perioral membrane, where there is no hard shell. The quantities to be injected depend on the size of the urchin, about 2 ml. should be used for the larger specimens, whilst for the smaller specimens 0·5 ml. is quite sufficient. (Tyler used 0·5 ml. per specimen with a volume of 30 ml.) Animals containing ripe sperm or eggs eject them through the gonophore in a matter of a few minutes, whilst unripe gametes are not shed at all. The eggs and sperm may be collected by immersing the aboral surface of the animal in a dish of sea water, or they may be sucked up with a pipette. Animals treated in this way remain quite healthy, and may be used again for obtaining sperm and eggs after about two weeks, or even earlier. An interesting modification of the method may be used to ascertain whether a sea urchin contains ripe gametes or not. If a drop of concentrated solution of potassium chloride be applied to a gonopore on the aboral surface of the body, the animal, if containing ripe eggs or sperm, will extrude a small quanity of them on the surface. This incidentally can also be used to ascertain the sex of the mature animals as the male and female sea urchins do not differ externally. The animals which are to be used for fertilization experiments may then be injected as above to make them discharge large quantities of sperm or eggs. The species of sea urchins at Inhaca which have proved to be most convenient for fertilization experiments are: *Tripneustes gratilla*, *Salmacis bicolor* and *Temnopleurus toreumaticus*. In temperate countries the sea urchins have definite breeding seasons lasting only a relatively short part of the year (in spring or summer, depending on the species). In tropical waters one would expect animals to breed throughout the year, as the seasons are much less defined. Actually this is not quite correct. At least some of the tropical echinoderms breed only during certain parts of the year, whilst others may have ripe sperm and eggs most of the time. The following observations have been made in this connexion by the author of this chapter.

1. *Tripneustes gratilla*, *Salmacis bicolor*, *Temnopleurus toreumaticus* are probably to be found with ripe sperm and eggs at any season (certainly in January, July, and September).
2. *Echinometra mathaei* fully ripe only in January.
3. *Diadema setosa* found with ripe sperm in January; ripe eggs not observed.
4. *Echinodiscus auritus* found with ripe sperm in July; ripe eggs not observed.
5. *Stomopneustes variolaris* was not ripe in September.
6. *Prionocidaris baculosa* was not ripe in January, July nor September.

Although fertilization in sea urchins can be performed rather easily, the raising of embryos presents some difficulties. The embryos are very sensitive to defects in the quality of sea water (probably its pH in the first instance —Mortenson, 1931). The sea water taken off the coast opposite the station is not favourable for the embryos and they do not develop beyond the cleavage stage. In the late blastula or early gastrula stages the embryos become abnormal and soon die off. To allow the development to go further the embryos must be kept from the start (fertilization) in water taken away from the shore (preferably brought from the open ocean).

Echinoderms other than sea urchins are not very suitable for fertilization experiments. Eggs removed from the ovaries cannot be fertilized, so that natural spawning must be made use of if fertilized eggs or embryos are to be used. Both starfish and brittle stars are known to spawn in aquaria, and even in fairly small glass jars. There is no information available as to the breeding season of these animals at Inhaca. The breeding seasons of the local holothuroids or of the sea lily are not known.

Some echinoderms have a high ability for regeneration —renewal of lost parts. When collecting specimens of

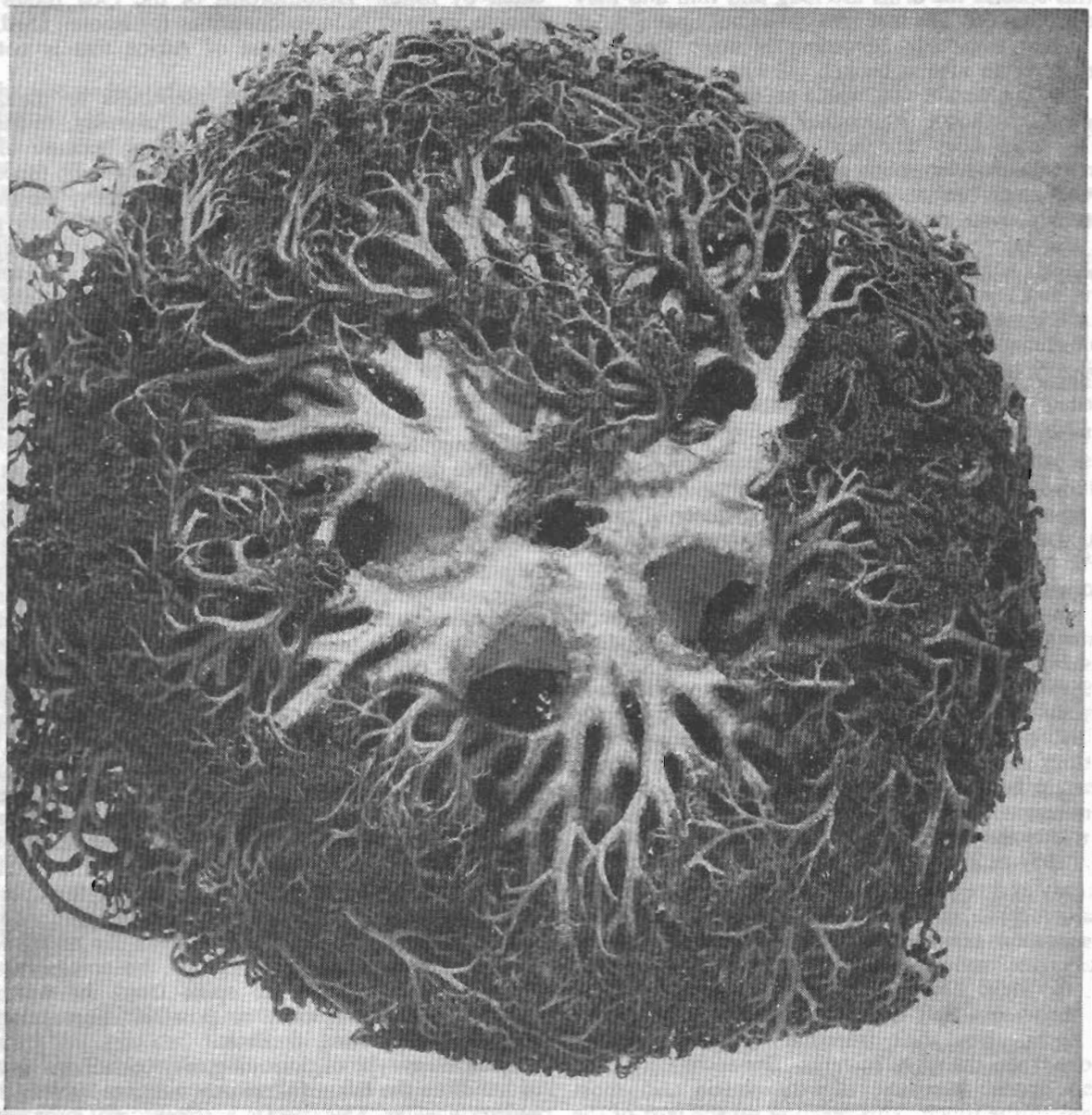


FIGURE 28
Astroboa nuda var. *nigra* a large Gorgonocephalid ophiuroid from coral reefs.

Linckia multifora on the beach one can often find specimens with unequally developed arms. Some of the arms may be shorter or be quite diminutive as compared with the other arms and the disc. The explanation of this is that in this species the arms are long and thin and may easily be broken off. The lost arm grows out again, but it is small at first, eventually becoming the same size as the other arms. If an arm is broken off with a part of the disc, it can regenerate the whole animal. During the period of regeneration the animal will have one large arm and 4 small ones. The brittle stars with their long and thin arms are even more exposed to the dangers of having the arms broken off, and correlated with this they generate even more quickly than starfish. These animals also possess the ability to throw off their arms spontaneously when they are molested. This phenomenon known as 'autotomy' is also shown by the starfish, *Luidia*, which for this reason is very difficult to bring home intact from an excursion.

In some ophiuroids the capacity for regeneration is made use of for the purpose of asexual reproduction. The animals break in two across the disc by autotomy, and then each half regenerates the missing half of the disc and three arms. This type of reproduction is practised only by small brittle stars with a disc diameter of under 6 mm. such as *Ophiactis savignyi*, and perhaps *Ophiocoma parva*. As it seems to be the rule that three arms are always regenerated the specimens reproducing by fission tend to have 6 arms instead of the usual 5; of the 6 arms 3 are younger than the other 3. It has been suggested that this type of reproduction is restricted to juvenile animals, and as these eventually grow larger they lose the capacity to break in half and become ordinary 5-armed brittle stars. This could not be confirmed by observations made on brittle stars at Inhaca: the largest specimens of the three species named above have 6 arms, and there seems to be no 5-armed form which could be interpreted as the adult form of the same species (J. B. Balinsky, 1957 p. 27).

Autotomy and regeneration appear in a different form in sea cucumbers; here the parts capable of being shed and regenerated are not external appendages but the alimentary canal and other internal organs. When handled roughly, or when kept in unsuitable conditions, these animals throw out first their Cuvierian organs, if they possess them, then their intestine together with the respiratory trees, through the anus. The secretion of the Cuvierian organs is sticky, slightly elastic and most unpleasant to the touch. This reaction on the part of the animal may be very disconcerting when attempts are made to preserve the larger species of holothuroids such as *Holothuria atra*. In this case the animals have to be injected with formalin and at the same time the anus must be kept closed by pressing it with the fingers or with a clamp of some sort, until the animals are dead. If the sea cucumbers are left alone after they have thrown out the intestine, this will be restored after a while by internal regeneration.

Adult echinoderms do not appear to be used as food by other animals, except that the smaller ophiuroids are eaten by fishes. Holothuroids of the East Indies and Pacific are used in large quantities for human food, but on the Indian Ocean coast of Africa this is not the practice.

Whilst being of no direct usefulness to man, the echinoderms of Inhaca are not harmful either. In Europe certain starfish are regarded as pests because of the depredations that they make on the oysters, especially where the latter are cultivated commercially. On Inhaca the local oyster does not seem to suffer to any great extent from starfish, and in any case there being no commercial use for oysters, the question of damages caused by starfish does not arise. Some sea urchins may become disagreeable in a different way, however. Their spines are very sharp and penetrate human skin readily. This has to be borne in mind when trying to extricate specimens of *Stomopneustes variolaris* or *Echinometra mathaei* from their retreats in the rocks. Even if not poisonous, the spines penetrating the skin cause considerable discomfort, and are difficult to pull out, as they break off easily and the tip remains in the wound. The situation is still worse in the case of two species of sea urchins which are distinctly poisonous. These are *Diadema setosa* and *Echinothrix calamaris*. Both the poisonous species may be readily distinguished from other sea urchins by their very long spines (approaching or even exceeding the diameter of the body). *Diadema setosa* is bluish-black with beautiful white eye-spots on the aboral surface but the spines are striped in young specimens. *Echinothrix calamaris* is a shade of brown, and the spines are banded with brown or violet and white. Both these species will bristle their spines at the approach of any person and the spines may be directed towards the disturber. The spines of both species are very sharp and penetrate the human skin even on a slight touch. Once in the skin the spines cause acute pain and a numbness of the affected part of the body lasting for about an hour. The wound may remain very painful for a much longer period. The only treatment that can be applied in case of a person being pricked by the spines of these animals is to remove the spine from the wound as quickly and as completely as possible. Fortunately the poison has no lasting ill effect.

A different type of poisoning may be suffered as result of handling the beautiful creamy pink sea urchin *Toxopneustes pileolus*. This species possesses very large pedicellariae, which may, if given the opportunity, scratch and grip the skin of an unwary hand and in so doing inject sufficient poison to cause a feeling of discomfort and pain in the affected part.

It is advisable, therefore, when collecting on the beach, not to take the above-mentioned three species of sea urchins with the naked hand.

KEY TO ECHINODERMATA

The five orders of echinoderms present very unequal difficulties for the classification of their representatives found on Inhaca. Only one species of sea lily is at all common on Inhaca. The sea urchins and starfish are represented each by a rather small number of species. Specimens are fairly large, and most of them may be identified without difficulty. Keys for classifying these animals based on easily discernible characters are appended. Ophiuroids present more formidable difficulties —the number of species is much greater, and the size of the animals smaller. It is therefore necessary to study the finer details of their structure under a low power microscope (dissecting microscope).

The following glossary will explain terms used in the keys for identifying Ophiuroids.

Radial shields (fig. 27): a pair of large plates situated on the aboral surface of the disc at the base of each arm.

Oral shields (fig. 27): unpaired large plates situated on the oral surface interradially, between the bases of the arms.

Jaws: parts of the body protruding into the cavity of the mouth interradially.

Teeth: calcareous granules or short spines situated on the surface of the jaws in the mouth cavity.

Dental papillae: a cluster of small elongated skeletal elements situated on the tip of the jaw in some ophiuroids (externally to the teeth).

Oral papillae: skeletal elements in the form of small plates or large granules situated in some ophiuroids along the sides of each jaw (these elements are therefore always distinctly paired).

Upper arm plates: the larger plates covering each segment of the arm on the aboral surface.

Under arm plates: corresponding plates on the oral surface of each arm segment.

Arm spines: a group of large spines arranged in a vertical row on each side of every segment of the arm.

Tentacle scales: small plates (one or two in number) situated at the base of each tentacle (reduced tube foot) on the oral surface of the arms.

The classification of holothuroids is largely based on internal features, and the recognition of many species can only be made with certainty by studying the shape of microscopic spicules situated in the skin. The key presented in this handbook makes use of external features only, so that it can be used in the field or laboratory with a minimum of dissection. It cannot therefore be considered as being completely reliable. For those who would like to use the more exact keys contained in the works of Clark (1923), Deichman (1948) or Cherbonnier (1952) it would be necessary to make microscopic preparations of spicules. For this purpose a small piece of skin of the specimen which is being studied must be boiled in a solution of caustic soda until the skin is completely dissolved. The solution is then allowed to stand for a short while until the spicules settle at the bottom. A sample of the sediment can then be taken with a pipette, placed on a slide, covered with a cover slip and studied under a microscope.

ASTEROIDEA

1. The margin between the oral and aboral surface of the arms more or less rounded. 2
   The margin between the oral and aboral surface of the arms drawn out in a very sharp keel. **Asteriidae** 10

2. Aboral surface of the body covered with paxillae (complex spines bearing several spinelets or granules on the tip of a common shaft). 3
   Aboral surface without paxillae. 5

3. Always 5 arms, a double row of conspicuous plates arranged along the margin of all arms (marginal plates); colour in life light buff. **Astropectinidae**
   Astropecten granulatus
   Usually 7 arms, the plates along the margins of the arms are obscured by spines and are not conspicuous, colour in life more or less greenish. **Luidiidae** 4

4. An enlarged central spinelet on many paxillae.
   Luidia savignyi
   No enlarged central spinelets on any paxillae.
   Luidia maculata

5. Arms long and narrow, several times the diameter of the disc. **Ophidiasteridae** 6
   Arms not very long, not exceeding diameter of the disc or exceeding it only slightly. **Oreasteridae** 7

6. Arms 7-12 times the diameter of the disc, colour in life usually yellowish or greenish. *Linckia multifora*
   Arms 5-6 times the diameter of the disc, colour in life a bluish grey, orange, or bright red. *Linckia laevigata*

7. Central part of the disc raised, and the height of the body decreases towards the periphery, this decrease continuing along the length of the arms; aboral surface of the body bearing conspicuous thick conical spines. 8
   Body flattened, central part of the disc not raised; aboral surface without prominent conical spines. 9

8. One or two very large spines on each side of every arm towards its distal end, whilst along the rest of the margin of the arms the spines are very much shorter, or are reduced to small thickenings. *Protoreaster lincki*
   The spines along the margin of the arms more or less equal in development, though varying in length from one individual to another. *Pentaceraster mammillatus*

9. Arms short, but the contour of the body between the arms is distinctly concave; a pair of conspicuous plates, devoid of spines, near tip of each arm on aboral surface.
   Asterodiscus elegans
   The contour of the body between the tips of each two arms is a straight line, the body having the shape of a regular pentagon; no conspicuous plates near tip of each arm on aboral surface. *Culcita schmideliana*

10. Plates on oral surface bear 2-4 spines each. *Asterina burtoni*
    Plates on oral surface bear 1-2 spines each. *Asterina dyscrita*
    Plates on oral surface bear 1 spine each (a few nearer the disc edge may have 2). *Asterina exigua*

OPHIUROIDEA

(incomplete list, after J. B. Balinsky, 1957)

1. Arms branched. **Gorgonocephalidae** *Astroboa nuda* var. *nigra*
   Arms not branched. 2

2. Arm spines short, closely adpressed to the sides of the arm. 3
   Arm spines fairly long at right angles to the axis of the arm. 4

3. Disc covered by close granules, concealing plates. Arm spines 8-12. **Ophiodermatidae** *Ophiopezella decorata*
   Disc covered by smooth plates, arm spines 3. **Ophiolepidae** *Ophiolepis cincta*

4. The tip of the jaw i.e. the angle of the mouth projecting inwards bearing a cluster of small elongated skeletal elements the 'dental papillae'. 5
   The tip of the jaws not bearing 'dental papillae'. **Amphiuridae** 13

5. In addition to the dental papillae each jaw bears 2 or more pairs of skeletal elements situated symmetrically along its free edge, these are the 'oral papillae'. **Ophiocomidae** 6
   No oral papillae on the free edges of the jaws. **Ophiotrichidae** 9

6. Disc granules taller than broad, at least near margin; tentacle scale single. 7
   Disc granules not taller than broad; tentacle scales generally 2 though there may be 1 distally. 8

7. Arms 5; size large. *Ophiocoma valenciae*
   Arms 6; size small. *Ophiocoma parva*

8. Colour greyish, variegated with lighter markings; arms 6 or more times disc diameter. *Ophiocoma scolopendrina*
   Colour usually jet black; arms 4-5 times disc diameter. *Ophiocoma erinaceus*

9. Disc covered, at least between the radial shields, with a coat of small thorny stumps or spinelets. 10
   Disc bare, though plates obscured by skin in older specimens. *Ophiotrichoides propinqua*

10. Arms 7-20 times disc diameter. 11
    Arms up to 6 times disc diameter. 12

11. Radial shields closely covered by a coat of thorny stumps which also cover the rest of the disc surface; a light (yellow in life) stripe along the upper side of arms, at least distally. *Macrophiothrix hirsuta*
    Radial shield completely or almost completely bare; no longitudinal light stripe on arms. *Macrophiothrix aspidota*

12. Disc completely covered by short spinelets which branch at the tips; colour green and white in life. *Ophiothrix echinotecta*
    Disc covered by rather long spinelets, but the radial shields are bare; colour in life reddish, brownish or yellowish. *Placophiothrix foveolata*

13. Tip of jaw occupied by a pair of oral papillae. 14
    Tip of jaw without oral papillae but occupied by the lowest tooth. 18

14. Two oral papillae on each side of the jaw, the second being at its distal angle. 15
    Three oral papillae on each side. 16
    Four oral papillae on each side. *Amphioplus integer*

15. 2 tentacle scales per arm pore; disc covered by scales, arms about 5 times disc diameter. *Amphiura kalki*
    No tentacle scales, disc entirely naked except for the radial shields and a few scales around them; arms ten or more times disc diameter. *Ophionephthys africana*

16. Margin of disc with distinct fence of erect plates. *Ophiophragmus sacensis*
    Margin of disc without fence. 17

17. Second oral papilla very small; outermost papilla very broad, with a serrated edge. *Amphylicus androphorus*
    First and second oral papillae subequal; outermost papilla with a smooth edge. *Amphipholis squamata*

18. Arms always 5, colour in life reddish-brown or whitish. *Ophiactis carnea*
    Arms usually 6 (rarely 5 or 7) colour in life greenish. *Ophiactis savignyi*

ECHINOIDEA

1. Mouth in centre of oral surface of the body. 2
   Mouth at anterior edge of the body; body ovoid. Spatangoidea *Echinocardium cordatum*

2. Body very flattened, disc-shaped, breadth several times exceeds height. Clypeastroidea 3
   Body only slightly flattened, breadth exceeding height not more than by a factor of 2. 4

3. The disc with 2 deep narrow slits extending in from the posterior margin. *Echinodiscus auritus*
   The disc perforated with two narrow slits, which do not reach the margin. *Echinodiscus bisperforatus*

4. Spines very thick with blunt ends. 5
   Spines thin and pointed at the ends. 6

5. Primary spines with purple spots or longitudinal lines at base; size larger, up to 6 cm. in diameter. *Prionocidaris baculosa*
   Primary spines without purple spots or longitudinal lines at base; size smaller, usually not more than 2 cm. *Eucidaris metularia*

6. The tubercles, serving for the attachment of the larger spines, perforated, spines hollow. 7
   Tubercles serving for the attachment of spines not perforated, spines solid. 8

7. Colour bluish-black, spines of uniform colour when adult; in life on aboral side 5 conspicuous white or orange spots. *Diadema setosa*
   Colour a shade of brown, spines banded with dark and white. *Echinothrix calamaris*

8. Body elliptical. *Echinometra mathaei*
   Body circular. 9

9. Spines relatively short, conical, thick at base and evenly tapering distally. *Stomopneustes variolaris*
   Spines tapering very gradually, not very thick at base. 10

10. Test at least aborally or in midzone with deep pits or furrows between the tubercles. 11
    Test not pitted nor furrowed. 12

11. Spines more or less bright red. *Salmacis bicolor*
    Spines black or blackish. *Temnopleurus toreumaticus*

12. Body fairly high; diameter exceeding height by a factor of about 3/2; colour brown or yellowish. *Tripneustes gratilla*
    Body more flattened; diameter exceeding height by a factor of about 2; colour pink or red. *Toxopneutes pileolus*

HOLOTHUROIDEA

1. Body not very elongated, length not more than 10 times breadth. 2
   Body very elongated, length at least 10 times breadth, usually more; no tube feet; tentacles pinnate. Apoda *Synapta oceanica*

2. Tentacles dendritic. Dendrochirota 3
   Tentacles peltate (with a central short stalk giving off short horizontal branches). Aspidochirota 4

3. Feet only in distinct ambulacral rows; colour in life pale pinkish or yellowish. *Cucumaria crucifera*
   Feet scattered in the interambulacral spaces; colour in life dark, brownish. *Thyone sacellus*

4. A ring of 5 white calcareous teeth surrounding the anal opening. *Actinopyga mauritiana*
   No calcareous teeth surrounding the anal opening. 5

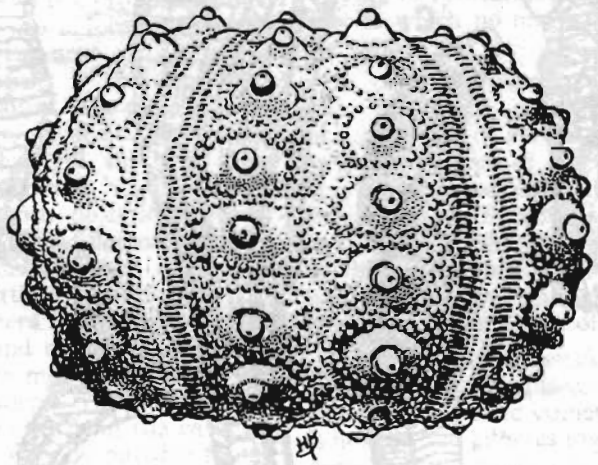
5. Large pointed tubercles on back and sides of body; colour in life a deep green. *Stichopus chloronotus*
   No large pointed tubercles on back and sides; colour in life black, brownish or greyish, never green. 6

6. Colour more or less uniformly black. *Holothuria atra*
   Colour grey mottled with white and black above, white below, skin very tough. *Holothuria scabra*
   Colour brown or brownish. 7

7. Size large; fully grown specimens up to 20 cm. and larger. 8
   Size small; fully grown specimens not over 15 cm. 9

8. Colour in life brown on upper surface, rosy on under surface. *Holothuria cinerascens*
   Colour in life dark brown on upper surface, paler on lower surface: skin very tough resembling *Holothuria scabra*. *Holothuria leucospilota*
   Colour in life light yellow with large dark brown spots. *Holothuria pervicax*

9. Colour in life yellowish or light pinkish grey with small darker spots. *Holothuria hilla*
   Colour in life dark brown. *Holothuria parva*



LIST OF REFERENCES

Ashby, E. Polyplacophora of South Africa. *Ann. S. Afr. Mus.*, **30**, 1931, 1.

Balinsky, J. B. The Ophiuroidea of Inhaca Island. *Ann. Natal Mus.*, **14**, 1957, 1.

Barnard, K. H. Cirripedia of South Africa. *Ann. S. Afr. Mus.*, **20**, 1924, 1.
— Marine fishes of South Africa. *Ann. S. Afr. Mus.*, **21**, 1925–1927, 1.
— Tanaidacea, Isopoda and Amphipoda of South Africa. *Ann. S. Afr. Mus.*, **32**, 1940, 381.
— Descriptive catalogue of the South African Decapod Crustacea. *Ann. S. Afr. Mus.*, **38**, 1950, 1.
— *South African shells*, Cape Town, 1950.
— South African Pycnogonida. *Ann. S. Afr. Mus.*, **41**, 1954, 8.
— Additions to the fauna list of South African Crustacea and Pycnogonids. *Ann. S. Afr. Mus.*, **43**, 1955, 1.

Bolwig, N. The influence of light and touch on the orientation and behaviour of *Gonodactylus glabrous* Brooks. *Br. J. Anim. Behav.*, **2**, 1954, 144.

Braga, J. M. Materiais para o estudo da fauna malacologica de Moçambique. *Ann. Jta. Invest. ultramar*, 7, (3) 1952, 65.

Carlgren, O. South African Actiniaria and Zoantharia. *K. Svensk. Vetensk. Akad. Handl.*, **17**, (3), 1938, 1.

Cherbonnier, G. Contribution à la connaissance des Holothuries de l'Afrique du Sud. *Trans Roy. Soc. S. Afr.*, **33**, 1952, 469.

Clark, H. L. The echinoderm fauna of South Africa. *Ann. S. Afr. Mus.*, **13**, 1923, 221.

Cohen, E. The marine angiosperms of Inhaca Island. *S. Afr. J. Sci.*, **36**, 1939, 246.

Crane, J. Basic patterns of display in fiddler crabs (Ocypodidae, genus *Uca*). *Zoologica N. Y.*, **42**, 1957, 69.

Dana, J. D. *Corals and coral islands*. London, Low, 1875.

Dandy, J. E. *in* F. W. Andrews. *The flowering plants of the Anglo-Egyptian Sudan*. Arbroath, Publ. for Sudan Government. 1950–56. Vol. 1–3.

Darwin, C. *On the structure and distribution of coral reefs*, 2 ed. London, Smith, Elder, 1874.

Day, J. H. On a collection of South African Polychaeta, with a catalogue of the species recorded from South Africa, Angola, Mozambique and Madagascar. *J. Linn. Soc. (zool.)*, **39**, 1934, 15.
—The Polychaete fauna of South Africa.
Part 1. The intertidal and estuarine Polychaeta of Natal and Mozambique. *Ann. Natal Mus.*, **12**, 1951, 1.
Part 3. Sedentary species from Cape shores and estuaries. *J. Linn. Soc. (zool.)*, **42**, 1955, 407.
Part 4. New species and records from Natal and Mozambique. *Ann. Natal Mus.*, **14**, 1957, 59.

Deichmann, E. The Holothurian fauna of South Africa. *Ann. Natal Mus.*, **11**, 1948, 325.

Edmondson, C. H. The ecology of an Hawaiian coral reef. *Bull. Bishop Mus. Honolulu*, **45**, 1928, 64.

Egerod, L. Eubank. An analysis of the siphonous Chlorophycophyta. *Univ. Calif. Publ. Bot.*, **25**, 1952, 325.

Eubank, L. Hawaiian representatives of the genus *Caulerpa*. *Univ. Calif. Publ. Bot.*, **18**, 1946, 409.

Gordon, H. A study of the ecology and behaviour of five species of Uca crabs. Unpublished thesis, Univ. Wits., Johannesburg.
— Synchronous claw-waving in fiddler crabs (genus *Uca*). Br. *J. Anim. Behav. (In the press.)*

Horst, J. C. van der. The Enteropneusta from Inyack Island. *Ann. S. Afr. Mus.*, **32**, 1940, 293.

Isaac, W. E. Marine algae of Inhaca Island and of the Inhaca peninsula, I. *J. S. Afr. Bot.*, **22**, 1956, 161.
— and Y. M. Chamberlain. Inhaca algae, II. *J. S. Afr. Bot.*, **24**, 1958, 123.

Kalk, M. Marine biological research at Inhaca, an interim report. *S. Afri. J. Sci.*, **51**, 1954, 107.
— The intertidal fauna of rocks at Inhaca Island. *Ann. Natal Mus.* (In the press.)

Kapelus, F. F. The anatomy of the enteropneust, *Sacoglossus inhacensis*. *Ann. Natal Mus.*, **8**, 1936, 47.

Kent, W. S. *The Great Barrier Reef of Australia*. London, Allen, 1897.

Lopes, A. P. Equinodermes da Ilha da Inhaca. *Documentario, Moçambique*, **20**, 1939, 71.

MacGinitie, G. E. and N. *The natural history of marine animals*. New York, McGraw-Hill, 1949.

MacLachlan, G. R. and Liversidge, R. *Roberts' Birds of South Africa*. Johannesburg, 1957.

Macnae, W. On four sacoglossan molluscs new to South Africa. *Ann. Natal Mus.*, **13**, 1954, 51.
— On the nudibranchiate molluscan families Polyceridae and Goniodoridídae. *Trans. Roy. Soc. S. Afr.*, 1958. (In the press.)

Marcus, E. and W. Macnae. Architomy in a species of *Convoluta*. *Nature*, **173**, 1954, 130.

Marcus, E. du B. R. On Turbellaria. *Ann. Acad. Brasil. Cienc.*, **29**, 1957, 153.

Mayer, A. S. Toxic effects due to high temperature. *Publ. Carneg. Instn.*, **252**, 1918, 172.

Millar, R. H. On a collection of Ascidians from South Africa. *Proc. zool. Soc. London*, **125**, 1955, 169.
— Ascidians from Mozambique, East Africa. *Ann. Mag. Nat. Hist.*, ser. 12, **9**, 1956, 913.

Moss, M. Marine angiosperms of Inhaca. *S. Afr. J. Sci.*, **33**, 1937, 344.

Nolte, D. J. Polymorphic coloration in Donax. *Caryologia*, suppl., **147**, 1954, 889.

Papenfuss, G. F. Notes on South African marine algae, II. *J. S. Afr. Bot.*, **9**, 1943, 79.
— New marine algae from South Africa, I. *Univ. Calif. Publ. Bot.*, **23**, (1), 1947, 1.
— Notes on South African marine algae, III. *J. S. Afr. Bot.*, **17**, 1951, 167.
— and Egerod, L. Eubank. Notes on South African marine Chlorophyceae. *Phytomorphol.*, **7**, 1957, 82.

Post, E. Weitere Daten zur Verbreitung des Bostrychietum VI. *Arch. Protistenk.*, **102**, 1956, 84.

Smith, F. G. W. *Atlantic reef corals* Univ. of Miami Press, 1948.

Smith, J. L. B. *The sea fishes of Southern Africa*, 2ed. Johannesburg, Central News Agency, 1953.

Stephen, A. C. Intertidal sipunculids of Cape Province and Natal. *Ann. Natal Mus.*, **10**, 1942, 245.

Tseng. A. Marine algae of Hong Kong, II. *J. Wash. Acad. Sci.*, **32**, 1942, 142.

Tyler, A. A simple, non-injurious method for inducing repeated spawning of sea urchins and sand dollars. *Collect. Net*, **19**, 1949, 19.

Vaughan, T. W. and Wells, J. W. Revision of the sub-orders, families and genera of the Scleractinia. *Spec. pap. geol. Soc. Amer.*, **44**, 1943, 1.

Verwey, J. Einiges über die Biologie öst-indischer Mangrove-Krabben. *Treubia*, **12**, 1930, 169.

Wellington, J. H. *Southern Africa, a geographical study*. Cambridge *Univ. Press, 1955.*

Wells, J. W. *Treatise on invertebrate Palaeontology*—Part F. New York, 1956.

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