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● FRONT COVER: This dance mask from New Ireland represented a deceased person and was used in ceremonials honouring the dead. Such masks often carried the names of particular persons. They are of *tatanua* type, one of several carved forms known popularly as *malanggan* carvings. The head consists of a carved wooden frame, with the face painted in red, white and black and with seashell opercula as eyes. The hair is in three sections: human hair on one side, off-white stringy plant fibres on the other, and a crest of light-brown coconut fibres in the centre. A short piece of bark cloth hangs around the nape of the neck. The height of the mask is about 32 centimetres (about 12½ inches). The mask was purchased in 1884 from Captain Thomas Farrell. Its registered number in the Australian Museum's Anthropology Department is E. 1182. BACK COVER: This X-ray photo of a *Calliaster* starfish was taken at the Australian Museum to ascertain whether X-ray could show the internal structures of starfish. Some of the structures are clearly shown. [Photos by C. V. Turner.]

Koonwarria, a newly discovered teleost fish, probably descended from the archaeomaenids, an extinct Australian fish family.

THE FOSSIL LAKE-FAUNA OF KOONWARRA, VICTORIA

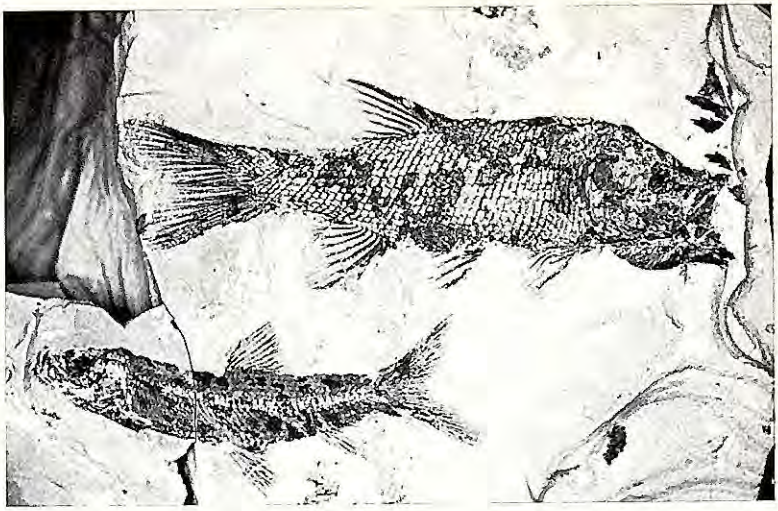
By MICHAEL WALDMAN
Geology Teacher, Stowe School, Buckingham, England

IN 1962 a road-gang straightening a bend in the South Gippsland Highway near Koonwarra, Victoria, removed part of a hillside and, while so doing, found fossil fish. A large collection was made immediately by the University of Melbourne, and in 1965 I began to study the fish and the palaeoecology of the deposit in the Zoology Department of Monash University, Melbourne. The fossils and the rocks in which they were embedded would, I hoped, give all the necessary clues in reconstructing a picture of the original environment. It soon became apparent that more material was needed, and, with the help of a bulldozer and several Monash University zoology undergraduates, a new exposure was made and many more fossils were collected in the succeeding three years. Mr P. M. Duncan, of Morwell, also collected many specimens, which he generously made available for study. Not only were fish found in the deposit, but also many arthropods, plant remains, and three feathers, all in a beautiful state of preservation.

Freshwater deposits

The Koonwarra fish-bed sediments are a part of a great thickness (perhaps as much as 20,000 feet) of freshwater deposits of Cretaceous age which cover several areas of southern Victoria.

At that time, large areas of what is now southeastern Australia were submerged beneath fresh waters. We may imagine this



Wadeichthys (top), a member of the extinct Australian fish family Archaeomaenidae, preserved on the same bedding plane as *Leptolepis* (bottom).

region as having been an area of fairly low-lying land with occasional ranges of hills. The lowlands would have supported very large numbers of streams, rivers, and lakes, and somewhere in this environment the Koonwarra biota lived, died, and was preserved.

Only scanty macro-fossil remains were known in the Victorian Cretaceous before the Koonwarra find. Among these were a dinosaur claw and a lungfish tooth from Cape Paterson, as well as a few molluscs, two partial skeletons of fish, and a turtle, all from western Victoria.

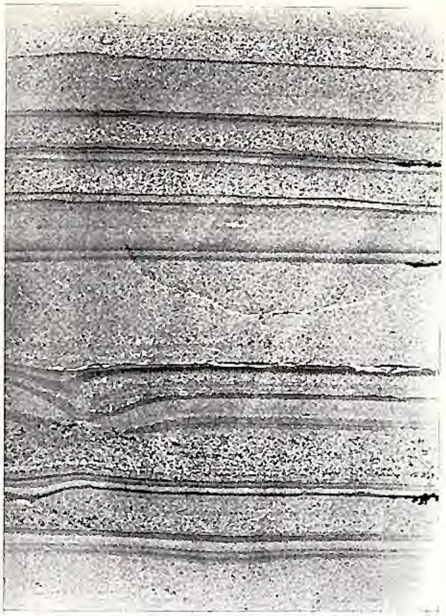
But why is the Koonwarra deposit so exceptional? Why are the rest of the Victorian Cretaceous deposits not filled with fossils of these types? The lack of exposures may have something to do with it, much of this part of Victoria being good farmland without much rock outcrop. A second feature is that finds are often not reported to institutions such as museums and universities. At Koonwarra, for example, we were told of someone finding fossil fish on his property "many years ago" while building a dam, but none of these specimens were ever kept or donated to museums.

Neither of these ideas, however, satisfactorily accounts for the rarity of fossils. For the probable answer, we must examine the nature of the sediment from which the rock was formed. It is generally coarse, sandy material, often showing evidence of having been deposited in river channels or under flood conditions. Such sediments do not preserve fossils well, because the organisms usually disintegrate before being buried, and their fragmentary remains go unnoticed. In such an area, however, there were undoubtedly quiet backwaters, billabongs, and many ponds and lakes of various sizes, all characterized by having comparatively still-water conditions. Sediment would be deposited gently in such areas without much disturbance by flowing water. When an animal died, it would be entombed quietly in the bottom-mud and be covered by more sediment.

Special kind of environment

The Koonwarra deposit, however, represents a fossilized still-water environment of a very special kind. It is made up of very fine-grained particles of silt and clay which have been deposited in thin, paired layers. These pairs of layers are caused by differences in sedimentation during spring-summer and autumn-winter, and are known as varves. They only appear in situations of great stillness of water, usually in deep lakes where they remain undisturbed.

The fauna is usually preserved completely, with fish, insects, and other organisms being found in an undamaged state. This initially seems to tie in with the varves being laid down in deep water. There is, however, strong evidence of mass-mortality, with many organisms being preserved together in the same layer, and this mortality occurs many



Varves from part of the Koonwarra fish-bed. The light, thick bands are those of spring-summer and the dark, thin bands are representative of autumn-winter.

times. In addition, we can tell from their scales that the great majority of the fish are only about one year old. They are buried in the same layers of sediment as complete and undamaged terrestrial insects. Young fish usually live in the shallows, and land insects are usually found in concentration close to the shore of a water-body, so there seems to be a conflict with the deep-water idea, particularly as only a few older fish have been found. There is no trace left in the rock of the mysterious cause of death, but we do know that the dead fish always appear in the very fine-grained part of each layer-pair of sediment. This means that they were always killed off at the same time in each year—that is, during the winter.

There are no geological traces to indicate that the fish-bed ever dried out, and so we cannot use desiccation as a theory to account for the mass-mortality. Besides, this would be much more likely to have occurred in the summer than in the winter.

How, then, can we account for this highly unusual faunal preservation? There are several theories, many of which do not agree with all the geological facts, but one, favoured by the author, that does fulfil all the requirements, is that based on a phenomenon common in cold regions and known as "winterkill".

Paradoxical situation

At Koonwarra we have an apparently paradoxical situation where the evidence seems to point to both shallow and deep water conditions simultaneously. But if we look carefully at the evidence for deep water, we see that it hinges mainly on the presence of the varves and the complete state of the fossils. If we can provide a suitable environment in shallow water to satisfy these factors, then there is no conflict of evidence.

Consider a shallow arm of a lake isolated from the main body of water by a submarine bar or similar obstacle, the whole lying among the foothills of a range in Victoria about 135,000,000 years ago. In the spring, this body of water would be populated with a wide variety of aquatic life, with terrestrial life falling in and being blown in from the land. Spring floods would bring sandy sediment into both main lake and arm, and as summer wore on and the volume of river-flow diminished, the sediment would become finer. With the coming of autumn, this decrease in grain-size would continue, with terrestrial organisms drifting in occasionally, until winter conditions ensued with the eventual freezing over of the lake arm. The ice would effectively isolate the arm and during the winter the oxygen in this ice-topped aquarium would be exhausted, thereby killing all the oxygen-breathing organisms. These would sink down into the bottom-mud to be covered by the last and finest suspended sediment. Next spring the ice would melt, the entombed year-old fish and other aquatic life would be replaced by a live fauna from the main lake as the water-level rose to spring floods, and the whole cycle would then be repeated.

This theory fits all the known geological facts, including the recurrent mass-mortality of the whole aquatic fauna, the presence of varves, the perfect preservation, and the presence of mainly year-old fish in the death-assemblage.

Preserved fish

Among the fish preserved at Koonwarra are: *Ceratodus*, a lungfish much like the modern Australian genus; *Coccolepis*, the last known genus of a group of extinct predatory fish, the palaeoniscoids; and *Leptolepis*, a rather herring-like early teleost. There are also two new genera—*Wadeichthys*, a primitive member of an extinct Australian fish family, the archaeomaenids, and *Koonwarria*, a teleost fish probably derived from the archaeomaenids.

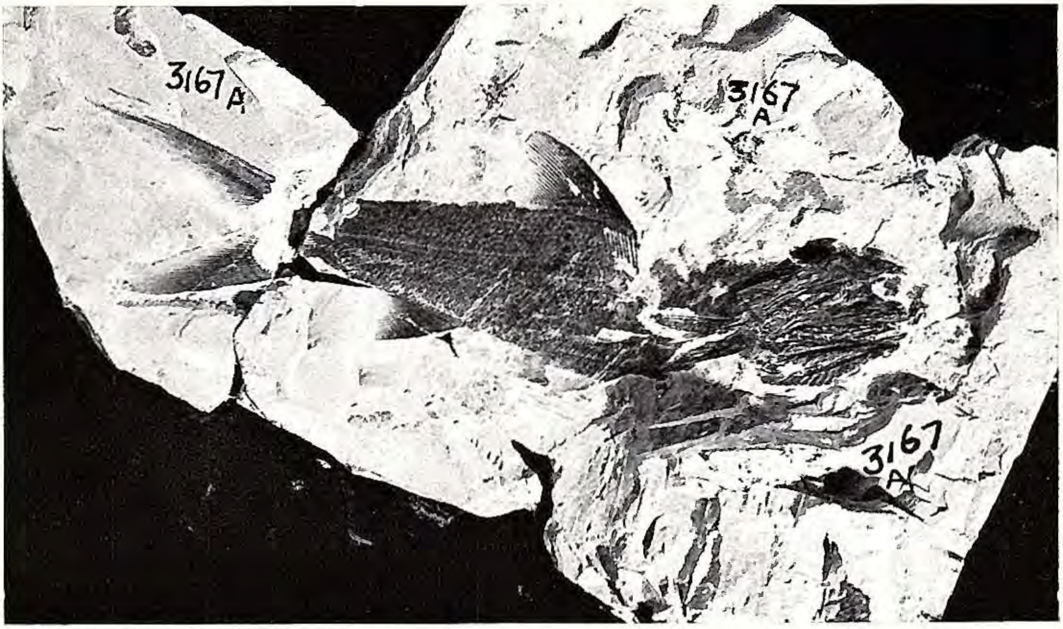
Coccolepis and *Leptolepis* are known in both marine and freshwater deposits of Jurassic and Cretaceous age in the Northern Hemisphere. Possibly these genera resembled some modern fish in being able to live in both salt and fresh waters, or perhaps different species lived in different environments. It must also be remembered that the continents at that time were very close together, probably making aquatic migration very much simpler than at present.

Superbly preserved feathers

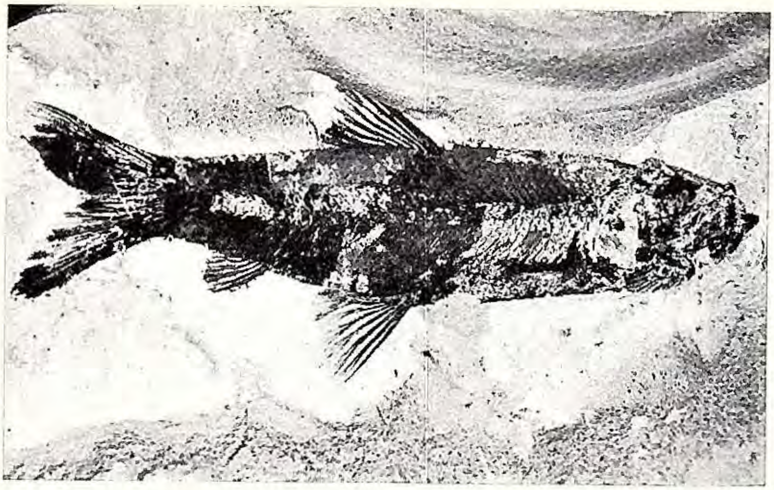
Apart from the fish, the beds are remarkable for other superbly preserved remains. Among these are three feathers, but unfortunately these tell us little about the birds from which they came. There is always the chance of finding a complete bird, however, and this would be very exciting, as we know little of Cretaceous bird-life.

The arthropod fauna is beautifully preserved in the fine layers of the varves, with a wide variety of aquatic and terrestrial forms being represented. These are to be described by E. F. Riek, of the CSIRO. The insect fauna includes mayflies, stoneflies, dragonflies, bugs, beetles, scorpion flies, and also two fleas. The fleas indicate that mammals may have lived in the vicinity of the lake. Lower Cretaceous mammals are extremely rare and are unknown in Australia. It would be a discovery of the greatest importance if such mammals were found at Koonwarra. Many tiny crustaceans (conchostracans and anostracans) are known from the deposit, as well as a limulid arachnoid ("king-crab"), found, incidentally, by two schoolboys out fossil-hunting.

The beds contain a good deal of plant material (to be described by J. G. Douglas, of the Mines Department of Victoria), over thirty species of plants being known from the site. Plants have been of great help in the accurate dating of the Victorian Cretaceous.



A slightly damaged specimen of the palaeoniscoid fish *Coccolepis*. Note the streamlined form and large jaws of this predator.



Leptolepis koonwarri, a species with a herring-like appearance, although probably not on the main line of herring evolution.

The Koonwarra fish-bed is the richest site of Cretaceous freshwater fossils known in the Southern Hemisphere, and it is hoped that other such sites may be discovered elsewhere in Victoria.

[*The photos in this article are by T. Gordon, Department of Zoology, Monash University.*]

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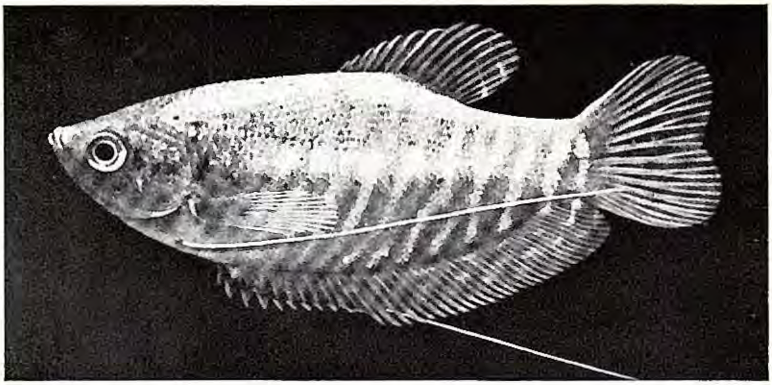
COLOURFUL FIDDLER BEETLE

The Fiddler Beetle (*Eupoecila australasiae*) is one of the Cetoniinae, a group of beetles known as Flower Chafers or Rose Chafers. It is a common diurnal species from eastern Australia, and is often found on *Angophora* flowers, where it feeds on pollen and nectar. Its ground colour is dark brown, almost black in some specimens, and the hieroglyph-like markings are a bright lime-green. Adults can be up to three-quarters of an inch in length. [Photo: Anthony Healy.]



The Snakeskin Gourami (*Trichogaster pectoralis*) has vertical stripes reminiscent of snakeskin. Its colour can change from light to dark grey, depending on the background and the fish's physiological state. The fish can breathe air quite efficiently—an important adaptation in the hot, often oxygen-depleted, water of the paddy-fields. It grows to about 15 cm (about 6 in). [Photo from Sterba, 1962.]

More Rice and Less Fish—Some Problems of the "Green Revolution"

By TIMOTHY P. MOULTON
University of California, Davis, Cal., U.S.A.

THE records are rather vague as to when the Snakeskin Gourami (*Trichogaster pectoralis* Regan) was introduced to the Malay peninsula from Thailand. However, it was in 1921 that the Malayan Department of Fisheries began an intensive campaign of distribution of the fish to many of the wet-paddy areas of the west coast of West Malaysia. In certain areas the fish established themselves very successfully, whereas in others they remained scarce or died out completely.

In the successfully colonized areas, the fish soon became an important feature in the life of the paddy farmer, providing a ready source of food and often a substantial cash income.

The "culture" of *Trichogaster* and the other native paddy-field fish requires a minimum of effort on the part of the farmer. The fish live in the irrigation canals and drains and various retreats during the dry months of the year, from about the end of December until April. At the onset of the rains, *Trichogaster* commence breeding, forming their characteristic bubble nests in the backwaters and deeper areas of the fields. When the fields are inundated by rain and irrigation at the beginning of the planting cycle, the fish enter the fields and grow rapidly on a diet of algae, plankton, and bottom organisms. The breeding potential of the fish is tremendous, and the fields can be stocked by relatively few breeding pairs.

Catching methods

The fish are caught by a variety of methods—by liftnets, casting nets and stake traps in the canals, and by gill nets, traps and sump ponds in the paddy-fields. The bulk of the harvest comes from the sump ponds (or *telaga*), which are sunk at low positions in the fields. The fish move into these ponds at the end of the season when fields are drying out, and are caught by bailing out the pond. The sump ponds also serve as a refuge for the fish during the dry period.

The other fishes which are native to the paddy-fields are: the Snakehead (*Ophiocephalus striatus*), the Catfish (*Clarias batrachus*, *C. macrocephalus*), and the Climbing Perch (*Anabas testudineus*). The total production of these species is, however, less than half that of *Trichogaster*.

One of the earliest colonized and most productive regions is the Krian district of northern Perak. It appears that in this area the peak production of paddy-field fish occurred during the time in which the area was being cleared from the jungle swamp (in the 1930's). As the amount of swampy area decreased and the drainage system became more efficient, the fish had less breeding places and retreats during the dry season, and consequently the population decreased somewhat. Nevertheless, the production remained very high until the past few years. Now, however, the fish are being threatened by modern agricultural practices—the "double cropping" of rice with two seasons a year, and an increase in the use of insecticides and fertilizers.

Survey carried out

To assess the importance of the paddy-field fishery, a survey was carried out in 1971 by the Fisheries Research Institute, Penang, and the Ministry of Agriculture and Lands, Malaysia. The survey recorded the production of fish and rice in single and double-cropping areas, and attempted to place the production of fish in its economic and social perspective. In addition, the effects of double-cropping were observed and the future trends in fish production were estimated. Recommendations were made on the basis of the observations, and in combination with the experimental results obtained at the Fisheries Research Institute, Penang, by the present author.

The survey has shown that, since the introduction of double-cropping and the increased use of insecticides, the production of fish has declined substantially. The production of fish in 1970–71 dropped to about one-third of the previous year's harvest. However, paddy-field fish are still quite important to the diet and economy of the farmers, especially in the areas which are still single-cropped. In fact in certain areas, the economic value of the fish harvest is more than the net return from one crop of rice!

It appears that the life-cycle of the fish is affected to a certain extent by the harvesting of rice twice a year. Under single-cropping the fish had a much longer period in which to grow and multiply while the rice plants were maturing. With the "hundred-day" varieties of fast-growing rice, the growing time of the fish is shortened, and it is not certain that the fingerlings reach maturity in this time. Hence, it is doubly important that the fish have refuges at the end of the growing period, so that immature fish can complete their maturation in the next season. (That is, the youngest generation of fish would not be able to breed until the second season of the life-cycle, although more mature fish could breed every season). Unfortunately, under the present conditions, the fish are subjected to two periods of drainage and harvesting per year, and thus have less chance of surviving to maturity.

The remedy appears simple: deeper sump ponds need to be dug, and the survival of an adequate breeding population assured by control of the harvesting. It may be necessary to restrict the harvesting of the sump ponds to once a year, as in the single-cropping cycle. If this were carried out, the decline in fish population would almost certainly be reversed. Unfortunately, little extension work is being carried out to encourage farmers to improve their methods of fish culture, and no scientific research is being carried out to determine the best solution to the problem.

The problem of insecticides

The problem of insecticides is more complicated, and will be the concern of the rest of this article. First let us note, however, that the effects of double-cropping and insecticides cannot be separated, since the increased use of insecticides is directly associated with the practice of double-cropping. Nonetheless, there is a strong inference that insecticides have contributed significantly to the decline in fish production. Certainly, there have been many instances of large-scale fish kills caused by insecticides.

The major insecticides which are used to control rice-stem borers in Malaysia are BHC (in various formulations, such as "Gammexane", "Dol Granule", etc.) and Thiodan (Endosulfan). Sevin (Carbaryl) and Malathion are used commonly against leaf hoppers in the Krian district, but as these insecticides are relatively non-toxic to fish and non-persistent in the environment they will not be considered here. Cost is a major factor limiting the use of many of the other organophosphate and carbamate insecticides, which are only occasionally applied.

Thus the problem of insecticides and fish resolves itself into a consideration of the

Above: The casting net, or *jala*, is used in canals and drains. The net spreads as it is cast, and folds together, enmeshing the fish, as it is retrieved (*right*).
[Photo: Author.]

first-mentioned chemicals, BHC and Thiodan. The choice of which of the two is to be preferred is quite a dilemma.

Thiodan is ideal in most respects; it is very effective against all species of stem borers, it is relatively non-toxic to species of Hymenoptera which are possible predators on pests, it has a low mammalian toxicity, and it is readily broken down in biological systems and excreted as a non-toxic residue. Unfortunately, however, it happens to be very toxic to fish (median lethal concentration, TLm or $L.C._{50}$, is about 50 parts per billion). This level of toxicity is certainly enough to kill all the fish in a paddy-field to which the insecticide is applied, and has also led to the abuse of the chemical as a fish poison in rivers and canals. (The poisoned fish appear to be quite safe for human consumption).

BHC, on the other hand, is much less toxic to fish, and can be used effectively in granular form at a concentration which does not kill the fish in the paddy-field to which it is applied. It is also quite effective against stem borers, although one species is resistant and cannot be controlled by the insecticide. The mammalian toxicity is similar to that of Thiodan. However, since BHC is more persistent in the physical and biological environment, its effects are likely to be more insidious than those of Thiodan.

It should be noted at this point that, although BHC is a chorinated hydrocarbon, it is not closely related to DDT, and its properties are somewhat different. BHC is less toxic to fish than is DDT, and is also less persistent in the environment. It is not known whether BHC has the same sub-acute effects as those of DDT, but some similarity can be predicted—i.e., the reproduction and viability of fish could be affected.

The persistence of BHC in the environment has led many countries to restrict its use. Japan, for instance, has restricted BHC, although it has been said that BHC gave Japan its self-sufficiency in rice, by controlling stem borer. (It might be noted, however, that Japan is still a leading exporter of BHC to Malaysia).

There is also the problem of the accumulation of insecticide residues in the farmers and other people who eat the fish. Although the levels of insecticide residues in paddy-field fish are relatively high (around

The lift-net, or *tangkol*, is used unbaited in irrigation canals and drains, especially after heavy rains. [Photo: Author.]

The stake trap. The stakes, or *belat*, are set close together across a canal or drain, and fish are guided into the trap, or *tempang*, which is seen at bottom left. [Photo: Author.]

10 to 100 parts per million of BHC and Thiodan in the reproductive tissues of experimentally exposed fish), the danger of acute toxicity to the human consumer is quite small. In the case of Thiodan, the likelihood of chronic effects is diminished by the fact that the residues are metabolised and excreted quite rapidly. The effects of the more persistent BHC residues are largely unknown, and a careful watch should be kept on the health of the Malaysian paddy-farming community, since they are exposed to higher dosages of BHC than are most groups of people in the world.

The obvious question which must be asked is—how important are the insecticides? Opinions vary, and the paddy-farmers are somewhat divided on the issue. The Malaysian Department of Agriculture recommends BHC (in granular form) and more recently Thiodan, to be used as a prophylactic measure against stem borers. It is considered that most of the time the incidence of stem borers is low, but that the insecticide is necessary to guard against outbreaks which could cause total crop failure. It is probable, incidentally, that double-cropping increases the chances of the pest population building up to plague proportions.

In the light of current opinion on the use of broad-spectrum, persistent insecticides, this policy seems rather risky, since the harm done to the ecosystem possibly outweighs the short-term benefits of crop protection. For example, it can be anticipated that severe problems of pest control may occur when a pest species becomes resistant to the insecticide and can multiply unchecked by chemical or biological control.

On the other hand, the importance of the fish harvest must be considered. The net income of a Malaysian paddy-farmer from his rice production is very small, and, in various areas of Krian district, the additional value derived from fish (i.e., from home consumption as well as sales) ranges from 10 per cent to 50 per cent of the income from rice. This was in 1971, when the production of fish had already dropped substantially. In addition, the fish probably benefit the rice plants by recycling some of the nutrients from ingested algae, etc., as well as possibly helping to control some of the insect pests which they eat.

The immediate reaction to this evidence is to think that harmful insecticides should be banned. But the political and social web is too complicated for such a sweeping step. The Malaysian Government is committed to a policy of providing self-sufficiency in rice to the country, even though neighbouring countries have a surplus production, and the high price of Malaysian rice has to be maintained by import restrictions and tariffs.

Furthermore, it is feared, on the one hand, that the necessary double-cropping of rice will interfere with fish production to such an extent that fish will no longer be important anyway, and hence not in need of protection. And on the other hand, total crop failure (due to an epidemic) would be disastrous to the individual farmer.

Thus, it appears that Malaysia is prepared to continue expanding the type of high-production monoculture which has come to be known as the "green revolution". The problems entailed in this practice are well documented in the more developed countries, which are now feeling the ecological consequences of what at first seemed the panacea for man's food requirements. Unfortunately, many of the Malaysian authorities tend to regard a deep concern about the environment as the luxury of a highly-developed economy. This is patently not so, and the uneconomical nature of their policies may be discovered too late to reverse the damaging effects on the environment.

Another aspect of the problem is the importance of the fish as a source of protein. At present, the freshwater fishery accounts for only a small proportion of the total fish production. But as the inshore fishing stocks become depleted, and the offshore fishing becomes more competitive, the freshwater fishery is likely to become more important. Conversely, the importance of rice production in the Krian district is likely to decrease as the new irrigation schemes in the north and northeast come into full operation and produce the bulk of the country's rice. Thus Malaysia is following another trend of the green revolution—that of substituting cereals for animal protein.

It is suggested that the Malaysian Department of Agriculture and Fisheries, or the newly formed MARDI research agency, should investigate the possibility of integrating fish and paddy cultivation in such a way as to maximise the production of the combined harvests, and concomitantly achieve a more balanced ecological system. It might even prove practical to reduce the cropping of rice to one season per year and hence reduce the build-up of large populations of pest species.

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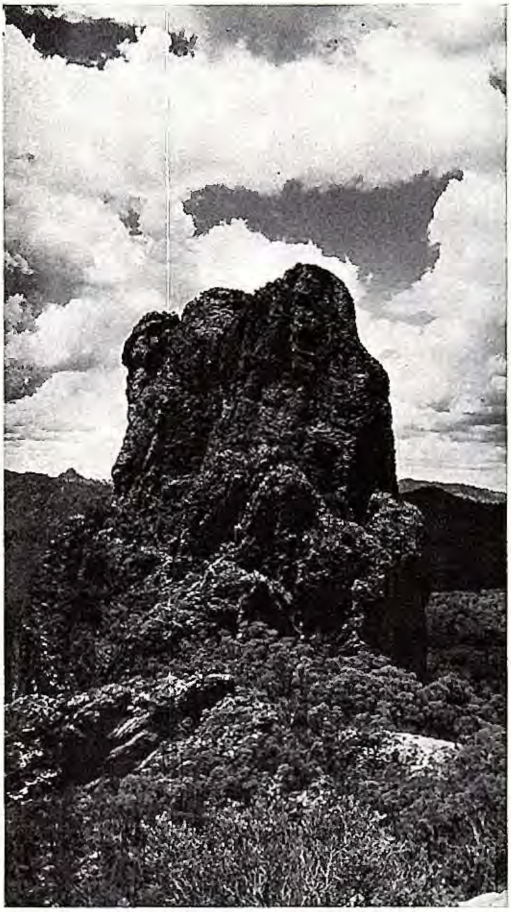
TRACHYTE SPIRE



This volcanic protuberance, Belougery Spire, in the Warrumbungle Mountains, New South Wales, is one of several stumps of trachyte rock that formed where more viscous lava plugged vents and fissures in the basaltic fields of a large shield volcano. Since those eruptions occurred about 13 million years ago, erosion has largely stripped away the softer explosive debris of the cones, leaving the harder upstanding spires of massive rock. [Photo: Anthony Healy.]

The northeastern part of the excavation of the old settlement at Wybalenna, showing room 8's hearth and brick floor. The mound covering the northernmost rooms of the terrace is seen just behind the chair. Miss Anne Bickford is at work in room 7; Miss Bronwen Geering and Mr John Whinray are standing. [Photo: Author.]

Recent Archaeology of Flinders Island

By JUDY BIRMINGHAM
Senior Lecturer in Archaeology, University of Sydney

THE last three years have seen increased interest in the prehistory and archaeology of Flinders Island, Bass Strait, with activity particularly centred upon a site called Wybalenna—a site which did not become historically significant until 1835. The excavation of a site of such recent date may at first seem surprising when current emphasis in Australian archaeology is on the origins and beginnings of man on this continent. Yet the problems of survival in the young colony were no less a question of interplay between man and his environment, although the setting was sociologically more complex and archaeological data about the young colony can usually be supplemented by textual material. Wybalenna illustrates this underlying continuity from prehistory to historical archaeology particularly well.

Wybalenna—"Black Man's Home"

Wybalenna is a promontory on the east coast of Flinders Island, the largest of the 120-odd windswept islands in Bass Strait. Its name was said to mean Black Man's Home, and the grassy headland, dotted with rippling she-oak, was once the scene of a thriving settlement housing nearly 200

A floorboard in situ along the edge of brick flooring of room 8. The scale is 1 metre (1.09 yards). [Photo: Author.]

people—commandant, surgeon, catechist or chaplain, and storekeeper and their families, soldiers, boat crews, convicts (35 in 1838), free settlers, and the Tasmanian Aborigines themselves, for whom the whole venture was planned and who numbered at times over 100.

This settlement was specifically set up to house and protect those native Tasmanians who survived the early years of contact. Its initiator and most notable commandant was George Augustus Robinson, "the conciliator", who, by 1835, when he became commandant, had spent seven years working among the Aborigines, often in extremely arduous circumstances. He stayed at Wybalenna encouraging, educating, and Christianizing his wards until respiratory disease had so reduced their numbers that extinction of the race was inevitable. He himself then left, to work among mainland Aborigines at Port Phillip, Victoria, and the settlement continued in varying circumstances until its forty-four remaining inhabitants were transferred to Oyster Cove, near Hobart.

Flinders Island was selected for the settlement after several other smaller islands had proved unsatisfactory for a permanent home. Robinson was a meticulous diarist, and left abundant papers describing his actions, aims, and ideals, as well as the daily activities of the island community. These included a map of the settlement (1838) with all buildings identified. The site itself, however, remains a significant source of information.

Excavation and survey

The excavation at Wybalenna began as an emergency operation, when brick-salvaging on the site late in 1969 unexpectedly uncovered wall stumps and brick floors of a long row of one-roomed terrace houses obviously of Robinson's time. The bricks were to have been used in the restoration of the chapel nearby, the one surviving building of the settlement period although long since converted into a shearing shed. Further investigation showed that the terrace was that originally built to house the Tasmanians themselves, and systematic excavation began in January 1971. Three rooms (numbered 9, 10, 11 in accordance with Robinson's map) had accidentally been exposed; a further two (7 and 8) to the north of them were excavated in 1971, together with a representative area behind and in front of the houses.

The main terrace walls were of lumps of limestone, with neat brick doorways and thresholds. Each room shared a chimney with its neighbour, and these and the partition walls were also of brick. Floors were partly of brick, partly boarded. Evidence suggests that the central boarded part of the floors was later bricked, but a reference in the Robinson papers suggests the reverse order—that the Tasmanians complained that brick floors hurt their feet, and were given boards. The majority of small finds during excavation came from areas where boards had rotted and beads, shells, and bits of glass and pottery had fallen through to the soft earth beneath. Another area particularly productive of finds was the old ground surface in front of each house, especially around the front door steps. Here were marbles, pipe stems, beads and shells for stringing, and scraps of shell as food debris, and it is not difficult to reconstruct the morning scene at the Aboriginal Terrace and its adjacent open grassy square in 1837 or 1838.

Two of the rooms showed alterations at a later date, one with a subsequent door-blocking, and one (room 7, the most northerly of those excavated and therefore the nearest to the chapel) containing a mass of bone material trodden down into the brick floor—predominantly sheep and cattle bone, and clearly related to the secondary use of the chapel as a shearing shed.

A survey of the whole promontory was also undertaken to check the locations of buildings marked in on Robinson's map. It proved possible to trace all the structures and most of the other features marked—the lagoons where the Aborigines used to take black swans to supplement their less attractive salt beef and mutton, the brick pit, the main north–south track across the west part of the settlement past the store, as well as hospital, gaol, barracks, storehouse and the various officers' quarters. It became clear that the excavation of almost any of these structures in future seasons would yield interesting results for comparison with the rather humble material remains of the Aboriginal terrace.

Historical results

Some of the information gathered from this dig is what may be called historical in the restricted sense. Robinson's statements—about the activities of the Tasmanians, their diet and equipment, and his own concern for their well-being—can be cross-checked, while a variety of additional information is also available. Clay pipe fragments, marbles, glass beads, penknives, and buttons from European clothing bear out in detail his account of the weekly market at which, he hoped, the somewhat bewildered Tasmanians would learn the use of money and the selection of items from European culture with which they passed their time—smoking, playing marbles, playing cricket, sewing, tailoring, and stringing beads.

The houses were extremely well-built, with lime wash over brick and limestone, and carefully made and laid bricks. Glass was found from windows, lead from door fittings, brass door handles and washers, and iron pot-hooks in the fireplaces. Physically there can be no doubt that at least after Robinson's arrival, when the permanent houses were built, no fault could be found with arrangements for the Tasmanians' well-being. At the same time there is no evidence of luxury in their personal possessions, which appear to display strong uniformity from house to house. Iron spoons, knives and pannikins, and a certain amount of mainly blue transfer-printed china, appear to have been standard

A door-blocking of later date in room 8. [Photo: Author.]

issue, together with clothing which was issued with regulation buttons—plain metal with single shank on the men's jackets, and bone with four holes on shirts and linen. Numbers of buttons have been found.

At present work on the finds from the settlement is directed towards identifying their place of origin. Many, like the transfer-printed china, and some at least of the clay pipes, were undoubtedly imported from Britain, but some items may well have been produced in the colony. The gradual building-up of information on trade distribution patterns from Wybalenna as well as other recently excavated nineteenth century sites, like Irrawang and Port Essington, is an important part of the programme.

Renewal of hunting

There is good evidence from Wybalenna that the mixed group of Tasmanians there retained some characteristics of their traditional habits and culture. Some, at least, of the debris around their houses came from traditional food rather than the abundant European diet supplied by the settlement. Large limpet shells, abalone, and turban and cart-rut shells showed the exploitation of the neighbouring rock-platforms, while wallaby and pademelon were also well represented. A few stone and glass flakes were found under floors, and one large round pounder (from an uncertain location in room 9). So far, no evidence of seal bone or mutton birds has been identified, although seal at least was traditionally part of Aboriginal diet, and it is clear, from Robinson's visit to James Monro on his way to the settlement, that some sporadic sealing was still carried out in the islands, if not off Flinders Island itself. *The Flinders Island Chronicle*, the little weekly newspaper written by two literate Tasmanian boys, comments often on the hunting activities of the Aborigines, which usually culminated in the eating of a "kangaroo" (their name for the local wallaby and pademelon), swan, or goose.

This renewal of hunting activity on the island, perhaps the first since the severance of the land bridge to the mainland some 7,000 years previously, could have had little impact on the local environment in comparison with the changes initiated by Europeans.

Robinson aimed at making the settlement self-supporting, and the promontory was gradually cleared, much of it being given over to the cultivation of cereals and vegetables and the grazing of sheep, cattle, and pigs. Livestock was also pastured on the small off-shore islands and brought in by boat as required. Further changes were brought about by lumbering, brick-making, and lime-burning, as well as the cutting and transporting of limestone. One of the few other activities which the Tasmanians could be prevailed upon to do for wages was the cutting of grass for roofing, and it is possible that this was quite extensive. The documentation of these environmental changes in the Furneaux Group, to which Flinders Island belongs, following so long a period of isolation and specialization is itself an aspect of the archaeological study of Wybalenna of as much concern as the typological study of the artefacts dug up.

FURTHER READING

There is not yet a published account of the Wybalenna Settlement, as G. A. Robinson's journals remain unpublished in the Mitchell Library, Sydney. N. J. B. Plomley's *Friendly Mission* is an account of Robinson's work up to 1834, and some material from the later journals can be found in Robert Travers' *The Tasmanians: The Story of a Doomed Race* and Clive Turnbull's *The Black Wars*.

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Lapita Pottery and the Origins of Polynesian Culture

By ROGER GREEN
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THE immediate origins of Polynesian culture have in recent years become identified with certain early sites, from New Britain to Tonga, containing a type of pottery known as Lapita (figure 1). Excavation of these sites in the Tongan, Fijian, New Caledonian, New Hebridean, and Santa Cruz groups and on small islands off the coasts of New Britain and New Ireland has provided data on other items found in association with this distinctive pottery. The outcome has been a slowly developing definition of an associated culture or "cultural complex". The latter term is often preferred, because the assemblage of artefacts recovered from these sites is generally quite varied. It is the Lapita style of finely executed, dentate-stamped motifs on certain pieces of pottery in every site (figs 2 to 5) that has provided the initial link in grouping these materials together.

Lapita pottery is named after an important site in New Caledonia where it was found.

Despite the fact that the discovery of Lapita pottery was initially made in 1908–1909 by Father Otto Meyer, on the island of Watom, in Central Melanesia, it was not until the archaeological recovery of similar pottery from sites in New Caledonia, Fiji, and Tonga between 1947 and 1957 that a basis was laid for the important position it has now assumed in Eastern Melanesian and Polynesian prehistory. In these areas Lapita pottery occurs in one of the early, if not the earliest, cultural horizons which can be identified archaeologically.

As a result of recent radiocarbon dates for a number of sites in the region, several chronological issues have been resolved, and archaeological assemblages with Lapita pottery can now be confidently assigned to a period between 1,000 and 500 B.C., give or take a few hundred years at either end. At the early end, radiocarbon dates of more than 1,000 B.C. are associated with Lapita pottery in Tonga, Fiji, and New Caledonia, for example, indicating a comparable antiquity in each island group. At the other end, the materials recovered by L. M. Groube and Jens Poulsen, of the Australian National University, have shown that somewhere after 500 B.C. in Tonga typical assemblages with Lapita pottery gave way to collections with fewer vessels, less decoration, and new motifs, resulting in a generally plainer and simpler style of pottery. Other changes, all in the Polynesian direction, occurred in the adzes, the shell tools, and the ornaments. In fact, some time after the 1st century A.D. pottery was abandoned altogether in Tonga, but not before derivative cultures with related assemblages of pottery and adzes had been established in Samoa and the Marquesas. On this basis, then, one branch of the cultural complex associated with Lapita pottery leads to Polynesia, and the hypothesis of many archaeologists in the 1959–1963 period that it formed the ancestral cultural complex from which Polynesian culture was derived has been sustained.

All this was not accomplished, of course, without creating numerous problems. In particular, the dating of the Tongan Lapita materials provided a major problem and for a long while the Tonga data appeared out of step with results from Fiji, on the one hand, and Samoa, on the other. Recent work in Tonga has resolved this issue, and the relevant materials have been moved back in time so that they fit reasonably well into the overall picture. Other problems remain. For example, there is some evidence that in Fiji a slightly later cultural complex with its own distinctive paddle-impressed pottery overlapped with the Fijian Lapita. Other data suggested that the makers of Lapita pottery in New Caledonia were not the first people to inhabit that area. To the west the increasingly earlier ages expected for Lapita assemblages in Melanesia failed to eventuate. On the basis of radiocarbon dates alone, in fact, one could maintain that the eastern Melanesia material was earliest, and that

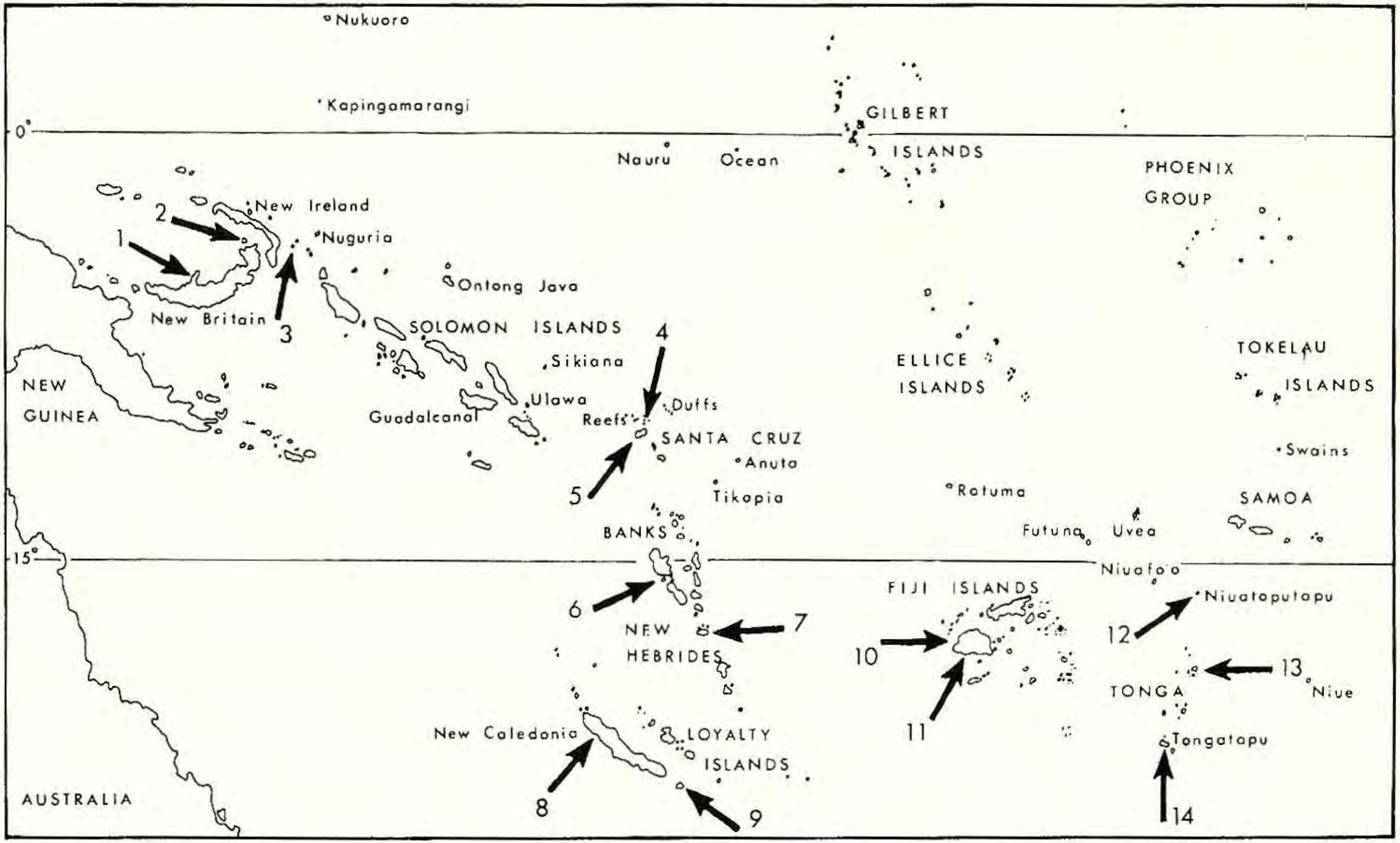

Fig. 1.—Lapita sites and principal workers: 1, Talasea obsidian source, C. Key; 2, Watom Island Site, O. Meyer, J. Specht; 3, Ambitle Island, Feni Group, W. R. Ambrose; 4, Gawa and Lomlom Islands, Reef Group, R. C. Green; 5, Santa Cruz and Te Motu Nöi, R. C. Green; 6, Malo Island, J. D. Hedrick; 7, Erueti, Efate Island, J. Garanger; 8, Site 13, New Caledonia, E. W. Gifford and R. Shutler, Jr; 9, Ile des Pins, J. Golson, C. Smart, D. Frimigacci; 10, Natunuku, Viti Levu, E. Shaw; 11, Yanuca and Sigatoka, Viti Levu, L. and R. Birks; 12, Niuatoputapu, G. Rogers; 13, Vavau and Ha'apai Groups, J. M. Davidson, A. Kaeppeler; 14, Tongatapu, L. and R. Birks, J. Poulsen, L. M. Groube. [Map by C. Phillips.]

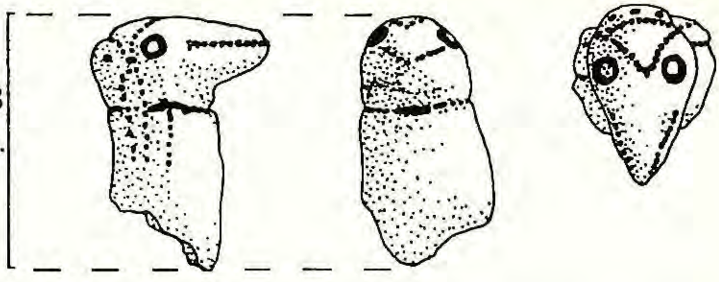

Fig. 2.—A model of a bird's head from Nanggu, Santa Cruz. [Drawing by C. Phillips.]

dispersal had taken place from there to Watom and the New Hebrides, on the one hand, and Polynesia on the other.

In some way interpretations arising solely from the Polynesian and Eastern Melanesian data appeared misleading, and many felt a more Melanesian oriented appraisal was required. This is now being supplied by excavation of materials from the New Hebrides, the Santa Cruz and Reef Islands, and Ambitle Island lying just off the coast of New Ireland. Here materials directly comparable to those early finds first acquired from Watom are coming to light which threaten to alter our notions of the Lapita pottery and its associated cultural complex considerably.

Main Reef-Santa Cruz Island group

My own involvement with Lapita had been indirect and academic when I began fieldwork in the Outer Eastern Islands of the Solomon Islands Protectorate. Thus I was more than a little excited when my first trip to the area resulted in the identification of two Lapita sites, one in the Main Reef Group and the other on the nearby high island of Santa Cruz. These and other sites located since were in an area currently inhabited by non-Austronesian speakers. This appeared important, for whatever views the various theorists have held about Lapita, most have supported the belief that the makers and users of Lapita pottery were Austronesian speakers, whose languages belonged to a subgroup of the Eastern Oceanic languages, which included Polynesian and Fijian. There was a strong temptation to see in this new evidence support for an hypothesis developed from the Fijian data that, contrary to many earlier theories, speakers of non-Austronesian languages had entered the island portion of Melanesia beyond New Guinea after its settlement by Austronesian speakers. In contrast, the archaeological and linguistic evidence from New Guinea suggested that there the non-Austronesians were first by many thousands of years, and the current coastal Austronesian-speaking populations of New Guinea represented a much later intrusion.

Though attractive, the hypothesis of an Austronesian-speaking Lapita population displaced by later non-Austronesian arrivals appeared not quite so simple after excavation and analysis of the sites. Previous studies of such sites had concentrated on the spectacular pottery. Only with analysis of the Tongan material had other aspects of their culture begun to receive attention. As a result, Groube has recently characterized the Lapita people as "Oceanic strandloopers", and expressed doubts about their possession of a fully developed form of Oceanic root and tree crop agriculture and domestic animals, especially the pig. My own efforts were therefore directed at recovering details of the size of the settlements, the post holes of former buildings, pits, fireplaces and ovens, any refuse which reflected the economy, and the sources of the various materials used in the artefacts. Fortunately, these results turned out to be as spectacular as the pottery, which was itself quite satisfying.

Lapita pottery designs have always been thought of as solely geometric and only to a minor degree using incising as a decorative technique. The pottery from these sites turned out to include both dentate stamping and incising as major decorative techniques. It also possessed zoomorphic elements—models of people and birds, drawings of human face masks (figures 2 and 3). Moreover, the range of geometric designs employed was wider than that known from any previous sites. The new materials form an adequate ancestral assemblage for the others and suggest that originally Lapita pottery was far richer in design elements and more elaborate and varied in style than was previously supposed.

The materials in these sites revealed a culture belonging to a people who lived in large settlements, from 1,100 to 14,000 square metres in size, with houses, ovens, and storage pits. The food debris indicated that they exploited the marine environment heavily, but there was hardly sufficient refuse to claim they had subsisted on marine resources alone. Rather, the evidence suggested that the settlements were occupied for some time, while the material culture indicated that vegetable products probably formed a substantial part of the diet. Only in this way can one adequately explain the various shapes of pottery vessels, the ovens, the pits, the stone adzes, and flake tools, all of which could easily have been part of the production, preparation, cooking, or storage of root and tree crops.

More spectacular, however, was the evidence for trade. Imports included obsidian for flake tools from 2,000 kilometres (about 1,333 miles) away in New Britain, from the same source as obsidian used in the much closer Lapita sites on Watom and Ambitle Island. Other imports included either the pottery or the materials for its manufacture, the oven stones, the metamorphic and ultra-basic rocks for adzes, and the chert for flake tools. Distances involved in their transport vary from 42 to 450 kilometres.

What, then, were the exports? Without direct evidence, it is difficult to be sure. But perhaps the building of ocean-going canoes suitable for voyaging over the long distances implied by the trade items, plus the expertise necessary to sail them, would serve as one answer. This is, after all, a not unlikely accomplishment for ancestors of those who explored and settled Polynesia. Moreover, this role is ethnographically attested for the Duff Islanders, latter-day Polynesians in the Outer Eastern Islands, who carried on just such an enterprise up to the beginning of the twentieth century.

Archaeological results comparable to mine were being obtained at the same time from Ambitle Island, of the Feni Group, off the coast of New Ireland, by Mr Wal Ambrose, of the Australian National University. Much of the pottery was very close in style to that in the Reef Islands; the obsidian proved to

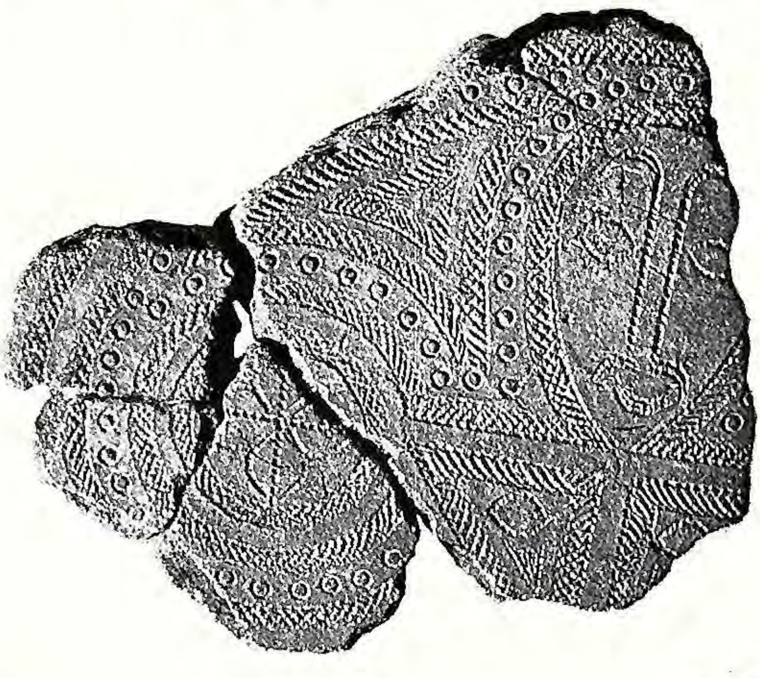

Fig. 3.—A representation of a human face mask on pottery from Nenumbo, Gawa, Reef Islands. [Photo: Cyril Schollum.]

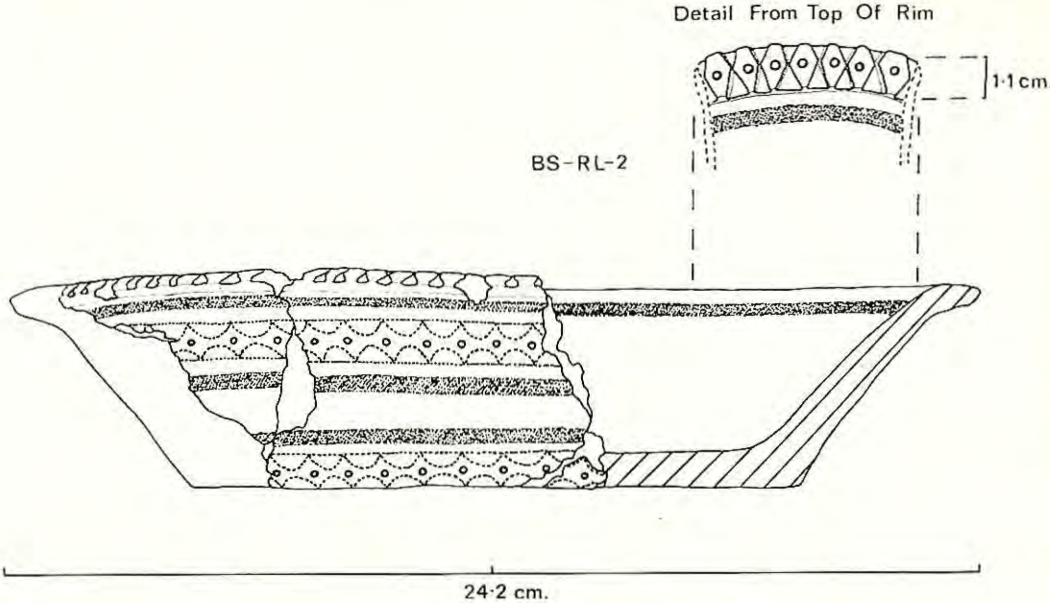

Fig. 4.—A flat-bottomed dish from Nenumbo, Gawa, Reef Islands. [Drawing by C. Phillips.]

be identical. Moreover, the results show that settlements with Lapita pottery in both areas date to a time between 1,000 and 500 B.C., an age range entirely comparable with that of Lapita sites in Eastern Melanesia and Polynesia. What are the implications, then, of this new evidence?

Another view of Lapita

It is notable that in Melanesia more Lapita sites occur on small offshore islands than on the adjacent mainland of the larger islands (figure 1). There is also accumulating evidence from the New Hebrides, New Caledonia, and the Solomons that the main islands of these group were already occupied by people with cultures belonging to other traditions, though Lapita sherds may sometimes occur in such sites, or the pottery from these other traditions in Lapita sites. Could it be that users of Lapita pottery represent a new type of cultural adaptation which rapidly spread throughout Melanesia? Was it their skill as canoe builders, sailors, and navigators that permitted them to take up an existence which led to their settling on these initially less populated offshore islands, or in the less favourable coralline coastal environments of the main islands, where they played a new role in servicing some of the earliest trading networks known from island Melanesia?

Such an hypothesis would explain the known location of Lapita sites in Melanesia and the apparently rapid dispersal of assemblages with Lapita pottery throughout the region. It would also explain the chronological overlap that the Lapita sites of Melanesia exhibit with those belonging to other cultural traditions from Buka to New Caledonia and perhaps even to Fiji. In these islands it appears that those who made and used Lapita pottery were not the first inhabitants; other Austronesians, and as far as Santa Cruz, even non-Austronesians, had probably preceded them. Only when they came to uninhabited islands, perhaps Fiji, almost certainly Tonga, did they have to pioneer a new adaptation. There, in the course of less than 1,000 years, one group could easily have evolved into Polynesians, as the archaeological and linguistic evidence implies.

This hypothesis might also explain why in Melanesia cultural complexes with Lapita pottery gav rise to so few later cultural traditions. After some 500 years, control over the extensive trading systems on which

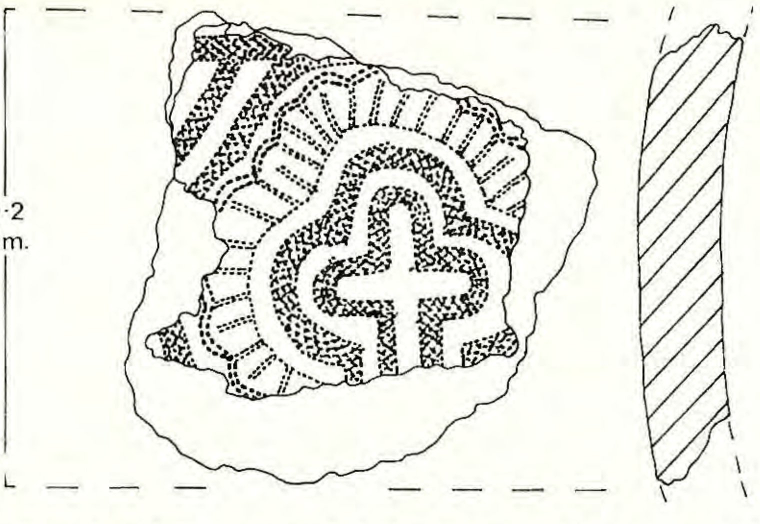

Fig. 5.—A cross motif from Nenumbo, Gawa, Reef Islands. [Drawing by C. Phillips.]

these people depended collapsed and the small populations and their cultures were absorbed into those of their more numerous neighbours. In Tonga and Fiji, on the other hand, where Lapita sites are more common and more widely spread than in the rest of Melanesia, the people with this culture formed the founding populations which prevailed, and in due course gave rise to or influenced new cultural traditions.

It is my view that the background sketched above makes the cultural complexes associated with Lapita pottery in Melanesia an excellent ancestral base from which to derive the earliest cultures of Polynesia. It also explains the cultural role of these early island hoppers in Melanesia, and goes some distance toward explaining why their effect on other cultures in that area was not more profound.

If this hypothesis, with suitable modifications required by additional data, can be sustained, then, strange though it may seem, the newly discovered Lapita sites of Central and Eastern Melanesia will have provided some vital clues in tracing the ancestors of the Polynesians. Unanswered, of course, is the question of the origin of Lapita pottery or the associated items of material culture, much less the race or language of those who made the prototypes from which these materials derive. This is another story, one still buried in the soils of island and mainland southeast Asia, as well as Melanesia.

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Interspecific Relationships Among Fossil Species

By JOHN PICKETT
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IN nature, living things and their environment interact in an incredibly complex yet finely balanced system which has come to be called the ecosystem by modern students of environment. Within the ecosystem there are three directions in which the living and non-living parts of the environment can interact, and these are: organisms may affect other organisms; organisms may affect the non-living environment; the non-living part of the environment may affect organisms. The first of these, known technically as coaction, is the one which will be looked at more closely in this article.

For coaction to occur, the minimum number of organisms required is two, representing the simplest possible and most easily understood situations. The organisms concerned may be individuals, or species, or populations. We propose to look at the different ways in which two species may interact, and to try and discover, from the fossil record, examples of as many as we can of the possible types of coaction pairs.

A member of a coaction pair may be affected in one of three ways: it may be advantaged, disadvantaged, or unaffected. If we represent these three conditions by the symbols +, −, and o, and make a tabulation, we find six possible pairs, as in the following table of coaction pairs and equivalent terms (from Clarke, 1954).

+	+	Mutualism
+	−	Exploitation
+	o	Commensalism
−	−	Competition
−	o	Antibiosis
o	o	Toleration

If we add another vector to this diagram, that of the relative size or strength of the organism (for it is just as possible, for instance, for a man to tread on an ant as for the man to suffer from the sting of the ant), then the number of possibilities is

Fig. 1.—Fossil skeleton of a 15-foot-long specimen of the fish *Xiphactinus*, containing within the rib cage the complete skeleton of a smaller fish, *Gillicus*, which it had devoured just before it died. [Drawing by the author, after a photo.]

increased to nine, as in the following table of coaction pairs with size vector added (after Lawrence, 1971, and Burkholder, 1952).

		smaller, weaker −	smaller, weaker o	smaller, weaker +
larger, stronger	+	− +	o +	+ +
	o	− o	o o	+ o
	−	− −	o −	+ −

−	+	Predation; weak damaged by strong
−	o	Amensalism; strong unaffected while weak suffers
−	−	Synnecrosis; mutual death or depression
o	+	Allotrophy; feeding the other
o	o	Neutrality; neither helped nor hindered
o	−	Allolimy; starving the other
+	+	Symbiosis; mutual aid
+	o	Commensalism; strong unaffected while weak benefits
+	−	Parasitism; weak benefits at strong's expense

While Lawrence's system presents points of view differently from that of Clarke (e.g., the − − situation represents in the one, competition, in the other, "synnecrosis"), it does at least highlight important differences such as that between predation (− +) and parasitism (+ −).

Let us now take a closer look at some associated fossil species, and review their relationship under these headings.

Predation

All animals are dependent on other species, either plant or animal, for their nourishment. Thus it is true to say of all animals, at least, that simple predation exists, even if the object of the predation is a plant species. Occasionally the fossil record yields up a specimen which shows very clearly the predation relationship, or, more simply, the diet of the predator. An ichthyosaur discovered in early Jurassic rocks at Lyme Regis in Dorset, England, for instance, had the stomach contents preserved along with the bones (Pollard, 1968). This was possible because thousands of undigested chitinous hooklets from the tentacles of cuttlefish had accumulated in the stomach. Pollard obtained the figure 478,000 for the number of hooklets in the gastric mass—this from a relatively small animal (the incomplete, fossilized specimen is just 2 feet long, but was possibly twice this size in life).

A very famous example is that of the large fish *Xiphactinus*, which lived in the seas of the late Cretaceous. Figure 1 shows a specimen of *Xiphactinus* from Kansas, U.S.A., which, in its greed, apparently caused its own demise by devouring whole a smaller fish, which proved none the less too large.

Close to home, the Aboriginal kitchen middens of the Sydney district, banks of sub-fossil shells, provide ample evidence of the predation of man. The shells were opened by breaking the postero-ventral corner of each on a stone, inserting a stick in the hole thus made, and prising the two valves of the shell apart. Huge banks of these shells occur at many places along the coast. They are usually dominated by the Sydney Cockle, *Anadara*, and frequently almost all the specimens show breakage of the postero-ventral margin (figure 2).

Although, according to the plan above, the situation (− +) defines predation, and the situation (+ −) parasitism, it is in fact possible for the predator to be somewhat smaller than its prey. Such an instance is afforded by the snails which bore holes in bivalve shells rather larger than themselves in order to get at the fleshy part of the animal. Bored shells like these are occasionally found as fossils.

Amensalism, synnecrosis/competition, allotrophy, neutrality/toleration

These four relationships are grouped because their nature is such that it is well-nigh impossible to find fossil examples to illustrate them. Competition can only be indicated by extreme circumstantial evidence. It is possible, however, to cite an example of the other expression covered by the same symbol

Fig. 2.—Shell of the Sydney Cockle (*Anadara*), from an Aboriginal kitchen midden. The corner of the shell has been broken open to prise the valves apart. [Photo: John Davies.]

(– –), namely, synnecrosis, or a close approximation, which leads to the death of both species. A condition known technically as pernicious epoecy may develop when animals (or plants) living as epizoans on another animal lead to its sickness or death. (Epizoans are animals which live attached, usually to the shell, of another animal, and are generally carried about by it.) Under the heading "commensalism" below, the case of oysters epizoic on ammonites is described. Such a situation eventually leads to the death of the causative agent as well, though this does not occur until after the death and subsequent sinking to the ocean floor of the larger creature.

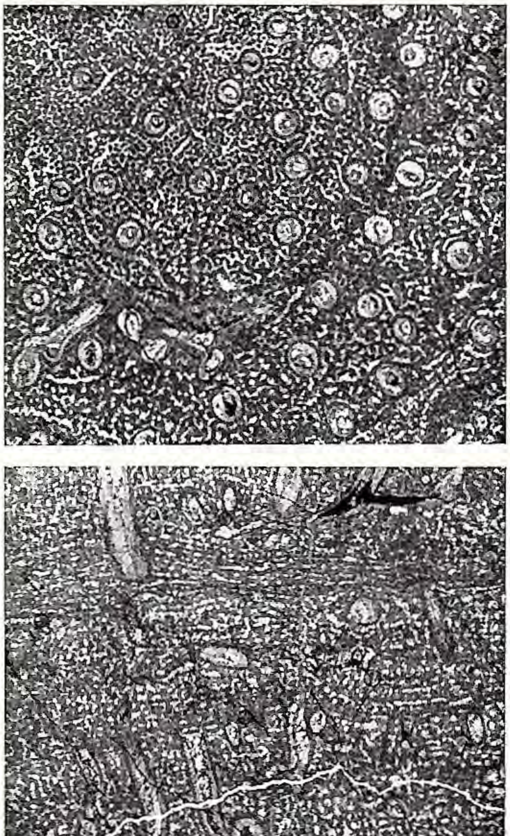


Fig. 3.—Close association of the coral *Syringopora* (vertical tubes) and the stromatoporoid *Stromatopora*, which occupies all the space between the branches of the coral. x $5\frac{1}{2}$. The top photo shows a transverse section, the other a longitudinal section. [Photos: John Davies.]

The relationship called neutrality or toleration is of such negative character that it is difficult to establish, as the situation is very close to having no relationship at all. The mere presence of two creatures in the same locality almost necessitates some kind of interaction, if only for the reason that both take up a certain amount of space.

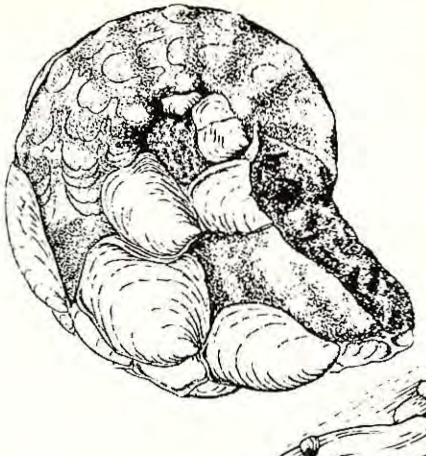
Allolimy, antibiosis

The suppression of one species by passive means is another unusual relationship, and is usually due to the effect of a chemical product of one organism "polluting" the environment for another, to use the current parlance. The famous example of this is the suppression of bacterial growth by chemical products of the penicillin fungus, and hence, of course, the name "antibiotic". A relationship of this type would be extremely difficult to establish in the fossil record, but is occasionally suggested where the attitude of fossil specimens (especially vertebrates) indicates they might have died by poisoning through some external plant or animal agency.

Symbiosis/mutualism

The term "symbiosis" means simply "living together", and in the wider sense, therefore, includes commensalism and parasitism. The term "mutualism" covers only the situation which is of mutual benefit (+ +) to the organisms, though the term "symbiosis" is sometimes loosely used with this meaning only.

The corals which live on present-day tropical reefs contain within their body-tissue tiny plants, unicellular green or yellow-brown algae, called zoochlorellae or zooxanthellae. These live in a truly mutualistic relationship with the coral. The plants, being photosynthetic, produce a diurnal pattern in the activity of the coral polyp which is reflected in the secretion of the skeleton. Although neither soft parts nor symbiotic algae of any fossil coral have ever been discovered, nor are they likely to be, we still have the record of the effect of the algae on corals as old as those from the Devonian and Silurian periods. On exceptionally well-preserved fossil solitary



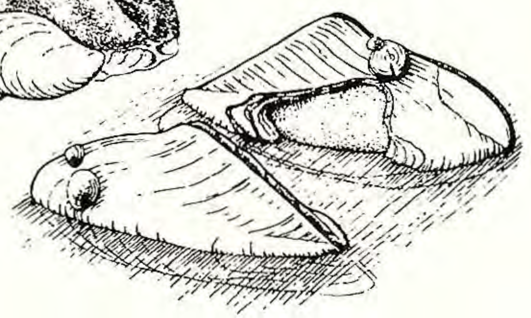


Fig. 4 (top left): Epizoic oysters on the shell of the ammonite *Ceratites*. [From Seilacher]. Fig. 5 (top right): The snail *Cyclonema* in position among the arms (broken off) of the crinoid *Glyptocrinus*. The snail lived permanently in this position and fed on the faeces of the crinoid. [Drawing by the author, after Bowsher.] Fig. 6: Small epizoic brachiopods (*Discinisca*) on the mussel *Gervillia*. The brachiopods are only found on that part of the mussel which is not buried. [From Seilacher.]

corals tiny bands corresponding to the daily growth increments can be observed, thus showing that reef-building corals had associated symbiotic algae even during the Silurian. From a close analysis of the pattern of bands on these corals, Scrutton (1965) was able to infer that for the Middle Devonian, the year was made up of thirteen lunar cycles of approximately 30½ days, indicating that the number of days in the year (397) was greater than at present!

Not uncommonly in Middle Palaeozoic rocks we find two very different kinds of coelenterate animals with limy skeletons growing in intimate association. One of these is always a member of an extinct group called stromatoporoids; the other, one of a number of types of coral. The stromatoporoid is always a species which produced a massive, laminated colony with a fairly smooth surface, while the coral is of a branching colonial species. The coral skeleton is entirely immersed in that of the stromatoporoid, and the growth of the two species is so finely balanced that neither outstrips the other, thus robbing it of much of its food supply. The tabulate coral *Syringopora* is frequently one of this pair; its association with the stromatoporoid is so close that the presence of two kinds of animal in these colonies was not realized for many years, and the compound "animal" was assigned to a special genus, *Caunopora*. It may be argued that in the "*Caunopora*" association the stromatoporoid derived no particular benefit, whereas the coral had protection of its skeleton by the massive stromatoporoid. The fact that *Syringopora* by itself is so common and obviously successful argues against this, however, as does the fine balance of growth rates of the interacting species.

Commensalism

Many examples of this type of association can be quoted from the fossil record. The simplest case occurs when larval stages of one animal settle on the hard shell of another, such as happens when larvae of worms, barnacles, or oysters settle on the shell of other animals. Interpretation of the attitude of such fossil epizoans helps determine the mode of life, as for instance the epizoic brachiopods on the mussel *Gervillia* (figure 6), which are only found on the postero-ventral part of the shell, because much of the remainder was below the level of the sediment/water interface. Not only did the *Gervillia* provide the substrate for the brachiopods, but they probably also benefited from the water currents set up by their host, a suggestion supported by their preference for that part of the shell near the siphons.

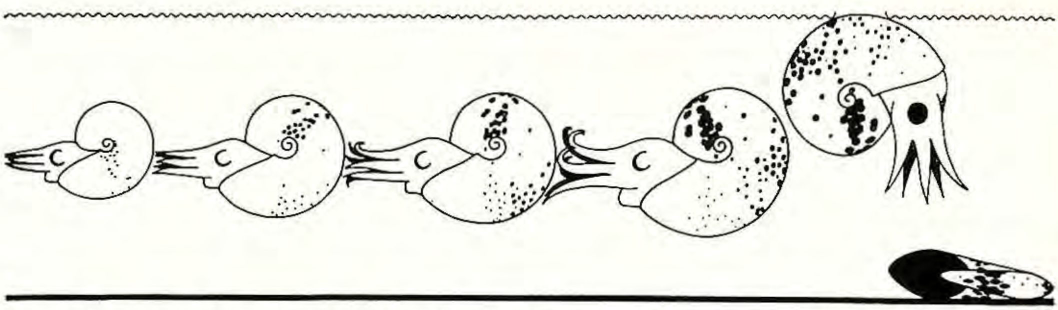


Fig. 7. Epizoic oysters causing the death of the ammonite *Ceratites*. Note the new generations and increasing size of the epizoans. [From Meischner.]

When one animal lives as an epizoan on another in this fashion, the condition is known as epoecy. If the epizoan should, for some reason, develop to such an extent that it interferes with the life functions of its host the situation is called pernicious epoecy. A classical example of this was furnished by Meischner (1968) when he described the effect of an oyster-like bivalve, *Placunopsis*, whose larvae settled on the shells of ammonites (in this case, *Ceratites*). Initially the effect of these is negligible, but as the *Ceratites* grows and succeeding generations of *Placunopsis* (which also grow) settle on the shell, the balancing mechanism of the *Ceratites* can no longer cope with the load of epizoans, and so the animal dies. Figure 7 shows the history of such a *Ceratites*. Thus a situation initially commensal becomes decidedly disadvantageous to the host.

An example of commensalism famous among palaeontologists because of the undesirability of the life situation from an anthropomorphic point of view is that provided by the group of gastropods including *Platyceras* and *Cyclonema*. These snails lived within the circlet of arms of stalked crinoids (sea-lilies), in a position above the anus, and fed on the faeces of the crinoid! (Bowsher 1955). See figure 5.

Two associations of worms with tabulate corals are also well known as fossils. The small favositid coral *Pleurodictyum* frequently has a commensal calcareous worm tube associated with the colony. The nettle-cells of the coral, to which the worm must have been immune, protected it from would-be predators. Similarly, tubes of a much smaller worm, *Chaetosalpinx*, occur between the walls of the common Palaeozoic coral *Favosites*, where the worm enjoyed the same protection from predators as in the previous case.

Parasitism

Parasitism we generally regard as the exploitation of the tissues of the host by the infecting agency, although our code symbol (+ −) includes more possibilities than just this. Because of the infection of the tissues, fossil examples are once again difficult to find. However, we can quote one example of true parasitism, and one of near-parasitism. Figure 9 shows part of the stems of crinoids which have been infected by an unknown agency (probably

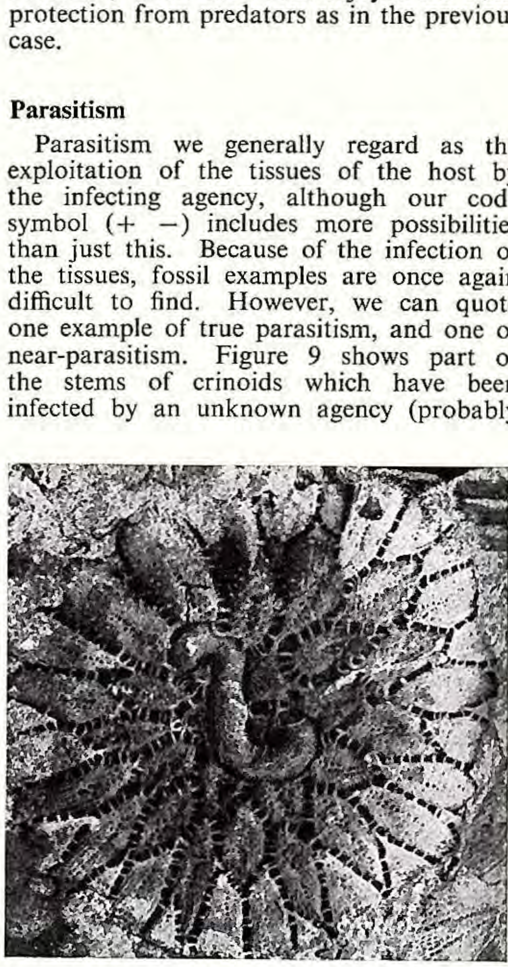


Fig. 8.—The coral *Pleurodictyum* with the tube of the commensal calcareous worm *Hicetes*, from Devonian rocks near Daun, Germany. x 2. [Photo: John Davies.]

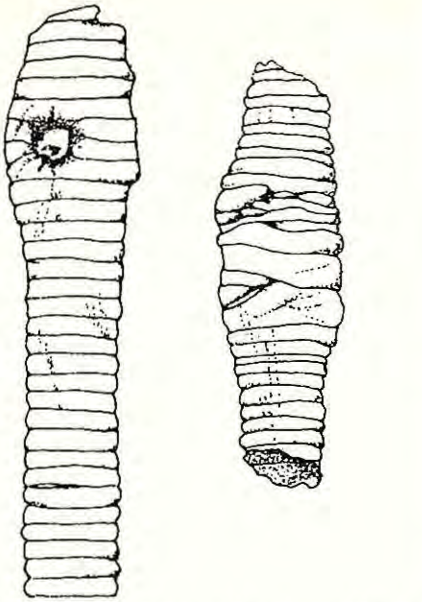


Fig. 9.—Swollen and distorted sections of fossil crinoid stems from Western Australia. Infection by a boring parasite, probably either a worm or a fungus, has caused great irregularity in the normal development of the plates. [Drawings by the author, after Etheridge.]

Fig. 10.—A fragment of the shell of the Permian brachiopod *Ingelarella* from Gerroa, N.S.W. The shell has been partly dissolved with acid, exposing the mud infillings of the tubes formed by a boring organism, probably a clionid sponge. [Photo: John Davies.]

either a small worm or a fungus), causing swelling and distortion where the crinoid has reacted to the presence of the irritant.

A whole family of sponges, the Clionidae, which still survives, characteristically bores extensive chamber systems in the shells of molluscs, to such an extent that the shell may be very much weakened. Although the sponge does not feed on the living tissue of its host, and does not penetrate the innermost layers of the shell (except accidentally, in which case the hole is fairly promptly covered with a new layer of shell substance), the weakened shell no longer provides the protection it did in its unweakened state, and the animal falls an easy prey to other predators. Figure 10 shows borings in the thick shell of a Permian brachiopod. The shell has been dissolved away with acid, revealing the mud which filled the borings and subsequently became hardened to rock.

Relations between living creatures are usually fairly easy to observe and analyse. When we discover that it is possible to demonstrate similar relationships for fossils, then it can truly be said that the study of extinct creatures begins to bring them to life

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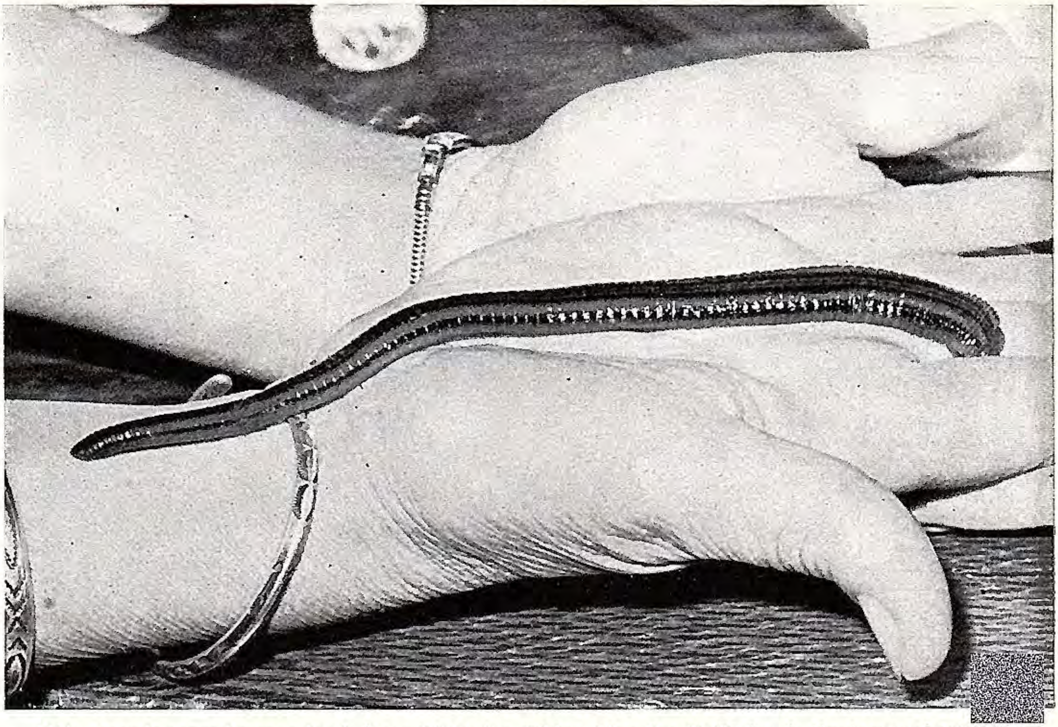


This aquatic sanguivorous leech from Lightning Ridge, New South Wales, is the largest freshwater leech known in the Australian Region. [Displayed alive by A. Elizabeth Richardson. Photo: A. Pepper, Grafton, N.S.W.]

LARGE FRESHWATER LEECH

By LAURENCE R. RICHARDSON
Honorary Associate of the Australian Museum

AN aquatic jawed sanguivorous leech collected by Miss D. Morris, of Grafton, New South Wales, from a dam near Lightning Ridge, N.S.W., was 145 millimetres (5·7 inches) long at rest. Fully extended, it reached a length of 216 millimetres (8.5 inches).

This establishes it as the largest freshwater leech known in the Australian Region. It is the size of the largest aquatic sanguivores elsewhere. These are in the Oriental genus *Poecilobdella*, which has some species up to 210 millimetres in length.

Although recognizable in the first descriptions of Australian leeches which were published in 1859, and illustrated, this large species has not yet been named.

Large as it is, it does not measure up to the largest of known leeches. These are macrophagous. They swallow entire earthworms, leeches, and other soft-bodied invertebrates. Most lack jaws and are terricolous, burrowers in the soil. Some have a close resemblance to earthworms, which is the more marked since the characteristic posterior sucker of the leech may be reduced to a small knob or transverse ridge.

The large terricolous leeches are known only in preserved contracted specimens. Extended lengths are usually estimated, the estimates being approximate at best, and not fully reliable.

Big leeches

One preserved specimen of the terricolous *Kumabdella octonaria* of Japan is recorded as being 270 millimetres (10·6 inches) in length. Fully extended, this species might reach a length of 380 millimetres (15 inches). I recently identified a leech of this species, which is the first time the species has been recognized since 1893.

Some preserved specimens of the terricolous *Americobdella valdiviana* of Chile measure 220 millimetres (8·6 inches). These are estimated as extending, in life, to about 300 millimetres (11·8 inches).

Even the large and common aquatic North American *Mollibdella grandis* has not been reliably measured in life from the largest specimens. It has been briefly referred to as extending to a length of 380 and even 455 millimetres (15 to 18 inches) in Minnesota, U.S.A. Specimens which I collected at Lac aux Rats Musquees, in the Province of Quebec, Canada, extended in life to a length of 255 millimetres (10 inches).

A large terricolous jawed macrophagous leech known in North America is "*Semiscolex*" *terrestris*, which is recorded as 205 millimetres (8 inches) long in the preserved contracted state. This can be estimated to reach a length of some 310 millimetres (12 inches) in life. This species has not been collected since 1890.

Terricolous macrophagous leeches are not yet known in the Australian Region, unless this is the nature of Benham's *Hirudobdella antipodum* of Open Bay Island, off the west coast of the South Island of New Zealand. Benham's account is not fully clear, but it suggests that the leech is terricolous. Benham describes jaws as in sanguivorous leeches, but the pharynx is very long, of a length known only in macrophagous leeches. However, it is a small leech, 50 millimetres (2 inches) extended. It has not been collected since 1904.

Otherwise, the macrophagous leeches in this region are aquatic, mostly small, 50 millimetres (2 inches) or less, extended. There is a larger species in New Zealand, which has an extended length of some 70 millimetres (2·8 inches).

Fish leech

A large marine fish leech in Tasmanian waters, a pontobdellid, is 190 millimetres (7·5 inches) long when preserved and contracted. It might possibly extend to 225 millimetres (10 inches). It is a giant among fish leeches, equalled in size only by *Pontobdella muricata* of the northeast Atlantic. The Tasmanian leech has not yet been identified.

Prospects for other large leeches in the Australian Region exist only among the jawed sanguivorous leeches. Our jawed sanguivores include both aquatic and terrestrial leeches.

The terrestrial leeches, bush leeches, are relatively small in other countries, usually less than 50 millimetres (2 inches) long. *Chtonobdella limbata* of central eastern N.S.W. extends to a length of 85 millimetres (3·2 inches), a size possibly equalled by several large undescribed bush leeches of eastern north Queensland which are known only in preserved contracted specimens.

We now have knowledge of eleven genera of aquatic jawed sanguivores in the Australian Region. The leeches in ten of the genera are medium-sized, reaching a length of some 80 to 110 millimetres (3·1 to 4·4 inches). Larger leeches are known only in the genus *Richardsonianus*, with two species exceeding 120 millimetres (4·7 inches) when extended.

From present indications, the leech from Lightning Ridge belongs to the genus *Richardsonianus*, which contains four and possibly five species. In these, the back is divided by five longitudinal dark bands. There are light contrast colour stripes between these bands.

Controversial descriptions

This genus is based on *Hirudo australis*, a leech from the Murray River, named and described in a paper by Bosisto published in 1859. Immediately following this paper, in the same issue of the same journal, is a paper written by Ludwig Becker. In this, Becker describes and illustrates a leech he refers to only as the "hirudo medicinalis of Australia".

Both papers are brief. The descriptions are given in the classical manner, and provide no more than pattern and colour for the recognition of the animals. There is definite evidence of collaboration between the two authors. From this, it is almost certain that Becker was concerned with a leech supplied to him by Bosisto.

It has been accepted since 1859 that both men were describing the same species of medicinal leech. But the two descriptions differ.

Bosisto refers to his *australis* as the "green leech", describing it as dark-olive to nearly black above, with four bright-yellow longitudinal contrast stripes, and the margins of the body and the venter both a deep ochre yellow.

Becker describes his leech as yellowish-brown above, this being the dominant colour of the contrast stripes, with the venter a "deeper, more rusty hue".

Such a difference in the colour of two leeches otherwise similar in their general external morphology has been acceptable since 1826 as colour variation in the one species. Experience from recent studies with Australian leeches makes this old tradition untenable.

There are now three, possibly four, species of *Richardsonianus* known to me with colours as described by Bosisto.

Another species has the colours of Becker's leech. This has been known to me in a few preserved specimens from the Murray and Murrumbidgee Rivers. Becker's leech still requires a name.

Becker did not use the name *australis*, giving the impression that possibly he considered the leech he described to be distinct from Bosisto's leech. It is doubtful that this is the case. Bosisto was a pharmacist. It was his responsibility to dispense on prescription a leech suitable for medical purposes. Bosisto recognized *australis* to be distinct from, but having the virtues of, the European *Hirudo medicinalis*. For this reason, he provided a new name in a proper form. Becker, a qualified physician, wrote of his leech in the manner in which he would have written a prescription: the hirudo medicinalis of Australia.

The large leech from Lightning Ridge is yellowish-brown above; the margins and the venter are of a slightly deeper hue. It conforms to the colours of the leech described by Becker, and it may well prove to be identical with Becker's leech.

The matter cannot be carried further until the final analysis of speciation in the "*australis*" complex has been completed.

Handsome Caterpillar

The striking caterpillars of the moth *Agarista agricola* (family Agaristidae) feed on the native *Cissus* vines. The caterpillar, found in eastern New South Wales and eastern Queensland, is banded in black and cream, with a bright orange band near the head and another near the end of the abdomen. The head and legs are also red, and the conspicuous spalute hairs are black. The moth is black, with an elaborate and beautiful contrast pattern made up of yellow, cream, red and blue patches. Owing to its habit of flying during the day it is frequently mistaken for a butterfly. [Photo: Anthony Healy.]

NEW BOOKS REVIEWED

BOOKS FOR CHILDREN

"POSSUMS", "KANGAROOS AND WALLABIES", and "KOOKABURRAS AND KINGFISHERS", by Bruce Edwards; THE PLATYPUS", by Bruce Edwards and Barbara Burton; Lansdowne Press, Melbourne, 1972; each book has 38 pages, 16 colour plates, and many black and white photographs and drawings; $1.95 each.

These four books form part of Lansdowne's new Young Nature Library series and are described by the publisher as "a scientific introduction for children from 9 to 13" to the various animals. Each book has a general introduction to the particular group, followed by details of individual animals, and concluding with a short section on conservation.

The books are profusely illustrated with colour and black and white photographs, drawings and reproductions of early engravings. While the colour plates are acceptable, the black and white photographs are poorly reproduced and make it difficult to distinguish particular features, such as, for example, the egg tooth in the two photographs of young kookaburras. It is also difficult, because of lack of contrast, to read many of the captions ov rprinted on the plates.

There are various minor errors which, it is felt, could have been eliminated; for example, Vlamingh did not observe quokkas in 1969 but in 1697, and aquatic is misspelt in the text. More serious, perhaps, is the misleading drawing of a clutch of six platypus eggs, although the caption states the correct number. Do pictures speak louder than words? In each of the mammal books, there is confusion in the use of the terms "animal" and "mammal"; in fact "mammal" is not mentioned at all in the definition of this group.

However, these four books cover the major points adequately and could well form a good introduction for the young naturalist.—*Patricia M. McDonald, Education Officer-in-Charge, The Australian Museum.*

GEOGRAPHY

REGIONAL LANDSCAPES OF AUSTRALIA—FORM, FUNCTION, AND CHANGE, by N. and A. Learmonth; Angus and Robertson, Sydney, 1971; 493 pages; 11 inches by 9 inches; ISBN 0 207 12003 X; price, $15.50.

For some years Griffith Taylor's book *Australia* has been a source of reference for those seeking information about our island-continent. This new book, being more comprehensive, more up-to-date and more attractive to both layman and academic, is certain to replace Taylor's book as a standard reference on the geography of Australia. There is a wealth of factual material here, gathered by two trained geographers from centres as far afield as Cunnamulla and Kununurra and as remote as Papunya and Kalumbury Mission.

Well-written descriptions paint a word picture of the landscape, with a balance between natural and cultural aspects. There is sufficient detail for the interested layman, the inquiring student, and the intending visitor, without the technical jargon characteristic of so many specialized books these days. The approach is traditional but perceptive, with emphasis on the essential features contributing to the distinctiveness of the regions discussed.

There are several other notable features of this book.

Statistical material current to the 1966 census is provided in an appendix. One advantage of this arrangement is its adaptability to later figures without difficulty. Other reference sources, a glossary, a comprehensive general index, and a botanical index complete the appendices.

Ten maps in full colour are admirably presented as an atlas-collection in the centre of the book. An explanatory description accompanies each map. Smaller two-colour maps are provided for each of the fifty-five regions.

Photographs, carefully chosen to illustrate features of general geographic interest, are profuse. The quality of those in black and white is excellent, and while the colour photographs are true-to-life they lack the crisp clarity of those in comparable publications.

A book such as this would be incomplete without presenting one or two minor frustrations for any reader. Mention of place names in the text without showing their location on a map is a common criticism of books on regional geography, and it applies in this case. Coverage of topics is generally good, but emphasis in a few instances seems to have been placed incorrectly. The Great Barrier Reef, for example, is given more coverage than the urban industrial complex of Newcastle.

This book is not a textbook, but will prove a worthwhile acquisition in any library. Its encyclopaedic nature will ensure its regular use over the years as a source of both information and pleasure.—*B. O'Rourke, Senior Tutor in Geography, University of Sydney.*

RESEARCH SEMINAR

THE DOMESTICATION AND EXPLOITATION OF PLANTS AND ANIMALS, edited by Peter J. Ucko and G. W. Dimbleby; Gerald Duckworth, London, 1971; price, $8.05. SBN 7156 0417 1.

This is the paperback edition of the proceedings of the first Research Seminar in Archaeology and Related Subjects held in London in 1968. In content it is identical with the cloth-bound edition of 1969, but in price it is much cheaper and thus more accessible to those for whom it appears to be designed—archaeology students. Fifty papers on a wide range of topics are presented, but to do justice to the overall theme of the seminar the number of contributions should have been double that figure.

Those included in this book reflect a European-Middle East orientation of interest, which is perhaps understandable in view of the quantity of research in those areas. However, this is no excuse for the scant treatment of the Americas or Asia and the Pacific. It is amazing that such important food plants as maize, rice, taro, and the sweet potato receive, at best, token mention, or none at all. New Guinea and the Pacific receive attention only *en passant* in Cranstone's ethnographic survey, while southeast Asia fares no better, even though two decades ago Carl Sauer proposed it as a major "hearth" of domestication, and recent research is justifying his claim. This narrowness of scope is hardly alleviated by the inclusion of one paper on yams to represent the tropical zones of Africa, nor is it justified by Darlington's rejection of the importance of non-cereal crops or non-herd animals.

One expects a research seminar to yield some new ideas or interpretations of existing ideas. Several papers, particularly those by Harris and Flannery, fulfill this expectation, but most do not. There are no in-depth studies of the man-plant and man-animal relationships which we loosely group under the term domestication and this is an astounding omission when we consider how this topic is taxing the minds of many researchers throughout the world. However, it is pleasing to see that non-food aspects of domestication (e.g., draught animals and sheep's wool) were considered worthy of inclusion. Overall, the volume has many interesting papers but is essentially an archaeological reference work. Unless, of course, you really are interested in the history of ferrets, chili peppers, and the baobab tree.—*Jim Specht, Assistant Curator of Anthropology, Australian Museum.*

MEET OUR CONTRIBUTORS . . .

JUDY BIRMINGHAM, born in England, obtained an M.A. degree in Classics at St Andrew's University, Scotland. She later attended the London Institute of Archaeology for four years, specializing in west Asiatic archaeology. Excavations and other fieldwork in Cyprus, Turkey, Palestine, and Persia followed. Miss Birmingham was appointed Senior Lecturer in Archaeology at the University of Sydney in 1961, and later did fieldwork at Zagora, Greece, and West Bengal, India. She developed an interest in Australian historical sites as student training digs, and this led to the establishment of the Australian Society for Historical Archaeology and excavations at the mid-nineteenth century sites of Wybalenna, Tasmania, and Irrawang, New South Wales.

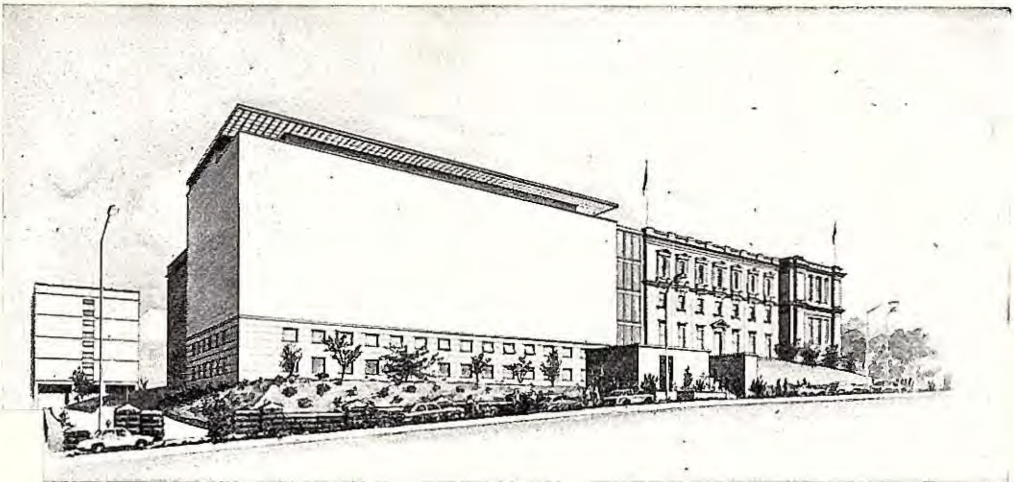
ROGER GREEN, an American, is Professor of Anthropology at Auckland University, New Zealand. He trained in archaeology and anthropology at the University of New Mexico and Harvard University, U.S.A., and came to the Pacific in 1958 on a Fulbright Scholarship. He has taught at the University of Hawaii, U.S.A., and has also been employed by the American Museum of Natural History in New York and the B.P. Bishop Museum in Hawaii. Dr Green was the first James Cook Fellow in New Zealand.

TIMOTHY P. MOULTON graduated B.Sc. (Honours) at the University of Sydney in 1968, majoring in zoology. He spent a year at the CSIRO Division of Fisheries and Oceanography, Cronulla, New South Wales, and then volunteered with the Australian Volunteers Abroad programme, going to West Malaysia. He worked at the Fisheries Research Institute, Penang, for two years on the problem dealt with in his article in this issue. Mr Moulton is now studying for a doctorate at the Division of Environmental Studies, University of California, Davis, U.S.A.

JOHN PICKETT is a Palaeontologist and Principal Research Officer with the New South Wales Geological Survey and an Honorary Associate of the Australian Museum. He holds an M.Sc. from the University of New England, N.S.W., and the doctoral degree of the Goethe University, Frankfurt am Main, West Germany, where he studied from 1962 to 1964. He has published in the fields of biostratigraphy, palaeoecology, and palaeontology, specializing in taxonomy and morphology of fossil corals and sponges.

LAURENCE R. RICHARDSON, M.Sc., Ph.D., F.R.S.N.Z., Honorary Associate of the Australian Museum, has been studying the Australian freshwater and terrestrial leeches since 1964. This was known previously as a limited fauna with few problems of zoological significance. Collections in the northern rivers region in New South Wales produced an entirely unknown fauna. Systematizing this and other Australian leeches required re-study of leeches in other parts of the world. So far, the leech fauna here proves to be distinctively Australian in nature. The studies have been supported by the Nuffield Foundation and the Australian Research Grants Committee. Papers have been published in Australia, Hungary, U.S.A., Canada, England, Japan, and Denmark.

MICHAEL WALDMAN received his undergraduate and graduate education in England (B.Sc. 1963, M.Sc. 1965, University of Bristol) and in Australia (Ph.D. 1969, Monash University). His M.Sc. thesis concerned the dinosaur *Megalosaurus*, and his Australian work involved the study of the Koonwarra fish-bed. From 1968 to 1970, Dr Waldman was research fellow at the National Museum of Natural Sciences, Ottawa, Canada, where he studied Cretaceous vertebrate remains, including a lizard, fish, dinosaurs, and coprolites. He then returned to England, where he now teaches geology and biology at Stowe School, Buckingham, as well as continuing his research into fossil vertebrates.



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