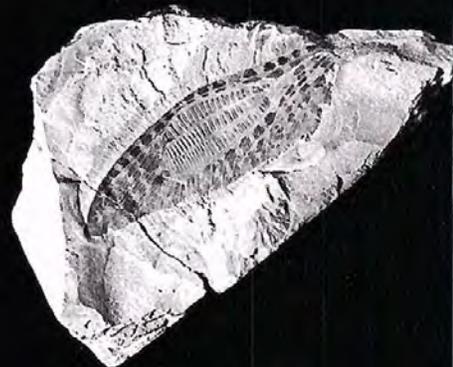
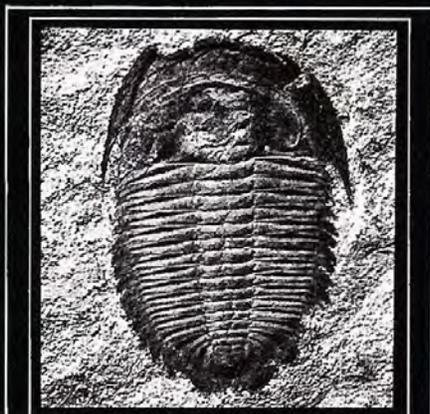


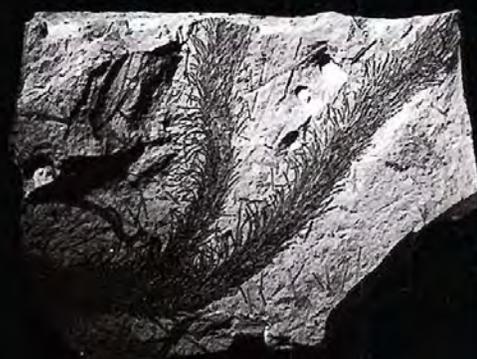
AUSTRALIAN NATURAL HISTORY



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COVER: The Rockhopper Penguin, *Eudyptes chrysocome chrysocome*, a small crested species which reaches 57cm maximum adult height. One of the four penguin species which breed on Macquarie Island, they leave for six months every year to spend the winter months at sea. (Photo: D.S. Horning.)

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THE EARLY MYSTERY OF NORFOLK ISLAND

BY JIM SPECHT

In early October 1774, Captain James Cook set sail from New Caledonia to return to New Zealand to refit and revictual his ship. On Monday 10 October "At Day-break as we were standing to the West, an Island was discovered bearing SWBS". Landing on the island the next day, Cook "took possession of this Isle as I had done of all the others we had discovered, and named it *Norfolk Isle*, in honour of that noble family". During his brief visit, Cook saw no signs of habitation, but noted that the island was "a near kin to New Zealand, the Flax-plant, many other Plants and trees common to that country was found here but the chief produce of the isle is Spruce Pines which grow here in vast abundance and to a vast size...".

It was due to Cook's positive appreciation of the potential of Norfolk Island that the British Government in 1787 instructed Captain Arthur Phillip to establish a small colony there to prevent its occupation "by the subjects of any other European power". This task was assigned to Philip Gidley King, who set up the first European settlement on the island in March 1788. Although both Cook and King found the island uninhabited when they landed, it was but a matter of days before the new colonists found tantalising evidence of earlier visitors. In April 1788, King's journal records that he saw bananas growing at two points inland from the colony. The banana can only be reproduced from cuttings, and not from seeds, and man is the only agent who could have brought the plant to the island. Later in the same year he recorded pieces of canoes, a wooden figure and coconuts washed up on the beach, while a turtle "wooded between the shoulders with a kind of peg" was also seen. In a letter to Lord Sydney dated 12 February 1790, King compared the canoe fragments to New Zealand forms, and the wooden figure "in every respect answers the description given of the idols seen in the Friendly Islands" (i.e., Tonga). By 1791, the first stone tools had been found "under ground some depth in the interior part of Norfolk Island, which I think is a proof that it has formerly been inhabited...". One of these tools was sent to Sir Joseph Banks.

Following these early reports of evidence for a pre-European settlement of Norfolk Island, nothing further was recorded until W.W. Thorpe and F.D. McCarthy, both of The Australian Museum, separately described

adzes, of characteristically Polynesian form, found on the island in the twentieth century. Among those reported by McCarthy were several adze blades which had been flaked to form but not finished by grinding. These adze blanks, together with several struck flakes of basalt, were found in the Emily Bay area of Kingston. Subsequently, further finds were made on the beach of Slaughter Bay, adjacent to Emily Bay, by Mr and Mrs Ray Hoare, residents of Norfolk Island with an intense interest in their local history. These finds were later reported to The Australian Museum in Sydney.

Such finds in themselves would cause little excitement among archaeologists; each can be compared with similar specimens from elsewhere in the Pacific Islands, especially in Polynesia. What is of greater interest is the fact that they appear to relate to a pre-European settlement of Norfolk Island, yet in the late eighteenth century when the first penal colony was founded, the island was uninhabited. Within the vast oceanic world of the Pacific, the early European explorers were continually amazed to find that Pacific Islanders not only had reached small isolated islands but also had succeeded in establishing viable communities on them. Easter Island, more than half as big again as Norfolk, had a flourishing population, even though it was more isolated. The smaller islands of Naufu and Ocean Island, with a combined land mass smaller than Norfolk Island and with a far less hospitable aspect, each supported substantial populations. Why should Norfolk Island have been the largest uninhabited island found by Europeans?

It was with this particular question in mind that Dr Jim Specht and Ms Hedy Czuchnicka from The Australian Museum, and Dr Foss Leach of the University of Otago, visited Norfolk Island in October-November 1976 to carry out an archaeological survey. It was hoped to visit the find-spots of the artefacts reported by various authors, and to try to identify archaeological sites of a pre-European age, which could be excavated to provide information about the original settlers of the islands. It was also hoped to get information which could help to determine why the island was uninhabited when Cook landed there in 1774. For this, we would need to know when the island was first visited, for how long, and whether more than one landing had occurred.

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National Library

In many ways, this archaeological study was to be very different from most studies in the Pacific Islands, where archaeology deals essentially with success stories of human colonization. Studies similar to ours had been conducted on several other islands found uninhabited by Europeans, but in most cases, ethnographic information suggested that those islands were visited casually, and deliberately, by the inhabitants of neighbouring islands to obtain resources which were lacking on their home islands. For example, Norfolk is composed mainly of basaltic rocks and we wondered whether the island had been used as a quarry source for stone to make adzes in the same way that the tiny island of Pitcairn appears to have been used. Many east Polynesian islands lack good quality stone to make adzes, a tool type which was prob-

ably the most important implement in day to day living in pre-European times. Although Pitcairn is only one-eighth the size of Norfolk, over three thousand stone adze blades, both finished and unfinished, have been found there, suggesting that the Polynesians may have regarded Pitcairn chiefly as a quarry, perhaps visiting or establishing a settlement there to guarantee access to its stone resources.

The visit to Norfolk lasted ten days, during which almost every part of the island was visited on foot. Thanks to the generous co-operation of the Norfolk Island administration and the local residents every known find-spot of artefacts was visited and tested and the total number of finds was increased from less than twenty to at least thirty-five adze blades, of which twenty-nine

Sydney Bay, Norfolk Island, 1855. Artist—J. Glen Wilson. Tinted lithograph, Rex Nan Collection.

View of Sydney Bay on the south side of Norfolk Island. Artist—Edward Dayes, 1763-1804.





John Fields / Australian Museum

Two different types of stone adze found on Norfolk Island—an Australian style blade (far left), and three eastern Polynesian style blades (right).

have been inspected. Even with this increased number of adze blades, Norfolk does not appear to have been a major source of stone, such as Pitcairn was, unless the visitors preferred to take with them blocks of stone rather than make their tools on the island. No evidence was found that any part of the island had been used as a stone quarry prior to European settlement.

Apart from the stone adze blades, all of which were found by local residents prior to the Museum visit, the survey produced no other finds and located only one possible pre-European site, on the beach area of Slaughter Bay where Mr and Mrs Hoare had collected all of their specimens of adzes. Here, between the high and

A view of Kingston on the shores of Slaughter Bay where stone artefacts have been discovered.

low tide levels, there is a scatter of beach pebbles and heavily worn flakes and adze blanks which appear to indicate the presence of an archaeological site.

A test pit was excavated just above high tide level, ending at nearly three metres depth on a former beach covered with water-worn pebbles. This former beach is at about the same level as the water-worn artefact found by Mr and Mrs Hoare further down the present beach. A second test pit at that point revealed no stone work that could be definitely attributed to human workmanship. If an archaeological site does exist in this area, it has probably been turned over and eroded by the sea, and no doubt the various tidal waves recorded here during the past two centuries have done much damage to the site.

Not only was this result disappointing, but it leaves in doubt the place of origin of a series of flaked stone tools published by McCarthy in 1934 which show no weathering by sand and sea action. These artefact were said by the finder Mr H. Rabone, a frequent visitor to the island, to have been found on Emily Bay. Local knowledge of the precise find-spot is inexact, but it is placed in the vicinity of the only building standing on the bay. The land behind Emily Bay has been used for many years as a sand quarry for construction work on Norfolk, since the dune here was the largest supply of sand on the island. Examination of the exposed profile of the dune, and a test pit on its seaward side, near the building, revealed no evidence of pre-European activity. It is possible, therefore, that the artefact attributed to Emily Bay in fact were found on Slaughter Bay, at a time before the erosional processes now operating on that beach destroyed the site there.

Kingston, which stands behind these two bays, is the site of the former penal colonies. The first of these settlements, finally abandoned in 1814, required the drainage of the swampy area now known as Kingston Common. The Common stands at the mouth of Watermill Valley, at the head of which is the area known as Arthur's Vale,

J. Specht





J. Specht

where King reported bananas growing in 1788. Several stone tools are said to have been found in that area, as well as some from Kingston itself. Our examination of these areas was hampered by the depth of silt which appears to have been deposited since European settlement. This silt resulted from slope wash off the surrounding hills, which were cleared of their vegetation for the construction of houses.

The degree of erosion caused by Europeans is well illustrated by a low cliff face above the beach at the main wharf. Here, under a metre and more of silt we identified an early European settlement covered by soil washed down from the hill behind the beach. With such a depth of soil washed down in the last two hundred years, the chances of finding pre-European sites of a greater age seem very slender, unless by chance.

Although most of the stone artefact have been reported from the Watermill Valley-Kingston-beach areas, others have been found from all over the island, both inland and from the coast. Isolated finds have been reported from Anson and Duncombe Bays, at the northern end of the island, from the interior in the Burnt Pine and Middlegate areas, and from Stockyard, Mission and Rocky Point Roads. The distribution suggests that pre-European settlers were not restricted to the southern part of the island around Kingston. However, consideration of the style of some of these tools raises some problems.

Most of the specimens published by Thorpe and McCarthy can be paralleled in eastern and central Polynesia. One and several others found since then are Melanesian forms, but two cannot be matched with tools from either Melanesia or Polynesia. These two blades are best compared with Australian forms. We are, then, faced with comparisons covering the entire south Pacific,

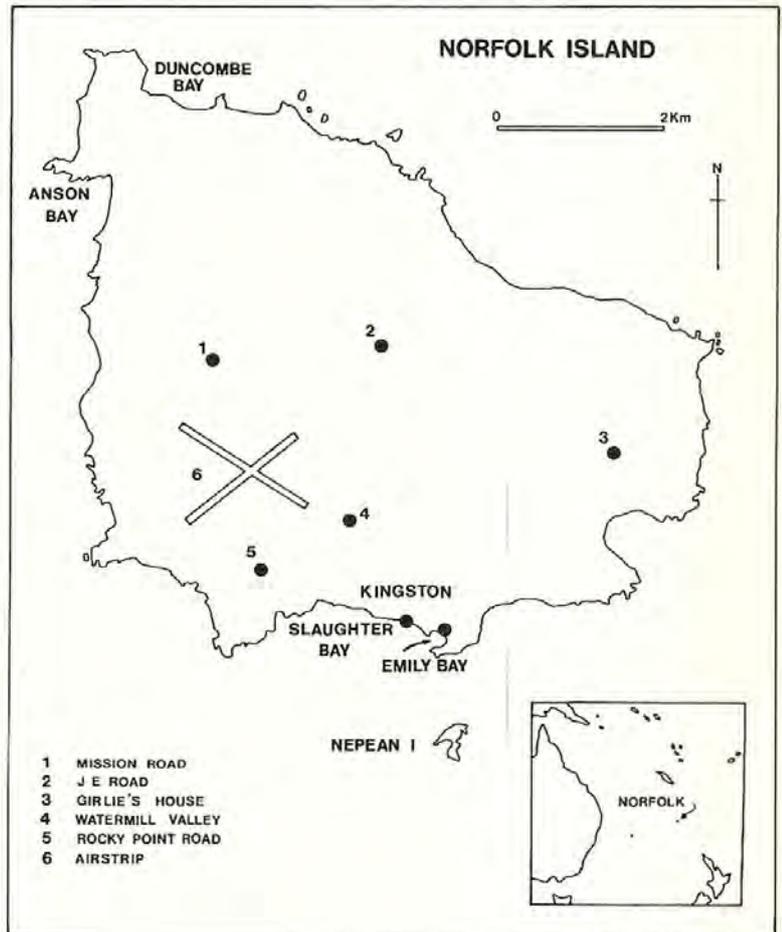
and the question arises, was Norfolk reached on several occasions, from each of these areas?

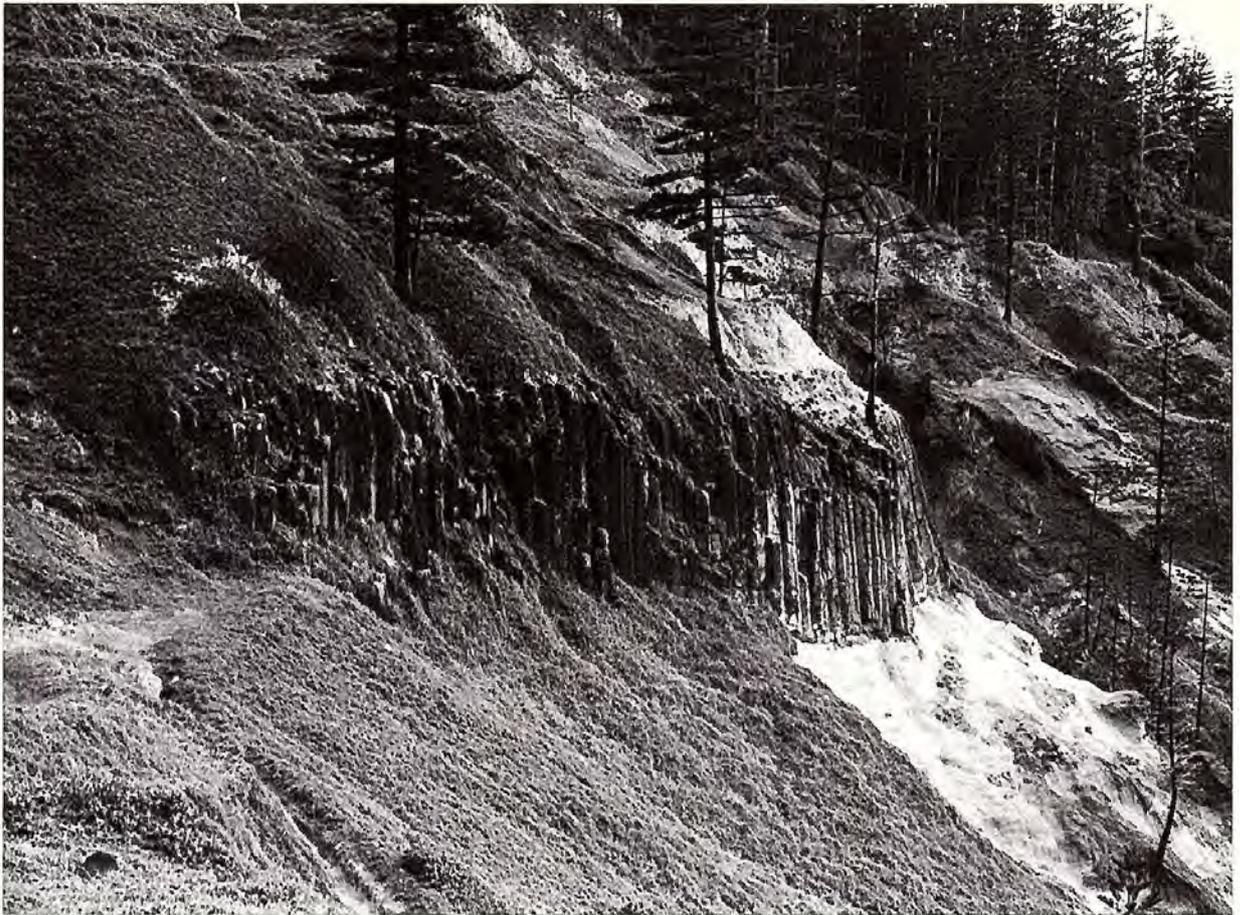
The likelihood of a settlement from Australia is very low. The water-craft used on the eastern seaboard of Australia were suitable only for coastal work, and are unlikely to have withstood the long voyage to Norfolk Island. It is possible that the tools were taken to Norfolk by a resident or visitor within the last two hundred years as curios. However, if we accept this kind of explanation, then the significance of the other finds should also be queried. One blade, of Melanesian style, found by Mr A. Tavener in a gully behind Girlie's House might also have been brought to the island by a European. This house had formerly been occupied by someone who collected artefact from around the world, and it is possible that the blade came from his collection. However, while we could attribute each of the finished blades to careless Europeans, it is difficult to explain the unfinished adzes and struck flakes from Emily Bay in this manner. Some of these eastern Polynesian forms could have been made by two Maori men brought to Norfolk soon after the initial settlement to teach the colonists how to process the flax found growing on the island. These two men were soon sent home when it was found that flax preparation and weaving had in fact been the task of Maori women. It is also possible to argue that some of the blades were brought by the Pitcairners who were re-settled on Norfolk Island in 1856, and by Melanesian students who came for training at the Melanesian Mission school.

Whatever explanation is chosen for these tools, it is

The cascade, one of the few permanent water sources on Norfolk Island.

Scale map showing sites of adze discoveries.





J. Specht

Columnar basalt formations emerge from surrounding severe slope erosion at Anson Bay.

impossible to explain away in like manner the stone tools found by the first settlers, some of which were clearly dug out of the ground. It seems reasonable to accept that some of the tools do indicate a pre-European settlement of the island. If so, what happened to those settlers?

The relative roles of drift voyages compared with deliberately navigated voyages in the settlement of the Pacific have been argued for many years. While the arguments have failed to resolve the basic question, they have produced a wealth of evidence to show that deliberate navigation across open seas was feasible over long distances.

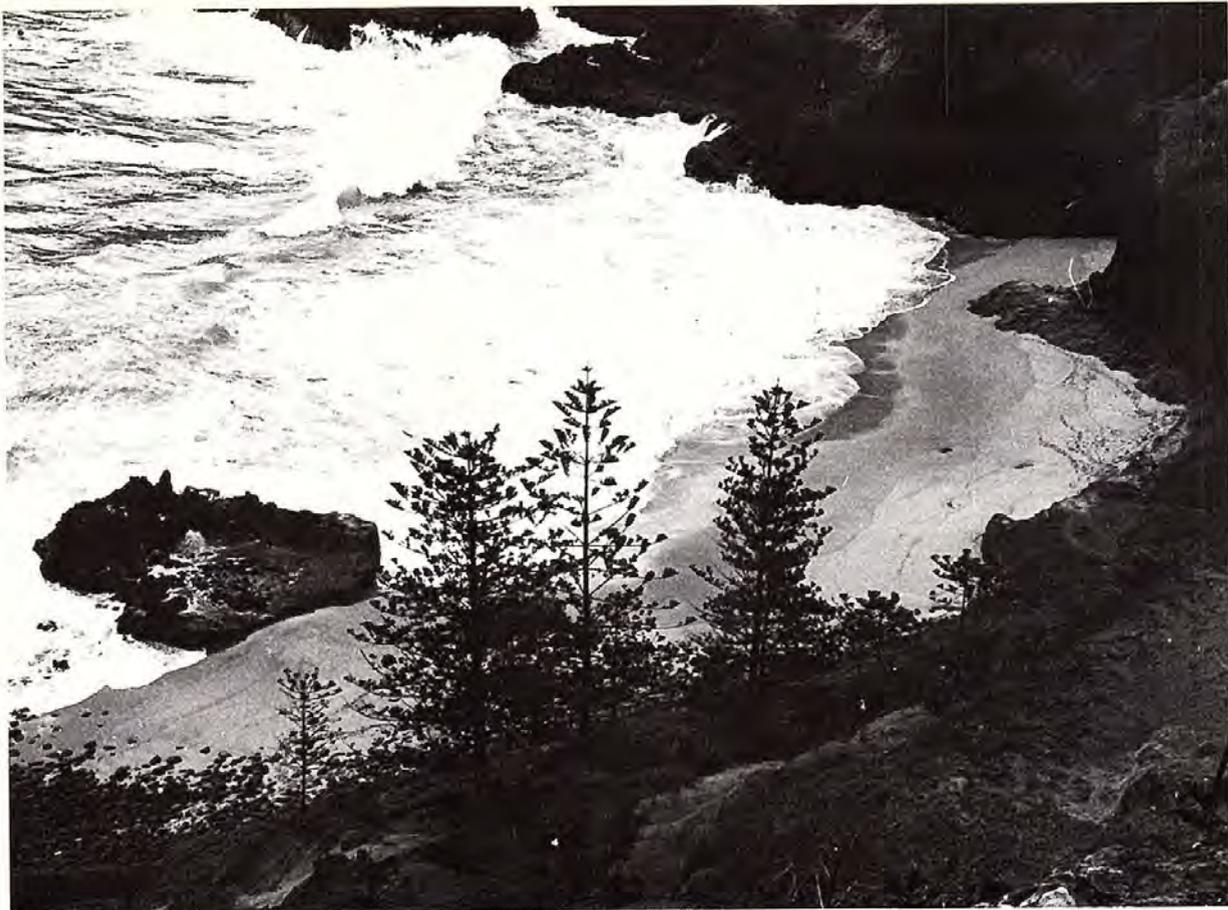
There are also many accounts of drift voyages by canoes caught in storms and blown off their courses, finally reaching land far from their destination. However, to prove that either of these events was responsible for the settlement of an island is virtually impossible. For the successful colonization of an island, both men and women must have been on the canoe. If the crew consisted solely of men, successful colonization would have been impossible; the men would either have died off without descendants, or could have attempted to return home. If, however, both men and women were on the canoe, they could have attempted to settle the island, and indeed may have done so successfully for a while. It may be objected that the small number of people involved would probably have been too small to produce a viable population to survive through many generations. However, a computer simulation study of the settlement of islands by small groups, carried out by Dr Norma

McArthur of the Australian National University and her colleagues, has shown that a founding population of less than ten men and women could establish a viable community whose population would increase and flourish for at least five hundred years. Hence, there is no reason to dismiss the possibility of successful colonization solely in terms of group size.

Just what did happen in the Norfolk Island case is open to conjecture. The archaeological remains available are all typical of male activities. Throughout the Pacific, women's activities have generally a low level of archaeological 'visibility'; in many archaeological excavations, the artifacts recovered would suggest that men only were present, although that seems most unlikely. Unfortunately, the finds of human bones on Norfolk cannot assist us here. These have come mainly from the Kingston area, where they were found eroding from the beach. Those for which racial identifications are available are all of European affinities, and none resemble Pacific Islanders. The convict era graves in the cemetery adjacent to Kingston, especially Murderers' Mound, are an obvious source of these remains.

The evidence, then, can be interpreted to indicate that Norfolk was reached perhaps from both Polynesia and Melanesia, but settlements, if established, apparently did not survive for long. A problem arises in determining when these visits occurred.

In the absence of organic materials from an excavated site, we cannot apply the radiocarbon dating technique.



J. Specht

Instead, only approximate ages can be suggested by comparing the adze blades with dated examples from elsewhere in the Pacific. One adze blade, a flaked specimen from Slaughter Bay, matches an early kind of adze found in eastern Polynesia, for which a date as old as one thousand years could be proposed. However, another blade is of a form widely distributed within the Polynesian area and used for hundreds of years right up to European contact. At best we can suggest that Pacific man, and perhaps woman also, first reached the island as early as A.D. 900 to 1100, and perhaps landed there again at a later date. The Australian and Melanesian-style blades offer no help in dating possible landings from those areas.

Although it lies almost midway between New Caledonia and New Zealand, Norfolk Island is isolated. Therefore, what is the likelihood of a drift voyage reaching the island? Professor R.G. Ward, of the Australian National University, and his colleagues have attempted to examine the settlement of the Pacific Islands by drift voyaging through a computer simulation exercise. Their results show that given present weather and current patterns, there is a low probability of a landing on Norfolk from New Zealand, the Kermadec Islands and Rapa, and none from any other islands. The most frequent point of origin for these successful landings was in the Kermadec Islands, which lie between New Zealand and Fiji-Tonga. This is intriguing, for the Kermadecs were uninhabited at the time of their discovery by Europeans,

though evidences for pre-European occupations have also been reported there.

During the survey we considered the possibility that a successful pre-European colonization of Norfolk may have been prevented by the lack of suitable food sources. This hypothesis seems unlikely since, with the exception of its impoverished molluscan fauna, the island would appear to offer the same potential for settlement as other Pacific Islands. All of the major food plants utilised by Pacific Islanders prior to European visits had been brought with them. Norfolk's avifauna was comparatively rich, even though the island lacked terrestrial mammals. As the early European settlers found, the numerous birds and their eggs could provide an important source of food, while the sea contained fish, which are plentiful, turtles and whales. These, together with eels from the freshwater streams, palm hearts, fern roots, and various fruits and berries, could have provided an adequate diet for a founding population that was waiting for its first crop harvest. The island had an ample supply of timber and basalt for tools, and a rich soil.

Further investigation of Norfolk's first visitors will be confined to the laboratory analysis of the rocks used to make the stone adze blades, to determine whether they were indeed made from local basalt. It is possible that remains of a pre-European settlement may yet be found buried under the ruins of the penal colony period, especially at Kingston. However, our study of 1976 did not disturb these important historical relics, the excavation of which must be tackled as a separate problem.

Anson Bay where Lt. King found the remains of a canoe in 1789. There were no signs of its occupants.



N. Coleman/AMPI

Pyrosoma, a pelagic tunicate.

Take a walk along the low-water mark on the rock platform at Long Reef and you will inevitably encounter a mat of brownish-purple, irregularly-shaped, leathery objects from which jets of water will be squirted. On closer inspection, it will be seen that this mat comprises a mass of erect, closely-packed, columnar individuals which locally are called 'cunjevoi' (the name given to them by the Aborigines) or, perhaps, more aptly, 'sea-squirts'. These seemingly repulsive objects are, in fact, quite sophisticated animals. They belong to the Tunicata (from the Latin *tunicata* referring to the animal's tough, outer coat), a group of animals within the phylum Chordata: as such, they have certain morphological features in common with fishes, reptiles, birds and man.

The scientific name of the local cunjevoi or sea-squirt is *Pyura praeputialis*. These animals, which form large masses along the lower rocky shores of New South Wales, Victoria and Tasmania, are usually only exposed by lower neap and spring tides. They are commonly cut open and their fleshy parts used as bait by fishermen. *Pyura* belongs to a class of the tunicates called Ascidiacea (from the Greek *askidion* meaning 'leather-bottle') because of their external appearance, shape and the consistency of the outer tunic.

Pyura is only one of many different kinds of ascidians which come in a great variety of shapes and colours. There are solitary forms similar to *Pyura*, with an outer tunic which may be either thick and opaque or thin and transparent. There are also 'compound' ascidians in which many small individuals share a single, common tunic. These are often brightly coloured and may form large encrusting sheets or stalked lobes, each lobe comprising numerous individual animals. Scuba divers in

both temperate and tropical waters will see brilliantly coloured compound ascidians forming amazingly beautiful shapes and patterns over the surface of other sedentary animals. Even on the seashores around Sydney, small mats of compound ascidians may be found, although individual animals may only be discerned using a hand-lens. The individual animals within the tunic are called zooids.

The basic body form of all tunicate zooids is similar but is described here from the local 'cunjevoi'. If a specimen is cut off the rock and the tunic carefully removed by cutting across the bottom of the column, then up each side to the siphonal apertures (the projecting cones on top of the animal), the purplish, fleshy zooid inside is exposed. The tunic is an interesting structure as it was once thought to be unique amongst animals in containing cellulose, the well known plant fibre. It is a closely related compound, tunicine, which has also now been found in minute traces in human skin. The tunic provides a convenient surface for attachment by a host of other organisms, for example seaweeds, sea mosses and scavenging worms. In this way quite a community is set up.

By cutting the soft-bodied zooid in half vertically, bisecting each of the two protruding cone-shaped siphons, most of the major internal structures can be seen. The body wall is quite muscular and, in fact, some ascidians are considered delicacies in other countries, especially Japan. Inside the body wall is a delicate plaited basket called the branchial sac or pharynx, which is the main food collecting and respiratory organ. The tubular oral or branchial siphon leads into the pharynx. At the base of this siphon is a ring of feather-like tentacles. These act as a filter to prevent the entry of over-large particles into

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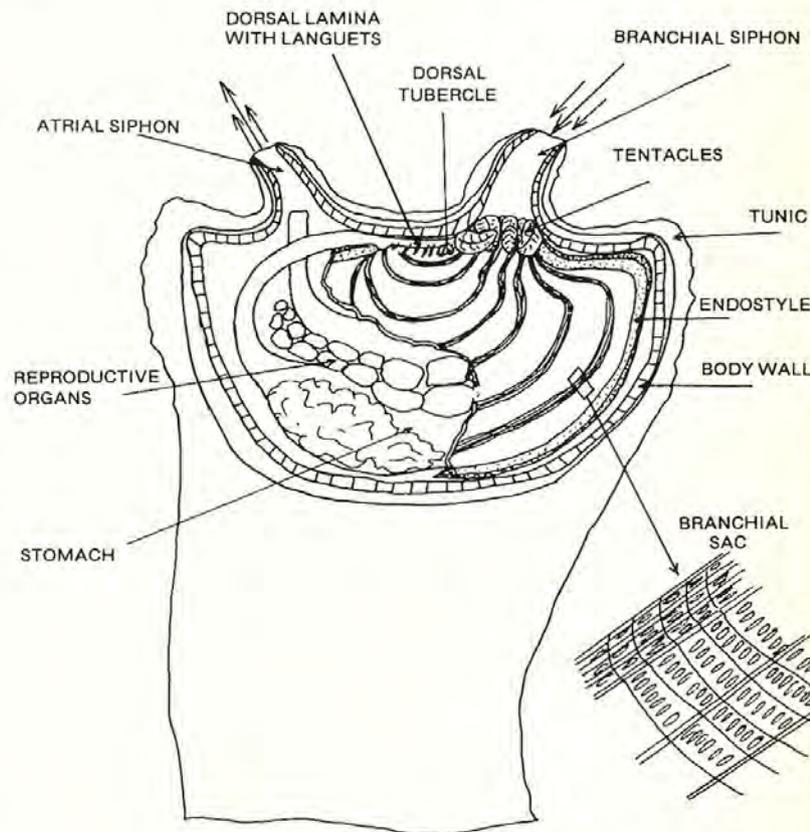
THE SOPHISTICATED SEA SQUIRT

BY FRANK ROWE

the branchial sac. This sac is perforated by numerous, regularly arranged openings called stigmata, which are outlined by cells bearing minute hairs or cilia. The beat of these cilia helps to draw food-laden water in through the branchial siphon. The water passes through the stigmata and out through the second or atrial siphon. The branchial sac has a ventral (lower) and dorsal (upper) side and these are distinguished in *Pyura* by the presence of tongue-like languets on the dorsal side and (as in all sea-squirts) a groove called the endostyle on the ventral side. The endostyle is very important as it comprises three large masses of mucus-secreting cells and, in the valley of the groove, long whip-like flagella which help to move the mucus out into the branchial sac. This mucus is then moved as a sheet across the branchial sac to the dorsal side where it is passed back to the oesophagus. As water is brought into the sac through the branchial siphon and passes through the stigmata, food particles are trapped in the mucus. In *Pyura*, the wall of the branchial sac is folded so that there are six to seven folds on each side of it, left and right. The oesophagus leads into a globular stomach which passes into the long intestine. The latter forms a U-shaped loop which brings the anal opening adjacent to the outlet or atrial siphon. In consequence, waste faecal matter can be washed clean of the animal in the stream of water which passes out through that siphon. In particular, such waste material is carried clear of the branchial siphon through which the food-laden water enters the zooid. In *Pyura*, the gut loop lies on the left-hand side of the animal beside the branchial sac. The reproductive organs may be found on both sides of the body (outside the branchial sac). Ascidians are hermaphroditic and both male and female sex cells are found in the same animal. To expose the gut and reproductive organs it is usually necessary to cut away the branchial sac. On the left-hand side, the reproductive organs lie in the loop of the gut. Structures that are more

difficult to see are the small 'sense' organs or neural ganglion and gland, which lie outside the branchial sac and midway between the two siphons. They are associated with a structure called the dorsal tubercle, a complexly folded organ at the top end of the dorsal lamina in the branchial sac.

Longitudinal section of *Pyura praeputialis*, with branchial sac cut away to show main features, about natural size.





N. Coleman/AMP

Pyura spinifera,
a stalked, solitary
ascidian.

The eggs and sperm of most solitary ascidians are probably shed into the sea, where fertilisation and development take place during the particular breeding season of the species concerned. In most compound ascidians the fertilised eggs are retained within the parent colony, from which fully formed larvae emerge. The larvae are completely different from the adult and could easily be mistaken for minute tadpoles. Whereas the adult cunjevoi is sessile, the larvae is motile and planktonic for its short existence of six to twenty-four hours. During this time it does not feed but seeks a suitable site on which to settle and metamorphose. The larva is important for several reasons particularly in that it allows the distribution of an otherwise static animal. In addition, the larva displays structures which show the relationship of the tunicates to other animals much more clearly than those of the adults. This is particularly highlighted by the structure of the larval tail which has a longitudinal support rod, notochord, surrounded by

Pyura-type larva.
Natural size about
2mm long.

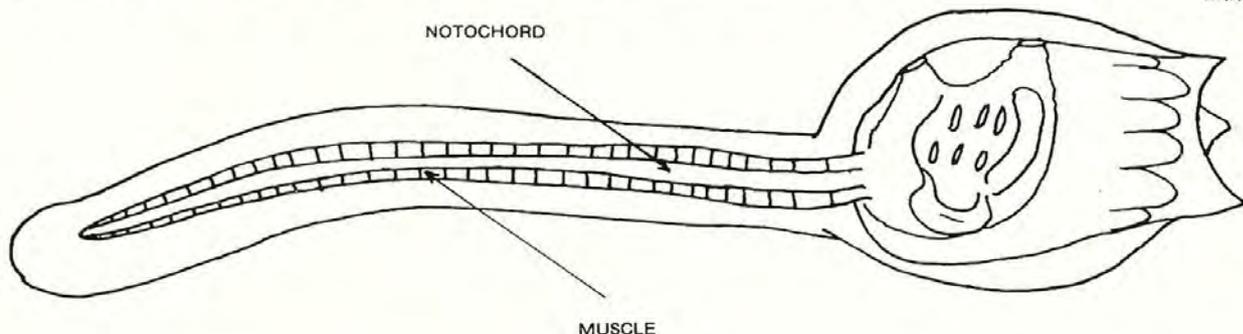
muscle cells and above which is a hollow nerve cord. During metamorphosis, the larval tail is resorbed, the only feature remaining in the adult being the neural ganglion complex. This larval tail structure is common in embryonic stages of other chordate animals, both invertebrate and vertebrate, ranging from the tiny lancelet *Amphioxus* to fishes, reptiles, birds and man.

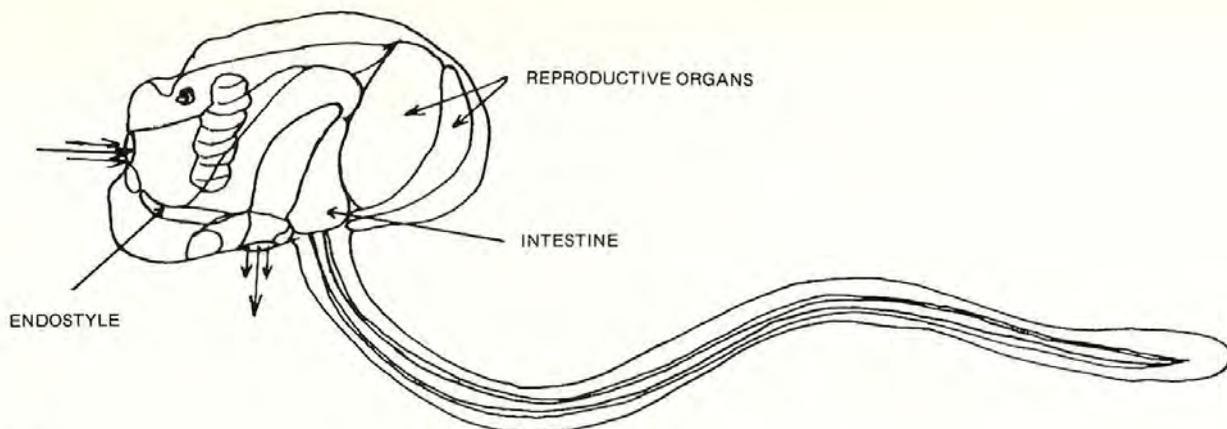
There are three classes of tunicates. Firstly, the Ascidiacea or ascidians which include forms that are fixed or sessile as adults but with tailed, swimming larvae. The two other classes, the Thaliacea and the Larvacea, comprise forms in which both adults and larvae are specialized for a free-swimming existence.

The Thaliacea, often called salps, include the pyrosomids of which *Pyrosoma* is the only known genus. In *Pyrosoma*, the zooids are colonial, forming long cylindrical colonies open only at one end. Each zooid takes in water through its external oral siphon but the discarded water from all the zooids is directed into the centre of the cylinder and out through its open end, the resulting jet of water slowly propels the colony through the water. The name *Pyrosoma*, meaning 'fire-body', refers to the ability of these animals to become brilliantly luminous. The largest colonies of *Pyrosoma* so far recorded have been seen off Mayor Island, New Zealand, with the biggest measuring some ten metres in length and one metre in diameter. The Thaliacea also include the barrel-shaped doliolids and the prism-shaped or cylindrical salps. Reproduction in the solitary salps takes place by the budding off of series of young zooids from the parent salp: these mature whilst still attached to the parent. Long chains of animals, with the oldest at the tip, trail behind the parent salp, clusters of young breaking off at intervals. These long chains of salps may be washed ashore.

The other pelagic class of tunicates is the Larvacea or Appendicularia. These are extraordinary in that they remain minute and larval-like throughout their adult life. Another remarkable larvacean feature is the delicate gelatinous 'house' secreted by the epithelium in which the animal lives or to which it is attached. In very complex houses, water, drawn in by the beating of the animal's tail, enters the house via an incurrent pore that is guarded by a fibrous mesh that filters out large particles. The water continues to circulate through passageways that act as a second, finer filter system: these trapped particles are later eaten. The excurrent pore is usually closed by a hinged door that opens suddenly as water pressure within the house builds up—this sudden jet of water propels the house through the water.

F. Rowe





F. Rowe

In some larvaceans, the house is provided with an escape hatch through which the animal leaves, a response probably triggered by the clogging of the filters. Houses are continually shed and newly secreted, often within a period of a few hours.

The tunicates are strictly marine animals which have not penetrated into fresh-water habitats. The ascidians extend to virtually all depths of the sea, on both hard and soft substrates and may be found in all latitudes. The pelagic tunicates are usually found in the surface layers of the sea and are, primarily, warm water forms. However, Larvacea may be found down to depths of three thousand metres and salps frequently inhabit deep waters and cold seas.

Some ascidians are well known as fouling organisms. Ascidian larvae may settle on the hard surface of ships' hulls, jetty piles, marker buoys, sewerage outflow pipes, etcetera. The sedentary adults can then reduce ship speeds by increasing friction as water sweeps past the hull, block outflow pipes or necessitate their removal from buoys requiring maintenance. Settlement on ships' hulls may result in a species being transferred into new areas, thus extending the distribution of that species: *Botrylloides leachi* a compound ascidian and *Ciona intestinalis* a solitary ascidian have spread from Europe to Australia in just this way. Of course, survival in the new environment depends on suitable conditions being available.

Since many ascidians will readily settle on any convenient hard surface, it is possible to study their life histories by placing artificial settling plates in the marine environments. Constant and repetitive observations over periods of a few years can result in finding out when the larvae settle, which types of surface the larvae prefer and how long the adult ascidians live. Most shallow-water ascidians live for about twelve to eighteen months. Information on settlement times and habitat preferences can be used to improve anti-fouling techniques.

It was mentioned earlier that some ascidians were the delight of gourmets. Within their own environment, the sea-squirts are not without enemies. Various fishes and nudibranchs (sea-slugs) are known to feed on the soft-bodied zooids and countless cunjevoi are used by man as fishing bait each season. Nudibranchs are particularly partial to the compound ascidians which are not as well protected as their larger solitary cousins. The larger solitary forms also provide a relatively safe harbour and

provider particularly for small crustaceans which may be found snugly settled in the branchial sac. Here the small intruder is protected and provided with an easily available food supply.

At present, some two hundred and fifty or so different species of ascidians are known to inhabit the coastline of Australia. Most of these (about sixty percent) have not yet been found outside Australian waters and are, therefore, considered endemic. This is a comparatively rich fauna in world context and merits more attention than it gets from local naturalists. There is more in a sea-squirt than meets the eye!

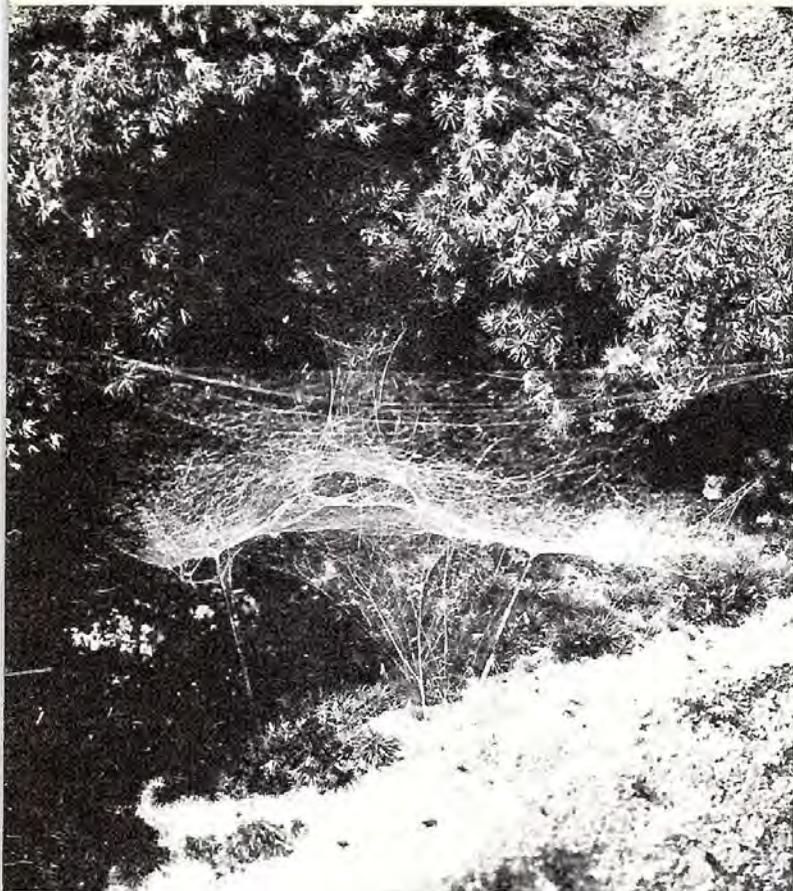
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Larvacean. Natural size about 5mm long.

Botrylloides magnicoecus, a compound ascidian





Australian Museum

A sheet web with central retreat funnel gusted out from a moss covered soil bank.

Spider webs are a familiar sight in the bush or garden, where they are epitomized by the spectacular 'cartwheel' shaped webs of the orb weaving spiders. Suspended in open spaces between trees and shrubs, their striking symmetry and the single-minded toil which goes into their construction have impressed mankind since ancient times. Like Solomon's ant, the industrious spider has been long and somewhat unfairly held up as an example to less instinctively endowed humanity. Snare web building is, of course, only one of the many functions of spider silk. It is through the development of a variety of silk-oriented patterns of behaviour that spiders have become the dominant arachnid group.

The ability to produce silk has evolved independently in three groups of arachnids—spiders, pseudoscorpions and some mites. In spiders, the silk producing glands are located in the abdomen. These glands open posteriorly via specialized ducts (the spools and spigots) placed upon a group of segmented spinning appendages, the spinnerets. In pseudoscorpions and mites, the silk glands are usually associated with the mouthparts. In these groups, silk is concerned mainly with protective functions, notably the construction of silk-lined brood and moulting chambers.

The main characteristics of spider silk are its high strength and elasticity. The silk of the drag line (the safety line which is continuously paid out behind as the spider moves along) is almost as strong as nylon thread

and twice as elastic. Not surprisingly, efforts have been made to use spider silk for weaving cloth. Unfortunately, it does not stand up well to the weaving processes, even if it were practical to maintain sufficient spiders for the purpose. According to one estimate, fifty-four thousand spiders, each separately housed to prevent cannibalism, would be needed for the production of a single kilogram of silk!

Spiders can produce several types of silk, each differing in both chemical and mechanical characteristics. Appropriate silks are required for purposes as different as egg sac construction, snare web building, prey catching and immobilisation, to mention only a few. Each type of silk is secreted in a separate abdominal silk gland of which at least six distinct types have been recognised. The ampullate glands, for example, provide silk for the drag line and for the framework threads of snare webs. Considerable amounts of silk can be stored in these large glands which, unlike the other silk glands, are required to produce copious amounts of silk throughout the life of the spider. The smaller, highly coiled cylindrical glands are the main suppliers of silk—often gold, brown or green in colour—for egg sac construction. These glands are found only in female spiders, their size and secretory activity increasing with the development of the eggs in the ovaries. It is interesting to note that some of the most primitive living spiders possess only two types of glands, which may be functionally equivalent to the ampullate and cylindrical glands.

Two other silk glands of particular importance are those which provide the 'sticky' prey-catching silk used in various types of snare webs. The aggregate or lobed glands are found only in the most advanced web-building groups—the Araneidae (which includes the common orb web spiders), the Linyphiidae (tiny sheet web builders) and the Theridiidae (including the red back spider and many others). They secrete a viscid, adhesive silk which is coated onto a double supporting thread such as the spiral of the orb weaver's web. As each section is finished, the spider breaks up the continuous coatings of viscid silk into discrete droplets by twanging the supporting thread with its leg. Prey animals, coming into contact with such catching threads, adhere to them, and their struggles simply gum them up further as they touch adjacent sticky threads.

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SILK, SPINNERETS AND SNARES

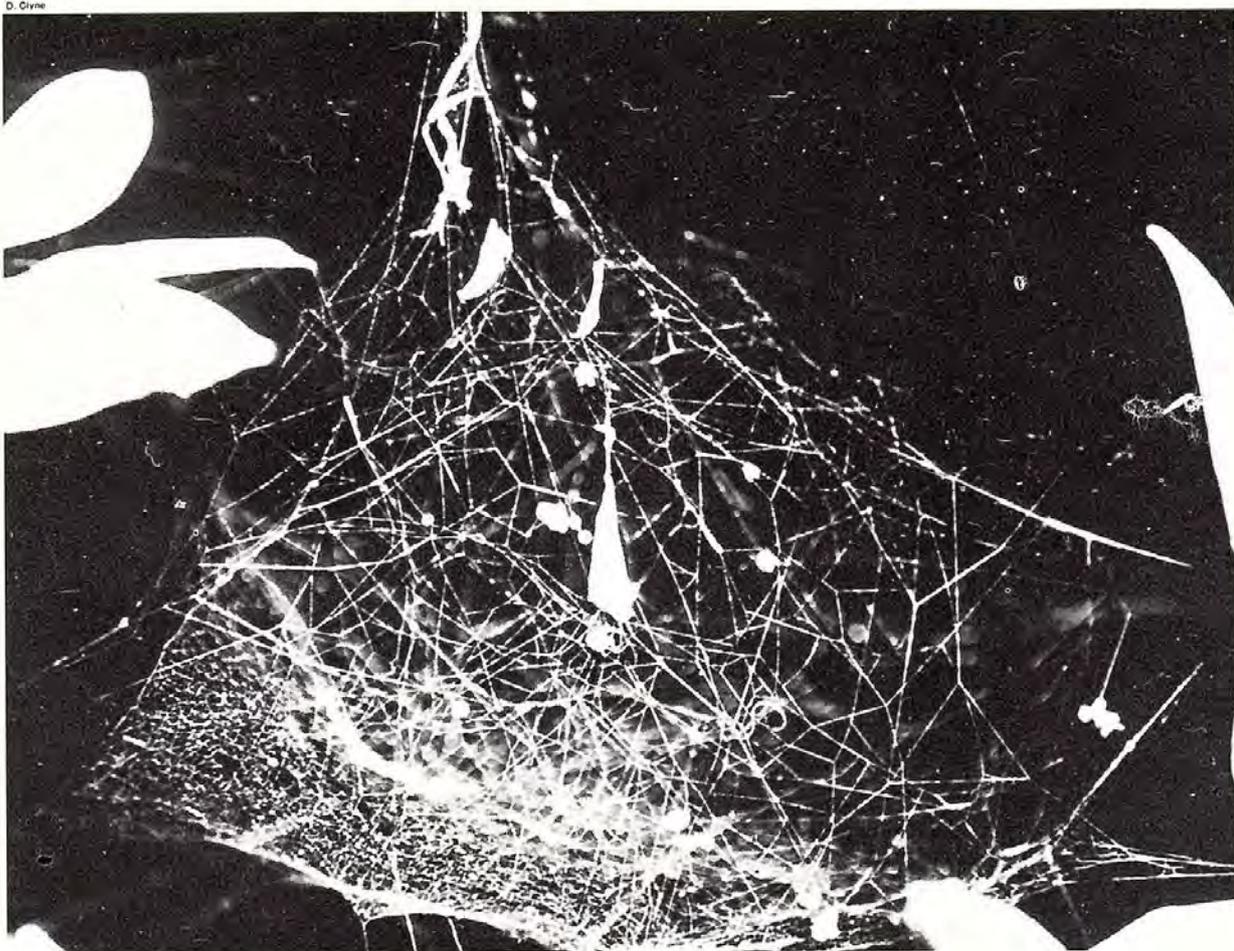
BY MICHAEL GRAY

The other type of catching silk is produced by the so-called cribellate spiders, a heterogeneous assemblage from many families. Familiar examples are the black house spiders *Ixeuticus* spp., whose irregular sheet webs are commonly seen on the walls of sheds and houses, and the net casting spiders *Dinopus* spp., which construct a stamp sized sheet web which they hold with their front legs and throw over their prey. Such spiders possess a specialised plate-like spinning organ, the cribellum, which is placed immediately in front of the true spinnerets. Silk from the small cribellar glands issues out through many tiny spools on the surface of the cribellum. The resultant mass of fine silk fibrils is further drawn out by the rhythmic combing action of the calamistrum, a row of fine bristles situated on each of the last legs.

These fibrils form a mat-like mesh of variable density placed upon two or more longitudinal supporting threads which are drawn out from the spinnerets at the same time. Such composite cribellate threads can differ greatly in appearance between different spider groups but they all function very effectively in entangling prey animals which come into contact with them in cribellate snares. Again, the struggles of the prey only entangle it more firmly in the fibril mesh and adjacent threads.

In use, silk takes the form of an elastic fibre, although it is secreted in the silk glands as a liquid. The change from the liquid to the solid fibrous state occurs as the silk is drawn from the spools and spigots of the spinnerets. This process places the cohesive liquid silk under longitudinal tension so that a rapid reorientation of the pep-

A composite web consisting of a three-dimensional maze of threads above and a closely woven sheet below.



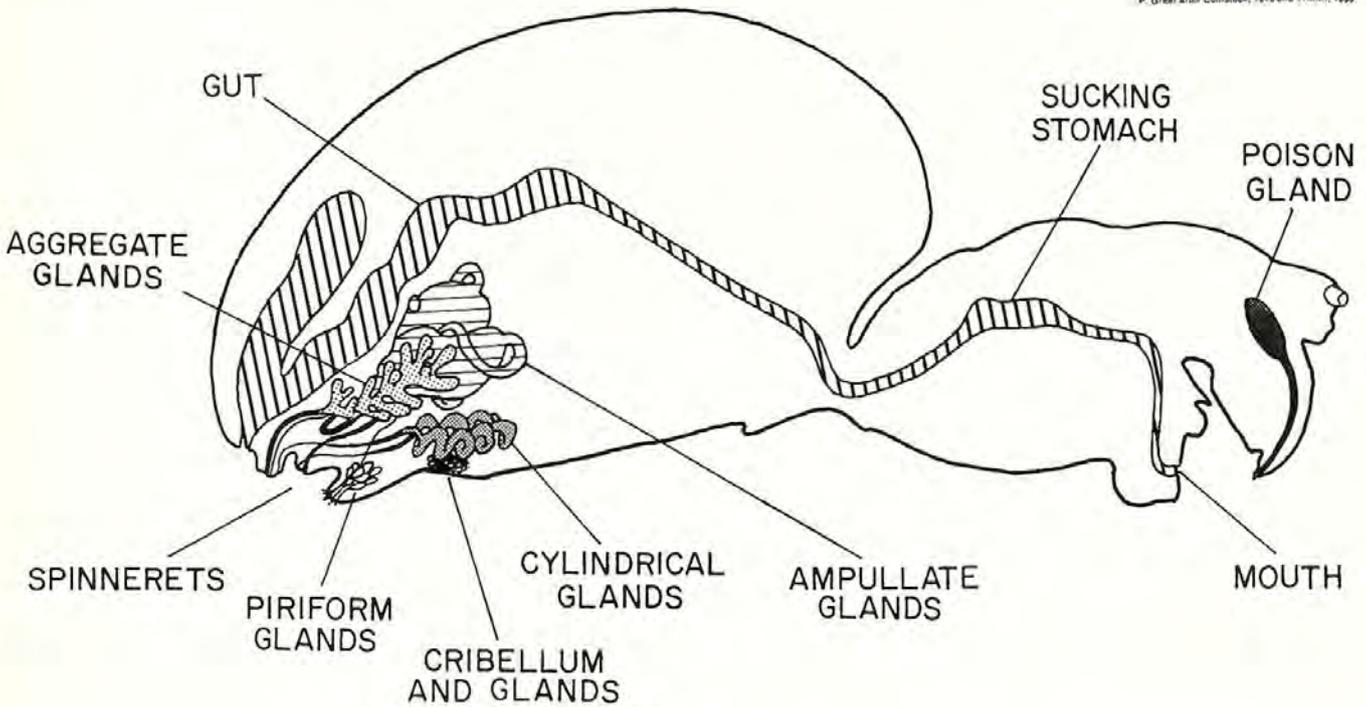
tide molecule chains, of which silk is made, takes place, converting it into a fibrous structure. Only the viscid catching silk secreted by the aggregate glands of orb web weavers and others remains in liquid form upon supporting silk fibres.

While the spinnerets are under direct muscular control and can be manipulated with considerable precision, the silk glands themselves lack musculature. Extrusion of silk from the soft-walled silk glands seems to be controlled primarily by variation of internal abdominal pressure. In addition, many spiders possess a muscular-cuticular valve placed around the duct of the ampullate glands (which produce drag line and framework silk). This allows precise control of silk supply from these important glands. However, exactly how the output of

updraft conditions are good these spiders climb to high points on vegetation and let out long strands of fine silk which eventually attain sufficient buoyancy to lift the spider up and away.

The spinnerets and silk glands represent the vestiges of abdominal limbs and associated excretory glands once present in ancestors of the arachnids. Spinneret structure can provide important clues to the relationships of the major groups of spiders. If one examines the spinnerets of the liphistiomorph spiders (an ancient and primitive group of spiders with segmented abdomens which have persisted virtually unchanged since Palaeozoic times in Japan, China and Southeast Asia), they are seen to be characteristically multi-jointed (ten to fifteen joints) and placed in the centre of the ventral surface of the abdomen. Contrast this with the two other major

A diagrammatic longitudinal section of a spider showing the disposition of the silk glands, ducts and spinnerets.



P. Greer, after Comstock, 1940 and Trimm, 1960

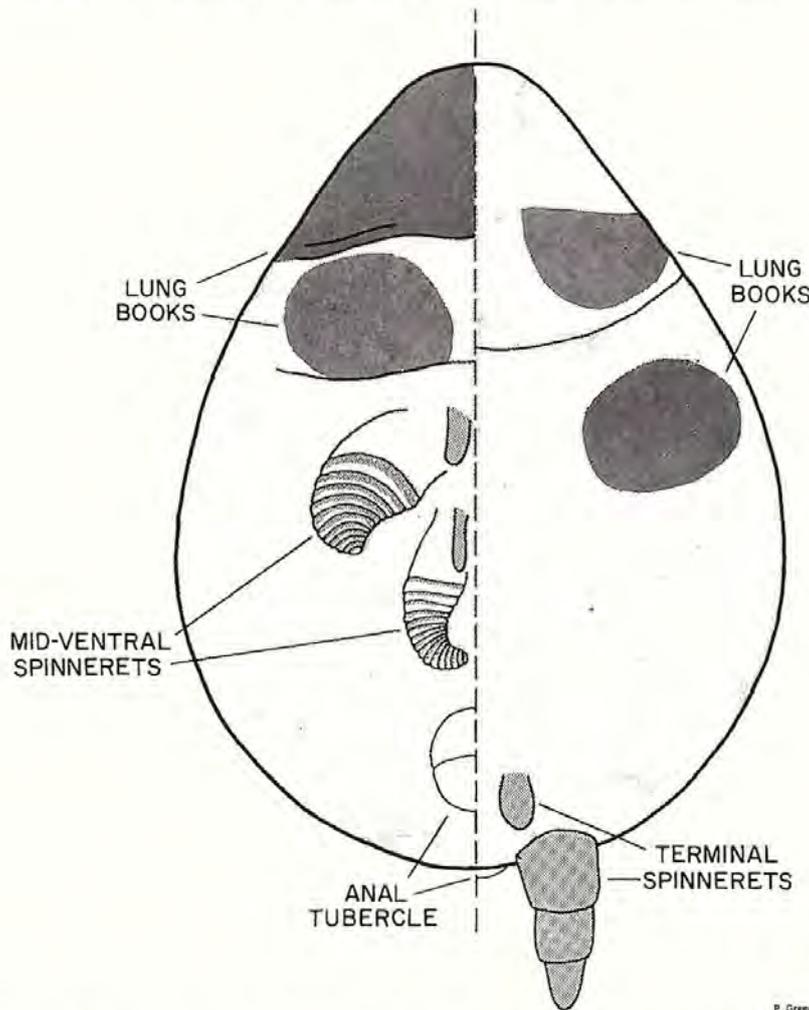
individual glands is controlled in a complex web building operation is not yet clear. Once silk has been extruded, the anterior spinnerets are touched onto the substrate thus forming the attachment disc—an adhesive patch of short silk fibres secreted by the small piriform glands—onto which other threads can be joined. The spider then walks or drops away from this attachment point and silk is automatically drawn out behind it. Alternatively, air currents are used to waft away the free ends of fine silk threads which may be drawn from the spinnerets with the assistance of the terminal bristles and claws on the last pair of legs. Eventually, the floating silk makes contact with a solid object such as a branch or leaf, to which it adheres, forming a bridge thread across the intervening space. Similar use is made of air currents during the dispersal stage of many species as spiderlings and, in some cases, as adults. On warm days when

groups of spiders, the Mygalomorpha (trapdoor and funnel web spiders) and the Araneomorpha (all other spiders or the true spiders). Not only has external abdominal segmentation in these groups been reduced or lost altogether (to form the characteristically smooth, sac-like abdomen), but also spinneret segmentation is reduced to two or three joints only, rarely four. The spinnerets have moved from a mid-ventral to a terminal position on the abdomen, a more efficient arrangement for silk manipulation. Again, only in the liphistiomorph spiders can the primitive number of eight spinnerets still be seen, though not all of them are functional in surviving species. By contrast, the mygalomorphs have lost all trace of the anterior median spinnerets and most have also lost the anterior lateral spinnerets so that their usual spinneret number is four. In all living araneomorphs, the anterior median spinnerets have been either modified to form the

specialised spinning organ called the cribellum or, in the majority, lost altogether; their former presence is often indicated by a small mound, the colulus, placed in front of the remaining spinnerets. Consequently, the usual spinneret number in araneomorphs is six.

The significance of the cribellum in the formulation of schemes of spider relationships (a process which involves the comparative study of a wide range of structural, behavioural and other characteristics) has been disputed for many years. There is little doubt that the cribellum is a direct derivative of the anterior median spinnerets which must have been possessed by the ancestors of the araneomorph spiders. Consequently, at the root of this

strongly suggest close relationships between them. While some of these suggested relationships have gained general acceptance, others are still disputed. One of the latter will serve to illustrate this aspect of the so-called 'cribellate problem'. The groups involved are two orb web weaving families, the non-cribellate Araneidae (= Argiopidae) and the cribellate Uloboridae. The araneid orb weavers are familiar to most people; their large wheel-like webs are a common sight in gardens. The less obvious uloborid orb weavers build smaller webs, usually slanted, in more sheltered sites—among low vegetation, in sheds, under houses. The orb webs built by these two groups of spiders are virtually identical both in the way in

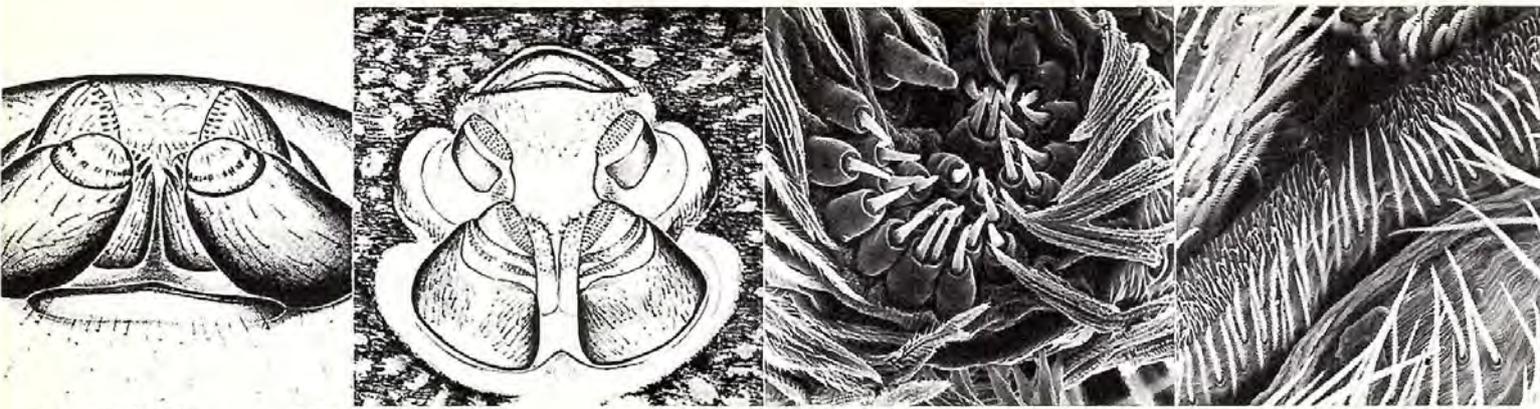


P. Greer

argument is the question of the origin of the vestigial remnant of the anterior median spinnerets, the colulus. Has it also arisen directly from the anterior median spinnerets, by a process of simple regression, or indirectly via a cribellate stage, or have both processes occurred? Various classificatory schemes which reflect these alternatives have been devised. One early scheme, the influence of which is still felt, suggested that all of the cribellate spiders were related and so should be placed together in their own group, usually called the Cribellatae. Other studies have shown that various cribellate and non-cribellate groups share certain unique morphological and behavioural characteristics which

which they are built and in their structure—the obvious exception being that the catching silk is viscid in the araneid web and cribellate in the uloborid web. One viewpoint suggests a common ancestry for the two groups based largely upon the assumption that a structure as complex as the orb web is unlikely to have evolved more than once. An alternative proposal has the two families evolved separately from unrelated cribellate and non-cribellate ancestors; orb web similarity is considered simply as an example of convergent evolution, i.e. such webs have evolved quite independently within each family. Morphological differences do suggest that the two families cannot be very closely related; nor can

A diagram contrasting spinneret structures and position in liphistiomorph (left) and mygalomorph (right) spiders.



B. Weston

B. Weston

Left to right: The spinnerets of a cribellate spider; the cribellum is at the front. The spinnerets of a non-cribellate spider; the colulus is at the front. End view of a spinneret showing the structure of the spigots; silk for the drag-line issues from the largest spigot. (SEM X300). A cribellum showing the flattened plate-like structure and the numerous small spigots upon its surface. (SEM X150).

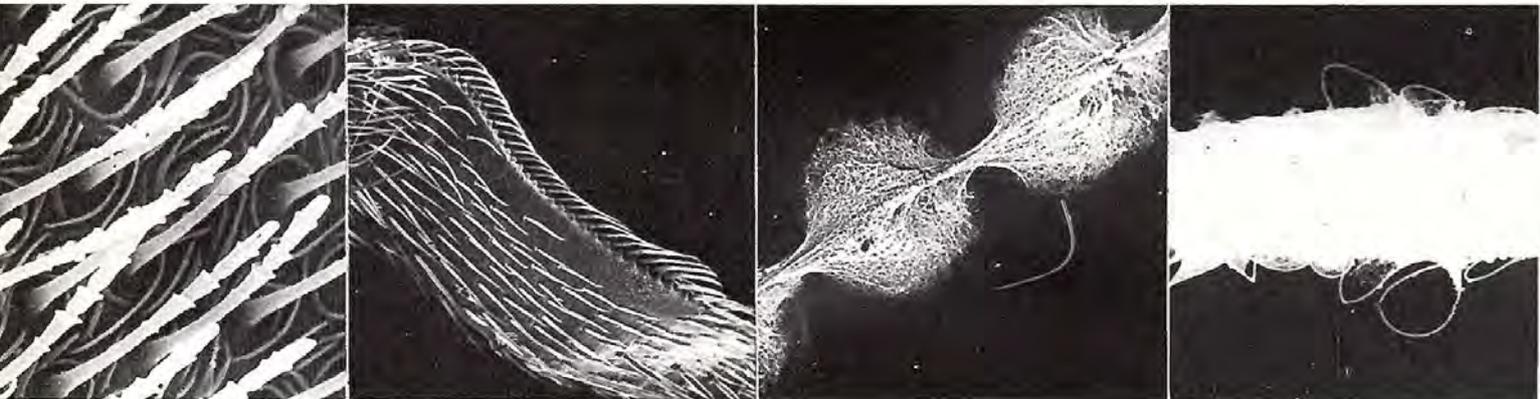
The uloborids be easily placed in a meaningful relationship with the closest relatives of the araneid orb weavers, the Theridiidae and Linyphiidae. Consequently, yet another option which, to some extent, compromises between the above viewpoints has been proposed. This places uloborid and araneid orb weavers in distantly related groups derived from common cribellate ancestors but their respective orb webs are considered to have evolved independently within those groups.

The most recent classificatory schemes relate cribellate and non-cribellate spiders at all taxonomic levels from species to family, a far cry from the early concept of an entirely separate group for all the cribellate spiders. Such classifications, which are by no means fully worked out or accepted as yet, are supported by the demonstration of several convincing examples involving non-cribellate spiders in which the colulus is clearly derived from a former cribellum. The regression in size and loss of function of the cribellum can usually be attributed to the successful exploitation of an ambushing or active hunting way of life, where the snare web has become unnecessary. A good example of this is given by the spiders of the family Gradungulidae. These spiders can be easily recognised by the greatly enlarged tarsal claws on each of the first two pairs of legs, which are used to grasp prey animals. Until recently, these primitive four-lunged araneomorphs, which hunt amongst the leaf litter of the moist forests of eastern Australia and New Zealand, were all thought to be non-cribellate. However, a few years ago another primitive araneomorph was collected in a cave in northern NSW. This spider not only possesses the typically enlarged tarsal claws of a gradungulid but also

has a functional cribellum and builds a very singular cribellate snare web. Clearly it is a gradungulid spider but one which represents an offshoot of a cribellate ancestor from which its non-cribellate relatives must also be descended. Such evidence clearly indicates that at least some non-cribellate spiders have reached that state via an intermediate cribellate stage. In this context it is interesting to note the existence of several families of primitive web-building araneomorph spiders, the Palaeo-cribellatae, all of which are cribellate or have cribellate representatives. Australia has two of these families: *Hickmania troglodytes* from Tasmania, the sole representative of the family Hickmaniidae; and the family Gradungulidae, whose membership of this group was only recognised with the discovery of its cribellate representative. The point is that this old or relict group of spiders is primarily cribellate and there exists no equivalent non-cribellate group of spiders.

Taken overall, the evidence strongly suggests that the cribellum is an ancient spinning organ which was present in the earliest araneomorphs but has since undergone independent reduction and loss in many descendant lineages of spiders. In some lineages this has evidently occurred a very long time ago, while in others the process can be observed going on now.

It is unfortunate that webs do not survive in fossil form; some first-hand knowledge of the ways in which silk was used by Palaeozoic spiders would be very useful in reconstructing the steps involved in the evolution of web-building behaviour. The spiders themselves, being relatively soft-bodied animals, have left only a fragmentary fossil record, which, nonetheless, extends back



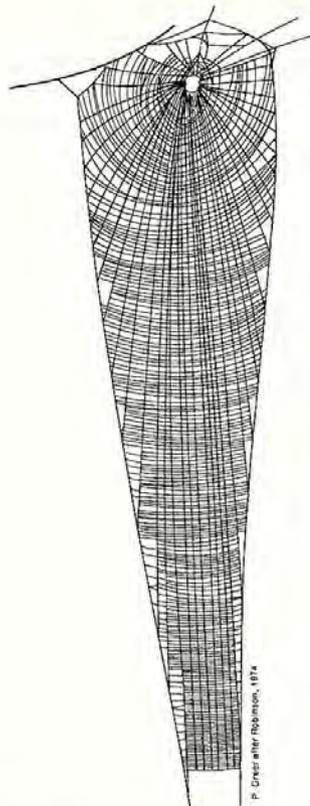
almost four hundred million years to mid-Palaeozoic times. The most extensive fossil remains come from Tertiary deposits some forty million years old; these include many specimens which were beautifully preserved in yellow amber derived from the sap of the vast coniferous forests of those times. They indicate that the spiders had reached a diversity of form very similar to that seen today. Consequently, it seems reasonable to assume that as long ago as Tertiary times, web-building behaviour was already very similar to that of Recent times.

The original uses made of silk by the first Palaeozoic spiders were probably related to aspects of reproduction. One example is the part that silk plays in the unique process of sperm induction. All male spiders, extant or fossil, possess a more or less complex system of ducts and processes on the last segment of the male palp, the appendage just behind the jaws. This is a sperm storage and copulatory organ which in fact represents an elaboration of the terminal claw of the unmodified palp seen in juvenile spiders and females. The process of getting sperm from the male genital pore on the abdomen to the palpal storage organ requires the use of silk. The mature male spider spins a small sperm web, usually sheet-like or, in some cases, simply a single thread. Spermatic fluid is extruded onto this web from the genital pore and the palps are then dipped into this until all of the fluid has been taken up into the storage ducts of the palps. During mating a spine-like projection called the embolus is inserted into the female genital opening on the abdomen and the sperm ejected.

The universal occurrence of this process of sperm induction and transfer in both primitive and advanced groups of spiders suggests that it is an ancestral trait. However, the silk involved in sperm induction does not always come from the spinnerets. In many of the species so far examined it has been found that sperm web silk is secreted by numerous tiny silk glands clustered on the mid-ventral area of the abdomen just in front of the genital pore. Although these 'epiandrous silk glands' are quite independent of the true spinnerets, they may be derived from segmental excretory glands like those which are thought to have given rise to the median spinnerets and their associated silk glands.

Another important and probably ancient use of silk was the provision of either a protective envelope around the eggs, the egg sac, or a lining for a retreat in which eggs are to be laid. Without this protection, the eggs would soon be eaten, dried out or damaged in some way. In the silk-producing pseudoscorpions and mites, protection of the eggs is one of the main functions of silk. Any strategy which increases egg security is of obvious advantage.

It has been suggested that the evolution of the snare web may be traced to the behaviour of early spiders in relation to their egg sacs. Within this context, an outline is given of the various behavioural stages recognisable in spiders living today which could reflect an evolutionary sequence of web development. Initially, the egg sac may have been carried about by the spider as it pursued its vagrant hunting life (in much the same way as do the wolf spiders of today). Later, some spiders acquired the habit of depositing the egg sac in a crevice in the ground,



P. Dreyer after Robinson, 1974

under a rock or in a log, where some protection from predators, parasites and the elements was provided. Other spiders adopted an aerial life on foliage where the egg sac could be effectively protected by suspending it within a network of threads. If at this early time spiders remained guarding their egg sacs, their movements could tend to cause an accumulation of silk threads in the immediate vicinity. In the case of the crevice dweller, this would result first in the laying down of irregular radial threads on the ground in front of the crevice retreat as a result of the spider's comings and goings. In this way the simplest 'snare' is arrived at—a series of silk trip lines serving to warn the spider of the presence of prey at a distance from the retreat entrance. By the further addition of threads, the transformation of a trip line structure into a more uniform sheet-type of web can be easily envisaged. A sheet web can better fulfil prey catching functions since a prey animal wandering onto it will be greatly impeded by the silk meshes.

Meanwhile, our foliage-dwelling aerial spider has also expanded its network of threads by random spinning of silk lines as it moves about, so that a three-dimensional maze or space web is formed much like that built by a daddy-long-legs spider. Though irregular, such a structure can be quite effective in arresting jumping or flying insects until the spider can arrive and subdue them by throwing more silk over the prey. In the further development of the maze web, movement of the spider to and from a retreat area could result in a thickening of the silk laid down in one plane so that eventually an irregularly

P. Wolf



An elongated 'ladder' orb web.

A section of viscid silk from the catching spiral of an Araneid orb web weaving spider. (X200 Ultropak Objective.)

meshed sheet would appear in the maze web. Flying prey would then be knocked down by the upper maze threads onto the sheet under which the spider waits. In the aerial situation gravity causes the spider to hang underneath its silk thread and so also ensures that the spider moves about upon the lower surface of its suspended sheet, a basic difference by comparison with the ground-evolved sheet dweller which runs upright on the upper surface of its sheet web.

The sheet is one of the commonest types of spider web (the irregular, coarse silk sheets of the black house spiders with their funnel-like retreat openings on the walls and windows of houses and sheds is a familiar example) and it has been developed independently by many different groups of spiders. Possession of the same type of web is not necessarily indicative of a relationship between groups.

Both cribellate and non-cribellate spiders make the abovementioned types of webs. As noted earlier, cribellate catching silk was developed much earlier than viscid catching silk and may have been present in all early araneomorph groups. Viscid silk is found in only three very successful families, the Araneidae (orb web weavers), the Theridiidae (comb-footed spiders) and Linyphiidae ('money spiders'). Its original use was perhaps simply to immobilise prey already enmeshed in a non-sticky web. Theridiid spiders, for example, throw out a swathing film of viscid silk over struggling prey using a specially adapted comb of bristles found on the fourth leg. Many also use viscid silk in its more advanced role of direct prey snaring; sticky vertical trip lines, attached to the ground from a maze web above, entangle the prey and, because of its struggles, break from their ground attachments and contract upwards, so hoisting the prey off the ground and making its escape less likely.

The development of more complex snares, such as the orb web, has involved the ordering of viscid or cribellate threads into more efficient prey-catching configurations. Such snares probably evolved in response to the great expansion of flying insects during Cretaceous times. The

An Araneid orb web.



fine, planar structure of the orb web renders it almost invisible to such prey. Basically, it consists of a two-dimensional framework made up of the outer frame threads and the inner radial threads onto which a continuous spiral of silk is placed. In fact, two spirals are constructed. The temporary or scaffolding spiral is made of dry silk and is spun from the hub of the web outwards. Its functions are to hold the radial threads in place and to provide additional footholds while the permanent or catching spiral (of viscid or cribellate silk) is laid down from the periphery toward the hub; at the same time the scaffolding spiral is removed and later eaten. Spiders of the genus *Nephila*, the golden orb weavers, do not remove the scaffolding spiral and their web is considered to represent a less advanced stage of development. Also known are both cribellate and non-cribellate groups which lay down only a dry silk scaffold spiral; however, opinion is divided on whether such webs, notably of the non-cribellate forms such as *Cyrtophora*, really represent an early stage of orb web development or only a later specialisation in which the sticky spiral has been completely lost. The earlier stages of orb web derivation from a maze or sheet type precursor remain even more conjectural.

There is a tendency in discussions such as this to regard the araneid orb web as the culmination of the process of snare web evolution. However, this orb web, remarkable though it is, represents only one line of web evolution. Some very specialised orb webs (such as that of *Poecilopachys australiasiae*, the two-spined spider) may have been derived via quite different evolutionary pathways. Similarly, most of the other web types mentioned above have probably evolved a number of times in



M. Gregg

separate lineages, perhaps developing particular specialisations for specific prey-catching purposes. Specialisation of spider webs is a subject in itself but some examples involving the orb web will serve to illustrate that there always remains room for improvement in particular directions. Moth capture is one of these. The tiny scales covering the bodies of moths can be easily shed on contacting a spider's viscid thread so that escapes are relatively frequent. Some spiders have overcome this by the development of a grossly elongated orb web that is up to ten times longer than it is wide. A moth hitting the upper part of this web will gradually roll down its length as it struggles to free itself, shedding clumps of scales on successive strands of viscid silk. The moth usually runs out of scales before it runs out of web and so is successfully captured by the spider.

The moth-catching strategy recounted above has involved the elaboration of the araneid orb web. However, some spiders have gone to the opposite extreme with the objective of capturing the same prey. The Magnificent or Bolas spiders (*Dichrosticus* and *Ordgarius* spp) are descended from orb web building ancestors. Their webs consist of a single viscid thread, the sole remnant of the viscid spiral of a former orb web. This thread, with a large globule of viscid silk at its lower end (the bolas), hangs vertically below the spider, from its second leg. By exuding an airborne specific chemical attractant, the Magnificent Spider causes male moths of a restricted group of species to fly towards it under the mistaken impression that the attractive odour is coming from a female moth. The wing beats of the approaching moth warn the spider that prey is near. The spider then begins whirling its silk 'bolas' in a circular motion below

it. The deluded moth flies closer and closer until it is hit by the whirling silk globule. Stuck fast, it is hauled up and immobilised by the spider.

The cribellate orb web of the uloborid spiders has also undergone reduction to a single thread structure, though the catching mechanism used is quite different. The spiders concerned (the Miagrammopinae) lay down a single horizontal thread, attached at both ends, amongst forest foliage. The spider sits at one end of the line and draws it tight, holding the slack looped below its body. Many long-legged flies are adept at using the framework lines of spider webs to rest upon, and it is this behaviour which is exploited by the miagrammopine spiders. When a fly alights upon the latter's cribellate thread, the spider releases its hold upon the tense line so allowing the slack to whip along it and entangle the fly.

The obvious success of the spiders, as a result of their use of silk, exemplifies the way in which evolutionary processes can adapt a former function and its related structures (excretion and excretory glands) for an entirely different purpose (silk production). Most other arachnid groups have rather well defined and restricted patterns of morphology and behaviour, which seem to have changed little since such groups first appeared. The scorpions are a good example of this, modern species being little different, morphologically at least, from their Palaeozoic ancestors of more than four hundred million years ago. Such evolutionary conservatism is reflected in the low species numbers of such groups—only some seven hundred species of scorpions are known compared to more than thirty thousand species of spiders. Consequently, it does not seem an overstatement to suggest that among the arachnids, the evolution of spider silk has been an event comparable in importance to the evolution of flight in the insects, or warm-bloodedness in the vertebrates. In their different ways, all of these events have permitted the development of new ways of life

The modified cribellate sheet web of a blind cave dwelling spider.

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A Bolas spider with its sticky silk bolas which it uses to capture moths.



M. Gray

EXPLORING MACQUARIE

Macquarie Island, a small, isolated island in the Southern Ocean, lies about 1470 kilometres southeast of Tasmania, 650 kilometres southwest of the Auckland Islands, New Zealand, and 1450 kilometres north of the Antarctic continent (54° 30' S; 158° 57' E). Politically under the jurisdiction of Tasmania, it is a state reserve, and is usually referred to as a national park. The island is thirty-three kilometres long and up to five kilometres wide, with an area of 118 square kilometres. The highest peak is Mt. Hamilton, with an altitude of 433 metres.

Macquarie Island has three distinctive physical features: coastal terraces, slopes, and plateaus. The terraces, or raised beaches, which surround the island except for a few areas on the west and south coasts, range from ten metres wide up to a kilometre wide, especially on the northwest coast. Here may be found the intriguing featherbeds—'floating' bogs of vegetation that can trap the unwary traveller. The slopes rise steeply from terraces to plateau. Their height ranges between 180 and 300 metres and varies in steepness from 35° -80° with an average slope of 40° -45° . Plateaus are distinguished by large flats, glacially rounded ridges, hills, lakes, and tarns. Running streams are abundant and may be found even in the smallest drainage basins in peat soils. The northern tip of the island forms a 100-metre high small plateau that is separated from the main part of the island by a low, sandy isthmus, over which waves cross in severe storms.

Geologists believe that the island is composed of Miocene or Pliocene organic crust which was uplifted along the Macquarie Ridge since the Pliocene, probably during the Pleistocene, when a small piece of the extensive submarine ridge which stretches from New Zealand almost to the Antarctic continent, was lifted slightly above sea level. This created an island without the shallow submarine shelf which normally occurs around continental islands or oceanic islands on extensive submarine plateaus. Instead it was surrounded by seas more than 5000 metres deep only a few

PART 1: SOUTHERN WILDLIFE OUTPOST

BY DONALD HORNING

Macquarie Island was discovered on 11 July 1810 by Captain Hasselburg (later spelt Hasselborough) after whom Hasselborough Bay was named. While sailing from Sydney to Campbell Island, New Zealand on the brig *Perseverance* with provisions for the sealing gangs, he chanced upon the island, which was crowded with fur seals, and named it Macquarie Island, in honour of the then Governor of NSW. He set a sealing gang ashore with the Campbell Island provisions, and sailed back to Sydney to report his valuable find to his employers. Thus the stage was set for the vast exploitation of seals and

penguins on one of the world's most southern island wildlife outposts. Within a space of ten years, nearly two hundred thousand fur seals were killed for their valuable fur and in 1820, the famous Russian explorer Bellingshausen reported their extinction. The harvest was then shifted to the bountiful elephant seal and in 1826 and 1827 more than one million kilogrammes of oil were procured. By 1834, even this resource was so depleted that sealing continued only intermittently until the 1870s. Several New Zealand companies then rendered Elephant Seals and King and Royal Penguins until 1919, when the

The two-man hut at Sandy Bay is one of five huts located around the coast and is frequently used by field parties in the region.

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ISLAND

kilometres off shore. It lies in a north-south direction, so that the west coast is continually pounded by steady winds and the currents of the West Wind Drift. Numerous small bays and inlets are found on the exposed west coast, but the more sheltered east coast is mainly straight with sand or shingle beaches broken by stretches of rocky shores. The rocks are basically igneous and include gabbros, pegmatites, dolerites, and basalts.

Macquarie Island is situated about 240 kilometres north of the Antarctic convergence, which separates antarctic and subantarctic waters. It has a much milder climate than Heard Island, which is 320-480 kilometres south of the current, but 100 kilometres north of Macquarie Island. Because of the effect of the different temperatures, Heard is classified as an Antarctic island, with a mean temperature of about 0° C, and Macquarie a subantarctic island, with a mean temperature of 4° C. The climate at Macquarie is oceanic and remarkably uniform. The mean temperature ranges from 3.0° to 6.3° C. Rainfall is moderate and fairly even throughout the year, with a mean annual total of about 143 centimetres. Relative humidity is high, averaging about 90%. As fog is common, the sky is overcast most of the time and average daily hours of sunshine vary from less than half an hour in June to just over three hours in February. Prevailing westerly winds are generally strong, with a mean velocity of 22 to 37 kilometres per hour. The climate can be accurately described as wet, windy, cloudy, and cold. By way of illustration, the daily occurrence of these weather phenomena was recorded at the Australian National Antarctic Research Expeditions station, located on the northern isthmus, for a year beginning November 1976: Precipitation, 314 days; hail, 60 days; snow, 67 days (may fall anytime during the year, including Christmas); fog, 67 days, but, strangely, only 5 days of frost. There were 251 days of strong winds and 64 days of gales. These figures do not reflect the climate of the island as a whole, however, because temperatures for example, decrease by about 1° at each 100 metre increase in altitude, and on the plateau, at 235 metres, the mean wind velocity is 32% greater and precipitation is 16% greater than at the station.

last sealing license was issued. Thus ended more than a hundred years of commercial ventures that directly caused the extinction of the fur seal, depleted the stocks of elephant seals and penguins, and saw the introduction of pests and weeds to the fragile environment of Macquarie Island.

Scientific visits to the island began in 1883. Several famous expeditions have paid short visits to Macquarie Island, including the British *Southern Cross* Expedition of 1898-1900, Scott's British National Antarctic Expedition of 1901-1904, and the 1928-29 German Expedition. Between 1911 and 1913, five men led by Sir Douglas Mawson were stationed on the island during the 1911-1914 Australasian Antarctic Expedition (AAE). During



J. K. Lamb

1914-1915, parties of three men maintained a radio and meteorological station. The British Australian New Zealand Antarctic Research Expedition (BANZARE) 1929-1931, also led by Mawson, took an elephant seal census, established a magnetic station, compiled bird studies, and collected soils and marine invertebrates. Mawson later persuaded the Tasmanian government to declare the island a wildlife sanctuary. No further expeditions visited Macquarie Island until 1948, when the Australian National Antarctic Research Expeditions (ANARE) established a station there. Intensive biological research continues, conducted by the Australian Antarctic Division, other government agencies, universities, and museums.

The flora and fauna of Macquarie Island have unfortunately suffered from the introduction of domestic animals and pests. As early as 1820, Bellingshausen reported that cats, dogs, and sheep were thriving on the island. Goats, introduced in 1878, were eaten by sealers shortly afterward. Another herd of twenty, introduced in the late 1940s near the ANARE station, were eliminated in the early 1950s because of their damage to the slopes of Wireless Hill, where albatrosses and petrels were nesting. A flock of sheep, kept for food near the ANARE station since 1947 were finally killed in the 1960s. Cattle, chickens and ducks were also present during this period. Pigs were landed about 1880 but fortunately survived for only a short time. (On the Auckland Islands pigs, notorious as pests, were responsible for uprooting plants, causing soil erosion, disrupting the breeding of Wandering Albatrosses and preying upon rarer bird species, causing a dramatic decline in their populations.)

In January 1878, five donkeys were brought to Macquarie Island to pack seal blubber to the digesters, but because of the boggy peat, they were a failure. In July 1917, two horses were brought to the island. One drowned while being towed to the beach; the other was used to haul a sledge, containing seal blubber, to the digesters. Another horse must have been introduced before the seal and penguin rendering operations ceased in 1919; the captain of a Norwegian whaling ship reported seeing two large, fat, long-haired horses on the beach

in November 1923. These horses had survived on the island for four and a half years without the benefit of man.

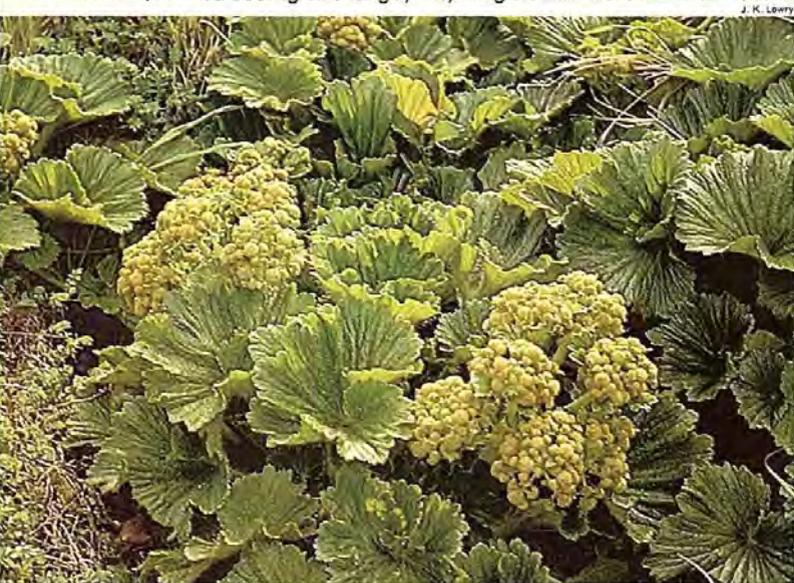
Wekas, or Maori hens—flightless rails—were introduced from Stewart Island, New Zealand in 1867 to provide an additional food source for the sealers. These birds primarily scavenge along the beaches, feeding on kelp fly larvae and elephant seal carcasses, probing for invertebrates and fish in the intertidal pools, and stealing eggs and young chicks of small petrels, and other birds. They also feed on seeds, especially the orange-red fruits of the creeping shrub, *Coprosma pumila*. Wekas were partly responsible for the demise of the native banded rails and the Macquarie Island Parakeet, both of which became extinct between 1880 and 1897.

Rats and mice are not particularly abundant at Macquarie Island although rats are known to eat birds and young chicks. They also feed on plant material and research is now being undertaken by the Australian Antarctic Division to determine their effect on the ecosystem of Macquarie Island. Mice are found mainly along the coastal terraces, where they feed principally on invertebrates, such as kelp fly larvae. There are about five hundred feral cats on the island and they have undoubtedly played an important role in reducing the population of smaller birds, such as petrels and prions. However, their principal diet now appears to be mice, rats, and young rabbits, and they may therefore, at present, have a more positive than negative effect upon the wildlife ecology of Macquarie Island.

French rabbits introduced from New Zealand to Macquarie Island in 1879 or 1880 are flourishing. They are found nearly everywhere and only the most wind-exposed areas of the plateau, where there is very little vegetation, have escaped their damage. Populations of these pests vary from relatively sparse to plague proportions and their densities may periodically shift from one area of the island to another. The tussock grassland and herbfield vegetation, especially *Stilbocarpa polaris* and *Pleurophyllum hookeri*, have suffered most from rabbits. Their tunnelling activities and feeding damage at the base of tussocks create erosion problems, especially on the steeper slopes. Continued heavy grazing can change grassland and herbfield to moss carpets or to bare ground which results in heavy soil erosion. The ground-nesting petrels that nest around the edges of the plateau may have suffered by the destruction of plant cover and by the burrowing activities of the rabbits. In an effort to reduce the rabbit population, rabbit fleas, an intermediate host for a myxoma virus, were deliberately introduced to Macquarie Island in the late 1960s. The fleas spread and now may be found on about 80% of the rabbits. It is hoped that if myxomatosis can be introduced to Macquarie Island, it will greatly reduce the rabbit population there, as it did in Australia. However, should the rabbits be exterminated, or their population levels significantly lowered, it is likely that the cats would once again threaten the petrels, which are beginning to re-establish themselves.

Macquarie Island is the most southerly island in the world to support a more or less continuous plant cover. It was covered by an ice sheet in the Pleistocene Age and most botanists believe that the present plants cannot be

The Macquarie cabbage, *Stilbocarpa polaris*, is commonly associated with the tussock, *Poa foliosa*, in grasslands on the coastal slopes.



pre-glacial survivors. How the plants arrived after the ice melted is an intriguing question. Unfortunately, there is no ready answer. Birds are capable of transporting seeds or spores in their feathers or in their crops. Some seeds at Macquarie Island are adapted to dispersal by wind. It is most unlikely (but remotely possible) that viable seeds arrived by rafting, in cracks of driftwood. Some of the species, particularly common chickweed *Stellaria media*, mouse-eared chickweed *Cerastium triviale*, and annual meadow grass *Poa annua*, may have been introduced by man. There are thirty-nine species of vascular plants and only three—all grasses—are endemic: *Deschampsia penicillata*, *Poa hamiltoni*, and *Puccinella macquariensis*. A new umbelliferan (member of the carrot family), *Hydrocotyle* sp., is as yet undescribed. Recently, a New Zealand orchid was found in featherbeds from several areas of the island. There are more than 150 species of hepatics, mosses, and lichens, but more will be discovered when current research of these cryptogams is completed.

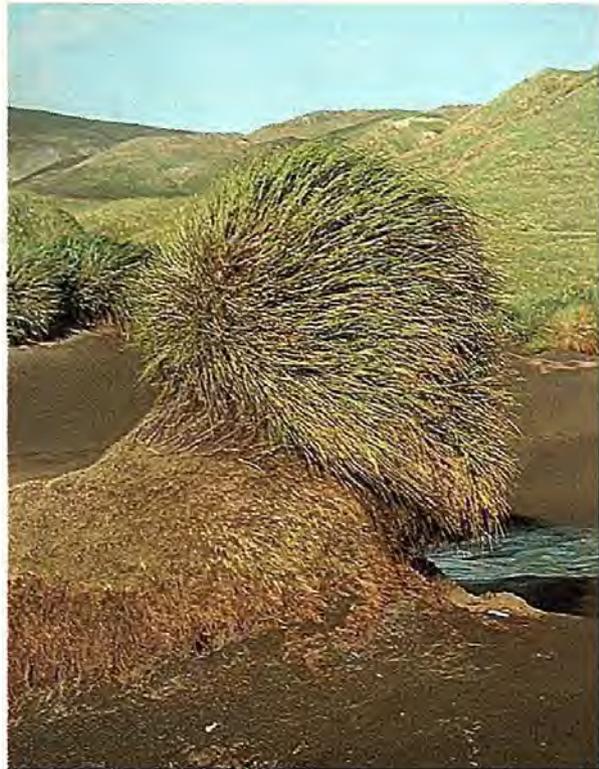
The vegetation of Macquarie Island consists of grasslands, herbfield, fen, bog, and feldmark. The grassland, or wet tussock formation, occurs on the coastal slopes and on most of the coastal terraces. It is characterised by stands of 'mutton-bird' tussock *Poa foliosa*. It may also be mixed with Macquarie Island cabbage *Stilbocarpa polaris*, ferns, or clumps of small vascular plants, mosses, and lichens, especially in areas subject to small soil slips. Grassland only occurs in areas devoid of heavy sea spray and high winds, and where the ground water is at least forty-five centimetres below the ground surface and the peat is at least ten to fifteen centimetres deep.

Sub-glacial herbfields are found on slopes and flats subject to moderate wind exposure, or areas with a high water table and not overly severe wind. They are dominated by the composite *Pleurophyllum hookeri* but other plants such as *Festuca erecta*, *Cerastium triviale*, *Stilbocarpa polaris*, and *Coprosma pumila* are associated with this formation. The distribution of *Pleurophyllum* is partly restricted by its inability to compete with *Poa foliosa* and by severe wind exposure, which prevents it from growing with the mat plant, *Azorella selago*.

Fens, or marshy tracts, occur on the raised beach terraces and valley floors of the plateau, where the water table is at or above the ground surface, and where the water is neutral or alkaline. The dominant plant is a rush, *Juncus scheuchzerioides*, and may be found in association with a grass, *Deschampsia penicillata* and a sedge, *Scirpus aucklandicus*.

Bogs occur on the west coast beach terraces and are scattered in herbfields, growing on wet flats. They exist only where the water table is above or at ground level, and where the soil is acid and low in soluble salts. Bogs are characterised by a carpet of mosses, sometimes intermixed with small vascular plants, *Colobanthus muscoides*, *Epilobium linnaeoides*, and *E. nerterioides*.

Feldmark, or tundra, occupies regions exposed to high wind velocities—which includes about half the island—and most of the plateau. The feldmark is not based on peat but is formed from a mixture of rock and glacial till, which ranges in texture from gravel to sand to clay. Two communities are found here and their distribution is based principally on wind exposure and, to a lesser



D. S. Henning

extent, on mean temperature. The mat plant *Azorella selago*, prefers the least wind-exposed areas but may be associated with the moss *Rhacomitrium crispulum* where wind speeds are higher. In very windy sites, where the mean temperature is lowest, a few mosses, especially *Ditrichum strictum* and *Dicranoweisia antarctica*, occur in dense buttons or small cushions. These may cover only one percent of the ground in places, and the cushions creep leeward as the shoots are killed back on the windward side.

Several groups of soil and freshwater invertebrate animals, other than spiders, mites, and insects, are present at Macquarie Island. The soil fauna includes both a wide range of species and large populations of nematodes, rotifers, and amoeboid, ciliate, and flagellate protozoans. Terrestrial invertebrates include a small endemic land snail, three species of slugs, earthworms, and tardigrades. More than fifteen species of tardigrades were newly recorded from Macquarie Island during the recent Australian Museum expedition. They were found amongst hepatics, mosses, lichens, and vascular plants. Freshwater oligochaetes, nematodes, copepods, ostracods, cladocerans, and isopods are common in freshwater ponds, lakes and streams.

There are about 120 species of terrestrial arthropods from Macquarie Island and nearly thirty percent may be endemic. Three species of spiders, three of ticks, and thirty-five of mites (representing nearly thirty families) are abundant in the soil, amongst plant litter, and associated with birds and their nests. Ten species of springtails are found in the soil and in litter. A new species of bark louse was discovered in 1960, living predominantly on the under-surface of *Stilbocarpa* leaves. A new species of thrips, also discovered in 1960, lives amongst the vegetation in grasslands and herbfields. One aphid, *Jacksonia papillata*, is common and was considered to be a grass

The tussock, *Poa foliosa*, is normally found on steep coastal slopes. On the wide exposed beach at Bauer Bay however, the grass has been left in isolated clumps of eroded peat.

feeder in other parts of the world until it was discovered feeding on a variety of herbaceous plants at Macquarie Island. The other aphid, *Rhopalosiphum padi*, a cosmopolitan grass feeder, was collected only once near the ANARE station.

Butterflies do not breed at Macquarie Island although a Red Admiral butterfly was seen in 1960. This lepidopteran is known as a vagrant to New Zealand subantarctic islands. Only one moth, the endemic pyralid *Eudoria mawsoni*, occurs here and larvae feed on mosses and the mat plants *Azorella selago* and *Colobanthus muscoides*. These moths appear to be well adapted to the Macquarie Island climate. Widespread around the island, they have been seen flying in mist and fog, and even walking across snow patches.

Of the twelve species of flies at Macquarie Island, six are endemic. Some have shortened wings and are incapable of flight, an adaptation commonly found on isolated wind-swept islands. There are no houseflies or

ously large family is well represented on other subantarctic islands, even those that have cooler climates and less vegetation.

Two species of wasps, both parasitic, have been discovered at Macquarie Island. Only one specimen of a scelionid, an insect egg parasite, has been seen. The nearly wingless diapiid *Antarctopria latigaster* is not common, but specimens have been found on the coastal terraces in some penguin rookeries, and in gullies up to one hundred metres in altitude. It is primarily a solitary parasite of kelp fly pupae, found on the beaches under rotting kelp and seal carcasses.

Macquarie Island provides resting beaches or breeding sites for a number of seals and sea lions. The Weddell and Crabeater Seals from the Antarctic are very rare visitors and the Kerguelen Fur Seal occurs occasionally. A few young males of Hooker's Sea Lions are seen each year on the beaches near the ANARE station. Leopard Seals, probably from the southern pack ice, are common



Small ponds on the plateau are good habitats for freshwater invertebrates such as oligochaetes, nematods, copepods and cladocerans.

blowflies, but coelopids, or kelp flies, can become a nuisance, with great swarms of them invading the ANARE station on calm, warm evenings. The larvae feed on rotting kelp, and the adults are very common along the coastal terraces.

This island has a paucity of beetles, compared with other subantarctic islands, that cannot be explained on the basis of latitude, present climate, distances from other land masses, or vegetation types. Only five species of staphylinids, or rove beetles, and one byrrhid, or pill beetle, have been discovered. The scavenging rove beetles are common, especially along the beaches, on the coastal terraces, under seal carcasses, under rotting kelp, in bird nests, and in plant litter. Although there is one record of the pill beetle found on moss, extensive searches failed to find more specimens in bryophyte and lichen mats—an excellent habitat for these beetles on other subantarctic islands. It is most surprising that at least a few species of weevils do not occur here. This tremend-

ously large family is well represented on other subantarctic islands, even those that have cooler climates and less vegetation. More than two hundred were flipper tagged in 1976-1977 and one sighting has already been made at Campbell Island. Future tag recoveries will yield valuable information on this seal, whose distribution is not well known. It is believed that Leopard Seals take a considerable number of Gentoo Penguins while at Macquarie Island.

The fur seal has had a disrupted history on Macquarie Island. The indigenous fur seals, exterminated by commercial interests by 1820 were possibly Kerguelen Fur Seals. For the next hundred years, any fur seal that strayed to the island was killed. The New Zealand Fur Seal has begun to colonise the island and the first pup known to be born on the island for more than 130 years was seen in 1965. These seals are found around the rocky coasts and colonies now occur on North Head, Handspike Point, and Hurd Point. Annual counts of adults and pups

show that the population is slowly increasing (there are now about a thousand animals), though very few pups are born there each year. Despite the sharp decline in Southern Elephant Seals at Macquarie Island during the sealing days, the population is recovering rapidly. About 110,000 Elephant Seals were estimated to live at Macquarie in the 1950s and their numbers are probably now nearing those before sealing began. These huge animals are a most noticeable aspect of the Macquarie Island fauna, thousands being seen near the ANARE station between September and December. Their preferred haulouts are the sandy beaches along the sheltered east coast, especially at the northern end of the island. Great rows of animals are often found lying on huge piles of rotting kelp on these beaches. September and October is the pupping season, and the pups are suckled for about a month before the females leave them. They live off their fat reserves for a month or so while they moult their dark, shaggy fur. Then they go to sea, returning as yearlings to moult again.

There are twenty-three species of birds that use Macquarie Island as a breeding ground. In addition, other species of birds arrive there from time to time as vagrants, blown from Australia or New Zealand. Four species of penguins breed on the island; and each has its particular nesting sites. Before penguins were boiled for their oil, there were two large King Penguin rookeries at Macquarie; however, the northern rookery at Hasselborough Bay was totally wiped out and has not been re-colonised. The large rookery at Lusitania Bay has survived and produces more than five thousand chicks per year. This penguin, a close relative of the Antarctic Emperor Penguin, does not build a nest, but carries a single egg or chick on its feet. They breed only every other year. The Gentoo Penguins nest in small colonies around the coast and are permanent residents. They build well-structured nests, mostly of tussock grasses, and lay two eggs. These penguins shift nest sites every few years and they have little effect on the vegetation. The Rockhopper Penguin, a small crested species, builds its nest of grass or small pebbles in sheltered cracks and crevices on the slopes along the coast. Sometimes they share rookeries with their cousins, the Royal Penguins. They, like the Royals, lay two eggs but almost invariably only one chick survives. By far the most abundant penguin at Macquarie is the Royal Penguin. One of the largest penguin rookeries in the world, with more than 500,000 birds, is found at Hurd Point. Many other colonies, some very large, exist on the island. Some are a considerable distance from the sea and may be found up to 170 metres altitude. This species, very closely related to the more widespread Macaroni Penguin, is endemic to Macquarie Island. Both Royals and Rockhoppers leave the island for six months of the year spending the winter months at sea. Millions of Royals ended up in the digestors, but fortunately they were harvested only at The Nuggets. Oil rich yearlings and adults that were returning to shore to moult were used. A gang of ten men, using several digestors, could process more than 2000 penguins a day, yielding about 2500 litres of oil. Apparently these operations had little effect on the penguin populations because they are very abundant today, even at The Nuggets.

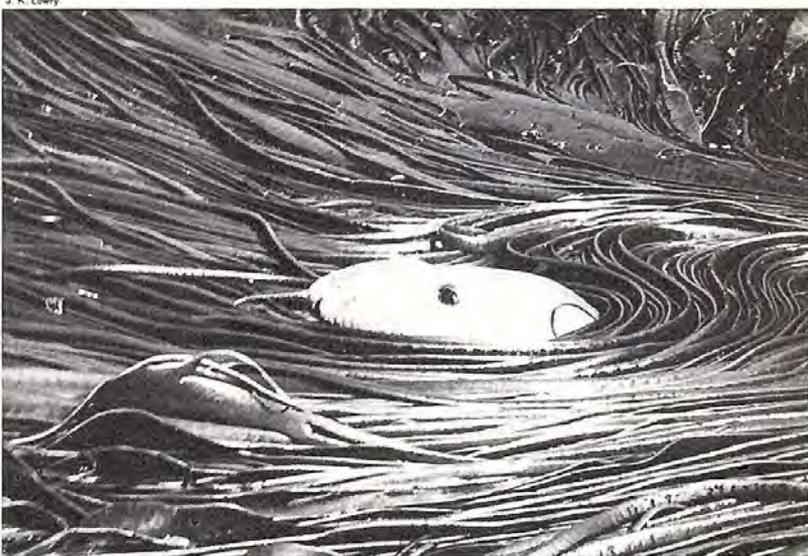


D. S. Horning

Of the four species of albatross that breed at Macquarie, only the Light-Mantled Sooty Albatross is common, breeding in small groups on precipitous hillsides. Their relative inaccessibility may have saved them from near extinction when sealers were using other albatrosses and petrels for food. Small numbers of Black-browed and Grey-headed Albatrosses are found on the remote, steep grassy southern slopes of Petrel Peak, situated on the southwest corner of the island. The Wandering Albatross, very nearly exterminated by the sealers, is certainly in a precarious state at Macquarie Island. These magnificent birds nest on open, level ground and both the birds and their eggs were highly prized. Today, less

A King Penguin chick ready to moult.

An Elephant Seal peers from a floating mass of Bull Kelp, *Purvillea antarctica*.



J. K. Lowry



than a dozen nests are founded each year and no chicks were raised to fledglings in the 1976-77 season. Indeed, its low numbers may preclude it from ever becoming a thriving breeding population again.

The six species of petrels have suffered because of man or his introduced animals. Giant Petrels were used as food and the smaller, ground nesting petrels such as the Blue Petrel *Halobeaena caerulea*, Sooty Shearwater *Puffinus griseus*, and White-headed Petrel *Pterodroma lessoni* were preyed upon by cats, or their nest burrows disturbed by rabbits. At one time, Giant Petrels were thought to be a variable species, partly because of the different white and dark colour forms. Ornithologists later believed that there were two subspecies and the white form lived predominantly in the colder, higher latitudes. Intensive studies of the two forms at Macquarie Island proved that they were distinct species—Northern and Southern Giant Petrels. In addition to other isolating mechanisms, the Northern Giant Petrel *Macronectes halli*, nests earlier in the year than does the Southern Giant Petrel *M. giganteus*.

Some studies have shown that birds reared at Macquarie Island have remarkable flight ranges. Some Giant Petrel chicks banded during one year were later recovered from as far away as Chile, Uruguay, South Africa,

PART 2: SUBANTARCTIC REFUGE

BY JIM LOWRY

Macquarie Island lies near the Antarctic Convergence—the water boundary of the Southern Ocean, where the cold antarctic surface waters meet the warmer northern waters and slowly sink. This great biological barrier marks the boundary of many of the animals that live on either side of it, and consequently shapes the nature of the antarctic marine fauna. As the Convergence moves to and fro past the island, water temperatures change from about 4°C to 7°C. The sea is rich in plants and animals and the island acts as a refuge for many of the seabirds and mammals which feed in the waters around it.

Before 1810 when man began exploiting the seals and penguins of Macquarie Island, a fur seal and an elephant

seal bred there in enormous numbers. Each species had populations in excess of 100,000 animals. The fur seal, which preferred the rocky coasts, was exterminated; but the elephant seal, which inhabited the sand and shingle beaches, still breeds there, as abundant as ever. Penguins are also there in great abundance. The Royal penguin has a population of 2.5 million birds and the King and Rockhopper penguins are also extremely numerous. The sheer numbers of so few species make one think of the early biological axiom 'towards the poles there are fewer species but greater numbers'. This concept centres around the idea that fewer species will be able to adapt to the harsher climatic conditions which prevail in higher latitudes, but those species will have

The exposed rocky shore of the west coast of Macquarie Island.

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Australia, New Zealand, Fiji, and Tahiti. Of the three Sooty Shearwater, or muttonbird, chicks banded here in 1961 by the noted ornithologist, Dr John Warham, one was later recovered at Avila Beach, California!

An endemic blue-eyed cormorant, closely related to other subantarctic species, nests in small colonies. They can be seen throughout the summer, flying with loads of grass and seaweeds to their nest sites on rocky shores. They lay two to four eggs and remain on the island after the breeding season. Black ducks are frequently seen on the coastal bogs, sometimes with ducklings. Southern Skuas spend six months on the island during their summer breeding season. They scavenge amongst elephant seal carcasses, and small petrels and young rabbits are included in their diet. Skuas, together with the perennial Southern Black-backed Gulls, provide a useful service to the ANARE station by feeding on the edible refuse. The Antarctic Tern, though no longer nesting on the island proper because of predation by cats, does nest on offshore sea stacks in small numbers. Three English or European birds breed on the island. All three species are self-introduced and probably arrived at Macquarie Island through the chain of New Zealand subantarctic islands. Only a few black-birds and their nests have been seen and they must be maintaining a precarious balance at

present. The starling is common and nests have been found in what appear to be most unlikely places—small rock crevices along the wind and sea spray exposed beaches. Redpolls are common, especially around the ANARE station and the valleys near Bauer and Sandy Bays.

Macquarie Island is one of the most remarkable wildlife sanctuaries in the Southern Hemisphere. It was exploited by man for over a century—from its discovery in 1810 until 1919, when seal and penguin rendering ceased. Introduction of alien animals, especially rabbits, and plants during this period has had adverse effects on the native flora and fauna. Fortunately, the island was made a sanctuary in 1933, and threatened populations are now gradually increasing. Sound conservation practices will retain this great natural heritage for many generations to come.

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A Grey-headed Albatross, stands among the tussock which cover Petrel Peak.

less competition and, therefore, be able to maintain large populations. There are certainly few species maintaining high populations on Macquarie Island itself, but is this also true in the shallow waters immediately surrounding it?

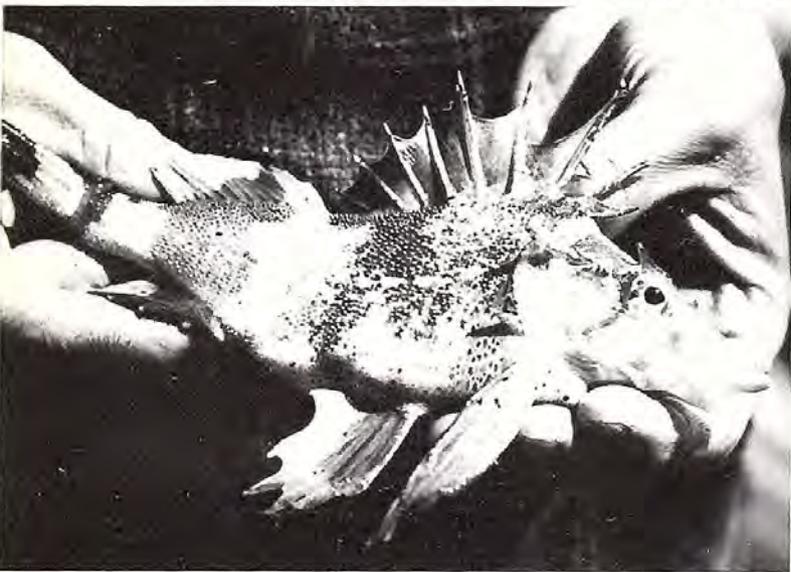
The intertidal at Macquarie Island is divided into several visibly distinct zones. High on the rocks and boulders the familiar red alga *Porphyra*, forms a wide band. Two gastropods *Kerguelenella lateralis* and *Laevilittorina caliginosa*, live here along with a large grey amphipod *Hyale hirtipalma*, and a giant isopod *Exosphaeroma gigas*. Further down the intertidal, a bare zone intergrades with a narrow band of red algae, mainly *Rhodymenia*. All of the above animals are found here together with a subantarctic limpet *Patinigera macquariensis*. The fringing Bull Kelp *Durvillea antarctica*, buffers the seas and forms a refuge for the chitons *Hemi-*



arthrum setulosum and *Plaxiphora aurata*. A small sea-cucumber *Pseudopsolus macquariensis*, is very abundant here. The holdfast of the kelp is burrowed by small isopods *Limnoria antarctica*, and this allows other animals such as amphipods and gastropods to become established. Below the Bull Kelp, a band of red algae forms a habitat for more amphipods and isopods, several molluscs and polychaetes.

The shallow subtidal bottom is usually coarse shingle grading into stones and boulders. Living under the stones is a small species of Plunder fish *Harpagifer bispinnis*, and in some areas the large isopod *E. gigas* and smaller amphipods in the genus *Paramoera*. Between the stones and boulders, concentrations of another gastropod *Cantharidus coruscans* are found. A sea anemone dwells in this habitat and several seastars are common. Some boulders are covered in a pink encrusting coralline alga and the large chiton *Plaxiphora aurata*, and limpet *Patinigera macquariensis* are often found here.

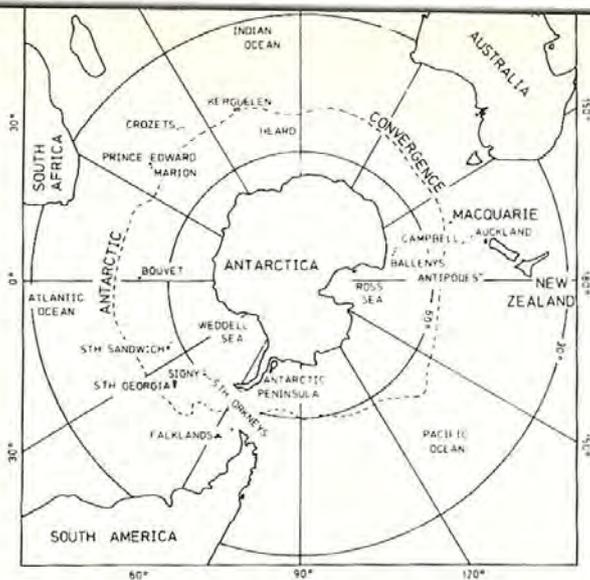
On other boulders the common brown alga *Desmarestia* forms a very dense overstory. Its tangled branches contain numerous small amphipods and isopods. Hover-



The Pigfish, *Zanclorhynchus spinifer*, is a common inhabitant of sandy bottoms below five metres apart.

ing just above the branches is the small brown antarctic cod *Notothenia magellanica*. A white hydroid *Orthopyxis platycarpa* and a red bivalve *Gaimardia trapesina coccinea* may also cling to its branches. In slightly deeper water, coarse sand bottoms occur. These submarine deserts harbour several species of polychaete worms and one species of amphipod. Small stones lying on the sand attract large numbers of a sand-dwelling amphipod and occasionally *Exosphaeroma gigas*. In some areas the Pigfish *Zanclorhynchus spinifer* is found in wave-generated sand troughs. Slightly deeper still, beds of the brown alga *Macrocystis pyrifera* grow on large boulders. *Cantharidus coruscans* lives on the *Macrocystis* fronds and several species of amphipods, isopods and polychaete worms live among the holdfasts. On the boulders, encrusting sponges, colonial tunicates, hydroids and bryozoans form a substrate for the same animals inhabiting the *Macrocystis* holdfasts.

In all of these habitats species which occur in other geographic areas are missing. In the intertidal, the familiar acorn barnacles which usually occur below the



band of *Porphyra* are absent. Mussels, which normally live above and below the *Durvillea* are also absent, as are rock oysters and the predatory gastropods which prey on them. Subtidally, one finds none of the familiar rocky shore fish families and only three species utilise the many habitats available. The Plunder fish *Harpagifer* lives under stones, antarctic cod *Notothenia* is demersal and lives among algae, and Pigfish *Zanclorhynchus* lives on sand bottoms. Amphipods and isopods may also be found under stones but brittle stars, crinoids and prawns are never found here. Because of the absence of soft mud bottoms, an array of animals including the burrowing sea urchins and sea-cucumbers, many families of benthic amphipods and isopods, many of the burrowing polychaete worms, and most of the infaunal molluscs are not found.

Why are so many of the animals familiar in other areas absent, and why are some groups poorly represented while others are abundant? To answer these questions it must be determined where the animals came from originally, how they have travelled and how they have adapted to living on such an isolated island. It is not hard to imagine how a large powerful swimmer such as the Elephant Seal could get to Macquarie Island, or how it could become established and thriving once it had gained a beach head. But it is more difficult to imagine smaller less mobile animals such as molluscs, polychaetes, and crustaceans or sessile sponges, tunicates and hydroids travelling to Macquarie Island as colonisers. The only continental land mass in a favourable latitude and current system is southern South America.

The southern tip of Tierra Del Fuego is about the same latitude as Macquarie Island and both areas are bathed by the circumpolar West Wind Drift. But Tierra Del Fuego is more than 13,000 kilometres from Macquarie Island. Large islands such as South Georgia or Kerguelen are favourably positioned but they lack the diversity of a continental fauna and they are also far away. New Zealand and the islands of the Campbell Plateau are much closer but they are to the east from Macquarie. Consequently wherever these animals came from originally they had a long journey. Most of the marine invertebrates from Macquarie Island so far discussed are poorly adapted for crossing large expanses of ocean by swimming or abyssal depths by crawling.

One possible way in which species may move such vast distances is by island-hopping on rafts of algae. The algae become detached from their original shoreline and drift with the associated fauna in the circular West Wind Drift current system. Occasionally one of these drifting rafts may be blown ashore on the subantarctic island where its refugees are given a chance to become established. Many groups of bottom-living animals are thought to move in this way. Another way in which species may be dispersed across oceanic expanses involves long-lived larval stages. Some species produce planktonic larvae which can live for three to twelve months as they float on the high seas, or they may suspend metamorphosis entirely until a suitable habitat is available. In this way the larvae could float in the West Wind Drift until reaching an island by chance and becoming established. Unfortunately, the first time the poor creature reproduced, its progeny would float away never to be seen again. For animals without larvae, crawling over the sea bottom or rafting near the surface seem most probable.

However, rafting is biased towards animals normally associated with algae or flotsam, animals which can survive long periods of drifting on the high seas and become established once a landing is made. Some hydroids, sponges, tunicates and barnacles among the sessile animals, and polychaetes, amphipods, isopods and crabs among the more errant animals seem well suited. Many of the animals missing from the Macquarie Island fauna are forms which normally have larval reproduction. The young stages in the life cycle are spent as tiny larvae floating with the currents. Some animals such as barnacles, lobsters, crabs and bivalve molluscs are heavily dependent on larval stages for reproduction and dispersal. For them the chance that their traditional reproductive strategies might adapt in accordance with the special conditions required to live on an isolated subantarctic island is very remote. Small blue mussels, which have larval reproduction, have been found growing at Campbell Island occasionally but their populations never persist, whereas they are known from the Auckland Islands where sheltered bays and slightly warmer temperatures make conditions more favourable.

One group of animals which does not reproduce by using larval stages is the peracarid crustaceans. These animals (amphipods, isopods and related groups) raise

their young in a brood pouch and release them as miniature adults. Because their complete life cycle is usually spent in one habitat they are not confronted with the problems facing animals with benthic adults and pelagic juveniles. In this way peracarid crustaceans might be considered to be pre-adapted for living on isolated oceanic islands, and they are one of the most successful marine groups, in terms of species, at Macquarie Island.

Other groups of animals which have successfully colonised the shallow water habitats around the island appear to have adopted similar reproductive habits. The young of the seastars develop in a compact cluster on the underside of the body of the adult. Most of the intertidal and shallow water molluscs studied so far brood their young in the mantle cavity and release them as miniature adults. Those that do not brood characteristically have short-lived larvae which are probably released into the water at an opportune time to keep them near shore.

Although polychaete reproductive habits have not yet been studied at Macquarie Island, studies in other areas indicate that they have the most diverse reproductive

The Seastar, *Anasterias directa*, broods its young on the underside of the body until they are released as young adults.



strategies of any of the marine invertebrates, allowing them to live in many varied environments.

Diversity is not high in the shallow waters around Macquarie Island. However, this is not due to the harshness of the environment but more to the physical shape of the island and the sea bottom surrounding it. Isolated geographically and surrounded by such deep seas, it is very hard to colonise. As there are no sheltered bays and inlets and no wide shallow shelf around it, maintaining populations once colonisation takes place is also very difficult. This involves specialised reproductive strategies which some groups of animals possess traditionally and which members of some other groups have developed, thus allowing them to maintain a foothold. In both cases these problems make living at Macquarie a precarious experience.

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The normally intertidal Bull Kelp, *Purvillia antarctica*, growing at ten metres depth near Gorilla Head Rock.



A MICROCOSM OF DIVERSITY

BY JOHN TERRELL

Bougainville, the largest of the Solomon Islands, lies eight hundred kilometres east of New Guinea in the southwestern Pacific. The riddle of Bougainville has puzzled scholars and visitors for years: *Why are the languages, the customs and the peoples of Bougainville so astonishingly varied?*

Since 1968, I have been studying the archaeology and anthropology of the peoples of Bougainville and other islands in the Solomons to discover how their ethnic diversity arose. My interest was not kindled by the idea that extreme human variation might be unique to these islands. Rather, it was the thought that Bougainville represents in microcosm the diversity of peoples, languages and cultures throughout the Pacific. If the riddle of Bougainville can be answered, we may thereby come to understand the reasons for the diversity of all Pacific Islanders. Additionally, according to modern ecology, very little is unique to islands, so that answers relevant to Bougainville may also help to explain human variation throughout the world.

Bougainville and adjacent Buka Island (which is separated from Bougainville only by a narrow channel) have a total land area of only 8987 square kilometres—about the size of Corsica, Crete or Puerto Rico. Yet on these two islands twenty different languages are spoken, comprising over fifty dialects, sub-languages and sub-language families. Twelve belong to the great Austronesian family of languages found throughout the Pacific, although these twelve are said to have features that set them apart as unusual members of that linguistic family. The remaining eight languages appear to be wholly

unrelated to these twelve. They form another family, the Bougainville non-Austronesian languages, which are related only remotely, if at all, to other non-Austronesian languages spoken in New Guinea and elsewhere in the Solomon archipelago. Indeed, four of the eight Bougainville non-Austronesian languages are also only vaguely related to the other four.

Remarkable ethnic diversity also appears in the biological characteristics of the local village peoples, and in their cultures. Visitors are usually struck by the superficial physical resemblances of all the islanders in the northern Solomons from Nihan (Nissan) some eighty kilometres north of Buka down to Choiseul, south of Bougainville. These islanders are all extremely dark-skinned, and for years foreigners used to speak of this region as the 'Black Spot of the Pacific'. Until recently, it was assumed that the peoples of the Black Spot must somehow be connected by common ancestry with Africans. But these impressions and speculations are deceptive. Modern biological research has disclosed that the peoples of the northern Solomons are no more closely related to Africans than are any of the other Pacific islanders. Moreover, the peoples of Bougainville are so genetically varied they must be ranked among the most heterogeneous peoples found anywhere in the world.

Similarly, village life and customs vary notably from place to place on Bougainville, sometimes clearly, sometimes subtly. For example, the famous anthropologist Douglas Oliver years ago identified no less than five separate culture areas on the island: three occupied by Austronesian speakers and two by non-Austronesian speakers.

Scientists and popular writers have usually explained the diversity of the Pacific Islanders by asserting that such marked ethnic complexity came about through a long, involved history of human migrations out of Asia, India or South America. While it is not known how long ago people first came to Bougainville, archaeologists and linguists now suspect that the island has been inhabited continuously for at least four or five thousand years.

In the past few years archaeologists, human biologists and other specialists studying the peoples of the Pacific have begun to see that historical reconstructions calling for migrations, invasions and long-distance diffusion are too simple. By now this long prehistory should have

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A group of young boys at Senakova Village, on the north coast of Bougainville Island.



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obliterated the differences that migrant peoples may have had from each other before they settled on Bougainville. It is now recognized that similarities and differences among peoples may also arise through adaptation to different living conditions, through isolation and through chance. Theories about human migrations, therefore, cannot explain the riddle of Bougainville.

Islands are not necessarily idyllic, carefree places. On the contrary, islands present a multitude of environments, some of which can be quite daunting. On Bougainville, geologists, soil scientists, botanists and other specialists have distinguished forty different land types that in some instances differ quite radically from each other in drainage, ruggedness, jungle vegetation and other ecological characteristics. Almost half the landscape of Bougainville and Buka is made up of hills or steep mountains. Much of the coasts of both islands is poorly-drained ground or actual swamp. It is far from astonishing that most of the islanders live either beside the coral-sand beaches of Buka and northern Bougainville where the land is flat, fairly well-drained and easily accessible from the sea; or on the gently-sloping plain that lies inland behind the swampy coast at the southern end of Bougainville.

These ecological contrasts alone, however, cannot account for the diversity of peoples on Bougainville. Subsistence practices, for example, do vary somewhat according to the local environment, but variation in language, biology and custom is far in excess of what we might expect if differences among village communities were only responses to differing ecological circumstances.

People in this part of the world have been able to lead strikingly settled lives. A physical anthropologist from Harvard University, Jonathan Friedlaender, discovered as late as 1966-1967 that eighty-six percent of the people he worked with on Bougainville resided in the village where they had been born, and ninety-five percent of the people in his studies lived within ten kilometres of their birth-place. Community life on Bougainville, then, used to be very isolated, and this isolation is clearly reflected in the pattern of language diversity and localization. A language or dialect is rarely spoken for more than thirty-two kilometres in any direction. Village communication over greater distances is uncommon, and the major focus of social, economic and political life is centered around each individual hamlet or village.

The degree of isolation between villages on Bougainville varies considerably from place to place. Since the most favoured land for settlement in the north is directly beside the sea, new ideas, products and other develop-

ments can be shared readily throughout the area. The situation on the southern plain is quite the opposite. Villages there are isolated from the coast by wide swamplands at the seashore. They can also be isolated from each other because of the hardships of travel by foot across the many streams and rivers that flow down from the central mountains and etch their way across the plain to the sea.

Some similarities and differences may be due to so many underlying factors that it is impossible to say that there is a single cause. A realistic example of the effects of chance might be the presence or absence of the art of pottery-making on the Solomon Islands. This depends upon multiple circumstances such as where and how long ago the craft was invented or introduced, the number of people who decided to become potters at that time, the mobility of these craftsmen or their apprentices, and their success in passing on their skill to younger generations of islanders.

Time is also important in the development of similarities and differences among peoples. Despite the popular belief that time has a controlling influence of its own over the course of history, time is involved in human diversity only because, as the old adage explains, 'Things take time'. Before the development of modern scientific methods of determining the age of archaeological specimens, it was very difficult to judge with any accuracy how old something was. As a result, scholarly histories of the Pacific islanders written before the 1960s all had little time-depth to them. Many people are still startled to learn that people were living in New Guinea

A group of villagers on Teop Island off the north coast of Bougainville, engaged in the construction of a canoe.



J. Terrell

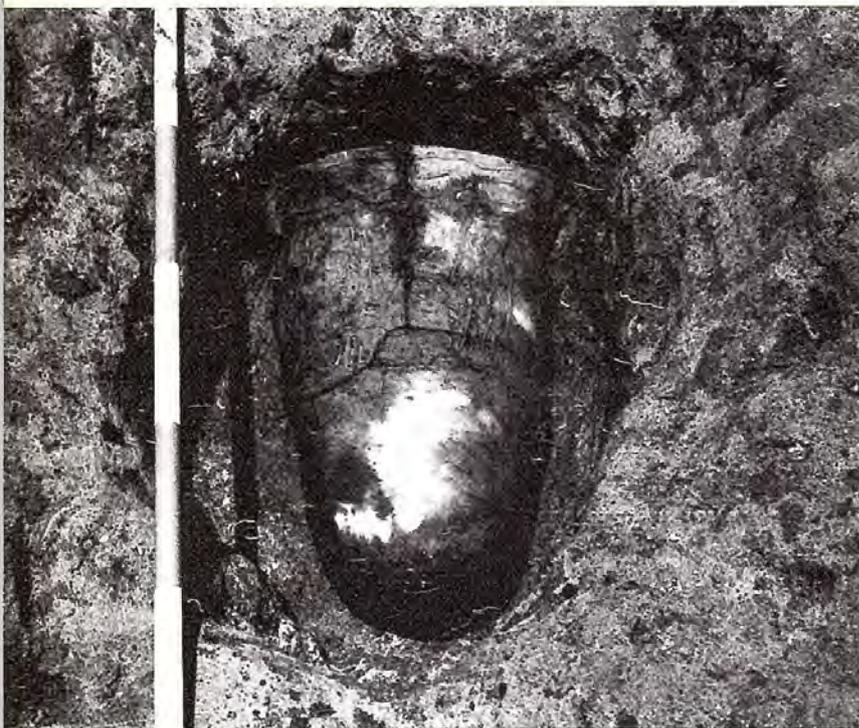
and Australia more than thirty to forty thousand years ago when the world was gripped by the last great Ice Age. We now know that people first entered the Pacific world sufficiently long ago for most of the similarities and differences among the islanders to have developed locally rather than in Asia, India or South America prior to migration to the Pacific.

Many archaeologists study the past in order to re-construct what happened in prehistory from the fragments that survive today. The past is frequently treated as a jigsaw puzzle to be pieced together with skill, diligence and a lot of patience. Much, however, has been irretrievably lost, and it is unlikely we will be really successful in constructing a totally coherent view from the potsherds, fragments of bone and bits of stone that remain buried in the ground. The jigsaw puzzle approach, then, is not very promising. Rather more useful is the view of prehistory as a laboratory in which to test our ideas and theories

Moreover, the old potsherds dug up which are the archaeological evidence for this new interpretation of the history of Bougainville pottery-making resemble potsherds found on Choiseul Island and in the Shortlands. These pottery resemblances indicate, I believe, that people have been migrating back and forth among these islands for hundreds of years. While scholars once wrote as if the *Torau* migration were a remarkable event, we can now see that little migrations or village movements between these islands may have been rather ordinary happenings during the prehistory of the northern Solomons.

But does archaeological evidence have anything to tell us about some of the truly striking differences among the peoples of Bougainville—differences such as those between the Austronesian and non-Austronesian languages on the island? Modern biological research has failed to substantiate one of the oldest theories about the

Left: A prehistoric burial urn still in the ground, found at Loiai. Right: The Loiai burial urn, after laboratory reconstruction, has been estimated by Carbon Fourteen Dating to be between six hundred and one thousand years old.



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about how things became the way they are today. An example from Bougainville shows how potsherds, bones and stones can be used to test theories about the origins and development of human diversity on the island.

Nearly all the people who live in southern Bougainville speak one of the indigenous non-Austronesian languages. There are a few villages on the coast, however, where people speak an Austronesian language locally called *Torau* or *Rorovana*. Scholars once believed that the *Torau* villagers migrated to southeastern Bougainville from the more southerly Shortland Islands sometime in the 1860s. Prevailing opinion also held that the *Torau* introduced pottery-making into southern Bougainville about the same time. Archaeological excavations on the east coast of Bougainville and on the southern plain have shown us that pottery-making is actually a very old craft throughout southern Bougainville, dating back perhaps some one thousand to one thousand five hundred years.

peoples of New Guinea and the other neighbouring Melanesian islands in the southwestern Pacific: that people who speak Austronesian languages do belong to a different race from people who speak non-Austronesian languages. This discovery is highly important, because it means we no longer have to explain the distribution of Austronesian and non-Austronesian languages in racial terms. Then why do some people on Bougainville speak Austronesian languages, while others speak non-Austronesian?

At present one can only guess at what the full answer might be, although archaeological information suggests that our guess may have real merit. Roughly ninety percent of the people who speak Austronesian languages live on Buka and in northern Bougainville. The rest live scattered in small villages along the coast of Bougainville, which is backed quite often by swamps and rugged terrain.



SOLOMON ISLANDS

It is probable that this contrast in population numbers and in geographic location has played an important part in the language prehistory of Bougainville and Buka. On the one hand, because of the limited amount of habitable land on Bougainville's southern shores it seems reasonable to think that villagers speaking Austronesian languages were never able to get much of a footing in the southern regions of Bougainville without moving into the mountains or up onto the southern plain. In both cases, they would have been isolated from the coast and from peoples on other islands. If their new neighbours in the interior spoke one of the non-Austronesian languages, it is likely that over the generations Austronesian-speaking settlers would have lost their former language and ethnic identity to become increasingly non-Austronesian.

On the other hand, the situation on Buka and in northern Bougainville has probably been quite different. The comparative ease of travel in the favoured coastal environment has surely made it possible for people to stay in touch with other communities even on the frontiers of human settlement.

It may never be precisely known how Austronesian languages got a footing on Bougainville. They have possibly been there from the beginning of human settlement. All of the seven Austronesian languages of Buka and northern Bougainville are directly related to each other historically. They all appear to have differentiated from each other on Buka and Bougainville. Therefore, I suspect that the differences between the Austronesian and non-Austronesian languages are differences that have unfolded locally over time, largely because of different degrees of isolation between village peoples in different parts of Bougainville. I would venture that all the languages of these islands are historically related to each other, but in some instances there have developed such radical differences that we can no longer see the inter-connections.

There is archaeological support for at least some of these speculations. Survey and excavation in the Buka area by R.J. Lampert and J.R. Specht from The Australian Museum and by my colleagues and I on Bougainville, have shown that villages on Buka and in northern

Bougainville have been trading with each other for at least two thousand years. Evidence from mortuary structures, stone monuments and old village sites on the southern plain of Bougainville indicates that old customs on the plain may owe their origins to ancient Austronesian-speaking communities in the Shortland Islands and on Choiseul some six hundred to nine hundred years ago. But true to our theory about the isolation of the southern villagers, these customs were gradually re-interpreted and changed over the generations until their character became distinctively local. Thus customs which began as Austronesian ultimately became non-Austronesian.

It is too early to say whether the riddle of human diversity on Bougainville and in the rest of the Pacific has finally been solved. But recent work in archaeology, human biology, linguistics and social anthropology on Bougainville is contributing a great deal to the long-sought explanation. It can be said with some conviction that the many similarities and differences among the village peoples of Bougainville unfolded locally over the course of thousands of years, due in part to differences in human ecology, to different kinds and degrees of village isolation, and to different accidental circumstances. The story of Bougainville, like the story of the Pacific islanders in general, need no longer be told as a tale of foreign invasions and migrations. It is a much more interesting story than that.

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Excavation of a prehistoric burial structure at Lolai on the southern plain of Bougainville.



IN REVIEW

SPECTACULAR SHELLS AND OTHER

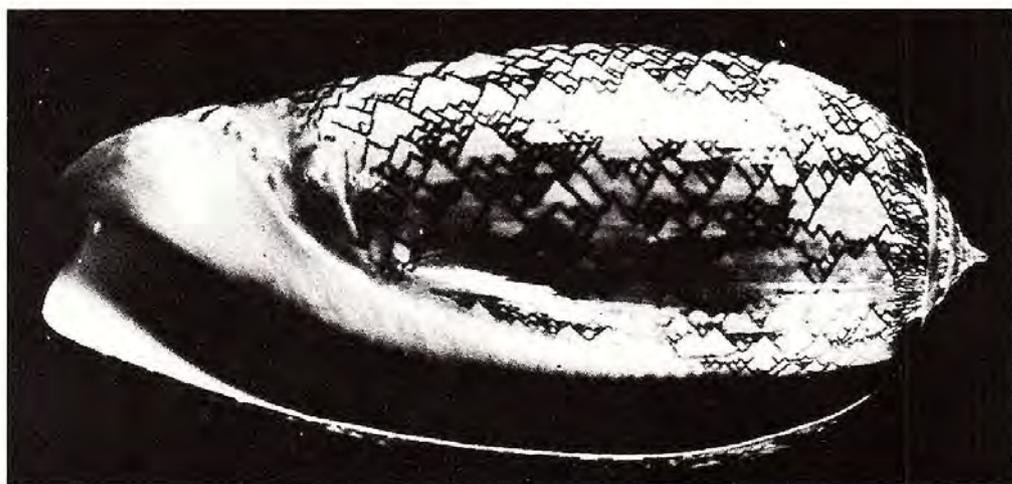
THE COLLECTOR'S ENCYCLOPEDIA OF SHELLS, edited by S. Peter Dance with photographs by Ian Cameron, *Australia and New Zealand Book Company, Sydney, 1976; (first published Blandford Press, London, 1974), 288 pages, illustrated, \$17.95.*

SEASHELLS OF THE WORLD, by Gard Lindner, translated by Gwynne Vevers, *Australia and New Zealand Book Company, Sydney and Blandford Press, England, 1977, 271 pages, illustrated, \$9.95.*

These two books have attempted to achieve the same end—a pictorial guide to world-wide shells. Both have a brief general introduction covering the classification, zoogeography and the biology of molluscs. The

Encyclopedia then presents a pictorial key to major groups down to family level followed by the treatment of individual species. These are arranged in families and are in a conventional systematic order. Excellent colour photographs are inserted in the text but not all species described are illustrated. There is a comprehensive index and a very short bibliography. The dust cover boasts that this is the "most useful overall work of reference that has ever been made available to the shell collector". While I doubt this claim the book would certainly be useful to the beginner.

Lindner's book is smaller in size than the *Encyclopedia* but has almost the same number of shells illustrated (1257 compared with about 1500 in the *Encyclopedia*) but 185 of the shells are photographed in black and white.



Far Left: *Terebra triseriata*. From *Seashells of the World*.

Top: *Ocenebra (Ocenebra) erinacea*. From *Seashells of the World*.

Bottom: *Oliva porphyria*. From *Seashells of the World*.

CREATURES

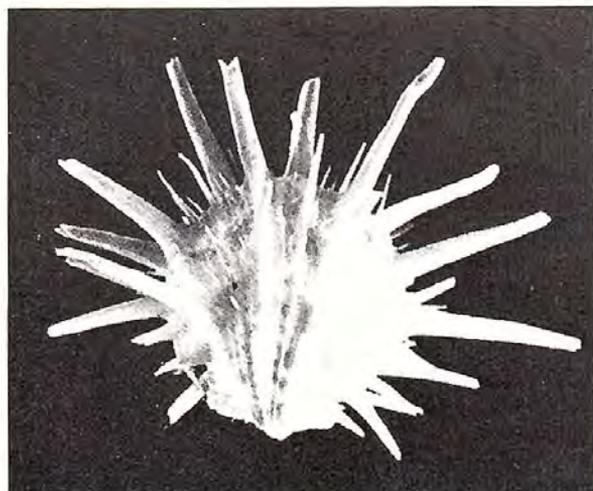
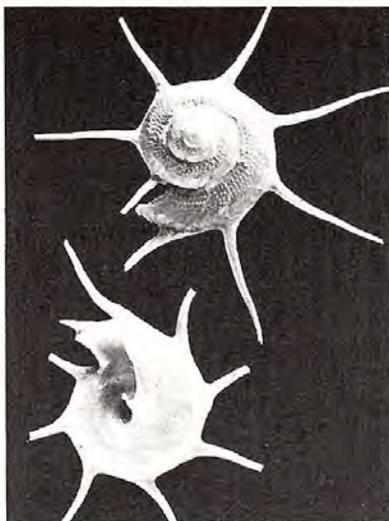
In this book the text is more comprehensive, giving a good introduction to higher taxonomic groupings (subfamily and above) in the main body of the text in which the main characters of each group are outlined and a list of the main genera is given. This part of the text is accompanied by black and white photographs and the later half of the book contains sixty-four excellent colour plates. The text for each plate is conveniently placed on the left hand page and is quite comprehensive. There is an index to families and genera but not to species. The bibliography is short but more comprehensive than that in the *Encyclopedia*.

Both books illustrate a few members of the 'minor classes' (Scaphopoda, Polyplacophora, Cephalopoda) and give a reasonable coverage of the Bivalvia, an impor-

tant class often sadly neglected in books on shells. There is the usual emphasis on groups such as the cowries, cones and volutes in both books. There are the usual errors and misidentifications but on the whole both books maintain a good standard of accuracy.

Both of these books would be useful additions to the shelves of the average shell collector. Lindner's book contains fewer species but has a greater amount of general information and consequently, may appeal to the person with a general interest in natural history. The greater amount of detail (such as dates of description being given for each species) in Lindner's book would also make it more useful to the advanced shell collector than the *Encyclopedia*.—Winston Ponder, Curator of Molluscs, The Australian Museum.

Top: *Guildfordia yoka*. From *The Collector's Encyclopedia of Shells*.
Bottom: *Glossidae*. From *The Collector's Encyclopedia of Shells*. Far Right: *Epitoniidae*. From *The Collector's Encyclopedia of Shells*.



This small handbook (approximately 21cm x 13.5cm) introduces the amateur to basic insect morphology, classification and biology. The first section on general structure is perhaps a little too concise and a number of terms which occur, with no explanation, later in the text could well have been explained in this section. The main part of the book consists of a key to the orders of adult insects. This is very well illustrated, both with line drawings and colour photographs of typical examples of each order and is quite adequate for most insects. However, atypical examples of several orders are difficult to key out without certain prior knowledge. For example, bugs of the Family Scutelleridae would be difficult to key out correctly without knowing that the hard covering over the body was the greatly developed Scutellum with the wings folded beneath. Instructions as to the use of the key are given on pages eight and nine. Step five of these instructions could prove confusing to the inexperienced student as the arrows mentioned do not appear, except for one on page thirty-five and in this case the direction of the arrow is the reverse of that mentioned in step five. The remainder of the book is devoted to very brief but useful discussions on types of life cycles demonstrated by insects, internal anatomy, habits and instruction in collection and preservation of insects. The bibliography given would be useful to anyone wishing to study the subject matter in greater depth.

This book fills a gap in entomological literature by providing an inexpensive, convenient and simply written, illustrated key to the orders of insects and should be readily understood by young students of biology while remaining a worthwhile book for adult amateurs. Thus as a teaching tool it should be quite valuable.

The text is well set out with clear printing of a good size for easy use in the field. The author has achieved to a high degree the purpose for which the book was written. —M.A. Schneider, *Department of Entomology, The Australian Museum.*

A FIELD GUIDE TO AUSTRALIAN FROGS, by John Barker and Gordon Grigg, *Rigby Limited, Adelaide, 1978, 229 pages, illustrated, \$19.95.*

John Barker and Gordon Grigg are to be congratulated on a splendid field guide to a fascinating group of animals—a group with which Australia is richly endowed.

The publishers on the other hand must be taken to task for the grossly inflated price of this modest volume. One can only assume that the publishers, having determined

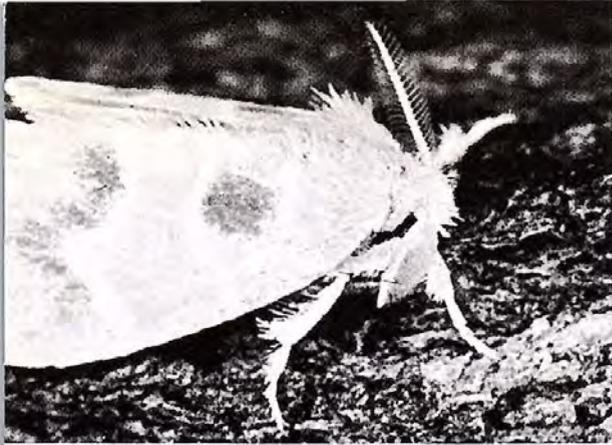
the size of their *captive* audience have decided to reap their profit from that audience alone. Although this may be good business it raises serious questions of publishing ethics. Certainly, by retailing this relatively slim volume at \$19.95 the publishers will have effectively priced the book out of reach of a substantial proportion of its potential audience, especially impecunious youngsters and students.

But to the field guide itself. Following a brief introduction the book is divided into four sections: nine pages on 'evolution, taxonomy and zoogeography', seventeen pages on the 'biology of frogs', and then the guts of the field guide—169 pages in which the species of frogs recognised by the authors as occurring in Australia are described. This section contains keys to the families, genera and species, 137 fine colour photographs of 123 species (and one sub-species!) and individual species accounts, each of which includes a small distribution map. The species accounts include notes on recognition characters, habitat, mating call, breeding and larvae, and similar species.

The book is generally free of typographical and other errors, but some examples will indicate that although errors and deficiencies occur, they are mostly of a trivial kind. Plate 12 is printed upside down, while the plates on pages 69 and 77 have been transposed. Plate numbers end at 22, and although plates of particular species are never more than a couple of pages away from the relevant descriptions, the plates are not included in the index. One particularly frustrating feature for this reviewer was the inconsistent approach to general; some receive lengthy and useful introductions (e.g. *Litoria heleioporus*) and their authors are identified, whereas others (e.g. *Adelotus*, *Myobatrachus* and *Cophixalus*) do not rate separate mention, and their authors are therefore not identified. The occasional distribution map is in serious error (e.g. that of *Cyclonana alboguttatus*). The distribution of *Litoria latopalmata* as given in the key (Page 60) is not consistent with that shown in its map (Page 65). For the nomenclaturist, the dropping of all 'ii' endings for specific names to 'i' is both annoying and unwarranted. The use of brackets to enclose the name of an author whose species is now placed in a genus different from the one in which it was originally described is a sensible convention, but has been inconsistently applied (e.g. *Limnodynastes terraereginae* Fry, *L. interioris* Fry and *L. dumerillii* Peters).

The keys are generally excellent, and as they are designed to be used in the field for living specimens they place great emphasis on living colours; this may cause frustration to the student or specialist who wishes to use this book in the laboratory, but it will be a boon to those who wish to use the book as it was intended—as a field guide. I suspect that the definitions of families on Pages 40-41 will prove ambiguous to the novice.

In conclusion, *A Field Guide to Australian Frogs* is an excellent book and a mandatory acquisition for anyone with a serious interest in the Australian fauna. It is also an attractive book which goes well beyond its intended role as a field guide. The pity is that its high price will keep it out of the hands of many people who would derive both pleasure and benefit from it. — H.G. Cogger, *Department of Herpetology, The Australian Museum.*



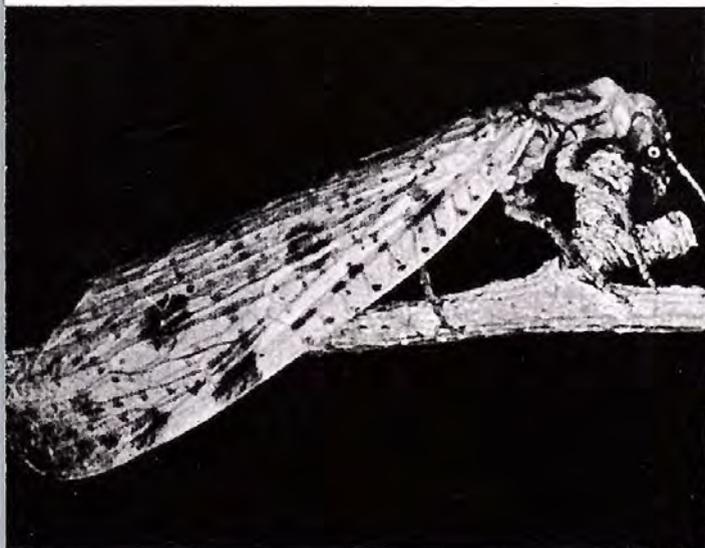
Above: *Lepidoptera*—
Moths and Butterflies.

Below: *Megaloptera*—
Alderflies.



Above: *Nocymystes
tympaenocryptis*; The Crater,
northern Queensland.

Below: *Limnodynastes
salmini*; Keepit Dam, NSW.



Below Right: Male *Litoria
chloris*; Ourimbah, NSW.

Below: *Coleoptera*—Beetles.

