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● **FRONT COVER:** The Brush-tailed Possum (*Trichosurus vulpecula*) is a common marsupial which is widely distributed throughout most of Australia. Several forms have been described and some of these have been given full specific rank. They show an interesting cline in their distribution, since the more southerly forms are larger and darker than are those from northern areas. In spite of intense urban development, the Brush-tailed Possum has remained abundant in the vicinity of large cities, due to its ability to adapt itself readily to its changed environment. Normally, it nests in the hollow limbs of large gum trees, but in cities frequently lives in the roofs of older houses. This pattern of behaviour ensures adequate refuges despite the clearance of trees caused by suburban house-building. **BACK COVER:** This strikingly marked jelly-fish, of the genus *Chrysaora*, turned up in Sydney Harbour and the mouth of the nearby Hawkesbury River in the early summer of 1968. Its appearance was something of a rarity, as the Australian Museum has no previous local records of it. It inflicts stings and is luminescent, like the related species, *Pelagia noctiluca*, a frequent visitor in these latitudes. Its colouring is striking, being transparent in the light areas and dark blood-red wherever there are spots. The specimen in the photo is juvenile; as the jelly-fish grow the dark markings become larger and intenser, so that the adult has a series of dark double ribs running from the centre of the umbrella towards the margin, with a single rib in between. The specimen photographed was taken at Manly, Sydney. [Photos: C. V. Turner.]



Bathurst Channel, Port Davey, with Mt Berry in the background. Open sedgeland dominated by Button Grass (*Mesomelaena sphaerocephala*) covers most of the area. The rockiness of the quartzitic Mt Berry is typical of the mountain ranges of the Southwest. [Photo: J. Thwaites.]

CONSERVING THE SOUTHWEST TASMANIAN WILDERNESS

By J. G. MOSLEY

Department of Geography, School of General Studies, Australian National University, Canberra, and Assistant Director, Australian Conservation Foundation

WHEN I was a small boy avidly reading travel books on the other side of the world one of the distant areas which most fired my imagination and gave me an interest in geography and natural history was the southwestern corner of Tasmania. The books described it as one of the world's last unexplored wildernesses, and took pains to explain the difficulties of travel through the treacherous horizontal scrub.

When in 1961 I was able to realize a boyhood wish and make an extended walking trip through the area some of the images of my youth were quickly shattered. To begin with, I found that much of the Southwest

consists of extensive and easily penetrated Button Grass plains. At the same time, it was easy to see how the Southwest had gained a reputation for inaccessibility. To reach the open plains the early travellers had to pass through a mountainous and densely timbered country, and most of the tales of travel hardship relate to journeys through this belt.

The second notion that I had to jettison was that parts of the Southwest are still unexplored, although I found that official reports still referred to the areas as "virtually unexplored". Cutting tracks where necessary, and following Button Grass leads



wherever possible, first the piners, then the Government surveyors, and finally the prospectors, had between them poked their noses into every substantial part of the Southwest before the end of the nineteenth century. The bushwalker explorers of this century scrambled up the last few virgin summits, and probably all that remains untrodden today are a few heavily vegetated side valleys.

In spite of these misconceptions, one of the main impressions I had formed about the Southwest proved to be correct. In 1961 the area was still unmistakably a wilderness. The Southwest had changed little since the days of the first white visitors. The only productive use of its natural resources had been the cutting of Huon Pine and small-scale mining. In over 2 million acres south of the Lyell Highway there lived only two families (both at Port Davey).

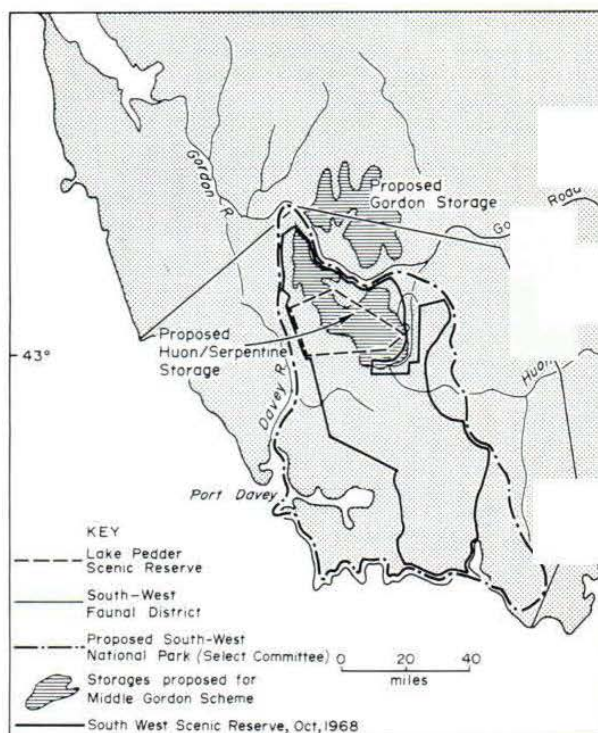
Although the productive use of the Southwest is infinitesimal, it is far from unused. Each summer visitors come from every part of Australia to enjoy the beauty and interest of the natural scenery and the challenge of wilderness-living on 1-week to 2-week pack-carrying and camping trips.

By the 1960's an unspoilt natural area the size of the Southwest was a rarity anywhere in the world, especially so close to industrialized western communities. Elsewhere in Australia there was no undeveloped area of comparable size outside the arid interior. In the eastern highlands of the mainland the larger blocks of wilderness had been whittled down, mainly through the extension of grazing, forestry, and water catchment activities, and, since the Second World War, through the spread of the protective fire road systems.

Early attempts at utilization

That the Southwest wilderness survived until the 1960's does not surprise those who are familiar with the region's forbidding appearance and climate. The area stands square in the track of the moist westerly airflow of the forties, and much of it has a mean annual rainfall of over 80 inches. Soils are skeletal or non-existent on the quartzite ranges, whilst podsol peats cover the plains.

Scattered stands of the valuable Huon Pine attracted small-scale settlement during



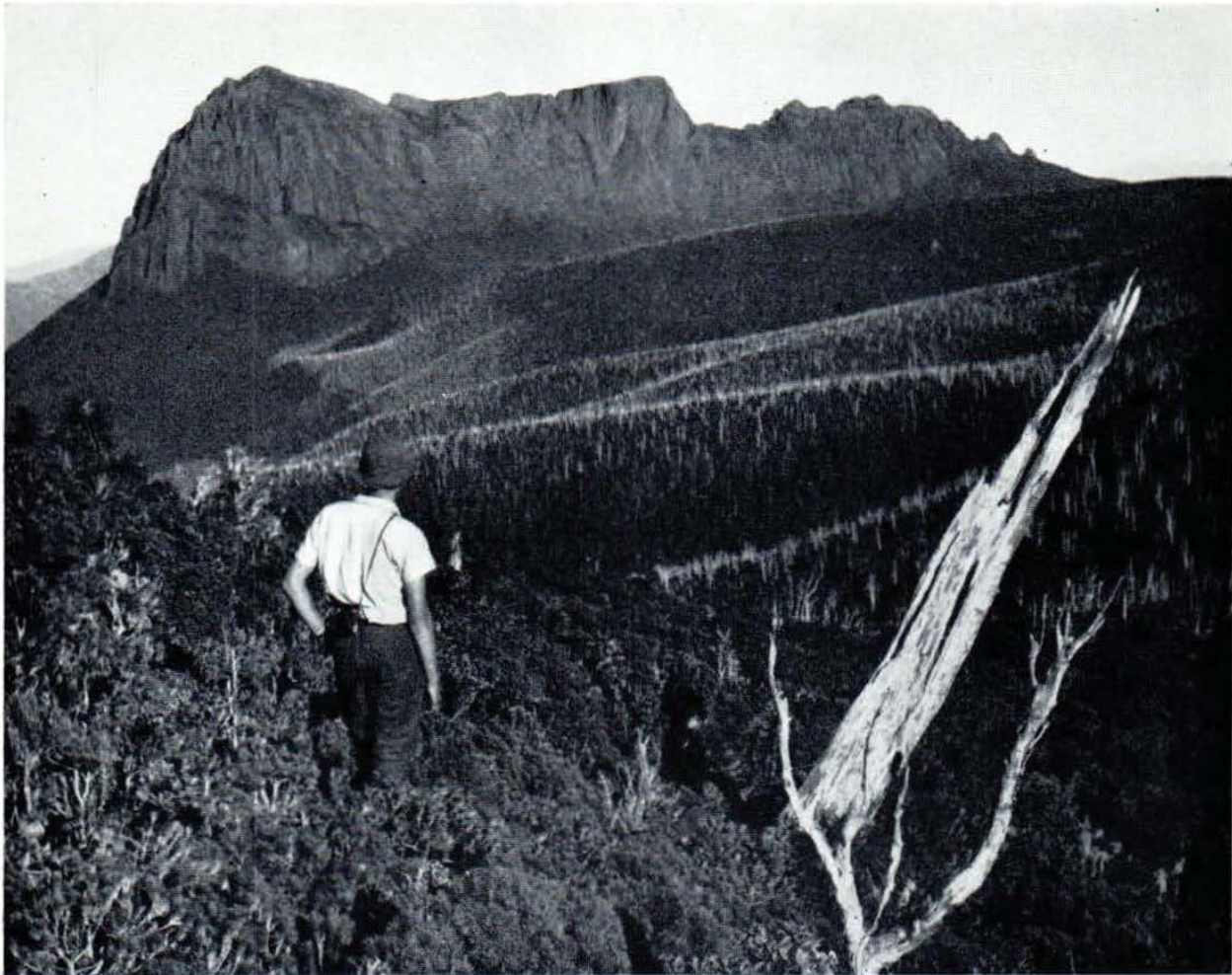
Southwest Tasmania, showing the national park recommended by a Select Committee of the Tasmanian Legislative Council and the park proclaimed in October, 1968. [Map by the author.]

the nineteenth century, but most of the usable timber had been cut out by the 1880's. An attempt to graze sheep on the Button Grass was a failure, and, while mineral finds transformed the landscape of the more northern parts of western Tasmania, no important minerals were discovered in the Southwest.

Hydroelectric power development

It was obvious from early in this century that the Southwest was capable of supplying one form of material wealth in abundance. The high all-the-year-round rainfall and the presence of suitable dam sites on the Gordon River gave the region a great potential for hydroelectric power generation. It is estimated that the full power potential of the Gordon and King Rivers is almost equal to that of the completed Snowy Mountains scheme in New South Wales.

Tasmania began to develop its hydroelectric power resources some 50 years ago, but the more accessible rivers were utilized first, and it was not until 1967 that parliamentary approval was sought for the Gordon River power scheme.



Precipitous Bluff (4,000 feet above sea-level), a dolerite peak. This scene is typical of the high plateau of the eastern part of the Southwest and the dense forests which bar the way to more open country further west. In the sub-alpine vegetation in the foreground scoparia bushes (*Richea scoparia*) and the Giant Heath (*Richea pandanifolia*) can be seen. The dead trees in the middle distance are native pines. [Photo: I. McKendrick.]

The northern part of the Southwest wilderness was finally breached between 1963 and 1966, when a 55-mile investigation road was built west from Maydena to the junction of the Gordon and Serpentine Rivers. The Tasmanian Parliament authorized the Gordon power scheme in 1967, and also vested control of the whole of the Southwest in the Hydro-Electric Commission. The first stage of the power scheme, which is scheduled to be in service by 1975, involves the building of a linked storage of 200 square miles which will become the largest freshwater lake in Australia. This will mainly occupy the Button Grass plains but it will also drown the natural Lake Pedder.

The passage of the bill was preceded by

the biggest conservation controversy Tasmania has ever known and led to decisions which will probably determine the future of the Southwest for many years to come.

Outcome of the Lake Pedder controversy

The ingredients of the controversy had been slowly brewing for many years before the Hydro-Electric Commission finalized its Gordon River power proposals. The first signs that an awareness of the nature-conservation value of the Southwest had begun to develop were the setting aside, first of the foreshore of Port Davey in 1951, and then in 1955 of a 59,000-acre scenic reserve including Lake Pedder and a part of the Frankland Range. Then in 1962 Mr R. H. Brown, M.L.C., proposed that the whole

of the Southwest should be made a national park, and this became the main objective of the Southwest Committee which was formed in the same year. In 1965 the Tasmanian Fauna Board asked that the Southwest be set aside as a national fauna reserve. The Government would not agree to this, but in the following year a 1,600,000-acre area was declared a faunal district, making it possible to proclaim separate fauna protection regulations for this area.

Early in 1967 it was realized that completion of the Gordon River power scheme proposal was imminent and a very active public protest campaign, headed by the Save Lake Pedder Committee, got under way. The Government was anxious for the bill to be passed as quickly as possible, but the Legislative Council (Tasmania's non-party Upper House), sensing the extent of public disquiet, appointed a Select Committee to consider various aspects of the power scheme, including the effect on Lake Pedder, and whether any modification of the scheme was practicable or desirable.

The Select Committee's report, published in August, 1967, contained recommendations of far-reaching importance. After giving its opinion that no modification of the power scheme was practicable or desirable, the Committee noted that the controversy over Lake Pedder reflected a heightened community interest in conservation and a concern for improved park control, and recommended the preparation of new legislation for national parks and wildlife conservation providing, amongst other things, for a reconstituted park authority. The Committee also recommended that the large area of about 1 million acres which had been proposed as a park by the Southwest Committee should be proclaimed as a national park prior to the start of work on the power project.

The Government would not create this large national park immediately but undertook to submit new legislation for scenery preservation before September, 1968. It also decided that after the passage of the bill it would create the Southwest national park with boundaries approximately similar to those recommended by the Select Committee. The proposed park includes the existing Lake Pedder National Park, parts of which are to disappear beneath the artificial lake after 1971. As a result, then,

of events which brought about the end of wilderness conditions in one half of the Southwest a decision was made to set aside the remaining half as a national park. Although it now appears certain that a large part of the Southwest will become a park, will this new phase guarantee the survival of its distinctive natural character? To be successful the park land use policy must be based on very careful consideration of the unique qualities of the region.

Unique character of the Southwest

There are two things about the proposed park in the Southwest which make it outstanding as a nature conservation area. Firstly, it is unique in non-arid Australia as a large roadless wilderness area, and therefore also as an adventure ground for all who care to visit it on foot. This alone would make the area worthy of preservation, but the Southwest is also a pristine part of a distinct natural region containing landforms and wildlife of immense scientific and popular interest.

Amongst the interesting physical features of Southwest Tasmania are those which are the result of past glacial action. On the high ranges there are hundreds of cirques, mostly containing small rock-basin lakes. Old lateral moraines are still quite evident on the slopes, and glacial outwash material floors many of the valleys. Port Davey, with its many tree-fringed inlets and islands, is a perfect example of a ria, or drowned valley system, the product of a rise in sea-level between 12,000 and 6,000 years ago.

The aspect of the Southwest which is of greatest biological interest is undoubtedly the native plants. Many of the plants are endemic and have affinities with other temperate and superhumid parts of the Southern Oceanic region, such as New Zealand and Chile.

The major communities are sedgeland, dominated by Button Grass (*Mesomelaena sphaerocephala*), which is the edaphic climax of the moor podsol peats; temperate rain-forest in which the Evergreen Beech (*Nothofagus cunninghamii*) is the chief species; and montane moorland, which occurs at levels of over 2,000 feet above sea-level and contains conifer forests, fell field, and coniferous and micro shrubberies.



Federation Peak (4,010 feet above sea-level) in the Eastern Arthur Range. This needle-like peak of pre-Cambrian quartzite is the goal of many of the Southwest's hardy visitors. Sub-alpine vegetation clings to the 1,500-foot-high cliffs, which arise from a deep glacially-eroded trough occupied by a string of lakes. [Photo: J. Thwaites.]

Of nine species of pine found in the region eight are endemic to Tasmania. In addition to the Huon Pine, already mentioned, they include such distinctive species as the large King Billy Pine (*Athrotaxis selaginoides*) and the aptly-named Celery Top Pine (*Phyllocladus aspleniifolius*).

Other interesting forest species include the Deciduous Beech (*Nothofagus gunnii*) and the giant Mountain Heath (*Richea pandanifolia*). Amongst the notable alpine plants are five species of cushion plants, and ten species of endemic *Richea*.

Eucalypt communities occur alongside forests dominated by beech and sassafras, and pose interesting problems in relation to the multiple factors of climatic change, soil, fire history, and succession. Human influence has not been great, although, according to Professor W. D. Jackson, Professor of Botany, University of Tasmania, thousands of years of firing by Aborigines may have extended the sedgeland up onto the slopes at the expense of the forest. Other fires,

including those of recent years, have destroyed areas of fire-vulnerable montane vegetation.

The Button Grass plains and the rain-forests do not appear to be rich in animal life. Like most aspects of the biology of the Southwest, the fauna is not well known. Since there has been no pastoral or agricultural activity in the Southwest and the area is free from many introduced species, such as the rabbit, some of the small native species may have had a better chance of survival there than elsewhere. Many of the small lakes and streams are in a pristine state, and the aquatic life should be of great interest. There are also kitchen middens and village sites on the coast which have not been thoroughly studied.

One of the most important features of this proposed park is the opportunity it offers to study distinctive soils, catchments, and plants and animals in circumstances which are as natural as one can hope to find anywhere. The size of the unit is of particular

value because, as well as being a factor contributing to the naturalness and the range of diversity, it is a vital protective shield against disturbance by man. One of the objects of the Southwest national park should be to preserve the area as a large permanent reference area and outdoor laboratory.

A park management policy for wilderness preservation

The greatest potential use of the proposed Southwest national park is for the enjoyment and study of wilderness—objectives which are quite compatible in an area of this size. Unfortunately, the simple act of creating a national park will not ensure that the area is managed to maintain its highest values. There will have to be a firm resolve at the outset to exclude anything that is likely to impair wilderness. For example, the unique qualities of the area will be spoiled if the area is “opened up” by road construction.

The chief needs, then, are for Government recognition of the fact that the prime value of the area is wilderness, and for a plan of conservation which will aim at preserving the area in a roadless condition. This will be a difficult decision for a tourist-minded Government to make, but preservation of the Southwest as a national wilderness park is more likely to benefit the Tasmanian tourist industry as a whole in the long run than opening up the area by means of motor roads. No other settled part of Australia will be able to offer its visitors the attraction of a true wilderness.

It would help to indicate the special character and purpose of the Southwest national park if the word “wilderness” could be introduced into the name of the park, as it has been in the case of the Elliott Price Wilderness National Park, recently established on the shores of Lake Eyre. The park management aims can be put into practice by means of a master plan. This plan could, for instance, set aside the approach

roads and the Lake Pedder section of the park for the location of facilities and relatively intense recreation. Possibly, limited accommodation could be provided at Port Davey but this would have to be serviced by air and sea. The less active could either fly over the area or visit the threshold sections on short walks, leaving the remainder of the area as true wilderness for all who care to make use of it as such. This policy would make the wilderness available for all.

Naturally, the national park should also be kept free of other conflicting forms of land use, such as commercial forestry. Where minerals of proven national importance are found within the park, conditions of working must be designed to give maximum protection to the wilderness. These are some of the main things which must be carefully considered if the Southwest wilderness is to survive within a national park. A false start could lead to gradual development of the whole park and the loss of its distinctive recreational and scientific advantages.

On 18th December, 1968, the Tasmanian Government gazetted a 473,500 acre scenic reserve, to be known as the Southwest National Park (see map), and appointed a special board of five members for its control and management. Unfortunately, the new reserve excludes some of the most outstanding parts of the park recommended by the Legislative Council's Gordon River Select Committee, including the Port Davey and Precipitous Bluff—Mt La Perouse areas. By omitting these vital areas the Government has not taken full advantage of the park potential of the Southwest, and conservation bodies have announced that they will seek to have the reserve extended to the full area recommended by the Select Committee.

FURTHER READING

Davies, J. L. (editor): *Atlas of Tasmania*, Lands and Surveys Department, Hobart, 1965. Includes various articles on aspects of Tasmanian physical geography.



A white-phase Reef Heron moves along in a "low stalk". In this foraging position the neck is held in and the head is more or less level with the body.

THE REEF HERON

By HARRY F. RECHER, Curator, Department of Environmental Studies, Australian Museum, and
JUDY A. RECHER

UNLIKE other herons, the Reef Heron (*Egretta sacra*) is exclusively a maritime species. Widely distributed from India and Japan to Tasmania and New Zealand, and found throughout Oceania, the Reef Heron frequents coral reefs, beaches, and coastal rock platforms, where it forages for a variety of fish and invertebrates. The Reef Heron is most abundant in the tropics, and on coral reefs in particular.

This account is primarily concerned with aspects of the ecology and behaviour of the Reef Heron on a coral reef. During 1967 we initiated a study of the Reef Heron on Heron Island, a small coral cay in the Capricorn Group at the southern end of the Great Barrier Reef. Previously we had studied herons in North America, and the work on the Reef Heron was planned to supplement and extend our earlier studies. In particular, the Reef Heron project was

to provide us with information on the variety of kinds and sizes of prey taken by herons in habitats having only one species of heron. All our North America study areas had at least six species of heron.

Two colour phases

The Reef Heron is a dimorphic species, occurring in two colour phases—white and slate-blue (dark). The two phases interbreed and both white and dark birds can be found in the same brood. Unlike a similar situation in the Florida Keys of North America, where hybridization between the white and dark phases of the Great Blue Heron (*Ardea herodias*) results in intermediate colour forms, there are no intermediate colours with the Reef Heron. The proportion of the white and dark phases varies between localities, with populations in the tropics tending to have a greater

proportion of white birds than populations in temperate regions. At Heron Island, white birds outnumber dark birds by two to one. In New Zealand and in the vicinity of Sydney, Australia, most Reef Herons are dark birds.

Why are there two colour phases? And why should there be such a marked difference in the proportion of the phases between temperate and tropical regions? Some investigators have suggested that white or light-coloured birds would be less visible to fish and hence would be more efficient at capturing prey than dark birds. If true, this would be an especially significant factor in the bright sun of the tropics and could help in explaining the colour variation between temperate and tropical regions. Among the questions we asked about the Reef Heron in our studies at Heron Island was whether or not white herons are more efficient fish predators than dark birds. The answer to this seems to be that they are not. We have not been able to detect any differences between colour phases either in the kind or quantity of prey taken or in the manner of foraging. Both seem equally efficient fish predators. Thus, it now appears likely that the cline in colour phases is a



A dark-phase bird forages along the edge of Heron Reef. This is the "upright stalk", with the neck extended and the head well above the body.

result of physiological rather than ecological differences.

Nesting

During November, 1967, when we made our first trip to Heron Island, there were approximately 160 resident Reef Herons. However, many of these were young birds and we estimated that only thirty-five or forty pairs of Reef Herons actually nested on the island. In addition, there was a single pair of the Mangrove Heron (*Butorides striatus*). Reef Herons begin nesting in late July or early August. Two or three eggs are laid in nests constructed of sticks in the typically haphazard style of herons. The nests which we located were all in *Pisonia* trees. There was no tendency towards colonial nesting, unless Heron Island itself can be considered a colony. Though many islands of the Great Barrier Reef appear to have suitable nesting areas and are frequented by foraging herons, not all have rookeries. This indicates that Reef Herons may aggregate into breeding colonies. By mid-November most young birds are fully fledged and no longer depend on their parents for food. Our observations indicate that at this stage (and very likely longer) the young heron is much less adept at feeding itself than is an adult. Young birds miss more often, capture a smaller weight of food per minute hunting, and take smaller food organisms than do adults foraging in the same area. This is also the case with herons in North America.

Foraging habits

Except for the occasional bird foraging for insects or nestling terns in the island's interior, Reef Herons foraged primarily on the reef at low tide. There the herons were observed to feed exclusively on fish. Heron Island Reef and nearby Wistari Reef were both utilized as foraging areas by herons from Heron Island. Movements of foraging birds between these two reefs were infrequent. However, without marking individuals, it is not possible to determine whether there are two different groups of herons, one foraging primarily on Wistari Reef and one on Heron Reef. We do know that a few distinctively marked birds consistently foraged over limited areas of Heron Reef and were found "where they belonged" on successive low tides over a 4-week period.

In a "partial crouch", this heron is waiting for a small fish to approach. Notice how the bird's silhouette resembles that of a clump of coral. In a "full crouch", the heron would touch or even rest on the water and the wings would be more fully extended.



When the tide begins to fall, the herons leave their roosting sites within the island's *Pisonia* wood and aggregate along the shore edge. As the reef becomes progressively exposed by the falling tide, individuals and small groups leave the loafing aggregation and disperse over the hunting grounds. As Wistari Reef is somewhat higher than Heron Reef and is therefore exposed for a longer period, those birds which hunted on Wistari began foraging before, and generally remained longer than, individuals on Heron Reef. The section of reef adjacent to the Heron Island Biological Station was the last to be available to foraging herons. These birds had from 2 to 3 hours in which to hunt. The actual time available for foraging varies according to the phase of the tidal sequence. Herons on Wistari Reef or on the farther sections of Heron Reef had from 1 to 2 hours additional hunting time. It would be interesting to know if the additional time available for hunting compensated for the extra energy expended in flying to these more remote areas.

The foraging behaviour of Reef Herons is distinctly different from that of other herons. Generally, Reef Herons forage as they move over the reef, perhaps carefully stalking prey organisms, but rarely waiting for prey to come to them. In hunting, birds tended to follow one of two patterns. Either they moved along with their neck held in and their head level with the body ("low stalk") or in a more upright, alert pose ("upright stalk"). In the latter posture, the neck is

extended and the head is held well above the body. Birds hunting in the "upright stalk" tend to move more rapidly and cover a greater area than birds moving in the "low stalk". However, individuals may alternate between the two hunting behaviours and the rate of movement may vary. Periods of careful stealth can be interrupted by sudden rushes or by periods of immobility. Often, when approaching a small pool or when a fish has been seen, Reef Herons break their silhouette by lowering themselves to the substrate ("crouch"). At times, the bird may literally be flat in the water or on the coral rubble. In this manner it can approach a fish with less chance of being seen, or can wait for the fish to come to it. Casting no shadow, the "crouched" Reef Heron looks much like a lump of coral. Perhaps this particular behaviour can help explain the seeming unimportance of colour in regard to an individual's ability to capture fish. Though "crouching" is one of the more noticeable features of Reef Heron foraging behaviour, it is not unique to Reef Herons. On one occasion in North America we observed a Louisiana Heron (*Hydranassa tricolor*) foraging in the same manner. It is interesting to note that the conditions under which the Louisiana Heron was foraging were similar to those encountered on Heron Island—clear water, bright sunshine, and scattered rock rubble.

Though more observations are needed for verification, there appear to be some interesting differences between individuals



Above: Moving stealthily forward in a "partial crouch", this heron is stalking a small fish. Note how the wings are held out or "cocked" and the legs deeply bent. Below: Lunging at a fish from a "partial crouch". Large fish may be grabbed or speared, but smaller prey are just picked up.



foraging in the "low stalk" and those in the "upright stalk". Most often the Reef Herons which foraged in the "upright stalk" were adults, while the reverse was true for the "low stalk". Secondly, the herons foraging upright searched for prey at some distance in front of them, occasionally stopping to scan the surrounding area. In contrast, herons which hunted in a "low stalk" foraged from the reef and water immediately in front of them. They seldom, if ever, stopped and scanned the area about them. Thirdly, herons foraging in the "upright stalk" took fewer but larger fish than herons hunting in the "low stalk".

On a few occasions we observed Reef Herons to "foot-paddle", that is, to extend a foot and use it to stir the substrate or a clump of algae to expose concealed fish. And once we observed a Reef Heron hunting in the classic heron fashion of standing immobile and upright, waiting for fish to approach. Normally, these hunting behaviours are inappropriate for reef conditions. Aquatic vegetation is scarce on the reef and usually the water is too clear to expect fish to approach a standing heron. Although such behaviour may be rare, we do see that Reef Herons can show foraging behaviours characteristic of herons in general.

An early morning aggregation of Reef Herons brought to the water's edge by game-fish pursuing shoals of small fish into the shallows.



Similarly, other herons may on occasion forage in a typically Reef Heron manner. Evidently herons inherit a wide repertoire of hunting behaviours, but those used depend on environmental conditions and, perhaps, individual abilities.

Normally Reef Herons foraged during the day, but they would also hunt on a nocturnal low tide, especially when there were no low tides during the day. At times, too, Reef Herons would forage along the shore at high tide. On early morning high tides, schools of game-fish would come into the shallows pursuing and driving shoals of small fish to the shore edge. At these times the entire Reef Heron population would be along the water's edge following the game-fish and

feeding on the small fish driven into the shallows. These early morning forays by game-fish may prove important to the Reef Heron population of Heron Island. Despite a rich and abundant fish fauna, a coral reef is not an especially productive habitat for herons. Reef Herons foraging on a coral reef appear to be unable to obtain any greater amount of food than herons foraging in a variety of fresh and salt water environments in North America. Indeed, they may actually need to forage longer for the same food. If so, this will help explain why coral reefs which outwardly would seem to be ideal heron habitats support so few species of heron.

[Photos in this article are by Harry F. Recher.]

BOOK REVIEW

AUSTRALIAN WATTLES. An Australia-wide selection, including species from remote areas of the tropical north and arid interior, as well as familiar and well-loved garden favourites. Horwitz Publications Inc. Pty Ltd, North Sydney. Price, \$1.00.

This attractive publication of some 34 pages presents 77 coloured illustrations of 56 species of *Acacia* reproduced from colour transparencies by Douglass Baglin. The brief descriptive text has been supplied by Barbara Mullins.

There are some 620 species of *Acacia* throughout Australia and a publication of this size must necessarily discuss only a small proportion of them. The selection has been wisely made, however, and representatives of the phyllodineous wattles, showing the wide range of shape and size of phyllodes,

stand beside representatives of those species in which bipinnate leaves are produced throughout the life of the plant. The range of inflorescence structure is equally well illustrated, from those in which the flowers are arranged in a ball-like head produced singly in the axils of leaves or along elongated racemes to those in which the flowers are arranged along a columnar spike.

Species have been chosen from all the Australian States, and from habitats ranging from coastal dunes through heath lands and forests to the dry interior. This booklet will have an appeal, therefore, to people in all parts of the Commonwealth, and will be a happy and instructive reminder of the wealth of variety to be found amongst the wattles, Australia's national floral emblem—*Joyce W. Vickery.*



Upland tussock grassland, with dark flower spikes of the liliaceous *Bulbinella rossii* in the foreground, on St Col Ridge, Campbell Island. Nesting Royal Albatrosses (*Diomedea epomophora*) can be seen in the foreground and on the more distant slopes. [Photo: F. C. Kinsky, Dominion Museum, New Zealand.]

The Australasian Subantarctic Islands

By J. C. YALDWYN

Senior Scientist, Dominion Museum, Wellington, New Zealand

Part I

SOUTH of Australia and New Zealand, between latitudes 50° and 55° S., but north of the so-called zone of Antarctic waters, lie the small and isolated Auckland Islands, Campbell Island, and Macquarie Island. They are usually called "subantarctic islands", though this term is difficult to define, and in New Zealand they are even referred to as the Subantarctic Islands of New Zealand. Politically only Auckland and Campbell Islands are part of New Zealand, while Macquarie Island, though well to the southeast of Tasmania and attached to New Zealand from the geological point of view by a submarine

ridge, is part of the Esperance District in the State of Tasmania.

A circum-Southern Ocean belt of surface water, bounded to the north by a narrow band called the Subtropical Convergence (where a rapid rise in surface water temperature occurs in a short distance) and to the south by a similar band called the Antarctic Convergence (where a rapid drop in temperature occurs in a short distance) is called the Subantarctic Zone. Those isolated islands which lie within this zone, but not mainland areas such as southern New Zealand and the Patagonian region of South America, are grouped

together as subantarctic from the point of view of climate, environment, flora, and fauna. As well as the Australasian subantarctic islands already mentioned, these include Kerguelen and Crozet Islands in the Indian Ocean, Marion and Prince Edward Islands south of South Africa, and Gough Island in the South Atlantic Ocean. Heard Island, southwest of Western Australia, and South Georgia, south of South America, are well within the Antarctic Zone and are true Antarctic islands.

Subantarctic islands in general are characterized by the lack of a permanent ice-cap, the lack of trees and forests (with the single exception of the Auckland Islands), a reduced flora but a more or less continuous plant cover, the presence of breeding colonies of large seals such as sea-lions or elephant seals, a reduced but not completely absent land bird fauna and the contrasting presence of a rich fauna of breeding sea birds, including large and conspicuous forms such as penguins, albatrosses, and mollymawks, as well as smaller burrow-nesting forms such as prions, shearwaters, storm and diving petrels.

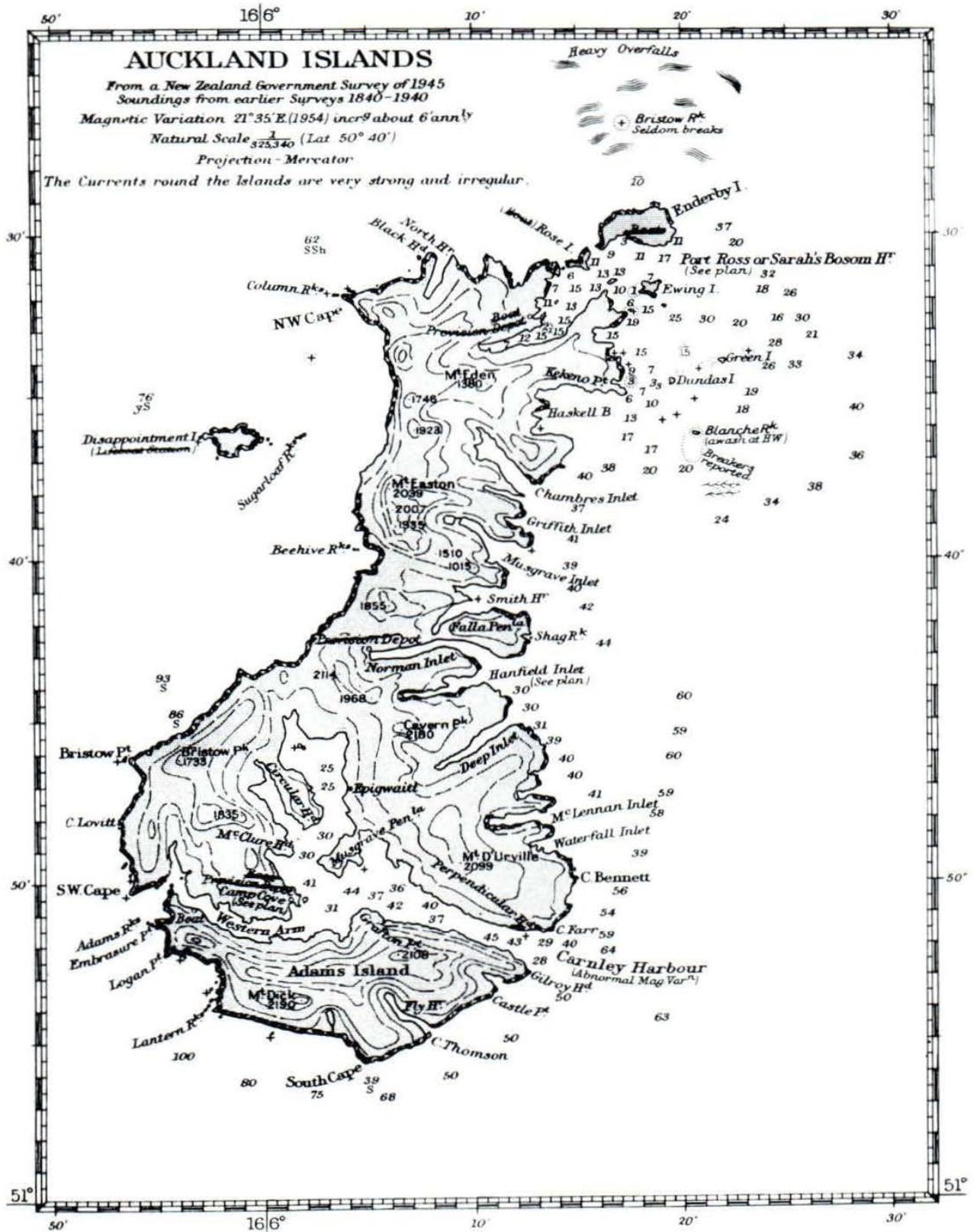
As might be expected, there is a progressive increase in the severity of the environment and a consequent reduction in the variety of flora and fauna as one moves south through the Australasian subantarctic islands. Taking the vascular plants (flowering plants and ferns together) as an example, the Auckland Islands, at latitude 50° S., some 300 miles south of the New Zealand mainland, have at least 150 recorded species; Campbell Island, at 52° S., has about 130 recorded species, while Macquarie Island, at 55° S., has only 38 species. South of the Antarctic Convergence, latitudinal reduction is even more dramatic; Heard Island in the Indian Ocean has a vascular flora of 8 species, though it is only about 300 miles from the subantarctic Kerguelen Islands with about 70 species, and finally the whole Antarctic Continent has only 2 known vascular plants.

In the case of insects, one finds a very similar picture of progressive latitudinal reduction. Excluding mites and other terrestrial arthropods, the Auckland Islands have more than 350 species of true insects

(probably many more, as the invertebrate fauna is insufficiently known), Campbell Island has about 260 species, while Macquarie Island has only 65. Heard Island, in the Antarctic Zone, has a mere 25 recorded species, contrasting with the Antarctic Continent itself, including nearby islands, which has, perhaps unexpectedly, over 60 species of true insects.

The terrestrial arthropod fauna (insects, spiders, mites, etc.) of the Auckland and Campbell Islands has been recognized as a depauperated fragment of an older subcontinental fauna with some transoceanic colonization. Indeed, the situation of the two island groups on a submarine plateau at an average depth of about 300 fathoms and connected to New Zealand (the Campbell Plateau) supports such an interpretation. In many ways the unbalanced representational nature of this arthropod fauna, with the absence of so many groups, and a high ratio of flightless insects, is like that found on isolated oceanic islands. This unbalanced nature, however, is probably in part related to the subantarctic environment, with the loss of flight being correlated with the prevailing windy conditions of these islands. In the case of Macquarie Island the picture appears to be rather different. Macquarie is more isolated in terms of submarine structure than are Campbell and the Aucklands to the north. Though joined to the New Zealand area by a submarine ridge, it is not on the 300-fathom Campbell Plateau, and, being entirely of volcanic origin, it contrasts geologically with the more complex history of the Auckland and Campbell Islands, involving Mesozoic metamorphic basement rocks as well as Tertiary sedimentation and volcanism. Macquarie Island, then, with its much poorer terrestrial arthropod fauna, appears to be a typical oceanic island. Its land fauna must have come by transoceanic dispersal. Its lack of weevils, and many other beetle groups represented on other subantarctic islands, appears to be strong evidence for an isolated oceanic origin.

Turning now to the individual subantarctic islands under discussion and leaving aside any consideration of the varied and, in the case of some systematic groups, surprisingly abundant marine fauna, let us consider



A map of the Auckland Islands taken from the British Admiralty chart of the area and based on a New Zealand Government survey in 1945. The total length of the islands is about 29 miles.

some of the variations in their history, physical environment, and biology.

Auckland Islands

The Auckland Islands, with the main island some 23 miles in length from north to south and a greatest width of about 15 miles, as well as several off-shore islands, including the large and important Adams Island, is the largest of the subantarctic island groups in the Australasian region. The Aucklands were discovered by Captain Bristow, of the *Ocean*, in 1806, 4 years before the discovery of Campbell and Macquarie Islands, and were so vigorously exploited for sealskins and oil, much of which passed through Sydney during the following 15 years, that by about 1820 the sealing potential of the Aucklands was virtually exhausted. Their scientific investigation dates from 1840, when three major naval expeditions, an American under Commodore Wilkes, a French under Admiral Durmont d'Urville, and a British under Sir James Clark Ross, visited the northern harbour of Port Ross, or Sarah's Bosom as it is called on some maps. The naturalists Sir Joseph Hooker and Dr Lyall were with Ross and made extensive investigations into the natural history of the island group.

An expedition by the Philosophical Institute of Canterbury in 1907, the wartime coast-watching occupation of 1941-45, code-named *Cape Expedition*, and the combined D.S.I.R. and Dominion Museum expedition of December-January, 1962-63, are the highlights of New Zealand's continuing work on the ecology and biology of the Auckland Islands. The main island rises to a height of over 2,000 feet and a major ridge runs north to south as a backbone to the island. The whole of the west coast is formed of high precipitous cliffs, while the east coast is less rugged and is indented by several fine harbours and inlets.

The vegetation of the Auckland Islands is distinctive, and characteristically and unexpectedly vigorous. There is a coastal forest mainly formed of the Southern Rata (*Metrosideros umbellata*), a Myrtaceae which rises in sheltered areas to a height of about 40 feet (see "The Auckland Islands Expedition 1962-63" by the present author, *Australian Natural History*, Vol. XIV, No.

9, page 273, March, 1964). Above the narrow band of rata forest (a unique feature for the Aucklands, as trees are characteristically absent from subantarctic islands) there is an extensive area of scrubland, usually difficult to penetrate but interspersed with relatively clear lanes of cushion plants and scattered tussocks. Above this scrub zone, a grassland zone, consisting mainly of *Chionochloa antarctica* tussocks and exposed peat, extends up to a height of about 1,600 feet at the northern end of the main island. Finally an upland fell-field, with open stony ground and many subantarctic endemic plants such as species of the composite *Pleurophyllum*, occupies the hilltops and peaks of the main ridge along the length of the island.

Hooker, in describing the vegetation of the Auckland Islands, wrote as follows: "It is especially towards the summits of these hills that the most striking plants are found, vying in brightness of colour with the Arctic Flora, and unrivalled in beauty by those of any other Antarctic country. Such are the species of *Gentian*, and a *Veronica* with flowers of the intensest blue, several magnificent *Compositae*, a *Ranunculus*—and a *Liliaceous* plant whose dense spikes of golden flowers are often so abundant as to attract the eye from a considerable distance". The last-mentioned is *Bulbinella rossii*, shown, in an accompanying photo, among tussocks on Campbell Island.

Campbell Island

Campbell Island lies some 150 miles southeast of the Auckland Islands. It is about 10 miles long, north to south, and about the same east to west. Both Campbell and Macquarie Islands were discovered by Captain Hasselbrough, of the *Perseverance*, in 1810, the former being named after the ship's owners, Campbell and Co., of Sydney, and the latter after the then Governor of New South Wales. Sealing was carried out vigorously until the 1820's, but after that the island was left in virtual isolation except for a few scientific visits such as those by Ross in 1840 and the Philosophical Institute of Canterbury in 1907. Starting with *Cape Expedition* in 1941, a permanent New Zealand station has been occupied at the head of Perseverance Harbour on

Campbell Island ever since. This station is now mainly meteorological in function but much valuable biological observation has been carried out over the years by station personnel.

The island is rugged and rises to a height of over 1,800 feet, most of the western coasts consist of high cliffs resulting from sea erosion, while two deep inlets indent the less precipitous east coast. Much of Campbell Island is covered with tussock and peat, and is very marshy, even on fairly steep slopes and lower ridges. There are coastal terraces, glaciated valleys, regular conical hills, a few small tarns, many small streams, but no rivers and no recent volcanic activity. True soil is scarce, acidic, with high organic and low nitrogen content,

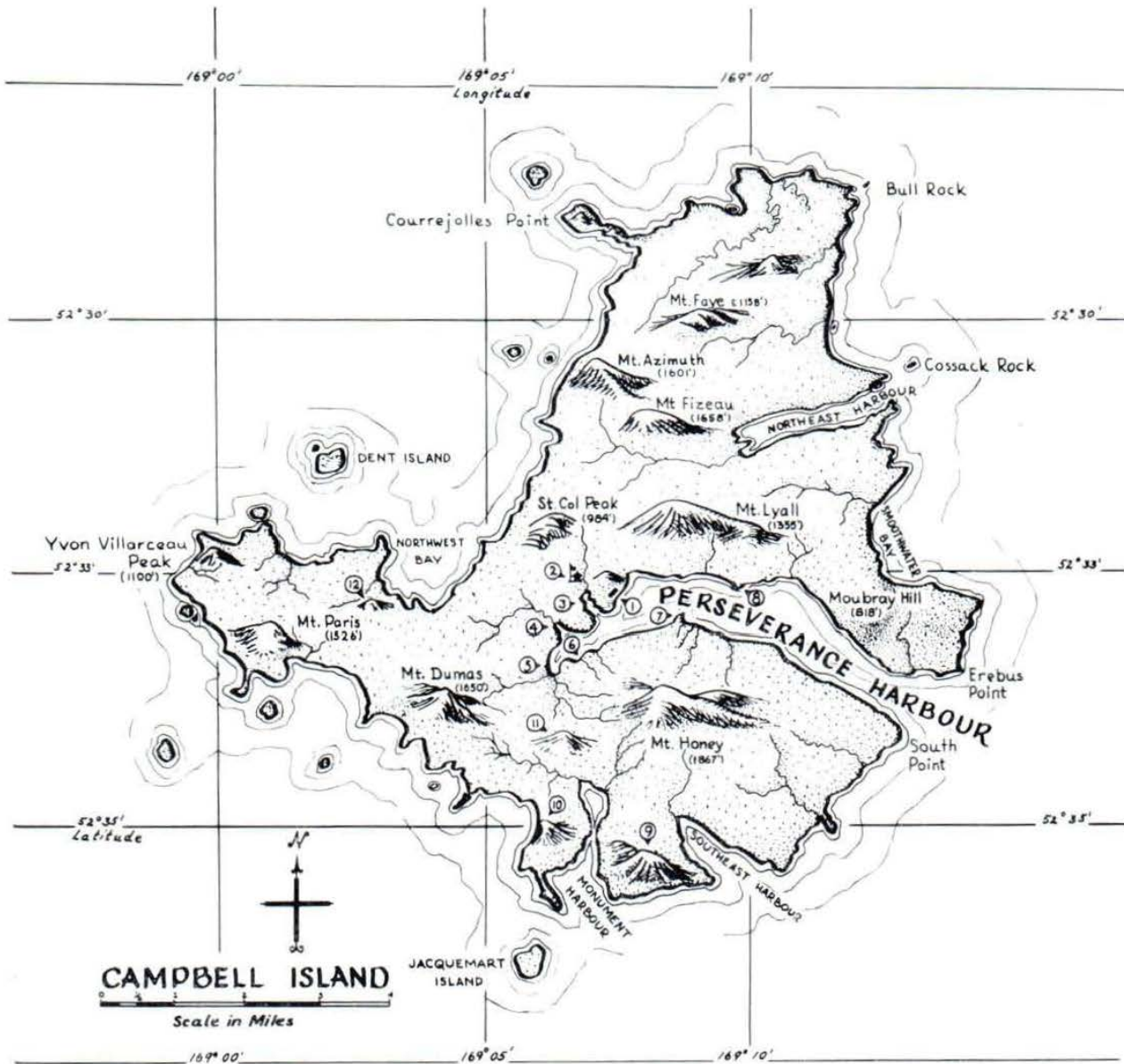
and the peat may be up to 35 feet in depth.

Campbell Island weather has been officially described as "unpredictable" (even as "foul" in some naval reports). Overcast skies and gale-force winds seem to be normal, but there are quiet days of brilliant sunshine. The yearly average rainfall of 57 inches is not high, but the number of days of rain in a year may reach the excessive figure of 322. The mean annual temperature is about 44° F and the relative humidity is often high.

The vegetation of Campbell Island, though reduced in species and without trees, is similar to that described above for the Auckland Islands. Clear zonation has gone, so that tussock grassland and *Pleurophyllum* composites can occur from



A colony of Black-browed Mollymawks (*Diomedea melanophrys*) nesting on coastal cliffs near Bull Rock, Campbell Island. [Photo: F. C. Kinsky, Dominion Museum, New Zealand.]



Key to Numbers

- | | | |
|--------------------------|--------------------|----------------------------|
| 1 Meteorological Station | 5 Garden Cove | 9 Puisieux Peak (1522 ft.) |
| 2 Old station | 6 Venus Bay | 10 Eboulé Peak (1010 ft.) |
| 3 Tucker Cove | 7 Shoal Point | 11 Filhol Peak (942 ft.) |
| 4 Camp Cove | 8 De La Vire Point | 12 Menhir Peak (650 ft.) |

This map is from the book *Subantarctic Campbell Island*, by A. M. Baily and J. H. Sorensen, published by the Denver Museum of Natural History, Colorado, U.S.A., in 1962.

sea-level to almost the highest altitude on the island. A great change has taken place in the vegetation of Campbell during the past half-century. Sheep were introduced in 1895, and, though abandoned as a commercial venture in 1927, probably over 1,000 remain there today. Sheep grazing has greatly reduced the tussock and brought about its partial replacement by the

apparently unappetizing *Bulbinella*. Sheep have largely eliminated succulent *Pleurophyllum* species and other endemic herbs from open areas, and now these can be found only in secluded places, inaccessible to the sheep's ravages.

[This article will be concluded in our next issue.]





The Common Garden Snail (*Helix aspersa*) is so adaptable that it has been successfully introduced to most parts of the world and is best described as a "world tramp" species.

Some Introduced Land Molluscs

By BRIAN J. SMITH

Curator of Invertebrates, National Museum of Victoria, Melbourne

AUSTRALIA'S native fauna of land molluscs—snails and slugs—is large and varied. It contains some hundreds of species found nowhere else in the world, some of which are as important zoologically in the study of land molluscs as the platypus and the kangaroo are in the study of mammals. It may, therefore, come as a surprise to learn that most people, especially those living in southern suburban Australia, have probably never seen an Australian native snail or slug. Everybody knows what snails and slugs are and how successful they are in sustaining the species at the expense of the suburban gardener's plants. However, like a good many other of the more spectacularly successful species of animals and plants designated by most people as pests, the snails and slugs found in suburban gardens of the southern States of Australia are, in nearly every case, introduced species from Europe.

Introduction of alien species of plants and animals into Australia has happened in two ways. First, by design: various people and groups amongst the early settlers wanted to see familiar animals and plants about them

in their new land, and so brought out and released such animals as the fox, the rabbit, the sparrow, and the goldfinch. The other method of introduction was by accident, and it was by this method that the snails and slugs got in and were dispersed. They probably came in on plants brought out for introduction, or in foodstuffs or on tools and implements brought by farmer-settlers. However they were brought out, there are now twenty-one species of land snails and ten species of land slugs living and spreading over large areas of Australia which were originally natives of Britain and Europe and were certainly introduced into Australia by the early settlers.

Snails and slugs belong to the order Stylommatophora of the pulmonate or lung-possessing molluscs. Apart from possessing an efficient lung, for breathing air, they also have a thicker, more impervious skin and a complex reproductive process with the ability to lay shelled eggs—all to assist them with their life on land. They can be either carnivores or herbivores according to the species, though many of the more successful ones have a very wide range of diet and will



The Sand-dune Snail (*Theba pisana*), which is found in vast numbers on many of the coastal sand-dune areas of southern Australia.

eat almost anything. Most of the introduced species are either herbivores or omnivores with a wide range of diet and seem to take just as readily to Australian native plants as food as to the introduced plants to which their ancestors in Europe were confined. They will also eat discarded paper, decaying meat, and even dead individuals of their own kind.

Snails

By far the commonest and best known of all the snails introduced into Australia is the Common Garden Snail, *Helix aspersa* Muller, which originally came from Britain and central Europe. However, this species, together with a number of the other introduced land molluscs, is best described as a "world tramp" species, as it is now found, through introduction, in every continent and every country where conditions are at all favourable to it. In Australia it has been recorded from every State, though its distribution is very restricted in the northern part of Australia. In the southern States it is the dominant land mollusc in most of the improved or developed areas. It is not

only found in suburban gardens and market gardens but in most of the areas which man frequents regularly.

This relationship between the distribution of these introduced land molluscs and the areas regularly frequented by man is an interesting one, as it gives us a key to their success. Most of these species have very poor dispersal capabilities "under their own steam". This is particularly true of the White or Sand-dune Snail, *Theba pisana* (Muller), which is native to the coastal sand-dunes of Britain and central-southern Europe and has reached near-plague proportions several times in a number of places in South Africa and Australia. In a recent distribution study on a population of this species at Portsea, Victoria, I showed that their distribution was very closely related to the areas regularly frequented by man; surrounding car parks and paths on the ocean beach-dune area the populations reached 200 snails per square foot, while only 30 yards away there was not even a dead shell to be found. This species is found on coastal sand-dunes along the southern coast of Australia from Western Australia to New

South Wales. It has also been reported from inland localities in Western Australia and in South Australia. This move inland has only happened in relatively recent times and is an ominous warning for the future.

Another introduced snail that has reached plague proportions in many of the slightly drier areas of Western Australia and South Australia is the Striped Snail, *Helicella virgata* (Da Costa). This fairly small white snail with a wide umbilicus has been a particular pest in the vineyards around Adelaide for a number of years and the plague of snails in Western Australia last year was also this species. Recently this species has been the subject of an extensive study of the biology and methods of adaptation into a new environment of an introduced pest by a research worker in Adelaide University, Mr D. Pomeroy. He found that this introduced species was able to withstand the extremes of heat and dryness of a South Australian summer and was a highly successful animal actively extending its range.

A small introduced snail that does not reach plague proportions, and indeed may go unnoticed because of its small size, is the Pointed Snail, *Cochlicella acuta* (Muller). This is, again, a very common species in all the southern States of Australia and seems to be the most successful at dispersal of any of the introduced snails. It is recorded from most places where any other introduced species is found, and in many places seems to have spread from the initial point of

introduction further into the untouched bush than any other species.

All the snails I have described so far have been herbivores or omnivores and could be regarded as pests by gardeners and farmers. However, not all the introduced snails can be classified thus. One small introduced snail with a thin, almost transparent shell is a carnivore which feeds on small worms, slaters, and even small snails. This is the Cellar or Garlic Snail, *Oxychilus cellarius* (Muller). It, too, is recorded from all the southern States, but is not very common. This species and its close relative *Oxychilus alliarius* (Muller) are both called Garlic Snails because, when confined in a tube for a while, they give off a distinct smell of garlic. This is particularly true of *O. alliarius*.

Slugs

Slugs are land molluscs without external shells and are, therefore, more vulnerable to extremes of climatic conditions and to predators. There are only about five or six species of Australian native slug, none of which is common, and each has its own fairly confined distribution range. In comparison the ten species of introduced slugs are common, especially in the southern States, are highly successful and have wide distribution ranges, in many cases embracing every State in Australia.

Perhaps the most obvious of the introduced slugs is the Yellow Slug, *Limax flavus* Linne. This is a large greeny-yellow slug



The small Pointed Snail (*Cochlicella acuta*) is perhaps the most adaptable of all the introduced species.

The large Yellow Slug (*Limax flavus*), which produces sticky yellow mucus, is one of the more unpleasant of the introduced species.



growing to about 4 inches long and producing thick, viscous, yellow mucus. It is a native of Europe but has been introduced into most parts of the world. It feeds mainly on decaying material and likes damp places. It is frequently found associated with sinks and drainage systems and will readily invade houses, especially kitchens. It is less common out in open country, being far more closely associated with man-made structures than many of the introduced species.

Perhaps the most commonly found of the introduced slugs is the Field Slug, *Agriolimax agrestis* (Linne), a small buff-coloured animal about 1 inch long, with brown mottles. This is a very great pest to seedlings and young plants, and is especially hard to keep out because of its small size. These animals can get through unbelievably small cracks. Again, this species is found in most of the southern part of Australia, but, like all the slugs, is confined to the damper parts. It is found commonly in suburban and market gardens and also in improved pasture.

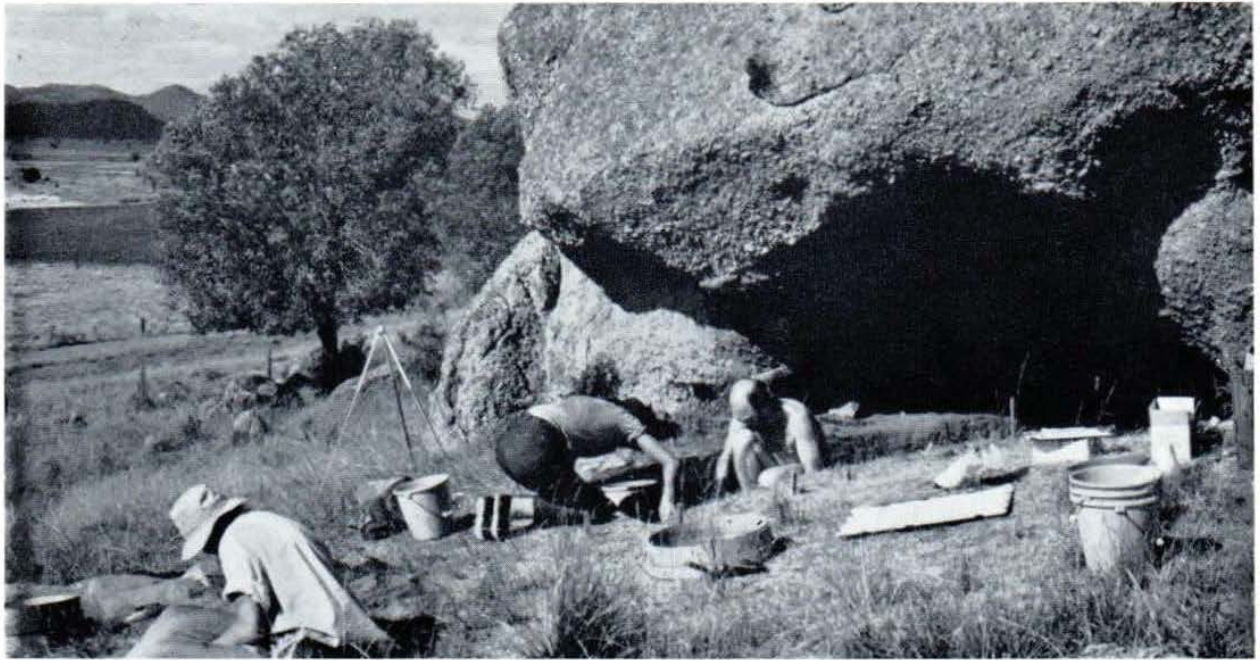
Another small slug, which, in some parts of Australia, is commoner than *A. agrestis*, is the Jet Slug, *Milax gagates* (Draparnaud). This is a black slug, about 1½ to 2 inches long, with a very pronounced keel on its tail. It, too, frequents damp places and in some parts, especially southeastern Australia, is a major pest of garden produce. It is a very voracious feeder and will just as readily take animal food. Like other species, it is native to Britain and central and southern Europe and has been introduced into many countries of the world.

Finally, I would like to say a little about one species of slug from Britain which, although it has been recorded quite a number of times from different parts of Australia, has failed to establish itself and, as far as I know, no instance of it breeding has ever been recorded in Australia. This is the common garden slug of Britain, the Giant Black Slug, *Arion ater* (Linne). This is extremely common in Britain, and I have seen them up to 7 inches long. It has established itself in some places in northern America and I understand that it is also established in some parts of New Zealand. However, for some reason it is not a successful world traveller; although it has undoubtedly been introduced many times into Australia and other countries it has failed to establish itself in most of them. It obviously has not got that certain resiliency and adaptability possessed by the other species that are necessary to be successful at colonizing new lands.

[Photos in this article are by the author.]

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The eastern entrance of the Sandy Hollow rock shelter, showing the alignment of the excavation in a continuous trench along an east-west datum line. The banks of the Goulburn River can be seen (far left) about 200 yards distant. [Photo: G. Moore.]

THE PREHISTORY OF THE HUNTER RIVER VALLEY

By DAVID R. MOORE

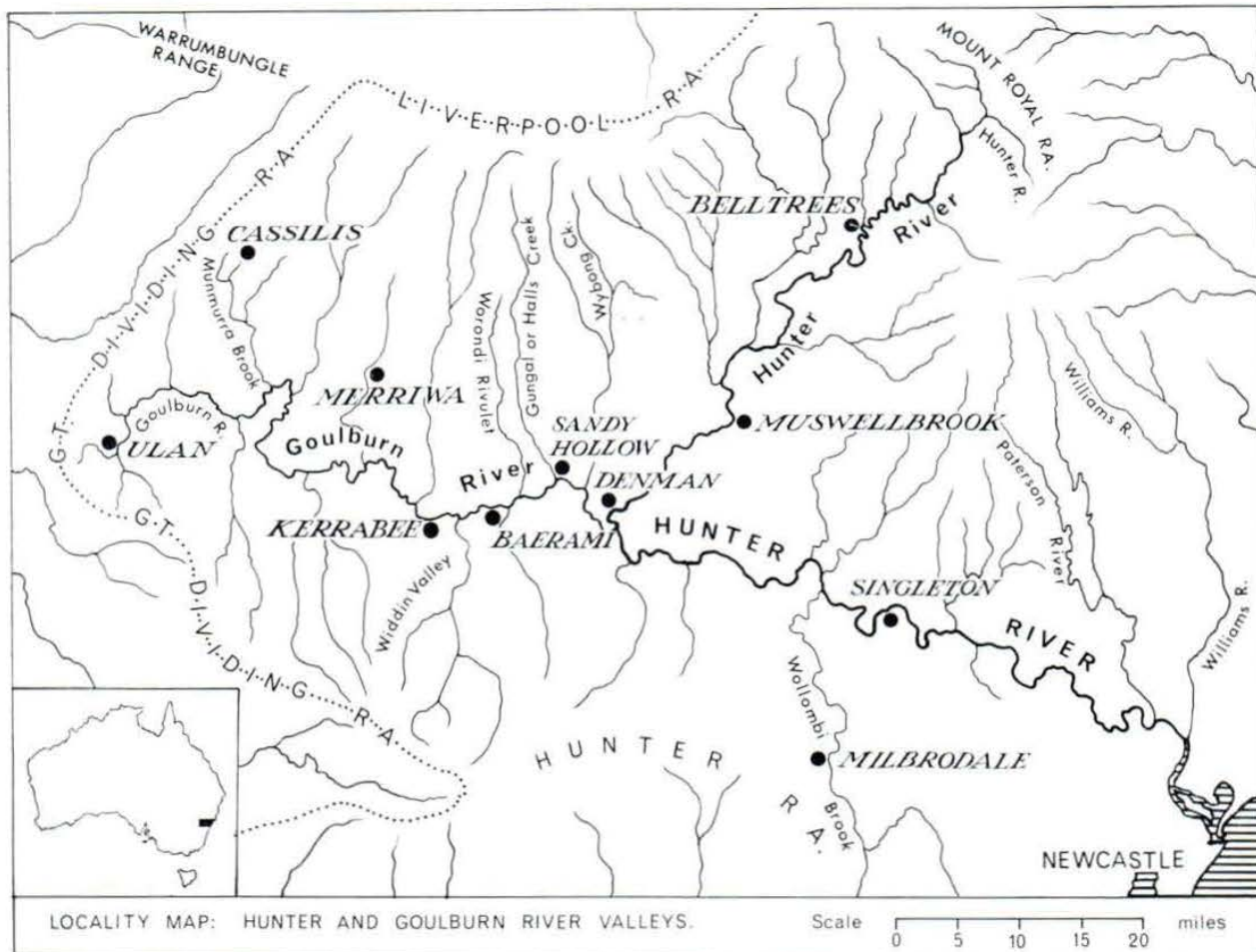
Curator of Anthropology, Australian Museum

THE Hunter River system, 100 miles north of Sydney, New South Wales, contains many fertile and well-watered valleys which, before European occupation, must have been excellent hunting grounds for the Aborigines inhabiting the region. Sir Thomas Mitchell described the valley in 1831 as being park-like, with light forest and grassy glades. With plenty of fish and shellfish in the rivers and creeks, marsupials and birds of many kinds in the open sclerophyll forests, and many species of edible nuts, wild grains, and berries, life should have been pleasant for the tribes as they moved about their territories.

As far as is known, at the time of first contact the tribal divisions were as follows: the upper Hunter, from its source in the Mount Royal Range down to about Muswellbrook, was part of the territory of the

Geawegal; the middle Hunter down to Maitland was inhabited by the Wonarua, who were stated to number about 600 to 700; the Hunter estuary and Port Stephens came in the territory of a numerous tribe called the Gaddhang. The upper Goulburn appears to have been roughly the dividing line between two extensive inland tribes—the Gamilaroi to the north and the Wiradhuri to the south—while south of the Hunter Valley itself were the Awabagal around Lake Macquarie and the Darginung on the northern side of the Hawkesbury.

Unfortunately for us, little interest was taken in the way of life of the Hunter tribes by the early European settlers. Relations with the Aboriginal people seem to have followed the usual pattern—a friendly and inquisitive interest on the part of the Aborigines at the start, rapidly followed by



Map: Elvie Brown.

misunderstandings and clashes as they became aware that their lands were being appropriated, then mounting hostility on both sides, leading inevitably to the collapse and disintegration of the tribal organization. Settlement on the middle Hunter began around Singleton after 1819, and by 1826 the settlers were petitioning Governor Darling for military protection against the attacks and depredations of the Aborigines. Nevertheless, some Aboriginal people appear to have been employed on properties from quite early in the history of settlement.

Since the ethnographic record for the Hunter is so scanty, it is only through archaeological work that we can obtain any idea of the prehistory of the valley or even of the details of the way of life of the Aboriginal inhabitants immediately prior to contact. Although farmers in the valley still occasionally plough up ground-edged axe-heads (known locally as "mogos", after a Wonarua term) and a number of amateur

collectors have searched and raked through the deposits in rock shelters for stone implements, no scientific excavation had been undertaken along the Hunter prior to 1965. In September of that year a systematic archaeological survey of the Hunter and Goulburn Valleys was undertaken by the Australian Museum, with financial support from the Australian Institute of Aboriginal Studies.

It seemed clear from the start, on both geographical and ethnographic grounds, that the area of the Hunter-Goulburn junction, in the vicinity of the town of Denman, was likely to be of archaeological importance since a number of writers, notably A. W. Howitt in his *Native Tribes of South-East Australia* (1904), mention contact, mainly hostile, between the Wonarua and the inland Gamilaroi. The latter reached the valley via the upper waters of the Goulburn and through what is now called the "Cassilis gap"—an easy way through the otherwise

rugged ranges, along the axis Cassilis-Merriwa-Sandy Hollow. It was near the last-named place, in fact, that, after field surveys of the upper Hunter and Goulburn Valleys, the first main excavation was conducted.

Upper Hunter Excavations, 1965-1967

The rock shelter excavated near Sandy Hollow took the form of a cavity in a huge conglomerate boulder, fallen from the scarp and now lying in a sloping paddock, about 200 yards north of the Goulburn River. Within the east entrance artefacts, including Bondi points, microliths, and a large quantity of waste flakes, were found to a depth of about 36 inches. These were mostly made from the excellent yellow chert and red jasper which are still found in the bed of the Goulburn. Outside the overhang were fireplaces formed from natural rocks and river boulders and containing a wide selection of bones and shells, all of which were found to represent species still existing in the area.

It appeared that the interior of the shelter, which contained a flat rock shelf, was probably used for sleeping, the overhang of the east entrance for making implements during rainy periods, and the area in front for cooking. This was probably so that when the prevailing nor'-easter was blowing the smoke did not pour into the shelter. Charcoal from a depth of 24 inches, the horizon most prolific in implements, was carbon dated to approximately A.D. 600 to 700, and a sample from 4 to 6 inches below the top of the deposit returned a date of about A.D. 1,400. Judging by the average rate of build-up of the deposits during the time-span so dated, first occupation of the site might have begun at about the beginning of the Christian era.

After this, the survey was continued downstream in the Singleton area. Here an interesting situation had been reported on in 1943 by F. A. Davidson and F. D. McCarthy, then Curator of Anthropology at the Australian Museum. At a number of points



The beginning of one of the series of trial trenches on the 200-foot terrace at Singleton. In the foreground artefacts can be seen sticking in the underlying clay. The dark longitudinal crack represents the base of the overlying topsoil from which the artefacts erode. [Photo: Author.]

along the 200-foot contour on the low hills bordering the Hunter upstream from Singleton considerable quantities of artefacts were eroding out of the soil during times of heavy rain. Many of these artefacts had been collected and analysed. On examination, they seemed to resemble closely the assemblage we had just excavated at Sandy Hollow, but also included a range of somewhat larger implements made from a pinkish quartzite.

On examining the terraces above Singleton in 1966, it was found that the same situation continued, whereas no trace of Aboriginal occupation could be found on the lower terraces, nor along the banks of the Hunter itself. Several series of trial trenches were dug at points on the 200-foot contour and a number of artefacts were found in a thin topsoil which lay on the heavy clay composing the body of the terrace. Unfortunately, no datable material was associated and it appeared that the artefacts might well have been mixed up and accumulated by wind and water erosion of the light soil prior to the establishment of grass cover by farmers.

It was puzzling that the Aborigines had apparently sat about 100 feet above the river on a windy waterless ridge to make implements, but this same situation was found to exist at a great many points along the river up to 10 miles above Singleton. One possible explanation seemed to be that, at the time, a lake had existed in the area and the tool-makers were in fact sitting around its verge, but on examination of the geological literature a more likely explanation emerged. It appears that this particular terrace contains the relics of a decomposed layer of basalt, through which the river has downcut. Good cherts tend to occur at the base of basalt horizons, and in fact at one point large outcrops of fine-grained yellow chert were found that appeared to have been split to produce blocks from which implements might have been made. Possibly, then, flaking was carried out at points on the terrace where the raw material was readily available. Although we were unable to find any traces of occupation along the river itself, this is understandable, because any sites which may have existed would certainly have been either swept away or covered with silt by the extensive flooding the valley has suffered during the past 150 years. It is



The painted cave at Milbrodale. This remarkably well-preserved art site is adjacent to the shelter excavated. The hand and weapon "stencils" show much interesting detail. The human figure is most impressive, being about life-size but having arms that extend some 18 feet along a slight ridge. [Photo: Author.]

likely that European clearing of tree cover has greatly accelerated the run-off of water from the valley fringes and increased the frequency and extent of flooding.

The next excavation was of a large sandstone rock shelter above Bulga Creek, near Milbrodale, on the southern fringe of the main valley. This site is not far from a very fine painted shelter. It proved to contain an assemblage very similar to that already obtained at Sandy Hollow. The deposits were comparatively shallow and a maximum depth of only 24 inches was excavated before the underlying rock shelf was reached. Charcoal from this site was subsequently processed and returned dates of approximately A.D. 500 from a depth of 12 inches and about A.D. 1,300 from 6 inches. These dates tallied closely with those from Sandy Hollow.

A comparative excavation on the upper Goulburn

At this point a major problem presented itself. The only scientific excavations previously carried out in the immediate vicinity of the Hunter Valley were a series of rock shelter excavations conducted in 1961-62 by F. D. McCarthy and N. B. Tindale in the Capertee Valley, about 50 miles southwest as the crow flies. McCarthy found an assemblage containing Bondi points and a range of geometric microliths similar to those of the upper Hunter. However, below this was a completely different industry, which was characterized by large flake implements, dentated "saws", and uniface pebble implements; this industry, which was named the Capertian, was dated from approximately 5,500 B.C. to 1,500 B.C. by McCarthy and to 9,000 B.C. by Tindale. The puzzle, then, was why there should be no Capertian material in the Hunter Valley sites and why the occupation appeared to have started so late. An additional problem was that McCarthy, as a result of an earlier excavation at Lapstone Creek, near Penrith, had postulated that the Bondaian had ceased about A.D. 1,000, to be replaced by an industry he named Eloueran, characterized by the ground-edged axe and the substitution of bone points for Bondi points. Yet it

appeared from the Hunter deposits that Bondi points had been in use up till the abandonment of the occupation sites, which was presumably after the establishment of European settlement in the valley.

Before continuing the survey downstream to the estuarine parts of the Hunter system, it was, therefore, decided to find and excavate an occupation site at the western outlet of the Cassilis gap. This area would have been in Gamilaroi territory, but close to the point at which contact with the Wonarua was periodically made. After extensive surveying in the area of Gulgong, Ulan, and Cassilis, a small rock shelter with apparently undisturbed occupation deposit was found on private property close to where the Goulburn River rises on the Divide.

This shelter turned out to be remarkably interesting and productive. The occupation deposits went down to a maximum depth of 48 inches and contained Bondi points and very fine microliths, many made from quartz and rock crystal. A number of bone implements had also survived. Plenty of charcoal remained as a result of innumerable camp-fires and, when processed, produced dates of about A.D. 1,200 from a depth of 6 inches and 5,800 B.C. from 30 inches. This latter is an exceptionally early date for the backed blade and microlith industry repre-

A general view of the main shelter at Milbrodale, with excavation in progress. This shelter stands about 50 feet above the valley floor, up a steep slope. Immediately above it is a second shelter. [Photo: Author.]



sented, so a further sample of charcoal has been submitted for carbon dating, to corroborate it. No material resembling the Capertian was found.

Discussion

It is obviously too early in the Australian Museum's survey to reach any definite conclusions, but a number of tentative points may be made. The consistency of the dates from the Sandy Hollow and Milbrodale sites suggests that possibly the Hunter Valley was occupied much later than the inland slopes of the Great Dividing Range. The pattern of carbon dates beginning to emerge from excavations in various parts of the continent seems to indicate that the original group or groups of Aboriginal people to reach Australia may have arrived somewhere in the northwest or north of the continent at least 20,000 years ago, and probably considerably earlier than that. Subsequently, with natural increase, Aboriginal groups spread slowly, over many millenia, across the continent, progressively occupying the tribal territories to which ultimately they became so closely attached. Obviously, Australia was a totally different continent in the late Pleistocene and early Holocene, and areas that are now prolific in food may in other periods have been unattractive, and vice-versa.

Dates of the order of 9,000 to 14,000 B.C. have been obtained on the western side of the Dividing Range, whereas the earliest sites known on the eastern coastal strip are dated to about 5,000 to 6,000 B.C.* It is conceivable that the Hunter Valley was not, in fact, occupied from the inland through the Dividing Range, which is fairly rugged in the Hunter-Goulburn region, except for the Cassilis gap. If, in imagination, one reforests the area, the routes into the upper Hunter would not be at all obvious. It may be, then, that occupation came from the coast, only after other obviously attractive areas, such as Botany Bay, Port Jackson, Broken Bay, Lake Macquarie, and Port Stephens, had been fully populated. This is something that the results of the extension of the survey to the lower Hunter and Port

* Since this was written, a date of approximately 18,000 B.C. has been obtained from an occupation site on the South Coast of New South Wales.

Stephens may support, if suitable sites can be found that have not been disturbed by amateur collectors and other causes.

On the other hand, it may be that the sites so far excavated in the upper Hunter are not by any means the earliest occupation deposits in the region. Unfortunately, one cannot tell the age of a site until after it has been "dug", nor are occupation sites always obvious, even to the trained eye.

Another problem concerns the time of abandonment of the upper Hunter shelters. All sites found, and this includes both Sandy Hollow and Milbrodale, were scattered with Bondaian material on the surface and there was no indication of any succeeding Eloueran period. Admittedly ground-edged axes were found at 6 inches at Milbrodale and on the upper Goulburn, but so also were Bondi points and microliths. It is impossible to date the actual surface material of deposits, because it almost certainly contains recent charcoal from bushfires, European campfires, and so on. However, the dates from 6 inches at Sandy Hollow and Milbrodale are consistent with the probability that both of these sites were occupied up to or even after European settlement in the Hunter Valley. Otherwise one has to postulate a prehistoric abandonment for no apparent reason. It would seem, therefore, that in the Hunter Valley, at least, Bondi points may have been in use until the disruption of tribal life and the acquisition of European tools.

However, impatient though one may be to find answers to these fascinating puzzles of prehistory, archaeological work is essentially slow and painstaking, so that the solutions to the Hunter Valley problems may not be known until several more years of survey and excavation and analysis have been completed.

FURTHER READING

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- McCarthy, F. D.: *Australian Aboriginal Stone Implements*. Sydney, Australian Museum, 1967. 99 pp.
- Mulvaney, J. D.: *The Prehistory of Australia*. London, Thames and Hudson, in press, 1969.

THE DECEPTIVE SIMPLICITY OF NEMATODES

By W. GRANT INGLIS

Director, South Australian Museum, Adelaide

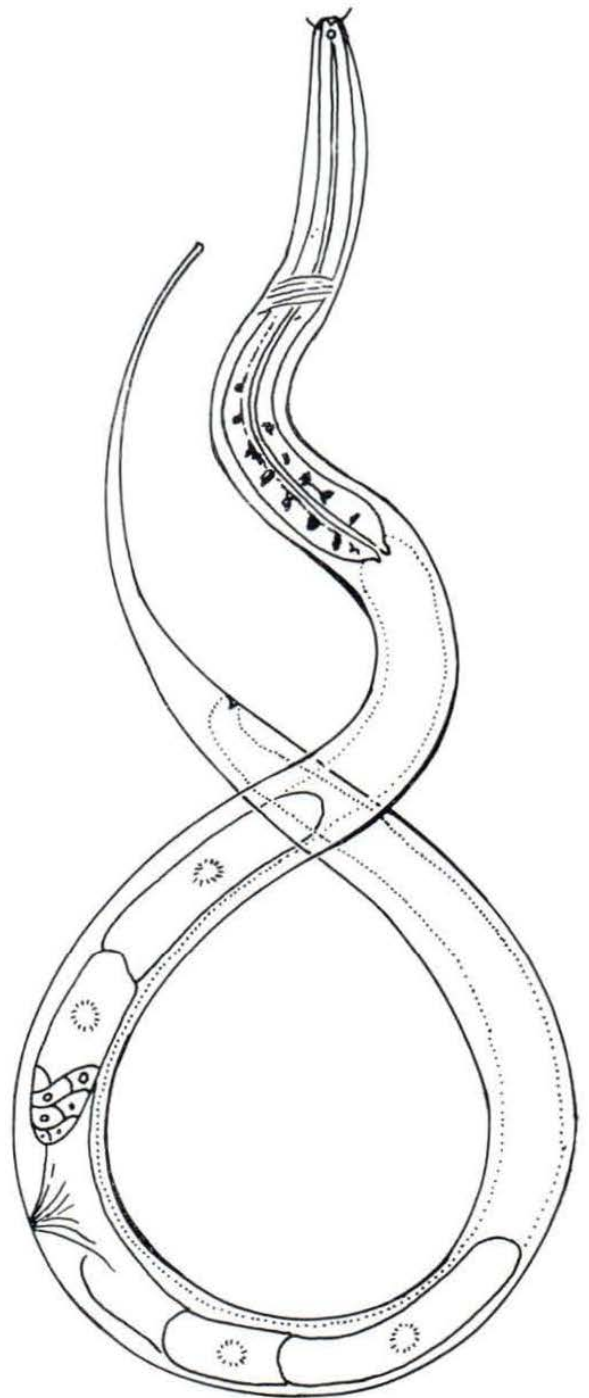
NEMATODES are simple worm-like animals found in very large numbers wherever there are liquid and a surface on which they can move or to which they can attach themselves, even in vinegar or on beer-mats. They are best known as parasites in domestic animals and plants and, as a result, are frequently dismissed as a largely parasitic group of animals. Nothing could be further from the truth. They are found free-living in the sea, on beaches, and in soil and fresh-water. But such free-living forms have been relatively little studied. In spite of this, about 13,000 species of nematodes have been named, of which 6,500 are parasites of vertebrate and invertebrate animals, 3,500 are parasites of plants or live free in soil and fresh-water, and 3,000 are known to occur in the sea or on beaches (totals are approximate). The parasites are well-known but the marine species, in particular, are so poorly studied that in collections I made on the coast of Western Australia most of the fifty species so far studied are new.

In keeping with their numbers, nematodes have many popular and semi-popular names. The worms attacking plants, such as vines, are called Eel-worms, while man can act as a host for a wide range of nematodes. Roundworm, Pinworm, Threadworm, Hookworm, and Guinea Worm are all names applied to nematode parasites of man, while Redworm of horses and Barber's Pole Worm of sheep are also nematodes.

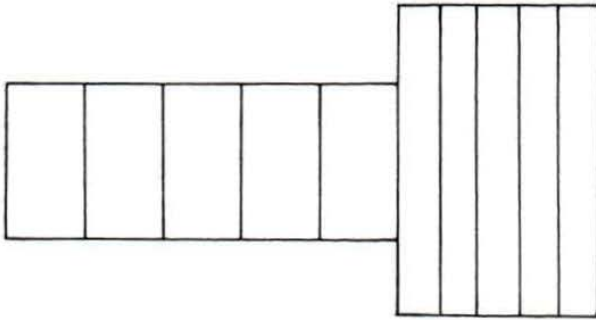
I shall not, however, discuss nematodes as parasites, as Dr E. S. Robinson has done so in *Australian Natural History* (March, 1966), but I shall describe the structural uniformity for which nematodes are notorious and the consequences this has had on their way of life.

Tube inside a tube

Nematodes are all structurally very similar and are typically long, narrow, cylindrical, worm-like animals pointed at both ends.



A typical free-living nematode (female with eggs).



The action of earthworm muscles. The long narrow arrangement at the left is due to the circular muscles contracting, squeezing the body, and lengthening the longitudinal muscles. The stout short arrangement at the right is due to the longitudinal muscles shortening, shortening the body, and lengthening the circular muscles.

They can be pictured as two tubes, one within the other. The inner tube, made up of a single layer of cells, is the gut and has a pumping organ at the anterior end. The gut is separated from the outer tube by a fluid-filled space, which arises during embryonic development as a result of the breakdown of layers of cells. This, for the technically minded, is why nematodes are called pseudo-coelomate.

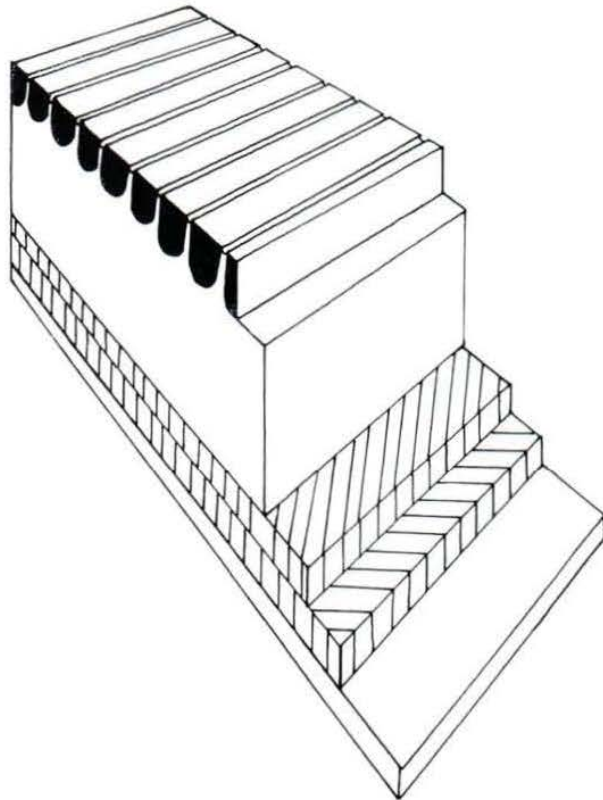
The outer tube is more complicated and has three layers: the innermost, consisting of muscles which run along the body; the middle, a very thin hypodermis which produces the outermost, the cuticle, which in turn covers the external surface of the worm. This, with minor modifications, describes the vast majority of nematodes, although they range in length from one thirty-second of an inch in free-living species to over 16 inches in *Ascaris lumbricoides*, the common parasite of pigs. Why should such a very common, successful, and numerous group of animals be so structurally simple and uniform in spite of this great size range?

To answer this question let us recall that in animals muscles can only contract, or become shorter. If they are to be used again they must be pulled back to their original length by other muscles. To enable muscles to act against each other in this way it is necessary to have some structure of constant length linking each pair. For example, the forearm is lifted up by the biceps shortening and is brought down by the triceps shortening which, at the same time, lengthens the biceps so that it is again ready to lift the arm. Here the muscles are acting against a bone

of constant length which cannot be shortened. If the bone could shorten, the system would not work and we would finish up with both muscles shortened and the upper arm as a whole shortened. This is one reason for having a skeleton.

Hydrostatic skeleton

Similarly, an insect or crayfish uses opposed muscles except that, although the principle is the same, the skeleton is outside the body. A third kind of skeleton is possible, a hydrostatic skeleton in which the incompressible part is a fluid under pressure, such as water or blood or the contents of cells. This kind of skeleton is fairly common and occurs, for example, in jelly-fish and nematodes. A nematode can, therefore, be pictured as a sausage-shaped balloon which remains constant in length and keeps its shape because of the pressure of the liquid in the body cavity.



Section of complex cuticle made up of annules outermost (top of diagram) and cross-spiral fibres innermost. The thick region between is made of a material with the consistency of butter, and the innermost (lowest) thin layer attaches to the body muscles. The annules run round the body.

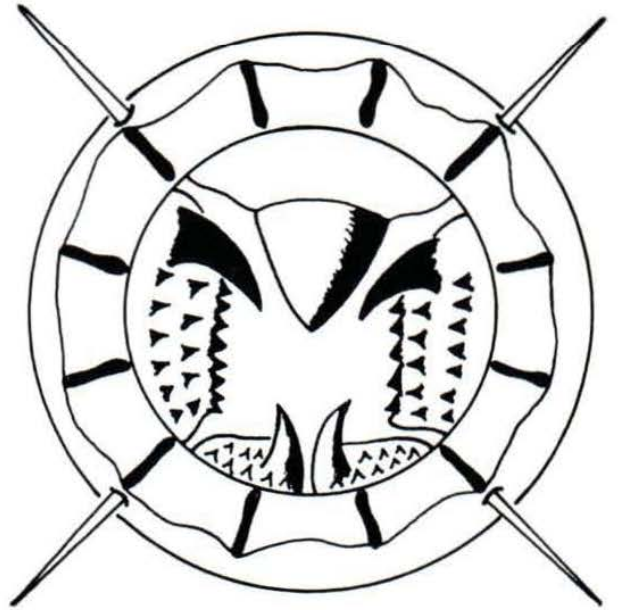
To make this tube-like body move, the muscles which run longitudinally up and down the body contract in blocks to produce a series of S-waves like those of most snakes. In fact, the way in which snakes move has been well studied and the results also apply to nematodes. This explains why, in nematodes, there is only one layer of body muscles; no more are needed. In earthworms, in contrast, there are two layers of muscles, one in which the muscles run up and down the body and one in which the muscles run around the body. Here the muscles of each layer act to lengthen each other by shortening alternately and using their internal body fluids as a hydrostatic skeleton. This explains why earthworms move by becoming thinner, squeezing part of their body forward, then becoming stouter and pulling their tail ends nearer their heads. In nematodes the muscles on opposite sides of the body work against each other, also using the internal pressure as the rigid element or skeleton.

The hydrostatic skeleton explains almost all the structural uniformity of nematodes. The body is cylindrical because this is the most economic way of spreading the internal pressure evenly over the body surface; but this has one inherent mechanical drawback. In any cylinder under internal pressure the tangential stress in the walls is twice the longitudinal. This means that when any closed cylinder—for example, a Scuba air-bottle—explodes under internal pressure a longitudinal split appears and the ends do not blow off (if the construction is sound).

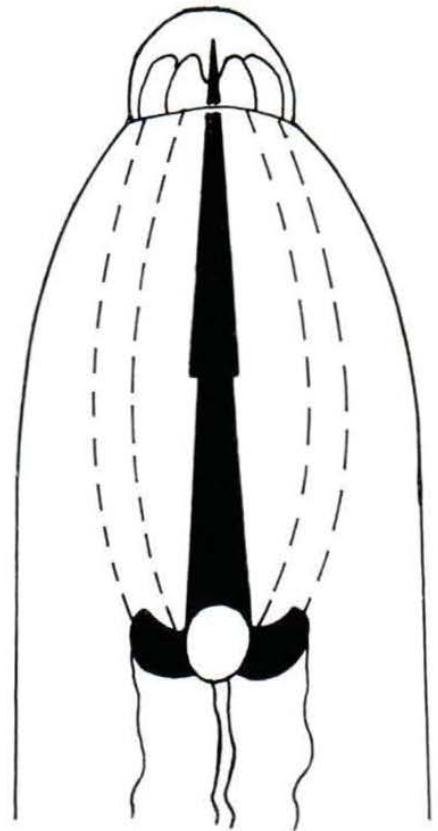
Now the strength of any animal using a hydrostatic skeleton depends on the pressure it can produce within itself; therefore, if the animal is to become stronger this pressure must rise. But in nematodes, although the longitudinal muscles will prevent their ends being blown off if the pressure rises, there are no circular muscles to prevent them splitting longitudinally. This is the responsibility of the cuticle. As a result, the cuticle can be very complicated in large nematodes.

Snake-like movement

An added complication is that because the worms move like snakes the cuticle must be flexible longitudinally. This requirement of strength in one direction with flexibility in another can be met in two ways—by



Heads of two nematodes. Above: *Steineridora* species, looking in to the mouth from the end of the body. The twelve rods support the mouth opening and the four processes are sensory setae. Below: tylenchid species, from the side. This nematode has the well-developed spear, characteristic of nematodes which attack plants.



developing strong rigid rings in the cuticle or by developing a lattice-work of spiral fibres. Both methods have been devised by human engineers for pressure hoses and electric cables and both have been evolved by nematodes to strengthen the cuticle.

With the evolution of a strong elaborate cuticle the problem of cuticle growth arises. This same problem has been solved by insects, crabs, and other arthropods by moulting when the cuticle is cast-off and a larger replacement grown. Nematodes have evolved the same answer to the same problem by moulting four times so that there are four larval stages and a fifth adult stage. The larvae only differ from the adults by being smaller and lacking a reproductive system.

Because of the internal pressure the oesophagus, which leads from the mouth to the intestine, works as a pump to force food into the gut. But this organ operates by opening a central canal by means of a series of radial muscles, so that any food must be brought close to its anterior end and must be in small pieces or liquid to prevent it blocking the oesophagus. The free flow of the food can be ensured by there being a hollow spear, particularly in plant parasites, or a series of teeth at the anterior end of the oesophagus. The number and arrangement of the teeth can be very complicated, particularly in free-living marine species.

Infective stages

There are other, less obvious, non-mechanical consequences of the body design. The moulting means that the life-cycle of any nematode is chopped up into stages. It is, therefore, interesting that the infective stages of all parasitic nematodes (i.e., the time when they attack a plant or enter an animal) occur just before a moult. More accurately, the worm can moult so far and does not complete the change to the next stage until its environment changes, by, for example, being swallowed by some animal. In many cases this occurs at the end of the third larval stage so that the third moult is only completed when the parasite enters a host, or changes its host if there are two in the life-

cycle. Many nematodes can remain in this suspended stage for a long time while waiting for their surroundings to alter.

The importance of the third-stage larva in this way enables us to trace the likely free-living ancestors of the parasites because many free-living rhabditoid nematodes do the same. Such nematodes eat bacteria and live under conditions which are liable to dry up fairly suddenly, such as dung, carrion, or temporary pools, and they have evolved the ability to produce third-stage larvae which are very resistant to drying, extremes of temperature, and other hazards. In some such worms this goes so far that they are unable to complete their development, even if conditions are ideal for survival, without first experiencing, for example, a period of drying or extreme temperature. Here we have a feature which, although common in (and some think characteristic of) parasites, originally had nothing to do with parasitism. This is a very good example of what is called pre-adaptation. Some structure or behaviour pattern is evolved to overcome one set of problems—in this case those of a free-living existence—and later the answer turns out to be very useful in, if not a prerequisite for, life in quite different circumstances—in this case to life as a parasite.

The way in which one part of an animal depends on some other part can be demonstrated with other groups, because such a functional unity is a general feature of organic life. But nematodes supply an excellent example because so many structures, organ systems, and aspects of their general biology can be fitted together as inevitable structural consequences of their functional organization. In addition, their morphological simplicity makes it possible to demonstrate this dependence of one part on another very easily. Nevertheless, this simplicity is only relative when we consider the complications involved in evolving a body as apparently simple as a tube inside a tube.

[The diagrams in this article are by the author.]

MEET OUR CONTRIBUTORS . . .

W. GRANT INGLIS was born and educated in Scotland (B.Sc. and D.Sc., Aberdeen, 1953 and 1965; Ph.D., London, 1958). He was on the staff of the British Museum (Natural History) from 1953 to September, 1968, when he was appointed Director of the South Australian Museum, Adelaide. He was leader of the British Museum (Natural History) East Nepal Expedition, 1961-62, and Honorary Dean of Studies at the Workingmen's College, London, from 1959 to 1964. Dr Inglis is particularly interested in comparative and functional anatomy, theoretical parasitology, and the philosophy of classification.

DAVID R. MOORE, Curator of Anthropology at the Australian Museum since 1965, was educated at Cambridge University and the University of Sydney. He came to Australia in 1949 and was assistant director of two films in which large numbers of Aborigines took part. Subsequently, he was for 5 years assistant editor of the Australian Encyclopaedia, and was appointed research officer in bibliography to the Australian Institute of Aboriginal Studies in 1961. He has taken part in archaeological expeditions to North Queensland and various parts of southeastern Australia. Mr Moore is active in the work of the Australian Institute of Aboriginal Studies, is honorary secretary of both the Anthropological Society of N.S.W. and the Advisory Committee on Aboriginal Relics (N.S.W.), and is a vice-chairman of the Foundation for Aboriginal Affairs. He has been awarded a Churchill Fellowship for 1969, in order to study methods of preserving rock art and museum techniques in Europe and U.S.A.

J. G. MOSLEY is Assistant Director of the Australian Conservation Foundation. Trained as a geographer, he has studied national park problems in several countries. He is well qualified to write about Tasmania since his doctoral thesis presented the results of a 3-year study of recreational land use in that State. Dr Mosley's current major project is an evaluation of Australia's national parks and reserves.

HARRY F. RECHER and JUDY A. RECHER: Dr Harry F. Recher is a product of the United States of America, and was born and raised in New York City. He received his undergraduate training at Syracuse University and his Ph.D. from Stanford

University. After completing his studies at Stanford in 1963, he was a National Institute of Mental Health Postdoctoral Fellow with Dr Robert MacArthur at the University of Pennsylvania and Princeton University. He was appointed a lecturer in biology at the University of Sydney in 1967, and took up his present position as Curator of the Department of Environmental Studies at the Australian Museum in August, 1968. Dr Recher and his wife, Judy A. Recher, also from the U.S.A., have worked together on avian behaviour and ecology in Puerto Rico, on both coasts of the U.S.A., and in Australia. Mrs Recher received her B.Sc. in biology from the San Diego College for Women, California, and was beginning a Ph.D. programme at Stanford University as a National Institute of Mental Health Fellow when she was, as she puts it, "lured away by the greater adventures to be found in the pursuit of sandpipers and herons".

BRIAN J. SMITH is Curator of Invertebrates at the National Museum of Victoria, Melbourne. Before taking up that position he was Lecturer in Zoology at Monash University, Victoria. He is a graduate of the University of Wales, and before coming to Australia worked on the nervous and reproductive physiology of slugs. He is continuing this work in Victoria and is also studying the taxonomy and distribution of land and fresh water molluscs, both native and introduced.

DR JOHN C. YALDWYN, Curator of Crustacea and Coelenterates at the Australian Museum since March, 1962, resigned in December, 1968, to become Senior Scientist at the Dominion Museum, Wellington, New Zealand. A world authority on oceanic shrimps with an extremely broad knowledge of, and interest in, other animal groups, he provided outstanding assistance to many scientists and amateurs throughout Australia and collaborated in biological projects in the Coral Sea, Great Barrier Reef, Gulf of Carpentaria, New Zealand Subantarctic, and eastern Pacific. He played an important part in the first meeting on Australian and New Zealand Decapod Crustacea in 1967, was treasurer of the Australian Marine Sciences Association 1962-1966 and president of the Royal Zoological Society 1964-66. He will continue his research on the shrimp faunas of New Zealand, the Indo-Pacific and southern oceans.



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