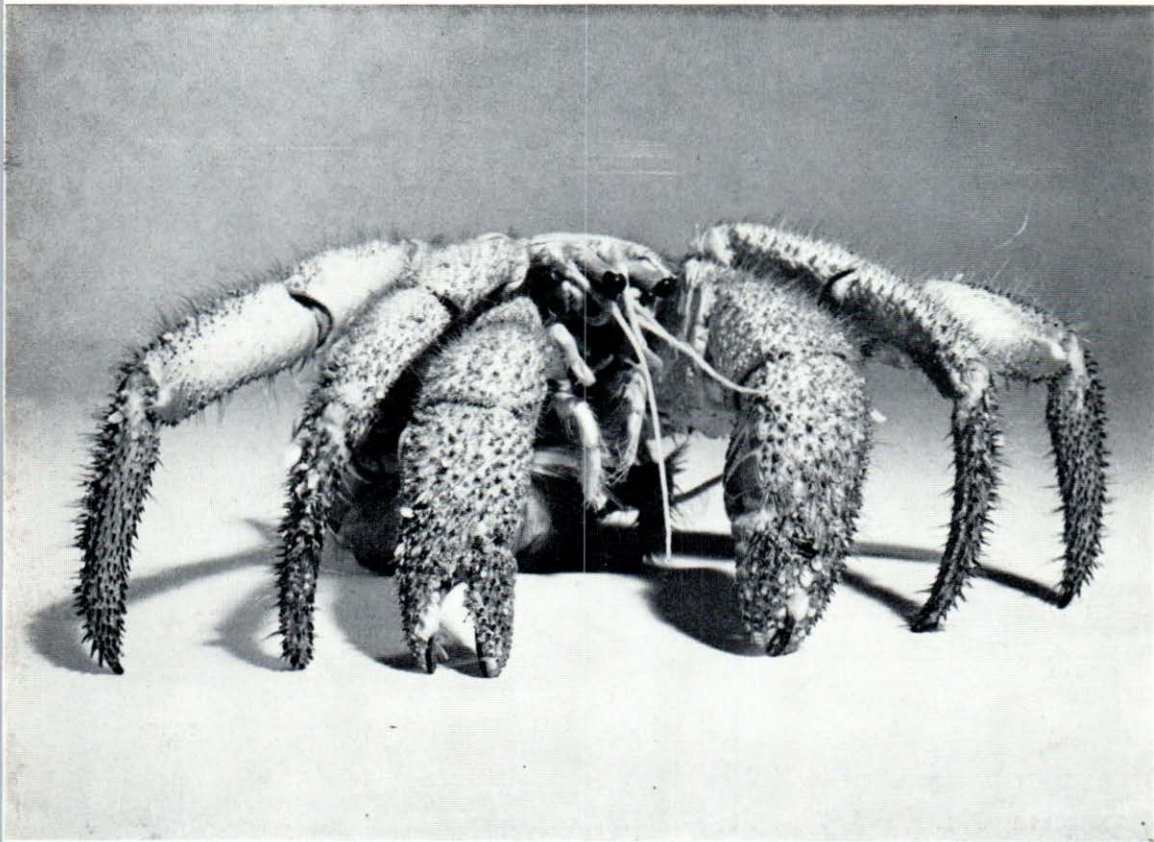


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● **FRONT COVER:** *Trizopagurus strigimanus*, one of the common large hermit crabs found in off-shore waters of southeastern Australia. It is bright red and covered with yellow spots and long golden hairs, and reaches about 7 inches in body length. Note the mouthparts hanging down beneath the stalked eyes and antennae. On the inner sides of both hands are ridges which are used to make a rasping sound; those on the hand at right are seen in this photo. An article on hermit crabs appears on the opposite page. [Photo: C. V. Turner.]



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HERMIT CRABS

By D. J. G. GRIFFIN

Assistant Curator of Crustaceans and Coelenterates, Australian Museum

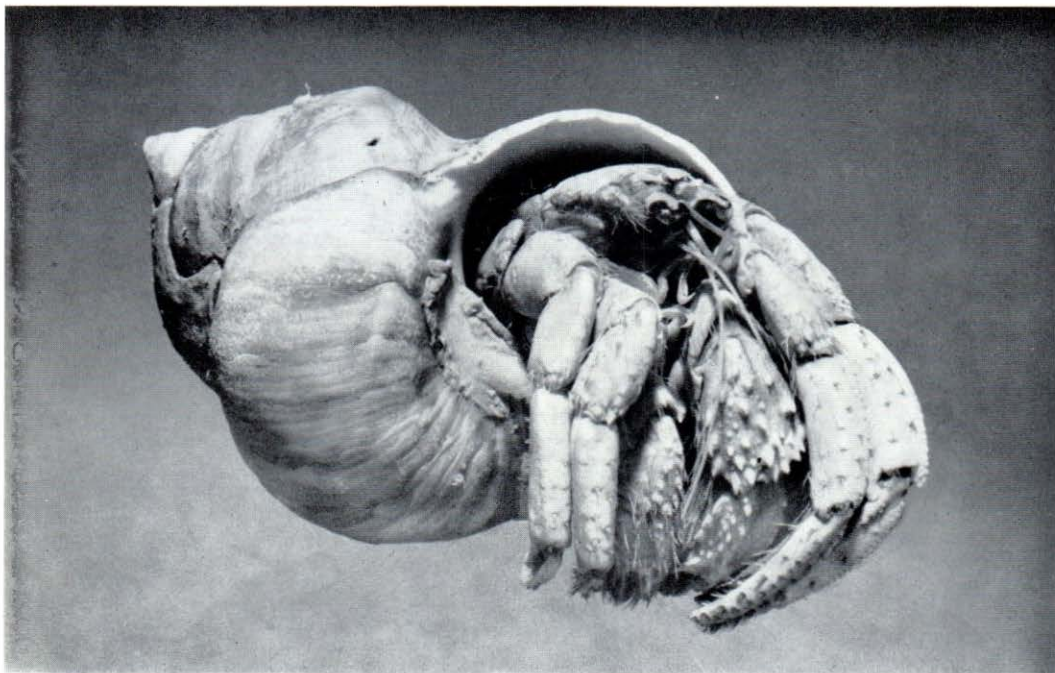
HERMIT crabs, because of their habit of protecting their soft abdomen within the empty shell of a gastropod mollusc, have for a long time fascinated naturalists interested in marine animals.

All crustaceans grow by moulting many times during their lifetime. After the old shell has been shed, the new one is soft and the animal is then extremely vulnerable to other animals which feed on it. During the few days after they have moulted, crustaceans usually hide themselves away under stones or in crevices. Hermit crabs, however, are constantly protected by the gastropod shell and thus have no need to hide during moulting.

Because of their use of gastropod shells, hermit crabs have another problem—that of finding a new shell whenever they become too big for the one they already occupy. Within the shells they are, of course, well protected at all times from predators. Whilst the abdomen is soft it is nevertheless provided with muscles which, together with calcified appendages at the end of the tail, hold the animal securely inside its shell. These muscles and appendages enable the

crab to retract quickly into its shell, where it closes the aperture very effectively with its large claws.

Hermit crabs are characterized by having the body longer than broad, and cylindrical, or nearly so; the carapace which covers the cephalothorax is soft towards the hinder part and the abdomen is spirally coiled and asymmetrical. The first and last segments of the abdomen are small and calcified but the remaining four are soft and show practically no trace of a division into somites. Into this soft membranous bag extend the gonads, digestive glands or liver and renal bladder, organs located within the thorax in related crustaceans. The appendages of the last abdominal segment, as already mentioned, are specially modified for holding the crab in the gastropod shell. The outer branch of the left appendage is large and sickle-shaped and the whole appendage is longer than the right one. The abdominal appendages or pleopods are reduced in number and often confined to the left side, one or two pairs usually being present on segments 2 to 4 or 3 to 5. The first pair of legs, the chelipeds, are usually massive, and



The hermit crab *Dardanus varipes*, partly emerged from its gastropod shell (*Tonna* species), which, in turn, is encrusted by sea anemones (*Calliactis miriam*). *D. varipes* is found in central and northeastern Australia and much of the Indian Ocean.

often one is very much larger than the other. The second and third pairs of legs are long, but the fourth and fifth are much smaller and sometimes modified as small nippers at their tips. As in shrimps, lobsters, crabs and their relatives, the eyes are on long stalks.

Classification of hermit crabs

Hermit crabs are only distantly related to the true crabs or Brachyura. Related crustaceans, the land hermits, have the whole of the carapace well calcified. In the robber crab (*Birgus*) the abdomen is symmetrical, small and calcified (see *Australian Natural History*, Vol. XIII, No. 9, March, 1961, page 283). Hermit crabs, together with a number of other groups, such as the half crabs, ghost nippers, mud shrimps and stone crabs, form the Anomura, one of the three major divisions of the reptant or walking decapod Crustacea.

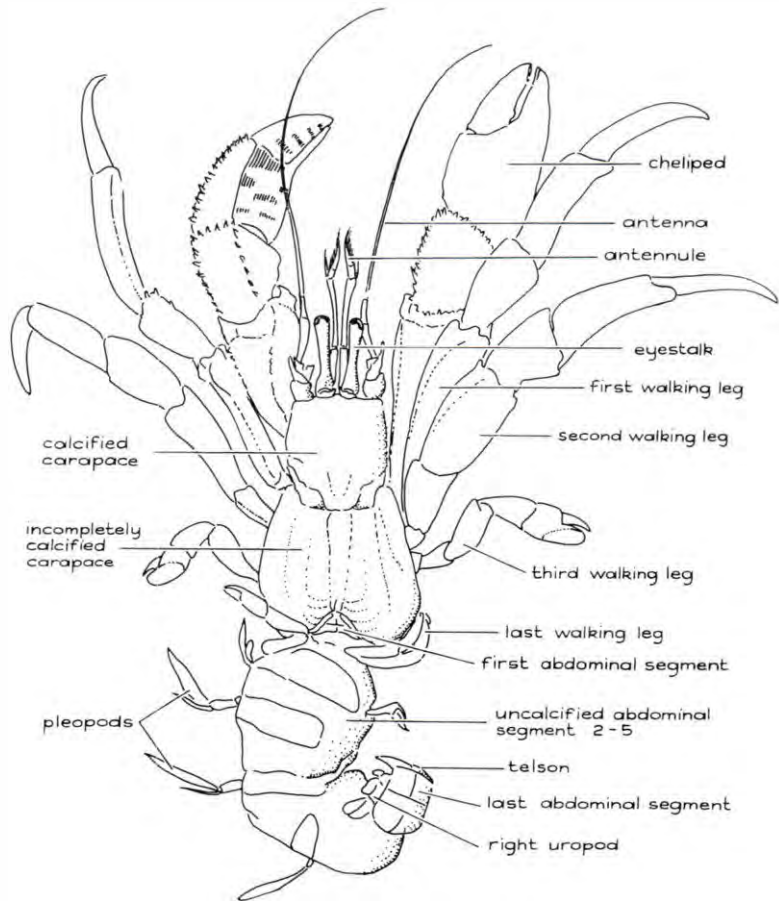
Some common eastern Australian hermit crabs

Among the common intertidal hermit crabs in New South Wales are the small

Pagurus sinuatus, which is red and usually found in turban-shells, and a very lively, related species, *P. lacertosus*. Both these species are found on rocky coasts. *Paguristes squamosus* is a very hairy species found on ocean beaches in New South Wales. This species is pinkish in colour when alive, with rough brown ridges on the chelipeds and legs; the eyestalks are green.

Paguristes tuberculatus occurs in shallow waters off New South Wales and is found also in Tasmania. The shells which this species inhabits are nearly always covered with colonies of bryozoan lace coral. Among the common large species found in offshore waters in New South Wales is *Trizopagurus* (formerly *Clibanarius*) *strigimanus*, a bright-red animal covered with yellow spots and long golden hairs; it reaches about 7 inches in total body length. The chelipeds in this species are of about equal size and the hands are provided on their inner surfaces with broad ridges which are used in stridulation. The sound produced by these crabs has been described as resembling that made by passing the point

A diagram of a hermit crab (based on a specimen of *Trizopagurus strigimanus*), showing the external parts.



of a penknife across the teeth of a comb. This species occurs around all southeastern Australia.

A number of large species of *Dardanus* are common hermits along the Barrier Reef. Among them is *D. megistos* (see *Australian Natural History*, Vol. 15, No. 8, December, 1966, page 240). The related species, *D. arrosor*, which has the chelipeds and legs prominently transversely striated, and *D. deformis*, are associated with sea anemones such as *Calliactis miriam* that are attached to the gastropod shells in which the crab lives. Not all true hermit crabs live in empty shells. A notable exception is the Australian Miner Hermit Crab (*Cancellus typus*), which is found in tunnels in soft rock, tunnels which it possibly excavates itself (see *Australian Museum Magazine*, Vol. XI, No. 2, June, 1953, page 44). *Cancellus*

is also sometimes found in dead colonies of Bryozoa. The chelipeds are of equal size and fold together so that, with the second legs, they completely seal the animal in its tunnel.

General biology

Hermit crabs are usually detritus feeders and scavengers. They may break open young barnacles or the tubes of polychaete worms and eat the contents. They may also scrape encrusting organisms from the sides of stones. Small bits of algae, protozoans, crustaceans and molluscs are sifted out of the sand or mud by the mouth-parts. Small organisms may also be filtered from the water.

Marine hermit crabs which live intertidally or in off-shore waters breathe by means of gills in the same way as do other aquatic

animals. These gills are feathery structures attached in series to the bases of the legs and sides of the body beneath the carapace. The land hermits (*Birgus* and *Coenobita*), on the other hand, have the branchial chamber richly supplied with blood vessels, and in *Birgus* there are special folds of tissue in the chamber which increase the respiratory area. In *Coenobita* the anterodorsal area of the abdomen is also richly supplied with blood vessels and can serve the crab's respiratory needs in the absence of the normal co-operation of the gills. *Birgus* and *Coenobita* can utilize atmospheric oxygen and are able to survive for many months in air after removal of the gills (for notes on *Coenobita* species, see *Australian Natural History*, Vol. 15, No. 2, June, 1965, page 37, and Vol. 15, No. 3, September, 1965, page 65).

As in related crustaceans, the developing eggs of hermit crabs are carried on the pleopods of the female, which are densely fringed with long hairs. The female spends much time aerating the eggs by removing her abdomen from the shell and waving the eggs to and fro by movements of the pleopods. When the eggs are ready to hatch the female again removes her abdomen from the shell and assists release of the eggs by gently wiping them with a brush of hairs on the last walking leg of the left side. The eggs hatch into zoeae, larvae which float freely in the sea. Each zoea has a pointed projection at the front of the carapace, and a long abdomen; only the anterior appendages are well developed in the early stages. The developing zoea moults up to three times during growth and in the last moult changes into a "glaucothoe", a larval stage which possesses the main features of the adult hermit crab but has the carapace extended outwards at the sides and not bent down.

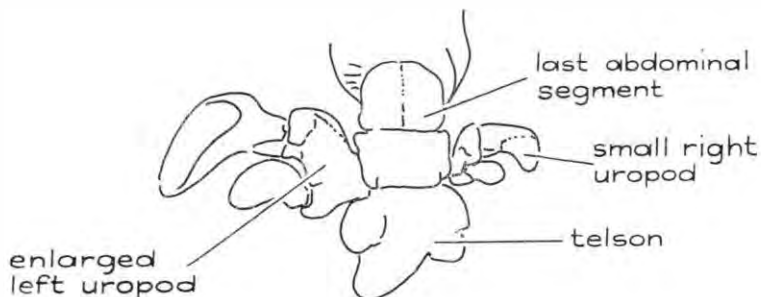
During the four or so days for which this stage lasts some of the internal organs shift into the abdomen, and the pleopods, initially present on both sides of all somites except the first, gradually degenerate or disappear. For a long time the glaucothoe was thought to be a distinct animal in its own right.

Shell-selection behaviour

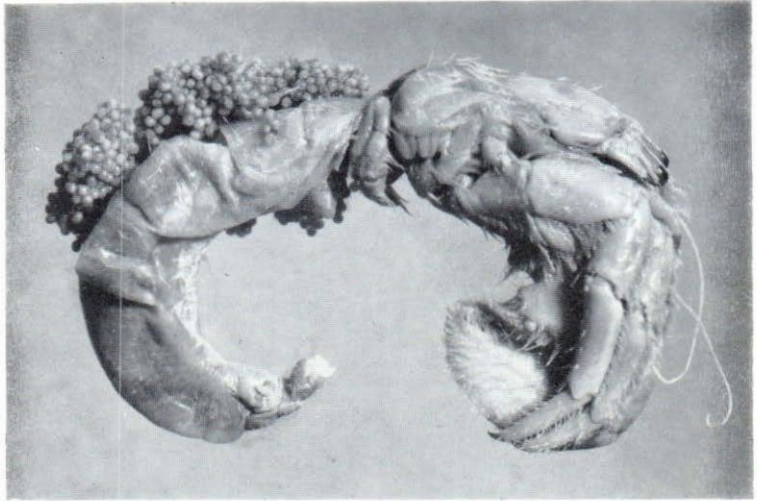
During its lifetime each hermit crab must find a suitable gastropod shell many times, for as it grows it gradually becomes too big for each successive shell. The crab actually moults inside the gastropod shell but when the time comes to change its home it investigates a number of empty shells. Although a crab will never attack a healthy gastropod in its shell, it sometimes will eat a sick snail.

For many years it has been apparent that different species of hermit crabs tend to inhabit the shells of different species of gastropods. Recent studies by Dr E. S. Reese, of the University of Hawaii, and others, have confirmed that this may be explained by at least two factors, an actual preference for certain species of shells and the relative abundance of shells of different species in different habitats. Visual orientation is important only in the early stages of shell selection, when the crab investigates any object such as a pebble or a shell which contrasts strongly with the background. After having made contact with the shell, only touch is important and special organs on the legs, cephalothorax and abdomen are used in this part of the behaviour pattern. However, crabs with only one appendage, or with the abdomen missing, are still able to select a satisfactory shell. A large number of features of the shell are important in determining whether or not it will be suitable for occupation by the crab. These include

A diagram of the tail fan (last abdominal segment, telson and associated appendages), showing the disparity in size between the left and right appendages which hold the abdomen firmly in the gastropod shell.



A female *Pagurus sinuatus* carrying eggs. Note that the masses of eggs are carried on one side of the abdomen only. The pleopods, which hold eggs, are reduced or absent on the right side. This species is one of the common intertidal hermit crabs of New South Wales.



movability, surface texture, external shape, nature of the aperture, internal size, and shape and weight of the shell. Crabs are able to discriminate very effectively between shells of the same species of different weights and select a shell appropriate to their own size. After entering a new shell the crab continues to investigate other shells and the amount of energy it exerts in this depends on the suitability of its recently acquired home. This behaviour associated with entry into shells is entirely inherited and is fully expressed when the glaucothoe enters its first shell; the ability to choose shells of particular species and of a particular weight does not depend on previous experience.

Relationships between hermit crabs, the gastropod shell and other animals

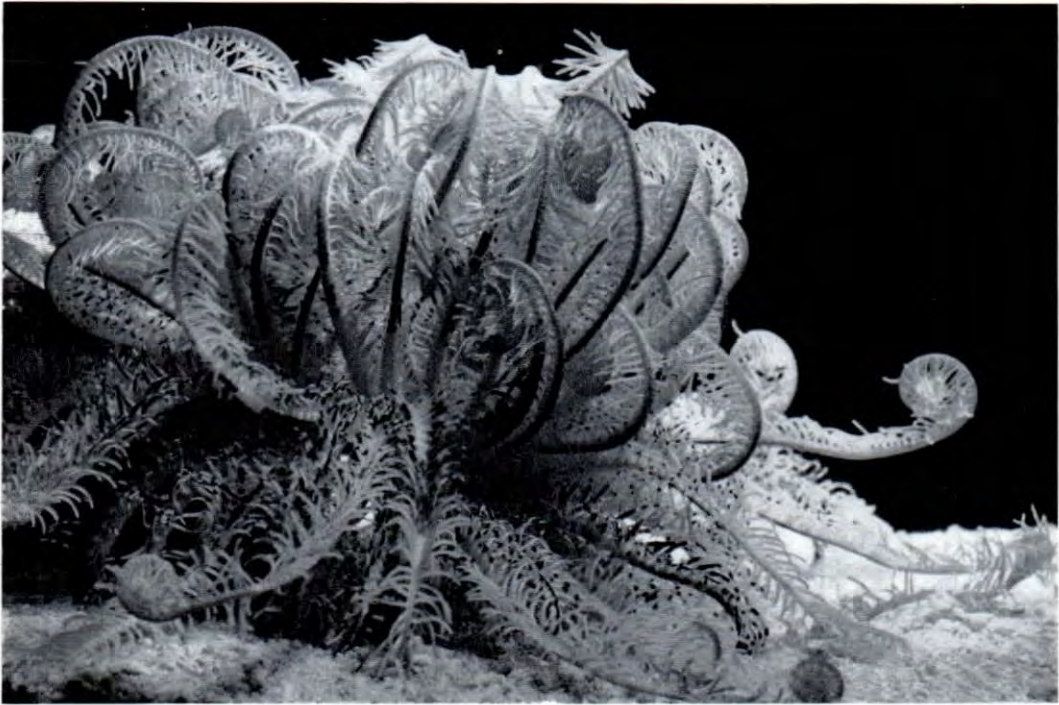
As already mentioned, the shells inhabited by hermit crabs are often the bearers of other animals, such as anemones, bryozoans, etc.

The behaviour of two European species of hermit crab which are usually associated with sea anemones has recently been studied by Drs D. M. Ross and L. Sutton, of the University of London. The anemone *Calliactis parasitica* is associated with both *Pagurus bernhardus* and *Dardanus arrosor*. In the case of the former, *Calliactis* prefers the same gastropod as does *Pagurus* and will often transfer to shells occupied by that

crab. The crab plays no part in this transfer. The anemone initially attaches to the empty gastropod shell by means of the nematocysts located in the tentacles. Once the pedal disc of the anemone has transferred to the new shell the tentacles release their hold on the shell and the anemone resumes its normal posture. The major factor stimulating the anemone to attach to a shell is some substance associated with the shell and derived from the original gastropod owner. In the case of the association with *Dardanus arrosor*, however, whilst the anemone will transfer to the gastropod shell occupied by the crab, significant numbers of *Dardanus* actually aid the anemone in making this transfer. This is particularly true of female crabs. Sometimes a *Dardanus* will pull a *Calliactis* off the shell occupied by another crab even though its own shell is already loaded to capacity with anemones.

Finally, recent observations by Professor H. Munro Fox, of London University, have confirmed observations made by Lt-Col. Wortley 104 years ago that the European *Pagurus prideauxi* not only transfers the anemone *Adamsia palliata*, with which it is associated, to its new gastropod shell each time it moves house, but also that the crab actually shares its food with the anemone.

[Diagrams in this article are by the author; photos are by C. V. Turner.]



Feather stars are among the most beautiful marine animals. This comasterid feather star, from Heron Island, has delicate yellow tips to its plume-like arms, which constantly move. Most of the side-pinnules on the arms are chalky white, with black flecks here and there. [Photo: Harold G. Cogger.]

Lesser Known Echinoderms of the Great Barrier Reef

By ELIZABETH C. POPE

Curator of Worms and Echinoderms at the Australian Museum

IT is at once obvious to anyone accustomed to reef collecting in the southern half of Australia that the echinoderms (starfish, sea urchins and their relatives) of the Great Barrier Reef are alien to him. Not only do the faunas of tropical and temperate seas differ markedly in regard to the species they contain, but there is also a different emphasis on the relative importance of the major groups—the classes. In the cooler seas of the south, starfishes and sea urchins dominate

the echinoderm scene intertidally, whereas in the tropics it is the holothurians (trepang, bêche-de-mer or sea cucumbers) that at once arrest attention. Brittle stars are also very numerous. Admittedly, sea urchins and starfish also figure in the tropic fauna but they are relatively less important than they are in the temperate zone. The extremely delicate and beautiful feather stars are fairly common in the tropics but may be considered rarities in the southern intertidal zone.

These major differences between tropic and temperate faunas of echinoderms are scarcely ever mentioned in popular accounts of the Reef and may even be obscured because books on the natural history of coral reefs tend to illustrate or discuss striking species like the Blue Starfish (*Linckia laevigata*), the Slate-pencil Urchin (*Heterocentrotus mamillatus*) or the Needle-spined Urchin (*Diadema setosum*), while the extremely common, sausage-shaped, rather ugly holothurians (which few people can name, anyway) receive only passing mention and the brittle or snake stars are almost ignored. For this reason only slight reference will be made here to echinoderms that figure prominently in well-known popular accounts of the Great Barrier Reef and an attempt will be made to highlight important or interesting species which are less familiar.

Feather stars (class Crinoidea)

Living feather stars rival some of the "feather duster" types of tube worms in the beauty of the colour and patterns on their delicate feathery arms. They are fragile and, unless given expert treatment, generally fragment, so they are unpopular with reef collectors. A recent Australian Museum expedition to the Swain Reefs, at the southeastern end of the Great Barrier Reef, paid special attention to the crinoids and brought back a fine and varied collection but, until it has been worked by an expert, little can be added to what has already been published about this group. A fine series of colour

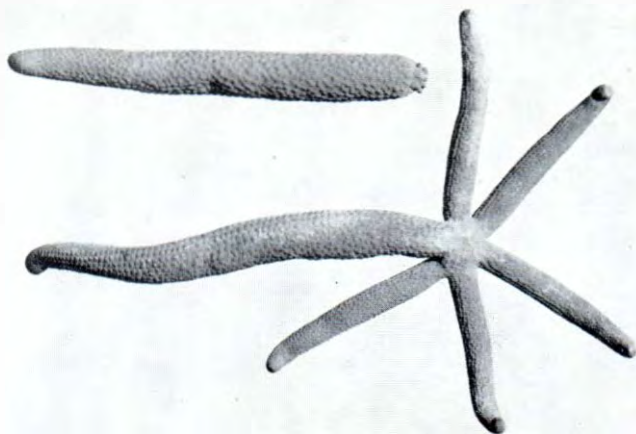
transparencies was obtained of living feather stars and one is reproduced in black and white here. Unfortunately, it cannot even be named with certainty but it is hoped that this gap in our knowledge of Great Barrier Reef crinoids will soon be closed.

Sea cucumbers, bêche-de-mer or trepang (class Holothuroidea)

Probably the commonest large holothurian along the Reef is the Black Cotton-spinner (*Holothuria leucospilota*), shown in an accompanying illustration. Sometimes they lie out in the open, on the bottom, but more often the rear end of the body is protectively tucked beneath a dead coral boulder or an algal clump. When disturbed they shoot out fine white threads of an extraordinarily sticky nature through the rear opening or anus. Hence the name cotton-spinner. This is regarded as a defensive mechanism since enemies can be entangled in the threads. A second black species (*Holothuria atra*) may be seen and, apart from structural differences which one can recognize, it is easy to distinguish from the other species because it cannot exude the sticky threads. It is not a cotton-spinner.

Another easily recognizable holothurian, even though its upper surface is dark, like the foregoing species, is the edible holothurian (*Holothuria edulis*), for its lower surface is a delicate pinkish purple and its body is more compact and solid than in some other species. Compactness of body is apparently a desirable quality, sought by trepang

Much commoner than its brilliant blue relative is the Grey Linckia Starfish (*Linckia guildingii*), shown here as a single arm (above) in process of regenerating parts lost by injury. The five new arms-to-be look like pimples on its right tip. Below, at a much later stage in the process, it is popularly called a comet, for obvious reasons. Ultimately all arms will grow to adult size. Other species can also regenerate in this way. [Photo: Howard Hughes.]





The many black bêche-de-mer (*Holothuria leucospilota*) which lie scattered about in this shallow tropical lagoon emphasize the prominence of holothurians, as a group, in the tropical fauna. [Photo: Otho Webb.]

fishermen. Trepang is a Malay word for holothurians and, as used by Aborigines at Cape Don in the Northern Territory, seems specially to be applied to edible species. Recently at Cape Don I was told "him trepang" as my Aboriginal instructor pointed to *Holothuria atra*, while "him not trepang" indicated the longer *H. leucospilota*, which is also black.

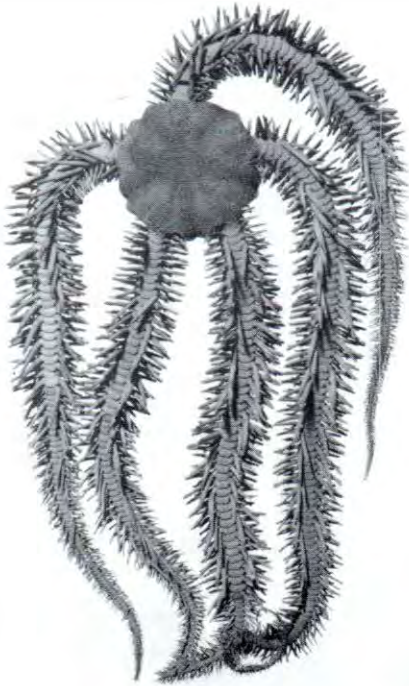
Another common species is the dark, bottle-green "prickly fish" (*Stichopus chloronotus*). It is generally smaller in size than the previous species mentioned, being 9 to 12 inches in length, and it has a very firm body-wall from which spiky processes project on all sides. It tends to frequent crevices or ledges round the bases of boulders. There are, of course, many other kinds of holothurians, even common ones, that cannot be mentioned here. They include not only large ones, sought as trepang, but also others, like the Tiger-striped Waterbag (*Synapta maculata*) and small, rather worm-like kinds belonging to the apodous group — so called because they lack the tube feet which are present in other groups.

The Snake and Brittle Stars (class Ophiuroidea)

The late Hubert Lyman Clark, an authority on Australian echinoderms, considered that the brittle stars belonging to the ophiocomid family formed the most striking group of ophiuroids along the eastern Australian coast.

A typical *Ophiocoma* is the handsome dark-red species, *O. erinaceus*, which occurs in countless numbers in the interstices of coral rubble or under boulders on the reef flats. As the tide rises their spiny, questing, dark arms wave about in the returning waters like dark worms. The red colour is so dark that it looks almost black but after preservation both the upper and lower surfaces dry to a dark grey. Another closely related species, *O. scolopendrina*, is also dark and sombre in colour but generally has light markings on its lower surface, especially round the mouth.

In the genus *Ophiocoma* arm spines are long, fairly numerous but simple and not thorny, as in some other genera, like the very



Probably the commonest of the larger brittle stars on coral reefs is *Ophiocoma erimaceus*, which is deep red to black in colour. [Photo: Howard Hughes.]

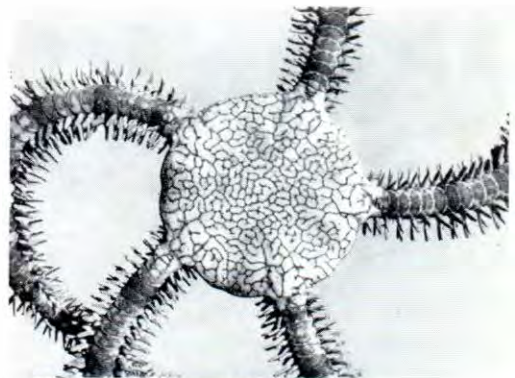
common *Placophiothrix spongicola* which, as the specific name suggests, is mostly found coiled up in crevices in sponges. Another distinguishing feature of *Ophiocoma* is the covering of granules on the body disc, thus differing from the closely related genus *Ophiomastix*, which has spinelets instead of granules. Two common species of *Ophiocoma* are illustrated to show typical colour patterns and general appearance.

Probably the most frequently seen ophiuroids on the Reef are the Smooth-armed Snake Star (*Ophioplocus imbricatus*) and *Ophiarthrum elegans*, with its soft-topped disc and spiky arms, but their drab colouring does not attract collectors as a rule. The very large, olive-green species *Ophiarachna incrassata* often lies openly in pools and is much photographed, but few people recognize its juveniles, which, instead of having plain green arms, carry alternating, broad, light and darker green cross-stripes.

Starfish and sea urchins

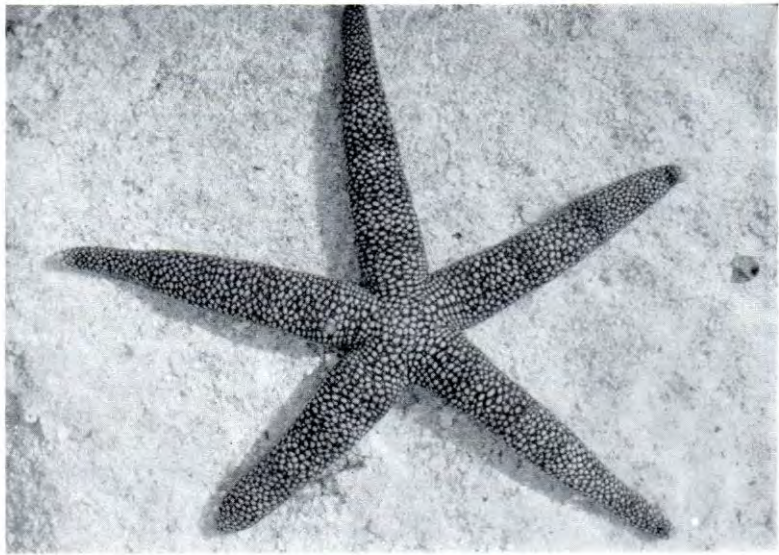
As these groups receive plenty of attention in popular accounts they are grouped together here and will be given scant notice.

Few people realize that two species of large blackish needle-spined urchins occur on the Reef. If one has live specimens it is easy to distinguish the better known *Diadema setosum* from *D. savignyi* by looking at the large anal tube which protrudes from the centre of the upper surface of the body. If the opening at its tip has a reddish or orange ring surrounding it, the species is *D. setosum*; if not it is *D. savignyi*. Other large urchins which sport injurious spines are *Echinothrix diadema* and its relative, *E. calamaris*. Their larger (primary) spines are much shorter than those of *Diadema* and, like them, are hollow, barbed and brittle.



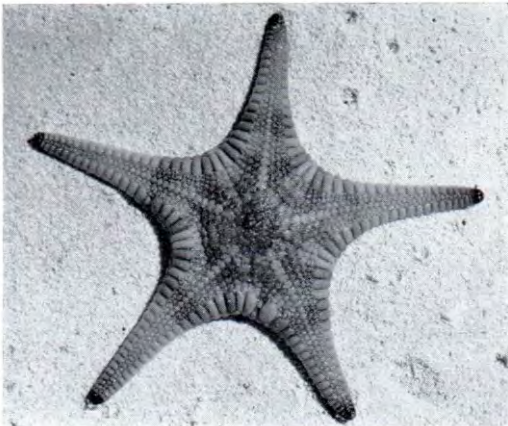
These two species of *Ophiocoma* typify the kinds of colour patterns and variations in spinulation found in the genus. Browns, greys and olives colour *O. insularia* var. *variegata* (above), while gold and black mark *O. pica* (below). [Photo: Howard Hughes.]

With tonings of brown on the raised tubercles and greenish-brown in between, *Nardoa pauciformis* is a striking looking starfish. It grows to a considerably bigger size than its very common relative, *N. novaecaledoniae*. [Photo: A. Healy.]



but the rows of very slender secondary spines, like bunches of sharp needles, are more solid and are particularly associated with the rows of tube feet. In *E. calamaris* both types of spines are cross-banded in light green and dark brown or sometimes dark red, while in *E. diadema* all spines tend to be uniformly dark.

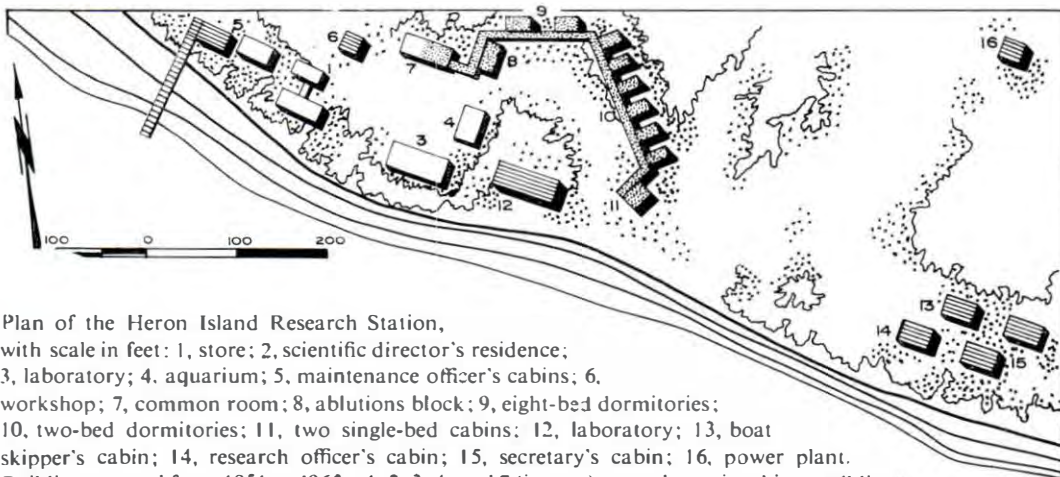
Several important starfish are illustrated, including the bottle-green and flesh-coloured



A most pleasing pattern of body plates and subdued colouring mark *Goniodiscaster coppingeri*. In life, the dark tips of the arms are curled up off the seabed, bringing their contained sense organs into an advantageous position to assess the environment. [Photo: A. Healy.]

Nardoa pauciformis (whose better-known relative, *N. novaecaledoniae*, is one of the commonest stars on the Reef) and the sombre coloured, though beautifully patterned, *Goniodiscaster coppingeri*. In the latter the five narrow arms are generally black-tipped, but the rest of the upper surface is toned in pale fawns and light and dark tonings of brown. The blue *Linckia* star is well known, but, by comparison with its relative the grey *Linckia* (*L. guildingii*), it must be considered rare. The grey *Linckia* is one of the commonest Reef inhabitants and is so frequently found regenerating that this is believed to be a regular method of reproduction for this species. Even a single arm can grow all the missing parts, provided there was a tiny bit of the body disc attached to it in the first place. At the stage when four of the arms are still small and the original one is still big, they resemble comets and are actually called this. Juvenile *L. guildingii* are often spotted by irregular brownish patches on their upper surfaces which disappear as they mature.

Many more starfish and urchins could qualify as lesser known and interesting members of our tropical fauna but in an article of the scope of this, the line must be reluctantly drawn before the half is told. The best way to learn about Australia's wonderful tropical echinoderms is to go reefing and see them for oneself.



Plan of the Heron Island Research Station, with scale in feet: 1, store; 2, scientific director's residence; 3, laboratory; 4, aquarium; 5, maintenance officer's cabins; 6, workshop; 7, common room; 8, ablutions block; 9, eight-bed dormitories; 10, two-bed dormitories; 11, two single-bed cabins; 12, laboratory; 13, boat skipper's cabin; 14, research officer's cabin; 15, secretary's cabin; 16, power plant. Buildings erected from 1951 to 1963—1, 2, 3, 4, and 7 (in part)—are shown in white. Buildings erected in 1964–1965—5 (one unit), 8, 9, 10, 11, and 7 (extended)—are shown in stipple. Buildings projected for future development—5 (second unit plus boat slips), 6, 12, 13, 14, 15, 16—are horizontally lined.

The Great Barrier Reef Committee— Its Work and Achievements, 1922–66

By O. A. JONES

Chairman of the Great Barrier Reef Committee

IN 1922, following an address by the late Professor H. C. Richards to the Royal Geographical Society of Australasia (Queensland), the Great Barrier Reef Committee was formed with eleven members, the late Sir Matthew Nathan, Governor of Queensland, being chairman and Professor H. C. Richards honorary secretary.

The original Committee was rapidly expanded to include representatives of Government Departments, Royal Societies, museums, etc., including overseas societies and institutions, some sixty in all. The objects of the Committee were simply but widely stated as being to carry out and sponsor research into all aspects of the Reef and its life.

Finance for the early work of the Committee was provided by a number of private individuals and the Universities of Sydney,

Melbourne and Queensland to an amount of £2,500, which was subsidized by the Queensland Government on a pound for pound basis over a term of five years. The Queensland and Commonwealth Governments also provided travelling facilities, and the latter clerical assistance and £1,000 for publication expenses. The Victorian Government assisted materially with boring operations.

Work during the period 1922–1928

A good deal of work was done during this period by individual members of the Committee, and early in 1924 Mr Chas Hedley, then of the Australian Museum, was appointed as Scientific Director; further, Mr F. Jardine, Senior Research Scholar, Deas Thomson Scholar and John Coutts Scholar, University of Sydney, and Mr G. A. V. Stanley, Science Research Scholar,

University of Sydney, worked with the Committee for two successive seasons on physiographic and geological aspects of parts of the Queensland coast bordering the Reef. Mr P. Crosbie Morrison carried out marine zoological work for one season while attached to H.M.A.S. *Geranium*.

Thus the early work of the Committee, apart from the deep bore on Michaelmas Reef, to which reference is made below, was largely geological and physiographical in nature. Papers arising from this work are to be found in Vols XXXVIII and XXXIX of the Queensland Geographical Journal (three papers) and Vols I and II of the Reports of the Great Barrier Reef Committee (some twenty papers).

Little was achieved in the way of biological results. Mr Hedley was able to do little during 1924-25 because of many other duties, and he died early in 1926.

Deep bores

Though not forgetting the urgent need for biological work, the Committee now focussed its attention on the origin of this 1,200 miles length of coral reefs. It felt that a number of deep bores might provide proof of one or other of the theories of Darwin, Murray, Agassiz and Daly.

It succeeded in sinking two calyx drill bores, 700 miles apart, one in 1926 on Michaelmas Cay, twenty-two miles NNE. of Cairns, to a depth of 600 feet, and the other in 1937 on Heron Island, about 48 miles NE. of Gladstone, to 730 feet. Neither bore reached "basement" rocks, but each yielded a great mass of valuable information.

In 1961 an oil exploration bore was sunk on Wreck Island about seven miles to the north of Heron Island. This revealed 398 feet of reef material, then marine Pleistocene and Tertiary strata to 1,795 feet, at which depth rock presumed to be older was encountered.

Though three bores in a length of 1,200 miles cannot be regarded as adequate "sampling", the evidence from all three does lend support to Darwin's theory of subsidence of the "platform" on which the reefs are built, at a rate no greater than the upward growth rate of the coral.

Biological work

The Committee's early attempts to get biological work carried out were frustrated because of scarcity of workers and lack of finance. This deficiency was spectacularly rectified when the Committee in 1927 arranged through the late Professor J. Stanley Gardiner for the formation by the British Association for the Advancement of Science of a committee representing the sections of Zoology, Botany, Geography and Geology with other co-opted members, with the object of organizing a British-Australian expedition to the reef.

The efforts of the two committees, the British and the Australian, were eminently successful and resulted in the British-Australian Great Barrier Reef Expedition 1928-1929, perhaps better known, after its leader, as the Yonge Expedition. Between 16th July, 1928, and 28th July, 1929, eleven scientists (ten British and one Australian) spent $10\frac{1}{2}$ to $12\frac{1}{2}$ months and seven (all British) 3 to 5 months on Low Isles, 45 miles north of Cairns: five of the staff of the Australian Museum spent four to six weeks at the temporary station and others from various universities and museums paid shorter visits. The personnel of the "permanent" party included a physiologist, zoologists, a botanist, a chemist, a hydrographer and geographers.

The results (other than geographical) of this year of intensive effort were published by the British Museum in an impressive series of six quarto volumes. This work constitutes the most detailed and comprehensive study of coral reef zoology and physiology yet carried out, and is still the basic source to which zoologists and physiologists turn when undertaking coral reef studies.

Geographical work

The geographical section of the expedition worked for the most part separately from the biological scientists and during this and a later (1936) purely geographical expedition, both led by Mr J. A. Steers, travelled the whole length of the Reef studying many dozens of reefs and cays in some detail. Significant results included the description of a previously unknown type of reef and island, one restricted to the seas within the

northern part of the reef (Low Wooded Islands of Steers or the Island Reefs of Spender), and the gathering of evidence bearing on changes of sea-level during recent geological times. The 1928 expedition made detailed and highly accurate maps of Low Isles and Three Isles, part of Western Hope Island, and several sand-cays. The 1936 expedition made twenty-four sketch-maps of sand and shingle cays and fifteen of low-wooded islands as well as several sections. Papers were published in the Geographical Journal and the Reports of the Great Barrier Reef Committee by Steers and in the former journal by Spender.

Low Isles, which should be regarded as a "type" reef, as not only was it the headquarters of the Yonge Expedition and the "type" of Steers' Low Wooded Islands, but it has also been resurveyed twice since 1936—by Fairbridge and Teichert in 1948 and by a three weeks' trip organized by the Committee in 1954. This visit by biologists, geologists and geographers of the Universities of Sydney and Queensland and the Australian and Queensland Museums resulted in a number of papers in diverse journals.

During recent years, Professor R. H. Greenwood and some of his staff have been engaged in preparation of a detailed map of Heron Island and reef including the various zones of the reef flat. This, apart from its geographical value, will, when complete, constitute a valuable base map for the plotting of biological information.

Geological work

There has been no organized geological expedition, but a number of members of the Committee have carried out geological work over the years. This includes the geological implications of the data from the deep boring, the geology of the continental islands and the nature and distribution of the sediments forming on the Heron reef and in adjacent waters.

The Heron Island Research Station

From the beginning the Committee had in mind, as an ultimate object, the establishment of a permanent research station on the Reef. At the conclusion of the Yonge Expedition,

it had hopes of adapting that expedition's huts for such a purpose, but was unable to do this for lack of finance.

In 1948 after the hiatus of the war years, the Committee and, in particular, Dr Ian Mackerras, set about raising money for this purpose. It took three years to obtain enough "capital" and to be assured of sufficient maintenance revenue to start building. In 1951 a "laboratory" twenty feet by ten feet was erected on a five-acre lease on Heron Island.

Heron Island was chosen as being the site with a flourishing and luxuriant reef closest to Brisbane. It has the further important advantage that workers at the Station are able to make use of the boat service to the tourist establishment on the island at least until such time as the Committee is able to provide its own means of transport. Indeed, the development of the Station would have been impossible without the assistance and support of the Poulson family, the proprietors of the tourist resort.

The Station grew slowly until 1964, although in the intervening period a large laboratory, a Maintenance Officer's house, an aquarium building and a small dining room-kitchen were built. Significant financial factors in the period were the Queensland Government's pound-for-pound building subsidy up to a maximum of £7,500 and the Commonwealth Government's assistance by way of transporting building material to the island in the lighthouse vessel *Cape Leeuwin*.

Affiliation of the Committee with the University of Queensland in 1959 at last opened the door to sizeable finance. A grant of \$20,000 by the Australian Universities Commission and \$47,000 by the Trustees of the Rockefeller Foundation enabled construction of sleeping cabins (for up to thirty-two people), a new cabin for the Maintenance Officer, a toilet block, and a private laboratory for the Director, extension of the dining-room and kitchen, remodelling and improving the laboratory, and the purchase of additional equipment and apparatus. The University of Queensland has generously provided salary and a research grant for the Scientific Director.

The object of the Station is twofold—to provide a research facility to enable a visitor from anywhere in the world to work on the problem of his own choice, and also to assist in the training of university students in field aspects of coral reef biology, geography, geology, etc.

With very small beginnings in the summer of 1951–52 the Station can quite fairly be said to be achieving these objects. Over sixty papers have been published on work carried out at the Station or on material collected on Heron reef or neighbouring reefs; during 1965, over 155 scientists worked at the Station, mostly for short periods but some for as long as fifteen weeks, and 118 students worked a total of 830 student days.

Major research projects in progress or starting shortly include a detailed ecological survey, a comparison of surface temperature variations in the open sea with those in the lagoon, and a study of the sea currents in the area about the Capricorn Group, all by the Scientific Director, Mr P. M. J. Woodhead; a study of mollusca extending over fourteen months by Professor Frank, of Oregon, U.S.A.; work on Polychaetis by Mr J. F. Grassle, of Duke University, U.S.A., extending over twelve months; and an ambitious study of the Green Turtle by Dr Bustard and other staff of the Department of Zoology, Australian National University, Canberra.

From June to November, 1967, a Belgian expedition will be working throughout the area between the Reef and the coast. The members plan to work from and on a ship, but to be based initially in the Heron Island area.

The Committee is fortunate in having as Director a distinguished zoologist in Mr P. M. J. Woodhead, with a wife who is equally distinguished in related zoological fields and who will continue her work on the reproductive physiology of fish.

The Committee has now \$100,000 in buildings and equipment at the Station, but research establishments of all kinds always require more money. The Heron Island Station is no exception. Now satisfactorily equipped for many kinds of research, there is still more which could not at present be undertaken there: in particular, operating

and maintenance funds are completely inadequate. Nevertheless, these are minor difficulties compared with those that have been overcome, and the future appears bright.

BOOK REVIEW

AUSTRALIAN BIRDS IN COLOUR, by Keith Hindwood. Published by A. H. and A. W. Reed, Sydney, Wellington, Auckland. Price, \$3.25.

This is a welcome addition to the series which was started with *Birds of New Zealand*, by Gordon Williams.

The first impression one gets when glancing through this book is that many of the species chosen are of birds which are rare or not easily seen. However, when one reads the text one is impressed by the pleasant style and the amount of information given, particularly on the group as a whole to which the species being discussed belongs and also their distribution both in Australia and beyond. There is much information on plumage and habits which is not at present found in any other available book on Australian birds. One would like to feel this is only a start and that the publishers will persuade the author to do a further series and thus make available to the public more of the great store of bird knowledge he has.

The photographs by eleven different photographers are very good and most of them are taken by the modern electronic flash technique, which gives the true colour of the iris of the birds.—*H. J. de S. Disney.*

MUSEUM TRUSTEES

Mr E. J. Kenny, who died in February, had given very long service to the Australian Museum, having been a member of the Board of Trustees since 1947. He has been replaced on the board by Professor A. H. Voisey, Professor of Geology and Head of the School of Earth Sciences at Macquarie University. Professor Voisey was formerly Professor of Geology at the University of New England, Armidale, and is the author of many geological and geographical papers. Last year he was elected President of the Royal Society of New South Wales and appointed a Trustee of the Public Library of N.S.W.

Dr K. L. Sutherland, Director of Research, Colonial Sugar Refining Co., and a member of the executive of the CSIRO, has been elected to the Australian Museum's Board of Trustees. Dr Sutherland was formerly Chief of the Division of Physical Chemistry, CSIRO, and Davy-Faraday Fellow, Royal Institution of Great Britain.

OPALS

By A. J. GASKIN

Chief of the Division of Applied Mineralogy, CSIRO, Melbourne

THE cause of the play of colours in precious opal has long been the subject of speculation and research. Optical interference effects were usually assumed to give the "fire" and the main issue was whether these could be related to regularly spaced cracks, parallel regions of different refractive index, or layers of almost molecular fineness within the mineral. Over a period of years, P. J. Darragh and I discussed such theories at intervals but remained unconvinced that simple interference could account for the intensity, purity, and angular distribution of the flashes of "fire" seen in high-quality opals. Diffraction gratings, made by ruling many thousands of parallel grooves per inch on the surfaces of glass plates, at very regular intervals, displayed some of the characteristic effects of opal "fire". White light striking such gratings is broken up into a reflected rainbow spectrum of particular brilliance and colour purity. We could not, however, visualize any possible structure in amorphous hydrous silica that could be regular enough to act as a grating, particularly as any such structure would have to be developed in a consistent manner in opals deposited under quite a range of field conditions throughout various countries.

Evidence of a structure in opal was produced, however, by J. V. Sanders, of the CSIRO Division of Tribophysics, who took electron micrographs of thin carbon films which he had deposited on opal fracture surfaces and then stripped off so as to provide a replica of the structural detail of these surfaces. He found that the mineral contained regularly arranged three-dimensional arrays of tiny holes (fig. 1) which could act as optical discontinuities and diffract light in much the same way as atoms in crystals diffract X-rays. We deduced that these were the spaces between close-packed spheres of amorphous silica, the spheres being in the "colloidal" range of particle size, i.e., less than one-thousandth of a millimetre in diameter but still much larger than the sizes of molecules. The spheres were in fact larger than any previously

known by us to exist in normal colloidal "sols" of silica. Dr Sanders developed the general principles of the generation of "fire" by such a system, whilst we investigated possible mechanisms for the formation of large colloidal spheres of hydrous silica. Laboratory work showed that these could be grown to the sizes seen in opals simply by adding silica solution to a stirred, boiling sol, whilst evaporation proceeded, for a period of a few weeks. Similar spheres grew in static silica sols at room temperature within a year. It seemed possible that we could prepare a synthetic model of opal if spheres could be grown to the range 0.2-0.4 micron

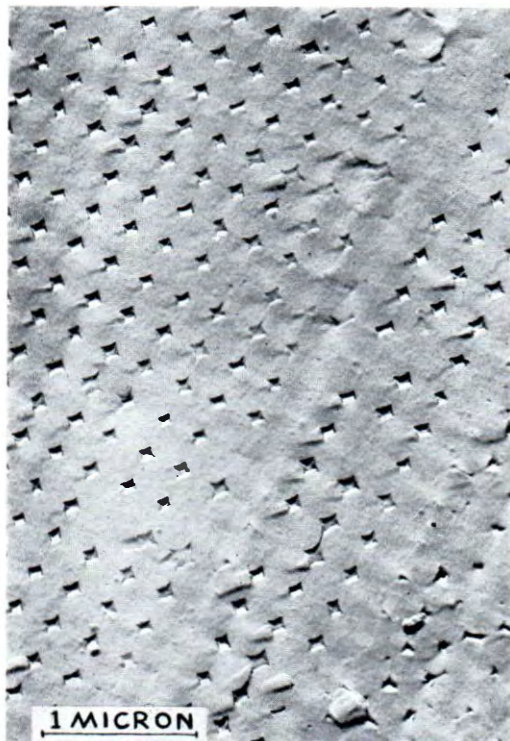


Fig. 1.—Regularly spaced star-shaped holes in fracture surface of precious opal from Coober Pedy. (One micron equals one-thousandth of a millimetre.) [Electron micrograph by J. V. Sanders.]

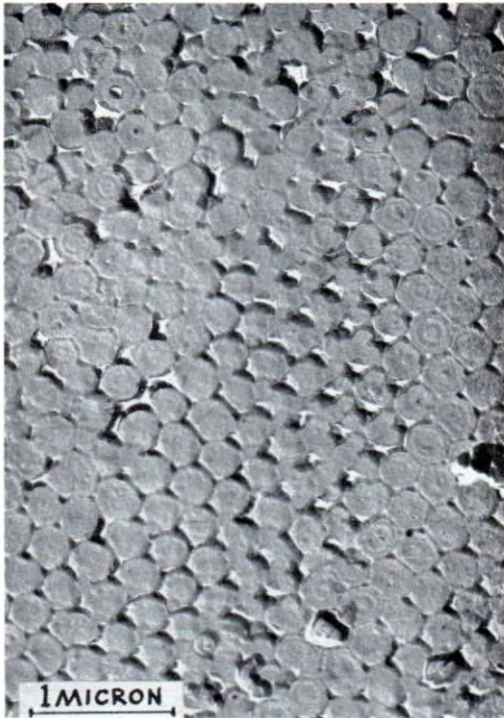


Fig. 2—Spheres, in precious opal from Andamooka, showing shell structure. This is an acid-etched fracture surface. [Electron micrograph by J. V. Sanders.]

in diameter, then closely sized and packed in regular beds.

This we eventually accomplished, after evaporating many gallons of water, by periodically removing crops of particles of the right size from the growth vessels using sedimentation techniques. When settled from still suspensions over a period of some days, such particles built up regularly packed beds displaying a more or less brilliant play of colours according to the perfection of our sizing methods. The analogy with opal was strengthened by the appearance in these layers of structures which are common in the natural stone. Mosaic patterns, as seen in opal, formed automatically in the sedimented beds of spheres. These are "pseudo-crystals" that build up from the base of a bed in parallel vertical columns as the spheres settle and fit into established arrays. Vertical grading of the colour of the "lire", from red or yellow tints at the base of columns, up through green to violet,

also appeared. This is a feature of much natural opal and indicates that the lowermost spheres are larger than those settled out at higher levels, since it is only the larger spheres that can form arrays with a spacing sufficient to diffract the red and yellow colours near the long-wavelength end of the visible spectrum.

Although it was possible to duplicate the general principle of opal deposition, the natural system still presented problems. From field studies, it seemed that precious opal had commonly formed in isolated cavities in rocks too impermeable to allow ingress of silica spheres in colloidal suspension, though capable of transmitting silica solutions. The spheres must therefore have grown to size within the cavities. Growth media must have had just the right stiffness to keep the spheres from settling until they were fully grown, otherwise they would have sedimented into packed beds, where further growth would be improbable, when still too small to produce light-diffracting arrays. Specimens have been found which show this premature settling effect: indeed much of the clear opal with only diffuse violet "lire" has probably been formed in this way.

Confirmation of the thin "gel" consistency of growth media was obtained from studies of flow patterns preserved in opal (fig. 3). These indicated that the parent media were not free-flowing liquids, but soft jelly-like substances weak enough to deform under gravity in a plastic manner and yet having enough internal structure and strength to hold small included fragments of rock in prolonged suspension. Similar effects can be reproduced in the laboratory, using thin gels made from 0.1 per cent silica colloids. The flow patterns seen in natural opal were apparently developed by slumping of the parent gel media as these dried out, or were disturbed by rock movements, at an early stage in the formation of the mineral.

Since the consistency of the suspending media would have determined the size of spheres settling in any cavity at any particular time, changes in the yield point of the media, either in time or in space, have been important in controlling the type and quality of opal deposited. Periodic dilution of the gels by ingress of extra water during wet climatic cycles could be expected to disturb the

continuity of the settling process. Such effects are seen in natural opal, the sudden onset of each discontinuity commonly being marked by a thin band of fine clay. Variations in gel consistency along the length of extensive thin vein-like cavities have also been identified. Sheets of opal formed in thin vertical cracks in boulders at Andamooka, called "Painted Ladies" for some obscure reason, illustrate this spatial variation. The upper extremities, furthest away from the local perched water table and presumably drier and stiffer than the lower parts at the time of deposition, contain the largest spheres and hence show red "fire" grading downwards to green and violet, thus reversing the sense of the usual gradation seen in opal formed in regularly shaped cavities.

Although we deduced that sphere growth and settling through gel media could account for the texture of opal, the uniformity in size of the spheres in any particular specimen was still a puzzle. Sedimentation could scarcely be expected to have acted as a sizing mechanism of such precision if the spheres grew continuously. However, further electron microscopy showed that the spheres were made up of a few shells of smaller particles giving a structure like that of an onion, suggesting that growth took place in steps representing completion of

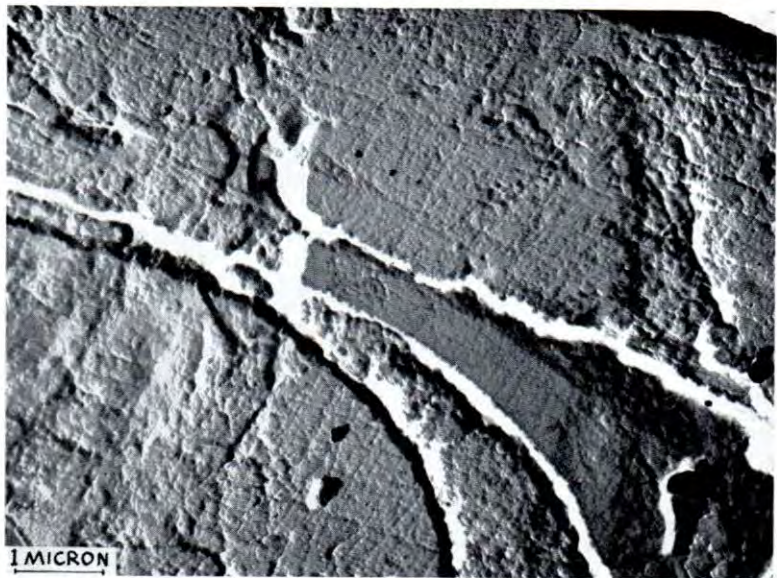
each shell. Media, therefore, would only have had to keep spheres suspended until either one, two, or three shells were completed, according to the yield point of the gel, before settling occurred. Since the primary particles in spheres are generally of constant size (about 0.04 micron) in any given locality, sphere sizes are fairly closely defined by the number of shells. Opal showing red "fire" is generally made up of sedimented layers of "three-shell" spheres. Green "fire", without red, usually indicates "two-shell" spheres, and violet, without green, "one-shell" spheres. Common opal often contains only individual primary particles or clusters of a few of these, such as exist in the "cores" of spheres with shell-structure. "Potch" from the opal fields usually contains spheres of the type found in precious opal, but lacks "fire", among other reasons, because it contains malformed spheres, foreign particles, or mixtures of spheres of different sizes. It may have formed typically from gels of greater stiffness and lower purity than those yielding precious opal.

Knowing some of the principles of formation of precious opal, the question of the special features of its environment of deposition drew our attention. All the available field evidence seemed consistent with the idea that the component spheres of



Fig. 3.—Flow deformation of layers of opal successively deposited in a cavity in claystone. [Photo: E. G. Beckhouse.]

Fig. 4.—Small clusters of "primary" silica particles in wood opal, showing lack of regularity in shape, size and arrangement. [Electron micrograph by J. V. Sanders.]



the mineral were formed by the aggregation of primary colloidal particles grown in siliceous ground-waters concentrated by slow evaporation, the water vapour diffusing up to atmosphere through a layer of permeable rock sufficient to protect the system from the destructive effects of near-surface weathering agencies. Suitable cavities to hold the parent solutions and provide free water surfaces for evaporation were, of course, essential. These, in fact, defined the points of deposition of opal in any favourable locality. At Andamooka, the spaces were deformation features in a boulder bed. At Coober Pedy, Lightning Ridge and Whitecliffs moulds formed by the solution of crystals or fossils have acted as host cavities. In these fields interconnected open joints have been filled only with "potch" as a rule, because such cavities have been too susceptible to flooding, drying, and the entry of deleterious materials, to sustain the delicate balance of conditions required for deposition of the precious variety of the mineral. Fair quality opal has, however, been deposited in parts of open joint systems that have been sealed off by the build-up of iron oxide coatings on the walls, in some Queensland localities. The so-called "boulder" opal has formed in such an environment. "Matrix" opal has filled the interstices of porous sandstone in some fields and some of it still retains sufficient porosity to permit the introduction

of artificial black pigments which enhance the "fire" by absorbing the diffusely scattered light responsible for the typical milky appearance of much opal. Wood opal generally lacks fire because the cells have not provided cavities large enough for good growth and arrangement of colloidal silica spheres (fig. 4). Fossil bone has been a satisfactory host, providing a range of larger cavities.

In the main Australian opal fields, porous Cretaceous and Tertiary sandstones and siltstones act as cover rocks overlying beds of bentonitic clay. The latter act both as sources of silica and local ground-water traps. Host cavities for opal occur typically along the wet zones at the junctions of the clays with the cover rocks. The amount of opal deposited has been a function of the rate of transmission of water vapour through the rock cover to the arid ground surface. For each pound of opal deposited, at least 5 tons of water must have been evaporated. From such figures, plus measurements of the permeability of the cover rock, we have calculated the order of time required for opal deposition. At Andamooka the mineral present could have been deposited within a period of 10 million years. We believe this period extended from late Tertiary to quite recent times.

The final phase of opal formation, a hardening process achieved by deposition of

further silica between the spheres, has also given the mineral a useful degree of transparency but often has proceeded too far, resulting in complete elimination of all optical discontinuities and loss of "fire". Glassy patch represents a typical end-product. Mexican opal, with typically diffuse faint "fire", is in a similarly silicified state. Australian opal has been hardened, in our opinion, by the drying out of the host rocks as erosion exposed sections of the local water traps. Opal from the deep, moist levels is still unstable, shrinking and becoming opaque after a month in dry air.

The studies described above have shown that precious opal is perhaps the most perfect example of general colloidal aggregation phenomena that may apply to all hydrous silica deposited in nature. Further CSIRO investigations are exploring the possibility that such phenomena might explain much that is still obscure concerning the formation of quartz veins, silicification processes, the hardening of cement and even the growth of diatoms. Detailed observation of the behaviour of colloidal mineral particles is not easy, but we hope it may prove to be a rewarding field.

Retirement of Mr H. O. Fletcher

Mr H. O. Fletcher, Deputy Director and Curator of Fossils at the Australian Museum, retired on 26th February after 48 years' service. He was farewelled at the museum by the trustees and staff and by the Deputy Chairman of the New South Wales Public Service Board, Mr E. W. Howitt, and the New South Wales Director-General of Education, Dr H. S. Wyndham.

Mr Fletcher entered the service of the museum in 1918. He was appointed Curator of Fossils in 1941 and Deputy Director in 1957. He received his early training at the University of Sydney, and later obtained his Master of Science degree at the University of New South Wales. He has also been Honorary Palaeontologist to the Department of Mines since 1937.

During his career at the museum Mr Fletcher devoted a great deal of his time to the taxonomic study of marine invertebrate fossils, particularly those of the Permian geological period. (Extensive outcrops of Permian rocks occur in the South Coast district and in the Hunter Valley, N.S.W.) His research papers have been published in the Records of the Australian Museum and other scientific journals.

Mr Fletcher was a member of the British-Australian-New Zealand Antarctic Expedition which, during 1929-31, made two cruises to the Antarctic continent under the leadership of the late Sir Douglas Mawson. Exploratory work was carried out in that area of the Antarctic which later became Australian Antarctic Territory and is now under the control of the Commonwealth Government. Mr Fletcher was awarded the King's Polar Medal and Bar.

In 1939 he was appointed second-in-command of the Simpson Desert Expedition, which was the



Mr Fletcher. [Photo: Howard Hughes.]

first to cross the centre of that desert. Mr Fletcher has also carried out fieldwork in many other parts of Australia and has been in charge of a number of expeditions to the Northern Territory and northwest Australia.



Above and Opposite

RARE CARVINGS FROM THE SEPIK RIVER, NEW GUINEA

These two carved human figures once adorned the gables of a *house tambaran*, or men's ceremonial house, on the Juat tributary of the Sepik River, northern New Guinea. They were collected on behalf of the Australian Museum, together with five other similar figures, by the late E. J. Wauchope between 1936 and 1938. They probably represent ancestors, and were placed on the men's house to protect it from harm. A group of six of these fascinating figures is featured in the new Pacific exhibits just inside the College Street entrance of the Museum. [Photos: C. V. Turner.]



THE BIOLOGY OF TADPOLES

By A. A. MARTIN

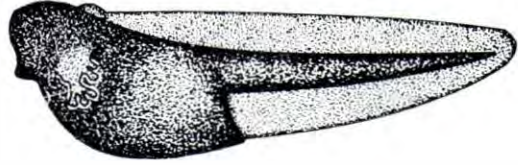
Assistant Lecturer in Zoology at the University of Melbourne

FROGS, in general, lead a "double life", and it is to this fact that the name of the class to which they belong, Amphibia, refers. It is derived from the Greek *amphi* (double) and *bios* (life). The first part of the life is spent as a typical aquatic, gill-breathing organism. Then a drastic transformation, or metamorphosis, occurs, and the remainder of the lifespan is passed on land. This sort of life-history, with an aquatic and a terrestrial phase, has come to be considered the "typical" one for frogs, and is worth examining in greater detail.

Most frogs disperse from water after metamorphosis, but return to the water for reproduction. Breeding frogs are always conspicuous by the noise they make, and this noise probably plays a part in guiding more frogs to the breeding aggregation. A second and more important function of the "mating call", which is made by male frogs only, is to specifically attract a female of the same species to the calling male. Sexual embrace (or amplexus) and egg-laying follow. Depending on the species of frog, the eggs may be laid in frothy masses which float on the surface, clumps on the bottom, strings of jelly wound around vegetation, and so on.

The fertilized eggs now undergo development, during which the main organ systems are formed. Eventually the embryo comes to look rather like a small fish, curled head to tail inside the egg. Microscopic examination shows an elongated body, consisting largely of a sac in which is stored the yolk that nourishes the embryo at this stage; a barely differentiated head which may bear filamentous external gills; and a long tail consisting of a central spine of muscle and a transparent fin. On the underside of the head is a prominent U-shaped ridge, the ventral sucker. At about this stage of development the embryo hatches, and clings to stones or vegetation by means of the sucker, continuing to live on its stored yolk.

A number of changes now occur simultaneously or in rapid succession. The yolk is used up, the mouth opens, and the embryo



A recently hatched embryo (greatly enlarged) of Ewing's Tree Frog (*Hyla ewingi*). Note the filamentous external gills behind the head. The beak-like projection below the head is part of the ventral sucker.

starts feeding. The ventral sucker disappears. The external gills are overgrown by a fold of skin, the operculum, and true internal gills, borne on gill arches like those of a fish, develop. The operculum forms a chamber around the gills, with one small opening, the spiracle. Water is pumped in at the mouth and nostrils, passes over the gills, and leaves by way of the spiracle. A pair of hind limb buds appear at the base of the tail, and this marks the end of the embryonic, and beginning of the larval, or tadpole, stage.

The tadpole's mouth

The most remarkable and complex external feature of a tadpole is its mouth. Close examination shows that the mouth is surrounded by a "disc" bearing a number of structures. Firstly, there are a pair of strong, horny jaws, and surrounding these are a number of rows of horny teeth. The disc is bordered by a series of papillae, or short tentacles. The exact functions of all these mouth structures are not known, but together they form a rasping or scraping organ. Tadpoles are typically herbivores, and feed by rasping algae and other vegetable matter into the mouth. Extraction of energy from plant material is a difficult process (which is why ruminant animals have such complicated digestive systems), and tadpoles, likewise, have very long, coiled intestines, which fill the greater part of their body cavities. There is no evidence, however, that the mouth structure is simplified or intestine shortened in the few tadpoles that

have assumed carnivorous habits: thus the general body form of tadpoles cannot be explained entirely as representing adaptation to vegetarian habits.

As the tadpole continues to feed and grow the hind limb buds develop into legs. At the same time the front limbs are developing, but they are contained in the gill chamber and are not visible. Eventually, however, the forelimbs erupt, and at the same time the tail starts to be resorbed. Major internal reorganization also occurs. The gill apparatus is lost. The digestive system becomes much shorter and simpler, since the frog is a carnivore, and the digestion of animal foods can be accomplished without the tadpole's long and elaborate intestine. Finally the small frog leaves the water and takes up a terrestrial existence. The time taken from egg to metamorphosis varies in different species from a few weeks to over a year.

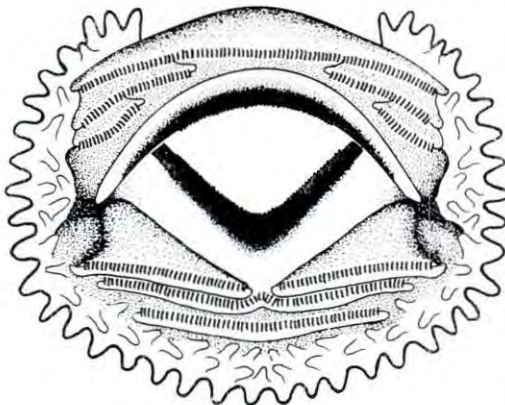
Diverse habits and behaviour

The life-history outlined above is typical of the European and North American species of *Rana*, on which a great deal of our knowledge of amphibian biology is based. When we come to consider the 100-odd species of Australian frogs, we are on much less sure ground. Some of them, certainly, have life-histories differing only in detail from the one just considered, but on the other

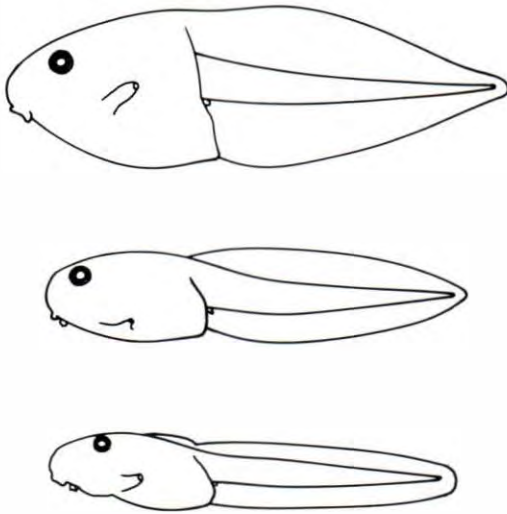
hand some interesting differences are evident. Gradually the idea is emerging that there is no "typical" frog life-history: on the contrary, the habits and behaviour of tadpoles are just as diverse as are those of frogs. Eastern Australia, offering a variety of habitats from rainforest to desert, and coastal plains to alpine meadows, makes an ideal area for a study of this diversity. At this stage our knowledge is restricted to a few species, but, as more and more is learnt of the life-histories of Australian frogs, a most interesting picture should become apparent. Some examples will serve to illustrate the trends suggested by recent studies.

The Northern Hemisphere species of *Rana* are typically pond breeders. Similarly, many Australian species use permanent ponds and dams for breeding. Tadpoles are, in fact, one of the most conspicuous and abundant animals of ponds, and a single pond may contain six or more species. Extrapolating from the relatively well-known *Rana* species, we might expect all tadpoles to feed in the same way and on the same foods. Ecologically, this would be a rather anomalous situation, since it is a general principle that no two species of animals occupying the same habitat exploit exactly the same food sources. The answer to this apparent puzzle is just starting to emerge in a couple of isolated instances, one of which may be taken as an example.

In eastern Victoria two species of froglet, Haswell's Froglet (*Crinia haswelli*) and the Brown Froglet (*C. signifera*), are common. They may be found breeding in the same ponds at the same time, but a study of their tadpoles shows some remarkable differences. In the first place, their appearance is so dissimilar as to suggest that they are following rather different ways of life. The *C. haswelli* tadpole is a plump, deep-bodied form with conspicuous, arched tail fins, whereas that of *C. signifera* has a flatter body and relatively small fins. If the two species are observed in a pond, a striking behavioural difference is also noticeable. The *C. haswelli* tadpole is an active swimmer, and moves rapidly and continuously in the surface layers of the pond. The tadpole of *C. signifera*, in contrast, is a sluggish, bottom-dwelling animal, spending most of its time resting on the pond floor. It is thus highly probable that these two tadpoles are exploiting



Mouth disc (greatly enlarged) of the tadpole of the Tusked Frog (*Adelotus brevis*). The structure and arrangement of the jaws, teeth and papillae vary between species, so a tadpole can often be identified simply by looking at its mouth disc.



Body form in three tadpoles of the genus *Crinia*. Upper: *C. haswelli*, a surface dweller in ponds. Middle: *C. signifera*, a bottom dweller in ponds. Lower: *C. riparia*, which inhabits fast-flowing streams. (These diagrams are not to the same scale)

different food sources. From our present very limited knowledge it appears that *C. haswelli* feeds largely on plankton (microscopic free-floating animal and plant life), while *C. signifera* feeds on the decaying plant matter in the bottom sediments. Thus the two species occupy entirely different "niches" within the habitat, living in different parts and feeding on different foods.

Life in temporary ponds

A permanent pond is a stable and persistent environment. It never dries up, and a flourishing plant and animal community therefore becomes established and continues from year to year. In contrast to this is the temporary pond, which dries out for part of the year; hence, the aquatic life it supports is displaced each time the pond empties, and must re-establish itself when the pond fills again. In a pond which contains water for 6 months of the year there will be time for a large and varied plant and animal population to become established, and many species of frogs use ponds of this sort for breeding. But what of a pond which is full for only a few weeks? In this case the system is so transient that it can be inhabited by only a very few specially adapted forms

of life. Thus we would not expect it to provide a suitable habitat for tadpoles, for as we have seen, they generally require large quantities of vegetable food. Yet in rugged or mountainous areas this is often the only kind of standing water that occurs. There is plenty of water in the form of rushing mountain streams, but these also do not appear a likely habitat for tadpoles, since it is difficult to imagine how they would resist the current. So steep, broken country would seem to be a most unfavourable habitat for frogs; it is surprising, therefore, to find that a variety of species does occur in such areas. As might be expected, it is in this kind of environment that some of the most unusual modes of life-history are found. The frogs occupying mountainous areas have, as it were, all been faced with the same problems, but have solved them in a number of ways. Again the point is best illustrated by taking a few examples.

Cannibal tadpole

One eastern Australian species, Fletcher's Frog (*Lechriodus fletcheri*), has become adapted to breeding in extremely temporary water in a very remarkable way. It breeds



A permanent pond near Benambra, Victoria. Note the frothy egg masses of the Spotted Marsh Frog (*Limnodynastes tasmaniensis*)



A temporary pond in a roadside ditch near Craigie, New South Wales. *Limnodynastes tasmaniensis*, with a larval lifespan of 3 to 5 months, can breed in relatively transient ponds such as this, as well as in permanent ones, and an egg mass of this species is visible here. Eggs of *Crinia signifera*, which has a larval lifespan of 6 to 10 weeks, were also found in this pond.

in almost any body of water, however small; its frothy egg masses may be found in shallow puddles, roadside ditches, the water that collects in wheel ruts on unmade roads, and so on. The *Lechriodus* tadpole has adapted to life in such situations by becoming a "facultative carnivore"; that is, it lives on plant food when this is present; but when it is absent (as it usually is in such ponds), the tadpole becomes a carnivore and even a cannibal. An aquarium full of *Lechriodus* tadpoles is a strange sight. All the tadpoles have pieces missing from their tails, and if no other food is provided the number of tadpoles gradually decreases as the smaller ones are devoured. If a dead frog is dropped into the aquarium one is reminded of the notorious piranha fish of South America: within minutes, the frog is reduced to a skeleton. A female *Lechriodus* lays about 300 eggs at a

time, and perhaps a dozen or less of these eventually give rise to frogs. Thus, by virtue of its extraordinary larval adaptations, *Lechriodus* can exploit a breeding habitat closed to most other species of frogs.

In passing, it should be noted that frogs breeding in temporary water must, of course, have one other adaptation: their life-history must be accelerated so that the tadpoles have metamorphosed and left the ponds before they dry up. *Lechriodus* is well adapted in this regard, too. Dr J. A. Moore, of Columbia University, has found that the larval stage of *Lechriodus* lasts for only 31 days.

For an example of a second sort of adaptation, we can return to the genus *Crinia*. *C. signifera*, which has already been mentioned, has a very close relative, *Crinia riparia*. The adults of these two species are barely distinguishable; their breeding habitats, however, are entirely different. *C. signifera* breeds in ponds, while *C. riparia*, as far as is known, is restricted to the rocky, fast-flowing watercourses of the Flinders Ranges, South Australia. Its breeding pattern shows a number of adaptations to this habitat. Firstly, its eggs are not deposited in the water, where they would presumably be in danger of being swept away by the current. Instead, they are laid under rocks near the water's edge. It is not known how the tadpoles get from here to the water; probably they wriggle overland soon after hatching. Of course, once they reach the water, they, too, have to overcome the force of the current. If a *C. riparia* tadpole is compared with one of *C. signifera*, its adaptations to the fast-flowing stream environment can be seen. Its body is flattened and streamlined, and its tail is muscular, but with a narrow fin, so that it offers less resistance to the current. Furthermore, its mouth disc is relatively very large, and functions as a sucker. Observation of *C. riparia* tadpoles in their natural habitat shows that they cling tightly to rocks by means of their mouths, and their streamlined bodies and powerful tails enable them to hold their positions against the current should they be dislodged. Here, then, is another instance of a life-history adaptation enabling a frog to occupy what at first sight appears to be an unfavourable habitat.

Philoria frosti female, with egg mass, in Sphagnum moss. The frog is about 2 inches long and the eggs are about one-sixth of an inch in diameter. j.



The Baw Baw Frog

As a final example we shall take a frog that has, perhaps, the most restricted distribution of any in Australia—the Baw Baw Frog (*Philoria frosti*). As far as we know, it occurs only above an altitude of 4,000 feet on Mt Baw Baw, Victoria. Most of the details of its life-history have been elucidated by Dr M. J. Littlejohn, of the University of Melbourne. *Philoria* breeds along creeks and rivulets, mainly among the Sphagnum moss on the Baw Baw plateau. It lays a small number of very large eggs in frothy masses, in the damp moss at the edge of the creeks. Thus far it resembles *Crinia riparia*. In *Philoria*, however, it seems likely that the tadpoles remain in the egg mass throughout their development, eventually emerging from it as small frogs. What makes this unusual life-history, lacking a free-living larval stage, possible is the enormous amount of yolk contained in the eggs of *Philoria*. It was mentioned earlier that nearly all frog eggs have enough yolk to carry the embryo to hatching or just beyond; in *Philoria* there is sufficient to provide for the entire development of the tadpole. Thus *Philoria* larvae do not have to become cannibals or resist mountain torrents in order to find food; they have, as it were, a built-in supply.

The best way to summarize this discussion is to consider tadpole nutrition in terms of

the amount of food provided by the parent generation towards the tadpole's development. *Crinia haswelli* and *C. signifera* larvae live in a richly productive environment, where food is readily obtainable. This means that only enough yolk need be provided to carry the embryos through to hatching; thereafter the abundant plantlife of the pond furnishes the tadpoles with food. With *C. riparia* the position is similar, except that the tadpole has to be highly modified if it is to obtain food from the somewhat rigorous environment. *Lechriodus fletcheri*, however, represents a vastly different situation. In this case each individual tadpole is provided initially with only a small amount of yolk, but the total quantity of yolk in the whole clutch of eggs is used to feed as few as 3 per cent of the larvae by way of cannibalism. This would seem to be a rather inefficient way of providing for the next generation, since it involves so much energy loss. In marked contrast is the highly efficient system of *Philoria*, where each embryo has sufficient yolk to remove altogether the need for an external food source. This represents, perhaps, the ultimate adaptation: a sort of parasitism in which the offspring has all its nutritional requirements during the developmental period provided by the parent generation.

[Illustrations in this article are by the author.]

MOSQUITOES IN AUSTRALIA'S ARID ZONE

By ELIZABETH N. MARKS

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DR I. M. MACKERRAS recently pointed out to a meeting of the Australian Entomological Society in Brisbane that Australia's desert regions, which are of relatively recent development, offer a unique opportunity for the study of the evolution of adaptations of insects to aridity.

These days, while professional entomologists are mainly in coastal areas, an increasing number of people travel through the interior of Australia, or are temporarily or permanently resident there, and many, if they knew how they might help, would be interested to add to scientific knowledge.

While study of physiological adaptations is a task for research scientists, insects may have behavioural adaptations enabling them to survive adverse periods, which can be revealed or suggested by field observations by naturalists. It is a common phenomenon that one particular stage of an insect's life-cycle is specially adapted to survive long periods of aridity; observations on the time after drought-breaking rains at which a given stage of an insect appears, or is

abundant, will throw light on its probable life-cycle; they may also enable the scientist to judge when he might plan to study it in the field. The accumulation of locality and habitat records for a species may indicate that its distribution is restricted to, or that it occurs in greatest abundance in, a certain climatic zone or a particular type of plant community.

Mosquitoes comprise the family Culicidae of the order Diptera (true flies). Because the females of most species require a blood meal to provide the vitamins necessary for production of viable eggs, and some species can carry diseases of man or domestic livestock, almost everyone can distinguish mosquitoes from other flies, and has the opportunity to collect them if strong-minded enough not to slap them first. It is relatively easy, therefore, for an amateur collector in a remote area to make a useful contribution to our knowledge of Australian mosquitoes.



Fig. 1: Australia's arid zone. [Map by the author.]



Fig. 2: A pool at the foot of Mt Olga where larvae of *Anopheles annulipes* and *Culex australicus* were collected and *Aedes explorator* was biting. (This is the type locality for *Aedes explorator*.) [Photo: Author.]

Particularly is this so in the drier areas, where these insects may occur in abundance for only a short period soon after rain.

The "arid zone"

Before we look at what we know and do not know about mosquitoes of the drier parts of Australia, we need to define the area to be considered. It seems appropriate to select the area which Australian scientists have agreed should be included in the "arid zone", the boundaries of which correspond approximately to the 10-inch rainfall line in the south, the 15-inch in New South Wales, the 20-inch in central Queensland, and the 25-inch in the north (fig. 1).

Sources of information

Where can we find information on the mosquitoes of this area? It is mostly hidden in published and unpublished reports, or in taxonomic papers and regional lists which deal also with species from other climatic zones, or on the labels of specimens in collections. The present paper makes no pretence to be comprehensive. It is based on records by E. P. Hodgkin and E. J. Britten from the Onslow-Roebourne district

of Western Australia, plus collections seen by the writer from other localities shown in fig. 1.

The only collections that appear ever to have been made regularly throughout the year in a district within the arid zone are those of Mr J. Wright, who, as Rabbit Control Officer for the Cunnamulla district, has a particular interest in mosquitoes as potential vectors of myxomatosis. Since September, 1965, he has sent in for identification over 1,000 specimens, representing eighteen species, and has shown that the commonest mosquitoes in his district after heavy rain are species previously rare in collections and still undescribed, while some species common 250 miles further east, which it had been expected would occur at Cunnamulla, are apparently rare or absent.

How many of our mosquitoes occur in the arid zone?

Approximately 230 species of mosquitoes are known from Australia (excluding three introduced species which are not considered in this paper) and at least thirty-five of these have been collected in the arid zone. Only

four are, so far as we know, restricted to it; several others appear to reach their greatest abundance within it; others again, common elsewhere, are widely distributed within it and clearly well adapted to aridity; it is only these species that we shall consider here.

How can mosquitoes survive aridity?

The larval and pupal stages of mosquitoes must be passed in water, therefore it must be the eggs or the adults which are able to survive prolonged dry periods. The stage that is adapted to cope with adverse climatic conditions seems to be characteristic of a genus wherever it occurs.

Four genera are known from Australia's arid zone. *Anopheles*, *Culex* and *Aedes* are of worldwide occurrence and *Tripteroides* occurs in the Oriental and Australian regions. Records of *Tripteroides* within the zone are few; they breed in container habitats; we know nothing of their adaptations to aridity, though these may be expected to be similar to those of *Aedes* favouring the same sites.

Although we have no experimental evidence, there is quite strong circumstantial evidence on the general means by which our arid-zone *Anopheles*, *Culex* and *Aedes* survive. This is based on what is known of these genera overseas; on observations of the same Australian species in higher-rainfall areas; and on records of the occurrence of larvae and adults, and of the habits of adults, in relation to weather information.

This evidence indicates that in *Anopheles* and *Culex*, which lay their eggs on the water surface of the breeding place, the adults are adapted by their habits to survive dry periods. They hide away deep in hollows and crevices, and females with fully developed eggs will still take blood when opportunity offers, to sustain them until a suitable site is available in which to lay. In *Aedes* it is the egg which survives, due in part to its physical structure and in part to the microclimate of the oviposition site selected by the female. A stimulus is needed to hatch it, usually the reduction of oxygen in its surroundings, which occurs when there is sufficient depth of water over it to last while its larval and pupal stages are completed. Further to ensure survival of the species, hatching of

some eggs in a batch may be delayed until the second, third or fourth time that the breeding place is filled.

The genus *Aedes* is a very large one and is divided into numerous subgenera, some of which occur on all continents. Of particular interest to us in their adaptations to aridity are mosquitoes belonging to the subgenera that are not known outside Australia and New Guinea, *Pseudoskusea*, *Macleaya* and *Chaetocruimyia*. As will be shown, there is suggestive evidence that, in these, adults as well as eggs can survive long periods of drought, so that they are doubly insured against disaster.

Mosquito breeding places in the arid zone

These may be permanent, semipermanent, or temporary. The permanent ones include waterholes in river beds, springs, bore drains, dams, earth tanks and large rock holes such as those at the base of Ayer's Rock. Semipermanent breeding places are generally of the same type, but smaller, and last at least a couple of months. Temporary sites include depressions that are filled by heavy rains or floods and hold water for a week or more, smaller rock pools, hollows in trees and stumps, and artificial containers such as domestic tanks, watering troughs, oil drums and old tyres.

Some mosquitoes of the arid zone

Two mosquitoes, *Anopheles annulipes* and *Culex australicus*, have been collected at almost every locality shown in fig. 1. *An. annulipes* is common throughout Australia; *C. australicus* occurs almost everywhere south of 17° S. except the tropical coast of Queensland. In the arid zone they are usually found breeding together, as in the pool at Mt Olga shown in fig. 2. *An. annulipes* breeds in the types of permanent and semipermanent breeding place listed above, in temporary ground and rock pools that last about 2 weeks or more, and occasionally in artificial containers. *C. australicus* does likewise but is less common in very large permanent sites and more common in artificial containers. *C. australicus* rarely bites man, for it prefers small mammals and birds, but *An. annulipes* attacks him readily.



Above: Fig. 3. *Aedes (Ochlerotatus) explorator* female. Below: Fig. 4. *Aedes (Chaetocruimyia) calahyi* female. (These are not to the same magnification.) [Diagrams: Miss S. R. Curtis.]



Myxomatosis workers have shown that adults of both species harbour in rabbit warrens (*An. nullipes* up to 4 miles from its breeding places) and may feed below ground. Mr Wright has found them in warrens and resting in rock shelters in the Cunnamulla area. Thus these species survive aridity by their ability to breed successfully in a wide variety of sites and to shelter and feed deep in crevices in rock or below ground where extremes of temperature and aridity can be avoided. We do not know whether there may be biologically distinct races of these species in the arid zone and in high-rainfall areas, nor has anyone looked at the eggs of arid zone females to see whether they could in fact survive drying.

The other common widespread Australian *Culex*, *C. annulirostris*, apparently is not well adapted to aridity. It favours breeding places with plenty of aquatic vegetation, and in the arid zone is associated mainly with large waterholes and bore drains. It has not been taken in central Australia.

The arid zone species of *Aedes* fall into two groups, those breeding in temporary ground pools (fourteen species in four subgenera) and those breeding in treeholes, small rock pools, and artificial containers (eleven species in four subgenera). In fact we have never found breeding places for some species, but can deduce what they are likely to be.

Aedes which breed in temporary ground pools have a slender pointed tip to the abdomen (fig. 3) which can be greatly extended as an ovipositor to deposit the eggs well down in the mud or soil of drying-out breeding places. The eggs require a high humidity for a day or two. Then, with the larvae fully formed, the shells become impermeable to moisture and they can remain for months, or in some cases years, before the breeding place is filled again and the eggs stimulated to hatch. In hot climates the larval and pupal stages are short, for development must be completed before the pool dries out.

Within our arid zone no one has actually collected eggs from the soil or observed them being laid there. *Aedes* larvae have been collected in pools resulting from recent rain. Mr Wright has taken *Aedes* biting 2 to 3 weeks after rain filled depressions in winter, and 6 days after in summer. There seems no doubt, then, that these species have drought-resistant eggs.

Ae. (Pseudoskusea) bancroftianus larvae are among those collected from temporary ground pools in the Cunnamulla district, and adults have been taken there and at Charleville, Longreach and Richmond in Queensland, and Palm Valley in central Australia. This species has quite a wide distribution in the southern half of Australia, including Western Australia and coastal districts of south Queensland. Again, we do not know whether the inland race might be biologically distinct. At Palm Valley, where adults were taken biting beside a rock pool in September, 1958, there had been no rain since May. These females were rather aged-looking, with scales rubbed off. There is no evidence that *Ae. bancroftianus* ever breeds in pools without its eggs first undergoing a period of drying, and the inference is that it had not bred at Palm Valley since May, but females which had since been

resting in sheltered sites sought the opportunity for a blood meal.

Most of the arid-zone ground-pool *Aedes* belong to the subgenus *Ochlerotatus*. We have no evidence yet to suggest that they, too, might survive as adults, but Mr Wright finds them resting in rock shelters. One species, *Ae. (O.) explorator* (fig. 3), is known only from Mt Olga, where females were biting at the site shown in fig. 2 a few weeks after a heavy storm. Until males are found we cannot tell the affinities of this species. The life-history also has not been worked out, though one larva found in a nearby site probably belonged to this species. Females which were held in a cloth cage for 2 days seemed well adapted to survival in a dry climate.

Ae. (O.) sapiens also is known only from the arid zone, from Richmond, Thargomindah, Bourke and Wilcannia, but has been found in large numbers only at Wilcannia, where females were rising in clouds from flooded country. Dr F. H. Drummond reared a male from a pupa from a roadside pool at Bourke but the larva is still unknown.

Two ground-pool *Aedes*, which Mr Wright has found in plague proportions after heavy rain in parts of the Cunnamulla district, are still undescribed and known by the temporary designations *Ae. (O.)* sp. No. 71 and *Ae. (O.)* sp. No. 85. *Ae. (O.)* sp. No. 71 is the most widely recorded arid zone *Aedes*; it has been taken also at Charleville, Longreach and Richmond in Queensland, and at Coolgardie, Leonora and Onslow in Western Australia; records from in between would be of great interest. *Ae. (O.)* sp. No. 85 has been taken in large numbers also at Wilcannia and is known from Charleville and Richmond, and recently a specimen was sent in from Alice Springs. Both these species seem to occur in greatest numbers within the arid zone. At Richmond, during a severe drought in 1952, their larvae were found in temporary pools filled by overflow of a bore drain after damage to its bank. However, during another dry period in 1962, when the same depressions were deliberately flooded from the bore drain, no *Aedes* larvae appeared in the temporary pools.

Ae. (O.) pseudonormanensis, another ground-pool breeder, is recorded from Cunnamulla, Longreach and Cloncurry, and

from Onslow and Roebourne. Dr E. P. Hodgkin has indicated that this may be a plague species in northwest Australia.

Aedes which breed in treeholes and other containers have less tapering abdomens (fig. 4) and usually deposit their eggs on the side of the breeding place just above the waterline. Australia's commonest treehole-breeding *Aedes*, *Ae. (Finlaya) notoscriptus*, has been recorded from Cunnamulla, Charleville and Coolgardie, but is undoubtedly more widespread. It is often a minor domestic pest, breeding in water tanks.

The most interesting arid zone container breeders belong to the subgenera *Chaetocruomyia* (two species) and *Macleaya* (five species). The former is represented by *Ae. (C.) calabyi* (fig. 4) and *Ae. (C.) wattensis*. These are quite easy to recognize with the naked eye as small mosquitoes (wing length about 2 mm or less), with a thick-set, humpbacked appearance. They have wide white bands on their hind legs and the front half of the top of the thorax is clothed with dense white or creamy scales. They also have strong thorn-like bristles on the hind tibiae. They are quite vicious biters, usually in the late afternoon or early morning. *Ae. calabyi* occurs in the south of Western Australia and the southeast of South Australia; records within the arid zone are from Queen Victoria Spring, and Kalgoorlie and Coolgardie districts. *Ae. wattensis* occurs in inland eastern Australia, including Victoria and Northern Territory; arid zone records are Koonamore (in the northeast of South Australia), Cobar, Cunnamulla, Richmond and Lawn Hill. Breeding habits of these two species are unknown, but are expected to be similar to those of others of the subgenus, whose larvae have been found in deep, narrow pipes, an inch or less in diameter, such as may occur in quite small stems or branches of eucalypts, acacias, or melaleucas, and whose eggs are flattened on one side, suggesting that they adhere to the surface on which they are laid.

It is presumed that the eggs can survive dry periods and we have good evidence that adults can do so too. Mr J. H. Calaby reported that at Queen Victoria Spring there was no surface water; it was in an arid area with, as far as he knew, no free water

surface within many miles. In mid-afternoon a thunderstorm came up. After the humidity began to rise, and a quarter of an hour or so before any rain fell, considerable numbers of *Ae. (C.) calabyi* and *Ae. (Macleaya) tremulus* appeared and continued to attack during the half-hour that rain fell. From September to December, 1965, M₁ Wright collected occasional *Ae. (C.) wattensis* adults in the Cunnamulla district, which was still suffering from a severe drought but receiving scattered thunderstorms. Curiously, he had not collected it again to the end of October, 1966, although the drought had broken and breeding places should have been available. He thinks the humidity was higher when it was collected; one cannot help wondering if atmospheric pressure also might influence its activity. *Ae. wattensis* has been collected from a rabbit warren in New South Wales.

The subgenus *Macleaya* is closely related to *Chaetocruomyia*; the adults differ in lacking the distinctive white dorsal scaling on the thorax; breeding places are treeholes, including in one case a moth-hole a quarter of an inch in diameter and 12 inches deep. One species, *Ae. tremulus*, is widespread, with arid zone records from Onslow, Roebourne, Leonora, Queen Victoria Spring, Koonamore, Cunnamulla and Longreach. It sometimes becomes a domestic pest when it colonizes domestic sites such as water tanks. From Calaby's notes, it too must be able to survive dry periods in the adult stage. The species of *Macleaya* are difficult to tell apart. There appear to be also four undescribed species in the arid zone, one known only from Coolgardie and one only from Cunnamulla, life-histories of both being unknown. The other two are known from Richmond, and one of them from Longreach also, but a planned revision of the subgenus will undoubtedly reveal specimens from other localities as well.

It will be seen that, although *Chaetocruomyia* and *Macleaya* are well adapted to aridity, we have as yet no records of them from central Australia, and none of *Chaetocruomyia* from the north of Western Australia.

How the amateur collector can help

Mosquitoes caught indoors in established towns are often common domestic species,

but plagues of mosquitoes attracted to light may include valuable males which, of course, do not seek blood meals. The collections most likely to advance our knowledge are those made in the bush, on the outskirts of towns, in camps, or in homestead gardens. Larvae can be preserved in methylated spirit. Adults are best preserved dry and can be placed in a matchbox, tin or clean, dry tube between layers of very soft paper tissue. This container must then have at least 1 inch of insulation, such as wood-wool, round it to protect specimens from damage in transit. The information needed with a specimen is locality, date, collector's name, time of capture, type of breeding place, and whatever else seems pertinent in the light of what has been said above.

"ENDEAVOUR" REPORTS

The Fisheries Branch of the Commonwealth Department of Primary Industry, Canberra, was recently asked by the National Library of Australia to advise on an appropriate method of disposing of stocks of the *Biological Results of the Fishing Experiments carried out by F.I.S. "Endeavour"*. It was for many years believed that the stocks of the Endeavour Reports, as they are commonly known, had been either exhausted or accidentally destroyed.

Under the scientific command of the first Commonwealth Director of Fisheries, H. C. Dannevig, the voyages of F.I.S. *Endeavour*, which was lost with all hands on a voyage from Macquarie Island in 1914, provided marine scientists from many countries with an opportunity to study Australian marine fauna on a scale which has probably never since been equalled. The work of these scientists laid the foundations for fisheries such as the southeastern (danish seine) trawl fishery and the east coast prawn fishery, as well as defining the Bight trawling grounds and providing the basis for much of our present information on the distribution and identity of species.

The bibliographic description of the set is as follows: *Australia—Dept of Trade and Customs, Biological results of the fishing experiments carried out by the F.I.S. "Endeavour", 1909–1914. Syd., 1911–1933. 6v. illus. diags 25 cm all issued. Title varies: v. 1–3, Zoological results . . .*

Vol. 1, No. 1, comprising Part I of "Report on some fishes obtained by F.I.S. 'Endeavour' . . .", by A. R. McCulloch, is not available.

The National Librarian, Mr H. White, has given approval for the offering, by gift or exchange, of the stocks of the report to learned institutions and marine research centres. Applications will be considered only when submitted formally by the librarians of such bodies, and should be addressed to The National Library of Australia, Canberra, A.C.T. (Attention: Clearing Centre). This offer by the library will terminate on 31st October, 1967.

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Reptiles and Amphibians: H. G. COGGER, M.Sc., Curator.
Mammals: B. J. MARLOW, B.Sc., Curator.
Fishes: Vacant.
Insects and Arachnids: C. N. SMITHERS, M.Sc., Curator; D. K. McALPINE, M.Sc., Assistant Curator.
Molluscs: D. F. McMICHAEL, M.A., Ph.D., Curator.
Crustacea and Coelenterates: J. C. YALDWYN, M.Sc., Ph.D., Curator; D. J. G. GRIFFIN, M.Sc., Ph.D.,
Assistant Curator.
Worms and Echinoderms: ELIZABETH C. POPE, M.Sc., Curator.
Minerals and Rocks: R. O. CHALMERS, A.S.T.C., Curator.
Fossils: Vacant.
Anthropology: D. R. MOORE, M.A., Dip.Anthrop., Curator.

EXHIBITION DEPARTMENT, ART AND DESIGN SECTION:

F. J. BEEMAN.

EDUCATION OFFICER:

PATRICIA M. McDONALD, B.Sc., M.Ed.

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EDITORIAL ASSISTANT AND PUBLIC RELATIONS OFFICER:

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The Australian Museum

The Museum is open free, daily, at the following times: Tuesday to Saturday, and public holidays, 10 a.m. to 5 p.m.; Mondays, 12 noon to 5 p.m. (during school holidays 10 a.m. to 5 p.m.); Sundays, 2 to 5 p.m. It is closed on Good Friday and Christmas Day.

To teachers and pupils of schools and other educational organizations special facilities for study will be afforded if the Director is previously advised of intended visits. A trained teacher is available for advice and assistance.

Gifts of even the commonest specimens of natural history (if in good condition) and specimens of minerals, fossils and native handiwork are always welcome.

The office is open from 9.30 a.m. to 1 p.m. and 2 to 4.30 p.m. (Monday to Friday), and visitors applying for information there will receive every attention from Museum officials.

College St., Hyde Park,
Sydney