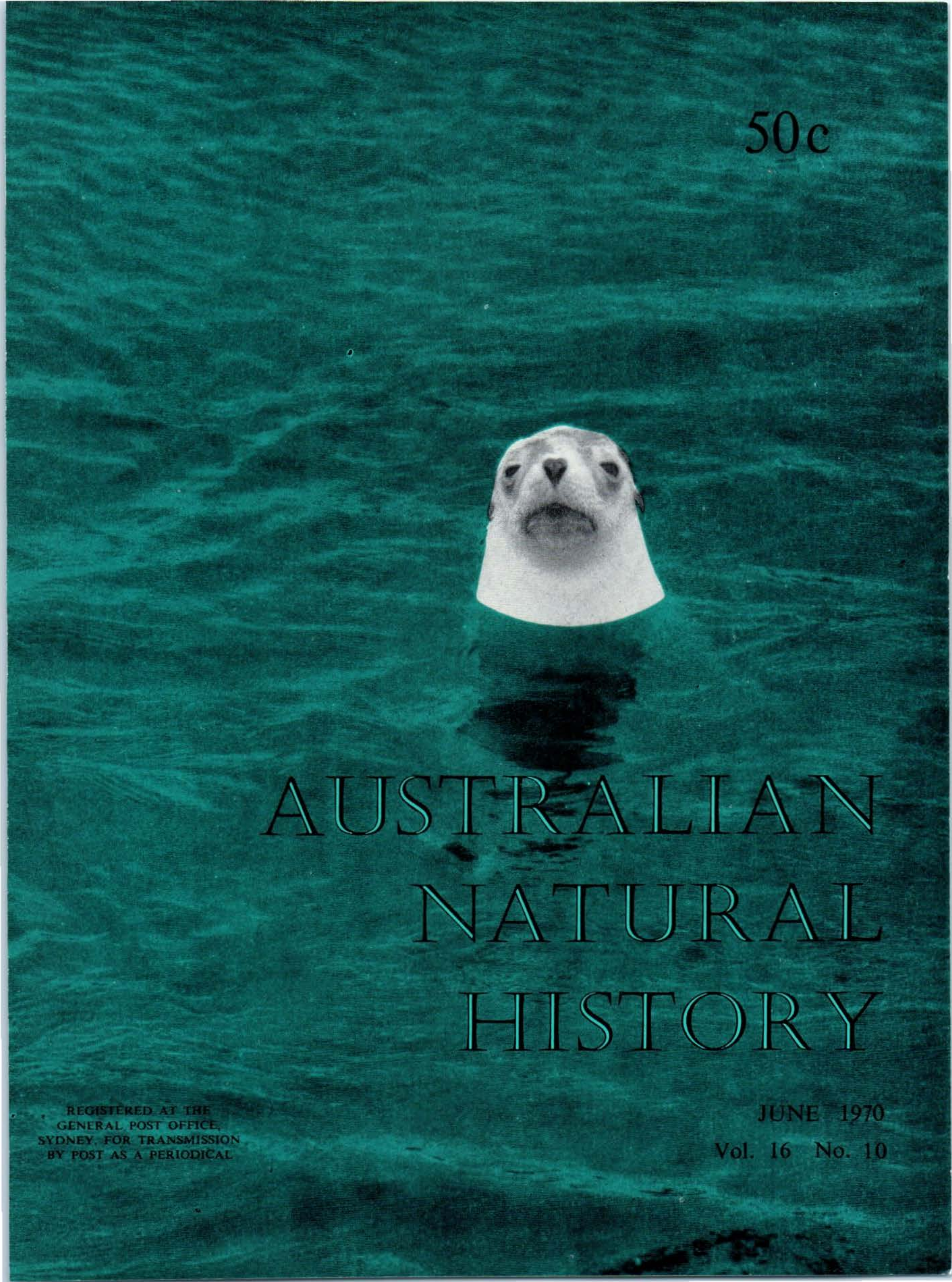

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● FRONT COVER: An Australian Hair Seal or Sea-lion, *Neophoca cinerea*, supports itself vertically in the water while watching the photographer from a safe distance. These sea-lions, which occur only on islands off the coasts of South and Western Australia, are being studied in Spencer Gulf, South Australia, by a research team from the Australian Museum. [Photo: Howard Hughes]. BACK COVER: A house pot from Aibom, Middle Sepik River, north New Guinea. This lively, painted, pottery figure (Registration No. E. 62362 in the Australian Museum's collection) is on exhibition in the Museum's Gallery of Melanesian Art. It was purchased in 1964 by a Museum expedition which collected in the Sepik area. Such figures, always sitting on an inverted pot, are manufactured only at Aibom. The women, as is usual in Melanesia, make the pot itself, but only the men are allowed to make the ancestor figure. The pots are placed on top of the wooden pillars supporting the roof of the house tambaran, or men's cult house. [Photo: C. V. Turner.]

Kinchega National Park, about 75 miles southeast of Broken Hill, surrounds the Menindee Lakes and borders the Darling River. After only 2 years of management by the National Parks and Wildlife Service, during which time stock have been excluded from the park, there is marked regeneration of the native vegetation. The park contains increasing numbers of Red Kangaroos and small populations of Euros and Grey Kangaroos. [Photo: Author.]

THE FUTURE OF WILDLIFE IN AUSTRALIA

By DONALD F. McMICHAEL
Director, National Parks and Wildlife Service of N.S.W.

RECENT years have witnessed a number of events which give heart to those who believe that the survival of our wildlife, and its continued presence in close proximity to our centres of population, are important for one reason or another. Perhaps the most significant have been the growth of the CSIRO's Division of Wildlife Research and its steady expansion of investigations into the biology of native species other than pests. The various State agencies concerned with fauna have also expanded their research effort in recent years, and an increasing number of university investigators have turned their attention to fundamental questions affecting the distribution and abundance of animals and plants in nature. This body of knowledge continues to accumulate and, for the first time, Australians are now in a position to take positive steps for the preservation of at least some wildlife species with a fair degree of certainty that those steps will be effective.

Another significant development of recent years has been the proliferation and growth of organized groups and societies interested in the future of Australian wildlife. There have been seemingly spontaneous awakenings of concern in towns and districts all over Australia, reflected in such bodies as the many fauna and flora conservation societies, the societies for growing Australian plants, field naturalists' clubs, and others with special interests, such as the creation of fauna and flora reserves or the preservation of particular species or environments.

Recent progress

Governments respond to public opinion, and the clearly expressed interest of these Australians has been reflected during the past few years in a renewed activity among the various State and Territorial Governments in the legislative and administrative fields. Almost all the States have made considerable progress during recent years in the permanent reservation of parks and reserves which will help to preserve wildlife habitat. More professionally trained staff are being recruited to lay down guidelines for wildlife management and to select those areas of habitat which should be given reserve status.

In New South Wales, wildlife management commenced in a serious way during the 1940's with the establishment of the Fauna Protection Panel and the appointment of a Chief Guardian of Fauna. The latter post was held with distinction for years by Allen A. Strom, who was able to recruit a small but dedicated staff of field assistants to implement a forward-looking programme of conservation of the wildlife resource. Recognizing that the future abundance of our native plants and animals was not going to be assured by protective legislation alone, but would only be guaranteed by habitat preservation, the Panel set about the establishment of a system of Fauna Reserves (subsequently retitled, more appropriately, Nature Reserves). The Fauna Protection Act allowed the permanent reservation of Crown lands for this purpose, and, once established, such reserved land could only be alienated by act of Parliament. Again recognizing that wildlife habitat in sufficient quantity could not be secured only by the Nature Reserve system, which was virtually limited to available Crown land, the Panel pursued the setting up of an extensive Wildlife Refuge system, under which owners of freehold land voluntarily agreed to retain appropriate areas in their natural state as sanctuaries for wildlife and to manage those areas so that their habitat value would not be lost, but preferably improved. At the same time, field officers of the Panel began a programme of public education in the value of wildlife, and of field surveys to determine the status of plant and animal communities throughout the State as a forerunner to improved management.

National Parks and Wildlife Act

In 1967, the National Parks and Wildlife Act was passed, which set up the National Parks and Wildlife Service and transferred to the Director of National Parks and Wildlife the powers and duties of the Chief Guardian and the Fauna Protection Panel. The decision to amalgamate the National Parks and Wildlife administration, which previously had rested in different Government Departments, was made in recognition of the fact that areas permanently reserved as National Parks were essentially similar to Nature Reserves, in that they preserved large areas of natural environment and thus maintained significant wildlife populations.

The staff of the Fauna Protection Panel were absorbed into the National Parks and Wildlife Service, and action for the conservation of wildlife was strengthened by the addition of specialists in new area selection and management planning. Additional biologists and field officers have also been recruited to strengthen the basic fact-finding effort and new management techniques are being introduced. Mr Strom subsequently returned to the Department of Education to promote the important work of conservation education in the schools, and Mr W. S. Steel, O.B.E., formerly Director of Fisheries and Game for the African State of Zambia, joined the Service as Assistant Director responsible for wildlife matters.

The kangaroo controversy

Perhaps the most controversial aspect of wildlife in Australia today is that of the kangaroo populations of the inland areas, and the various developments outlined above are epitomized by the story of kangaroo management in New South Wales. Apart from the dingo, possibly no other group of animals is so surrounded by a mass of fact and fantasy, emotion, and cold-blooded unconcern as are the kangaroos, yet no other animals are under such intensive management in this State or are more likely to survive as a part of our rural environment.

Kangaroos are the largest marsupials and range widely over the continent. Ignoring the smaller wallabies and paddymelons, the kangaroos include four main species—the Eastern Grey or Forrester, an inhabitant of the coastal forests of south-eastern Australia; the Western Grey, which ranges widely from Western Australia to South Australia; the Euro or Wallaroo, an inhabitant of forested hills and mountain country throughout Australia, and the Red Kangaroo, which lives on the inland plains throughout the continent. In New South Wales, the Euro is reasonably abundant, and its habitat is unlikely to be seriously diminished because of its general unsuitability for other purposes. The Euro is not a significant pest species on rural properties in N.S.W., and is not hunted commercially. The two species which predominate in public thinking are the Red and the Eastern Grey—the most prolific species, most commonly seen, and most frequently giving rise to grievance on the part of the rural community and, consequently, the basis of the kangaroo hunting industry.

Like almost all native mammals in New South Wales, kangaroos are protected by law. In the years up to 1952, the Red Kangaroo and the Eastern Grey were sufficiently common throughout the western division of New South Wales as to warrant the declaration of short "open seasons" in which they could be killed freely, and the annual reduction in their numbers kept the populations overall at reasonable levels. However, the animals which were killed were not utilized for the most part, but simply left to rot where they had fallen. A few professional hunters were licensed to take limited numbers of kangaroos for the skin and fur trade.

Licences replace open seasons

About 1959 the Fauna Protection Panel decided that more precise control over the animals' numbers was desirable, and abandoned the open-season system in favour of the issuing of licences to specific properties whose owners or managers could show that the numbers of kangaroos were so great as to be causing damage to pastures, crops, or other assets, such as fences. These licences, known as Section 25A licences, were issued, theoretically, only when the Panel was convinced that numbers were too great and damage was being done, but lack of sufficient staff meant that a precise assessment could seldom be made. Also, a significant build-up of kangaroo numbers began to take place at that time as a result of good seasons, the proliferation of surface water in the form of farm dams, and the removal of saltbush habitat and its replacement with grasses and succulent ephemerals. Consequently, numerous Section 25A licences

A Red Kangaroo (*Megaleia rufa*) lies dead on the plain, shot as an agricultural pest. The authorities responsible for wildlife management hold the view that kangaroos shot as pests should be used for man's benefit, as a true conservation measure. [Photo: Author.]

for large numbers of kangaroos were soon being issued, and almost overnight a new industry sprang up to utilize the kangaroo resource which was now legally available. This industry was primarily based on the sale of kangaroo meat for use as pet food or for human consumption outside Australia. The hunting was undertaken by licensed kangaroo shooters, who sold the meat and other products to the operators of mobile freezing units, known as "chillers" or "boxes", from where the meat was dispatched to processing plants. Within a few years, the numbers of operators had increased to such levels as could only be maintained by a large and flourishing population of kangaroos. Then came the drought.

With the combined impact of intensive hunting and drought, kangaroo numbers fell away rapidly, and the difference in population size throughout much of New South Wales was obvious, even to the casual observer. Whereas a few years previously kangaroos had been seen in numbers over vast areas of the State, they had now quite suddenly become rare. Public reaction was swift and laid the blame squarely at the feet of the kangaroo meat industry and the Fauna Protection Panel. However, as usual, the emotional reaction of those who feared for the kangaroo's survival was based on a lack of knowledge of the facts about the biology of kangaroos, the attitude of the Panel, the economics of the meat industry, and the impact of the drought.

What in fact happened was that the Fauna Protection Panel began to limit the issuing of licences in New South Wales, the industry began to move into Queensland, where greater stocks were available, and the kangaroo populations continued to decline because of their physiological response to drought conditions. Eventually a rationalization of the industry in New South Wales was agreed upon, in order to stabilize it as a useful tool of wildlife management, and to ensure that economic pressures would not predominate over the interests of conserving kangaroo stocks.

Present situation

The present situation is, it is believed, a happy one for both kangaroos and the meat industry. In the first place, kangaroos are still protected animals, and may only be shot under licence when shown to be too numerous and causing economic loss. The appointment of more field staff in wildlife management, including the stationing of five officers in the western division of the State, will ensure that licences are issued only when the population numbers warrant it. During recent months whole sections of the State have been closed to kangaroo shooting to allow reduced populations to build up again after the drought: this, in fact, is happening. In the second place, the State has been divided into zones for management purposes and only one operator is licensed for each zone, with a limited number of shooters consistent with the numbers of kangaroos which are licensed to be taken. When the numbers of kangaroos increase, the industry can expand by the employment of additional shooters and chiller boxes; if necessary, it can retract again as conditions change.

Inside a modern kangaroo boning-out plant. Here the frozen carcasses of kangaroos are processed for the recovery of meat, skins, and other by-products. [Photo: A. M. Fox.]

A royalty of 10 cents per carcass, paid by the kangaroo dealers, has now been increased. The money so raised is used by the Service to employ research and management staff to better understand and control the population size. A higher royalty also gives the operator an incentive to utilize the product more efficiently. At present, an average-sized kangaroo, if wholly utilized, is worth about $12. By diversifying the usefulness of the carcass by-products, greater stability is ensured to the industry and, again, this leads to more efficient management.

New avenues in the management programme which are currently being explored by the National Parks and Wildlife Service are ways of passing on some of the return on kangaroos shot to the grazier or farmer on whose property they grew; interstate co-operation to ensure that illegal shooting does not take place in border areas; and the establishment of techniques of handling which will allow kangaroo meat to be used for human consumption. It is certain that once kangaroos are regarded by rural property owners as an asset, and not as a pest, then the future of the kangaroo will be just as sure as that of the sheep and the cow.

Apart from the direct management programme outlined above, the Service is progressing with the establishment of significant areas of kangaroo habitat as parks and reserves. At present Kinchega National Park (160,000 acres), near Menindee, and some smaller Nature Reserves on the western slopes and plains are securely preserved, but investigations of several significantly large areas in western New South Wales, currently nearing completion, should soon lead to an adequate system of sanctuaries where our most famous native animals can live undisturbed as a guarantee against any unforseen factors in the management programme elsewhere in the State.

BOOK REVIEW

THE CAMEL IN AUSTRALIA, by T. L. McKnight; Melbourne University Press, 1969; price $4.50; 154 pages.

During the past few years, relatively few monographs have been published, in book form, which deal with the biology of indigenous Australian mammals. These have been devoted mainly to the monotremes and marsupials, while the placental mammals have received scant attention. Introduced mammals in Australia have suffered even further neglect, and it is in consequence very pleasant to find a book devoted specifically to the biology of an important member of the mammal fauna which has been introduced here.

The Arabian camel or dromedary, *Camelus dromedarius*, has not existed as a wild animal for about 2,000 years and is known only in a state of domestication over a large part of its geographical range. In contrast, the Bactrian or two-humped camel, *C. bactrianus*, may still exist in its natural state in the Gobi Desert of Mongolia, although large numbers are also domesticated.

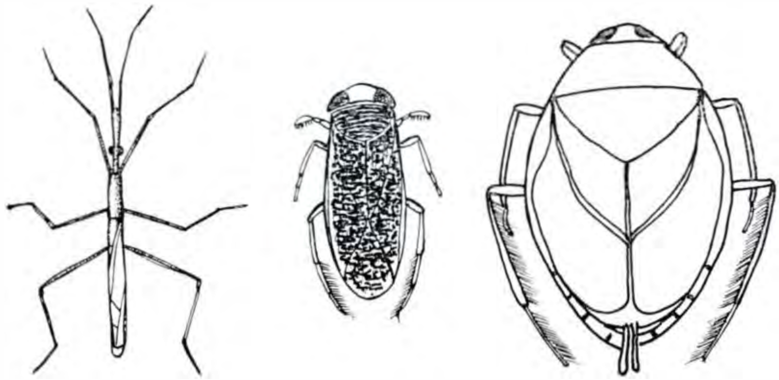
During the early days of European settlement in Australia, dromedaries, which had been introduced with Afghan drivers from India, played a very important role in the development of the country. Their adaptation to life and work in arid environments made them eminently suitable for use as transport animals in the outback. As they became replaced by mechanical means of transport, they were either turned loose or escaped and became feral and have since built up their numbers in suitable desert areas of Australia.

This book is extremely well written and makes fascinating reading. The first two sections deal with the systematics of the Camelidae and with aspects of the biology of camels. The remaining chapters concern the history of introduction of camels into Australia, their use, and their subsequent decline in importance.

Although primarily concerned with the historical aspects of camels in Australia, the book contains a wealth of general information on all aspects of camel biology, extending from discussions on the physiological adaptations of these animals to arid conditions to aspects of camel husbandry. It is, in consequence, a most valuable publication which concentrates much of the scattered literature on camel biology into one volume.

The book is pleasantly presented and reasonably priced. It contains several interesting photographs illustrating the past history of camel use in Australia. The only criticism which can be levelled against it is the presentation of references in the form of notes pertinent to each chapter and the division of the bibliography into various sections headed Articles, Books, Newspapers, etc. This cumbersome method of citing references often makes the tracing of a particular reference a matter of some difficulty.

In general, *The Camel in Australia* is a most interesting and stimulating book which is strongly recommended to anyone who wishes to know more about the biology of camels and who is interested in the impact that this introduced animal has had on the development of the Australian outback.—***B. J. Marlow, Australian Museum.***



Three insects found in ponds. From left: Water Measurer, Water Boatman, Round Water Bug.

POND LIFE IN AUSTRALIA

By JOHN CHILD
Economics Research Fellow, University of Otago, New Zealand

I THINK of a pond as a more or less permanent body of fresh water, entirely enclosed by land and not more than about 100 yards in diameter. In very dry seasons the water may dry up, but the pond will be renewed at the next rain. Large ponds eventually become small lakes; the distinction is not very important. A pond has some creatures which will not usually be found in freshwater streams, and the latter will contain species not found in true ponds. However, there is considerable overlap, and the pools, backwaters, and billabongs of Australian streams will have many of the forms of life mentioned here. Furthermore, most lakes, especially if they have gently sloping shorelines, will harbour around their margins many of the same creatures as a small pond.

Because of the relatively low and intermittent rainfall in many parts of Australia, ponds in some regions are inevitably short-lived; these have a life of their own, of plants and animals which grow quickly to maturity, produce eggs, larvae or seeds to carry on the species, and then develop some protective coating to enable them to survive in a resting state while the water has evaporated. Such intermittent ponds, and the adataptions for survival of their inhabitants, are a fascinating study, but cannot be dealt with here.

The permanent pond is wonderfully rich in the variety of life it supports, and makes a very satisfying field for natural history study. This, I think, is partly because it has a definite area and fairly clear boundaries, enabling the student to feel (rather incorrectly) that he can come to know all of its inhabitants. Unlike the seashore, the ocean, a river, or a desert, the pond is manageable, and one is not tormented by the nagging thought that around the next headland, or over the next ridge, there may be new wonders. But even taking samples of plants and animals from the middle or the bottom of a quite small pond will require some ingenuity in manufacturing collecting gear, unless the pond is shallow enough to allow you to wade all over it.

In this article I give a very brief survey of some of the plants and animals of a typical Australian pond, and point out some of the problems they face in this habitat.

Pond zones

Until now I have spoken of the pond as a single entity, as if it were a uniform habitat, and for some animals this is true. The

Green and Gold Bell Frog (*Hyla aurea*), for example, probably covers most of the area of its pond and of the surroundings in the course of its hunting and mating activities. But careful inspection will quickly show that "the pond" really consists of a number of differing habitats, and that certain species are very selective. This is most readily seen in the case of plants. If the pond is in a fairly regular depression, there will be clearly defined concentric rings of plants around it. This is obviously not accidental; in the struggle for survival each species can dominate over others only in the limited range where overall conditions suit it better than its rivals. Encircling the pond are zones of decreasing soil water content, and this is probably the main reason for the different zones of plant life. As plants form the basis, ultimately, of all forms of animal life, and as they provide shelter and camouflage, if not food, for some animals, such as spiders, frogs, and snakes, it is important to look closely at the plants growing around the edges, in the water itself, and on the surface. For example, many spiders inhabit the sedges and rushes at the edges of ponds, using the stiff stems as anchorage for their webs, or the flower heads as places to lie in ambush for insects; their body colours and forms are marvellously adapted to blend in with the vegetation.

In the water itself several more distinct zones are apparent, again often most clearly recognized by the plant life. First there is the surface, which may be partly covered with a layer of floating plants, such as the tiny green Duckweed, a true flowering plant (family Lemnaceae), or the reddish Water Fern (*Azolla*). (As a simple test of the adaptation of these plants to their special habitat, try to float one on the surface upside down.) Floating on the surface may be the leaves of rooted plants, such as Pond Weed (*Potamogeton*), with rounded leaves and upright flower spikes, or the fern Nardoo (*Marsilea*), with round leaves in four segments, or the long green ribbons of Eelweed or Ribbon Weed (*Triglochin*). The surface zone has its distinct population of animal life, also.

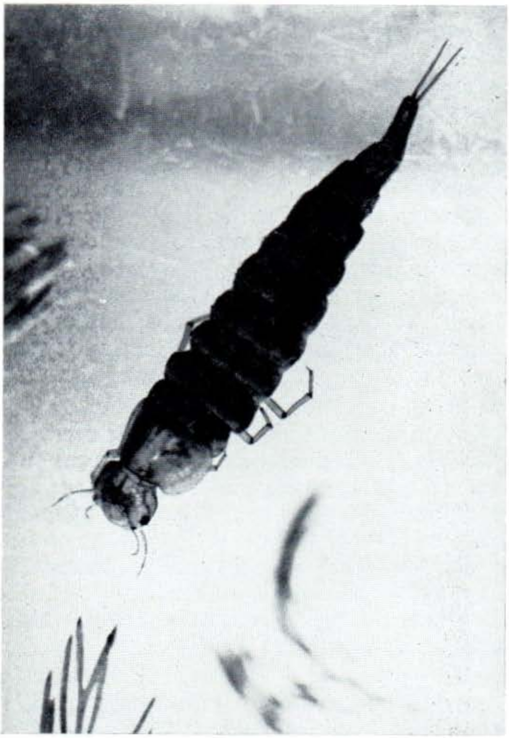
Secondly, there is the shallow-water, or margin zone, where the water is only a few inches deep. This teems with a unique population of fairly small active animals, most of which are crustaceans. In this zone the water is warmer, the oxygen concentration higher, and the microscopic plant life probably very abundant.

A third zone is the mud or silt at the bottom of the pond, a favoured habitat of a number of animals.

Finally, depending somewhat on the size and depth of the pond, there is the central free-water zone, where the water is too deep for rooted plants to reach the surface. In a small, shallow pond this zone will not be important.

Plants and oxygen supply

In the water itself plant life is vitally important because it provides the oxygen necessary for all other living things (except some bacteria). Green plants alone have the remarkable capacity to take two common simple chemicals, water and carbon dioxide, and combine them, using the energy of sunlight, into starch and sugar, which form the basis of all animal food. During this



Larva of the Diving Beetle. These larvae are predatory, and are known as Water Tigers.

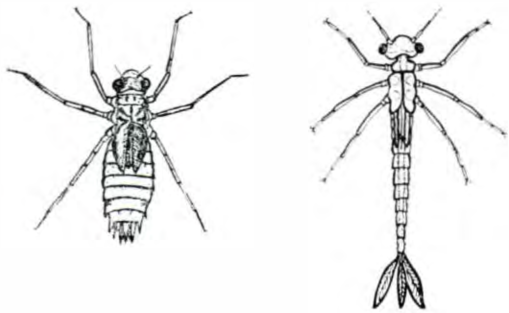
process, known as photosynthesis, oxygen is released. On a sunny day you can often see tiny silvery bubbles of oxygen coating green plants in a pond. Some of this oxygen dissolves into the water, and is available for water-dwelling animals.

If you want to keep pond animals alive at home, in an aquarium, it is essential to supply growing green plants, or else use a more elaborate mechanical oxygenator ("bubbler" or "aerator"). As rooted plants are slightly more difficult to manage, free-floating submerged plants are preferable. Species of Water Milfoil (*Myriophyllum*), with finely divided leaves, Hornwort (*Ceratophyllum*), which has a rather hard feel, or the leafy *Anacharis* or *Elodea*, are hardy, well tested aquarium plants. Obviously those which merely float on the surface, with their leaves in the air, will not help supply oxygen.

Here I can mention only a few of the general problems facing animals which live in ponds, and show how they have solved them. Let us take the problem of obtaining a continuous supply of oxygen. Air-breathing, or land, animals, obtain their oxygen from the atmosphere. Many water-dwelling animals do the same. Some insects, for example the Backswimmers (family Notonectidae) and Diving Beetles (family Dytiscidae), come regularly to the surface and collect a bubble of air, which they trap under abdominal hairs, or wing covers. Similarly, some water spiders, when they hunt beneath the surface, carry down a layer of air caught in the body hairs. Mosquito larvae and pupae have tubes which they poke through the surface film of the water. Some insects obtain their oxygen from air in the stems of submerged water plants.

But coming to the surface for air every so often has its disadvantages: it uses up energy, and exposes the insect to surface predators. Many have therefore adapted themselves more fully to living under water, and have evolved some form of gill to absorb the oxygen dissolved in the water. Gills often have a leaf-like or feathery form, which gives a large surface area exposed to the water.

Damsel fly larvae have three leaf-like gills at the end of the abdomen; the larvae of the closely related dragonflies have internal gills, in the rectum, and the animals are constantly drawing water into the rectum and expelling it. In an emergency they can use the violent expulsion of the water to propel the body forward, in a series of rapid jerks: they have "invented" jet propulsion!



Dragonfly larva (left) and damsel fly larva. Note the three leaf-like gills at the end of the damsel fly larva's abdomen. The dragonfly larva's gills are internal.

A second general problem for pond animals is control of the correct balance of chemicals in the body fluids. Strong solutions, separated by only a thin membrane from weaker ones, tend to lose their strength by the process of osmosis. Somehow, animals which live in fresh water have to be able to control this process, so that the animal does not lose valuable chemicals. Probably some of the gill-like structures help in this regulation.

The variety of pond life

I have already mentioned some of the groups of animals which live in ponds, and I can only mention briefly a few more of the main groups. The books mentioned at the end of the article will help you to identify many of them.

Molluscs

Many species of gastropod (snail-like) molluscs live in ponds, usually feeding on the water plants, and sometimes crawling upside-down under the surface film. The Pouched Pond Snails (family Bullinidae) are interesting because they have the spiral reversed. Most snails, if held with the spire upright, have the aperture on the right, but the bullinids have it on the left. The Wheel Snails (family Planorbidae) are very small, with the spiral flattened into a wheel shape. Bivalve molluscs, such as Freshwater Mussels,

Snail-like molluscs that live in ponds. From left: *Bullinus*, *Notopala*, and a Wheel Snail (*Planorbis*). The Wheel Snail's spiral is flat and wheel-shaped, as shown in the lower drawing at right.

are not found in true ponds, but are present in mud at the bottom of pools or billabongs.

Crustaceans

Larger crustaceans (yabbies and shrimps) are usually found in lakes or streams, but a host of smaller forms are common in ponds, especially in the margin zone. These are so small and delicate that they have been called Fairy Shrimps or Water Fleas. The ones that resemble animated seeds moving fairly smoothly and rapidly are enclosed in two lateral "shells", and belong to the group Conchostraca. Those with bodies flattened sideways, and moving more or less vertically in the water by twitching their long antennae, are Water Fleas (family Daphnidae). Small bean-shaped animals scratching busily at the debris on the bottom are Ostracods. The Cyclops group, about one-tenth of an inch long, have their bodies rather flattened from top to bottom, and one large, red, central eye. Closely related to them are the Calanoida. In both of these groups females commonly carry one or two egg-masses. As the body wall is transparent, many of these are fascinating to study alive, with the aid of a microscope or a strong hand lens, as the internal organs are plainly visible.

Insects

The edges of the pond, and the water surface, are the haunts of True Bugs (Hemiptera) of several families. Water Measurers (Hydrometridae) are slender, long-legged creatures which stalk about rather slowly; in contrast, the Water Striders or Pond Skaters (Gerridae) skim across the surface very rapidly.

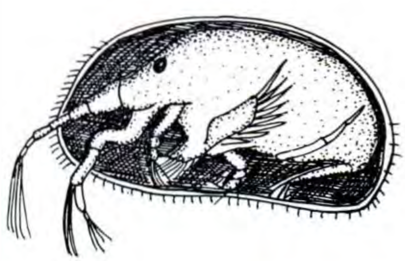
Many families of beetles have larvae which are aquatic, and some adults, too, live largely under water, but have to surface for air. The Whirligig Beetles (Gyrinidae) singly or in groups, flash about on the surface in a pattern of crazy twists, avoiding collisions at the last minute, like Sydney taxi drivers, by skilful steering. Diving Beetles (Dytiscidae) have beautifully streamlined bodies and can swim rapidly; they and their larvae (the Water Tigers) are predators.

The more sluggish insects are most easily found by pulling out a handful of submerged water plants, and allowing it to expand in a basin or pie dish of water. This will usually yield larvae of damselflies, caddisflies and mosquitoes, and perhaps some water bugs, like the fearsomely named Toe Biter (*Nepa*). More active adults, such as Backswimmers, Water Boatmen (family Corixidae), Diving Beetles and Round Water Bugs (*Sphaeroderma*), must be collected by netting or by using a kitchen strainer on a long handle.

It is well worth while to scoop some of the mud and debris from the bottom of the pond, at varying depths, and allow it to clear in a basin or jam jar. This may yield blood-red larvae of the Midges (family Chironomidae), which are interesting because their blood contains the same oxygen-carrying pigment, haemoglobin, as our blood. (Most insects and other invertebrates have colourless blood.)

Collecting techniques

There is so much to see and study and collect at a pond that time is always too short. But by taking a variety of glass containers, preferably with screw tops and wide mouths, and a selection of nets and scoops, it is not difficult to take a good sample of the pond's



The Ostracod, a crustacean often to be found among the debris on the bottom of a pond. Only its long antennae, used for scraping food debris into its mouth, protrude from the bean-shaped shell.

population back home or to school for more leisurely study. The important rules are: first, avoid having too many animals in any one container; second, always provide some green plants to ensure an oxygen supply.

[*The illustrations in this article are by the author.*]

FURTHER READING

J. Child: *Australian Pond and Stream Life*, Periwinkle Series, 1968.

W. D. Williams: *Australian Freshwater Life*, Sun Books, 1968.

D. Clyne: *Australian Frogs*, Periwinkle Series, 1969.

J. G. Pendergast and D. R. Cowley: *Freshwater Insects in New Zealand*, 1966.

BOOK REVIEW

AUSTRALIAN WILDLIFE CONSERVATION, by Vincent Serventy. Angus and Robertson, 1968. 76 pages. 75c.

Education is a prime need of conservation and, in particular, a conservation programme is required in the schools. However, teaching conservation within the school system is hindered by a number of factors—failure of education authorities and teachers to recognize the need, a lack of properly trained personnel, and, especially, an absence of suitable teaching aids and texts. Vincent Serventy appears to be well aware of these needs, and his pamphlet *Australian Wildlife Conservation* is aimed at providing teaching ideas and a text for a school programme in conservation. Unfortunately, *Australian Wildlife Conservation* cannot be recommended for school use. Though Mr Serventy is to be commended for his astuteness in recognizing the need, I personally do not feel that the approach he has taken to conservation is a very desirable one. It is the classic emotional and alarmist appeal for wildlife conservation—an oohing and ahhing over animals—which has pervaded the conservation movement among amateurs for too long. Far more serious, the text is often misleading and many of the ideas presented are based upon antiquated biological concepts.

The following examples are typical and illustrate the need for careful editing if conservation and natural history topics are to be made meaningful to, and suitable for, children. On page 1 of *Australian Wildlife Conservation* we find a statement about marsupials that "These are mainly found in Australia, but there are still some marsupials in South and Central America." Mr Serventy should know that a marsupial also occurs in North America (the Virginia Opposum, *Didelphis marsupialis*), but actually his statement doesn't exclude North America as a place to find marsupials any more than it excludes the Antarctic or Africa. In other words, it is misleading. On page 3 we find "Australia is a land that time forgot, an Ark. . . .", ". . . a living museum . . .", ". . . our unique wildlife. . . ." These are fallacious statements, cliches from nineteenth-century natural history. Any flora or fauna is unique in the sense that it is not duplicated elsewhere and it is futile to justify conservation on the basis of uniqueness. Referring to Australia as "an ark" or "a living museum" carries the implication that the flora and fauna of Australia are relicts, remnants of a flora and fauna which at one time had a much wider distribution. There is very little evidence to support such a view and it would have been more in line with current biological theory, and less trite, to discuss the flora and fauna of Australia as a study in island biogeography. On page 6 Mr Serventy claims that "mangroves and marine marshes" . . . "are the richest plant growing places on this earth". This is a rather unique way of expressing productivity and perhaps it should be conserved, but it also happens to be incorrect. Mangrove and marsh communities are *not* the most productive communities in the world. True, they are very productive, but some rainforests, coral reefs, and agricultural lands are more productive (e.g., Golley et. al., 1962. Ecology 43 (1): 9–19). There are other examples which could be taken from the text, but two definitions in the glossary are particularly disturbing and must be pointed out. First, evolution is defined as "a theory developed by Charles Darwin . . .". This is incorrect. Charles Darwin developed a theory of evolution. Scientists and philosophers had been discussing and theorizing on evolution for a long time before Darwin presented his theory in 1859. One could even look upon the Book of Genesis as a theory of evolution. Second, it is misleading to define monotremes as "the most primitive group of mammals which lay eggs". Terms such as "primitive" and "advanced" have little or no meaning, and in this instance the definition carries the implication that there are other mammals "more advanced" than monotremes which also lay eggs. This, of course, is incorrect. It would have been simpler to state that monotremes are the *only* group of mammals which lay eggs and make no value judgments as to how "primitive" or "advanced" monotremes are.

The misuse of resources and the rapacity of the white Australian have been ably documented by several authors, but a useful book of wildlife conservation in Australia has yet to be written. When it is, it will be based on a broad foundation of economics, sociology, ecology, and animal behaviour. It will, in the words of the late Aldo Leopold, aim to create a "land ethic", but it will succeed only if it presents its case in the context of an industrialized, technological, and over-populated world. It should also deal with conservation on a global scale and be especially concerned with problems of human over-population. Such a text is needed, and perhaps it is most important that it be suitable for school use. It is paradoxical that people, and especially young people, have never been more sophisticated and aware of the world than they are today, but are simultaneously farther removed and more ignorant of the "land" and their dependency upon the world as an ecosystem. An effective text on conservation would recognize the sophistication of young people and attempt to resolve the paradox; *Australian Wildlife Conservation* does not.—*H. F. Recher, Australian Museum.*

Bushflies on a tourist's back. [Photo: John Green.]

The Bushfly

By R. D. HUGHES
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THIS article is concerned only with the bushfly (*Musca vetustissima*), which is a familiar nuisance to those enjoying open-air activities on a warm day in most parts of Australia, as is shown in the photo on this page.

Over the past two years the four members of the CSIRO's bushfly research section have been asked many fascinating questions about bushflies (apart from "How can we get rid of them?"). A large number of the biological points raised can be reduced into four general questions, and in this article I will piece together the many observations each of us have made, to try to answer them. Most of our studies have been made on the bushflies of the Canberra area, but I think the answers given will apply to at least the whole southeast corner of Australia—from Port Pirie, South Australia, to Newcastle, New South Wales.

Where do bushflies come from?

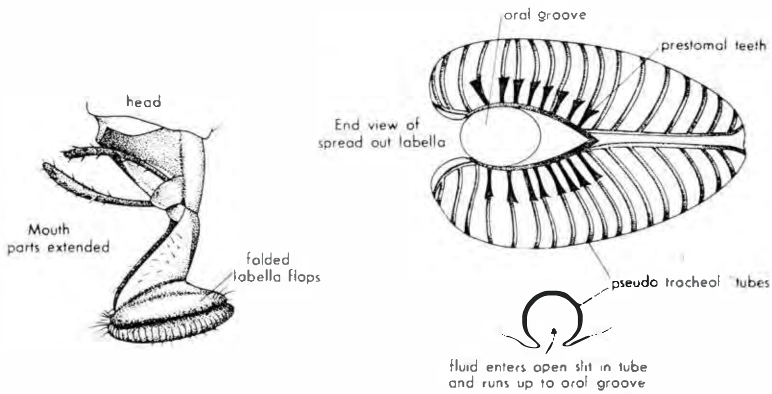
Bushflies are present for most of the year in some warmer parts of Australia, but in the southeast they are apparently absent during the colder months. K. R. Norris, working earlier in the Canberra region, could find no trace of them during the winter, but they reappear with unfailing regularity each spring. One of the most exciting parts of our studies to date has been the gradual accumulation of observations showing that southern bushflies die out each winter and then large numbers of bushflies emigrate from Queensland each spring to repopulate areas of southeast Australia hundreds of miles away.

We knew the flies were present around Cunnamulla (Queensland) all through the winter, so by regularly visiting, from July onwards, places between there and Canberra we were able to collect examples of the first flies appearing at each locality. We got clues about their origins by dissecting them and making an assessment of their age from the stage of development of their reproductive system. All the first flies collected south of the Queensland border turned out to be quite old adults—which showed they had not emerged from the ground nearby after having spent the winter as maggots or "pupae". Furthermore, our examination showed that the first flies in more southern localities were older than the first flies further north. From many fragments of evidence like this we have formulated the theory that flies bred during the late autumn and winter in the north emerge in spring and, with the help of the warm north to northwest winds, sweep down into New South Wales. We can show that some of the original Queensland flies get as far as Canberra and the Riverina over a period of 7 weeks, but as they have laid eggs en route it is probably their progeny, emerging during late September in the central west, that later actually repopulate more southern areas.

Where do bushflies breed?

Because of the prevalence of bushflies in the dry inland and their presence in areas which have experienced long droughts, there has always been some mystery surrounding their breeding places. But if the flies can travel hundreds of miles in a few weeks with only the help of warm winds, the fact that the species is known to breed in the fresh droppings of a variety of large animals probably represents the whole story. While it has proved possible to rear maggots in a variety of media we have never been able to induce flies to lay eggs normally on anything other than faeces. The fresh faeces of man, dogs, cattle, sheep, horses, and emus are known to have been utilized naturally by the bushfly. In our experiments the larger, moister droppings of sheep and the moist dung pads of cattle have both been found to be ideal breeding sites. Female bushflies are readily attracted to a freshly-dropped dung pad as a food source, but if they contain mature eggs their behaviour changes soon after making contact with it. They search over the surface exploring crevices and under the edges of the pad, where the dung will remain moist for the longest period. Then after a preliminary sensing with the extended ovipositor, the female becomes absorbed in the process of laying eggs. The presence of one egg-laying female seems to stimulate others to oviposit nearby, and the rich dung pads which occur on the spring pastures around Canberra may at times be ringed by bushflies, upside down and facing outwards as they oviposit, as shown in an accompanying drawing.

Communal egg-laying by bushflies under the edge of a cow dung-pad. [Drawing by Gwenneth Palmer.]



The lapping mouthparts of a bushfly. [Drawing by Marina Tyndale-Biscoe.]

The eggs are usually laid in very moist places, and we have found that the air around them must be nearly saturated with water vapour if they are to hatch. Often the eggs are immersed, but an examination of their outer skin shows tiny raised areas, with a spongy air-filled structure, which probably allows air to be absorbed into the egg from the surrounding liquid.

The time taken for the eggs to hatch varies with the prevailing temperature. The shortest incubation time was about 6 hours at 107° F. At lower temperatures it may take a day or more for the eggs to hatch, but below 56° F they would not do so. Hatching maggots enter the mass of dung directly, and commence feeding near to the surface or to an internal air-space. Such spaces develop either under the crust which forms on the dung pad or through the activities of other tunnelling insects. The larvae obtain air through tiny tubes opening at spiracles on their tail-ends, so larvae feeding head-down in moist dung repeatedly appear tail-first at the nearest air surface.

The maggots feed and grow quickly, shedding their skins twice to allow for expansion. At 80° F they become fully developed in 3 or 4 days. It takes much longer at lower temperatures, and growth and development cease below 50° F. The fully-fed maggots usually leave the old dung pad to pupate in loose soil nearby. If the soil is unfavourable the maggots may travel some distance to pupate, often entering the soil near the base of some nearby vegetation.

The pupal stage lasts a little longer than the larval feeding period, then the adult flies emerge from the soil.

Why do bushflies come to annoy us?

We have made some studies of the needs of bushflies. Without water older flies can survive only 15 hours at 80° F—about as long as a summer's day. Without sugar or some other energy food most flies die within 2 days. Without protein food female flies cannot develop their eggs to complete the life-cycle. So flies may come to us for water, "sweets", or "meat".

Further information was obtained by a close examination of the bushflies which approached and settled on us. Usually the flies were mostly female. The few males around were obviously less interested in us, sitting mostly on the car nearby. This observation suggested that the need of females for protein was the prime reason for their approach. However, when flies settling on us were caught, killed, and dissected, it was found that females in all stages of egg-development were involved. Young flies with no sign of egg-development were particularly well represented, it is true, but those which had clearly eaten a protein meal were also present. Furthermore, at cooler times of the year, even flies containing eggs ready to lay came to us. There was obviously more than one reason for the flies' visits.

Flies can obtain water by sucking at any free water surface with their proboscis (see illustration on this page). Drops of rain-water or dew, and nectar, could readily provide all their needs, but spilt liquids and our tears, sweat, and saliva may be useful alternative sources. Because of the proboscis, food can only be taken in liquid form. Nectar and other plant exudates are probably the fly's natural sugar sources, while the dissections revealed that a large proportion of the flies had recently fed on animal faeces, which can be a good source of protein. Our sweat, tears, and saliva are probably too dilute to be useful food sources, but blood and serum from wounds, scars, and sores could supplement the fly's protein diet. While bushflies do not actually bite, they have tough prestomal "teeth" on the proboscis with which they can rasp away at soft tissues and around old wounds—sometimes reopening them.

While at least a proportion of the flies visiting us have come for water or food, the rest must have some other reason. It seems likely that they have behavioural mechanisms just to keep them in the company of large animals (that includes us). Such animals could be future sources of food and water, but, perhaps more importantly, they could be potential sources of the droppings that are both an adult food and the breeding places for the species. So the well-fed bushfly just hangs around us, or any other animal, finding a spot in the sun, out of the wind, and where movements of the skin or clothes are least disturbing. It may be coincidence that sweat often accumulates in such spots, but the dilute food materials it contains could well be a "cocktail" reinforcing a habit that is to the long-term advantage of the bushfly.

Would getting rid of bushflies upset the balance of nature?

We don't think there would be any harmful repercussions if it were possible to devise and apply some method of getting rid of bushflies. To come to this conclusion the following questions had to be answered: Knowing the major activities of the bushfly, what would happen if those activities were not carried out? Would organisms doing the same thing (the bushfly's competitors) be likely to increase in its absence and cause a nuisance? Are there any useful organisms which depend substantially upon the bushfly for most of their food? Among the incidental activities of the bushfly are there any that would be missed?

The bushfly is one of the group of organisms involved in the decomposition of animal faeces. Such "decomposers" each utilize part of the food content remaining, and so assist in the *sequential* degradation of these waste products into the soil. The bushfly is a pioneer species in freshly dropped dung and, although it does not normally consume a major share, the tunnelling action of the maggots contributes to the drying out of the mass and may render it more favourable to later decomposer species. However, we know that bushflies are absent from most areas of Australia at some season of the year, so this role in decomposition is unlikely to be crucial.

Other pioneer "decomposers" of dung do occur in Australia and may be expected to be favoured by the absence of the bushfly. Those known to occur frequently with the bushfly do not seem to be potential pest species. Fortunately, that serious pest the buffalo fly is apparently confined to the wetter parts of the tropics, where the bushfly occurs only marginally and then usually at a different season.

Organisms utilizing the bushfly as a major food item seem to be mainly generalized predators, taking wide varieties of insects among which the bushfly is merely the most numerous. Some small sand-wasps (commonly misnamed policeman flies) often catch bushflies to stock the "larders" of their developing young in holes in the sand, but they will happily use any similar-sized insect. The most commonly seen parasite of the bushfly is a nematode worm which, after release as larvae on a dung pad, enters and kills many maggots. Some infected adult flies survive, but in the females their eggs are replaced by more "packets" of infective larvae to be laid on fresh dung pads. As with the other known natural enemies of the bushfly, this worm is not highly specific and occurs in other common, dung-breeding flies.

Although it is a memorable feature of the Australian scene, apart from its scientific interest, the bushfly seems to have no intrinsically good qualities that would be missed. It has an incidental role as a minor vector of eye infections of stock and man. For this reason its elimination, if it proved possible, would be an additional benefit.

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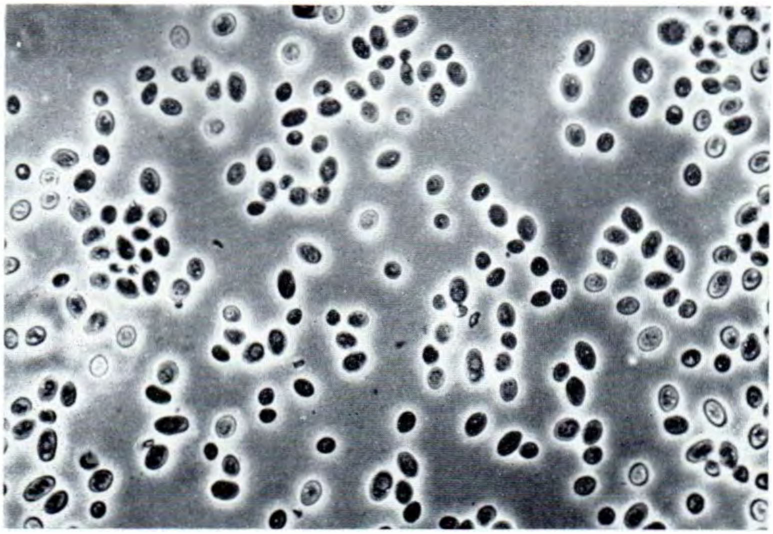


Cells of a normal bakers' yeast strain. (x 500).

YEASTS

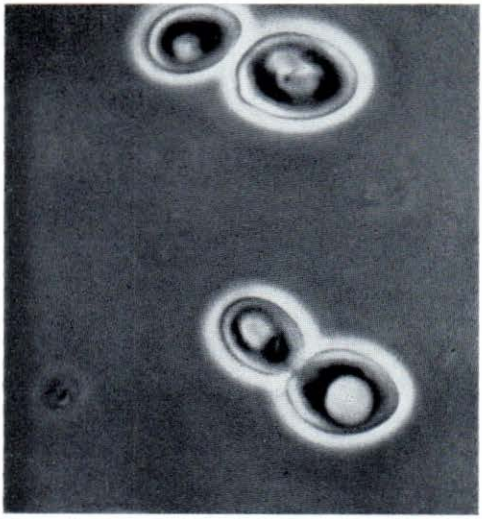
By D. W. KINSEY
Senior Research Biochemist with M.B.T. Research Laboratories, Sydney

EVER since man has existed he has suffered from diseases caused by microbes but he has also, and just as significantly, benefited from the advantageous effects of many other microbes. Only as recently as the seventeenth century did he have the slightest suspicion of the existence of the invisible world of countless living organisms which surrounds and outnumbers him so enormously. For instance, one normal healthy person can have as many micro-organisms in his mouth as there are people in the entire world.

One economically very significant part of this invisible world is the group of living organisms which causes those processes referred to as "fermentations." This word covers such things as the production of fermented beverages, vinegar, large numbers of organic chemicals, antibiotics, tea, tobacco, cheese, bread, and many others. Some of these fermentations are caused by moulds and some by bacteria, but perhaps the most significant group of industrial organisms is the yeasts.

Yeasts first entered the limelight when it was discovered, in the mid-nineteenth century, that the fermentation of wines and beer was not a spontaneous chemical process but the result of the activity of countless small oval organisms which were thriving on the sugar in the brews and producing alcohol and carbon dioxide gas as their end products.

The fact that micro-organisms have been used to such advantage by man is in fact primarily a function of their small size. A typical yeast cell is about three ten-thousandths of an inch long, and there are five million million of them to the pound. This small size means that, in relation to their weight, they have very great surface area exposed to their environment and hence can absorb food and reproduce at almost unbelievable speeds. Similarly, they can produce the desired end product at an equivalent speed. Thus 1 pound of yeast cells, with a combined surface area of cell wall equal to 7,000 square feet, could, under commercially attainable conditions, increase to 3 tons in 24 hours provided sufficient food and space were made available.



Normal vegetative reproduction in a commercial yeast strain. The new cell is being produced from the parent by the unique process of budding. The conspicuous pale areas within the cells are the vacuoles. (x 1,800). As the cells are free to drift around in their liquid evironment it is unlikely that the two cells at the top have separated from each other by budding. Their proximity to each other is probably only coincidental.

The true nature of yeasts

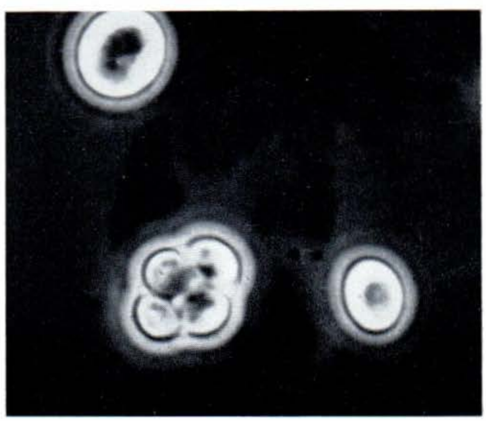
Yeasts are microscopic fungi. In common with the more conspicuous fungi, such as moulds, mildews, mushrooms and toadstools, they lack the green photosynthetic pigments associated with other members of the plant kingdom and therefore are dependent on organic food and not carbon dioxide for their nutrition. In common with all other living things except the viruses, yeasts are composed of cells—small discrete sacs containing an internal chemical organization which is remarkably complex. As with the even smaller bacteria, yeasts exist typically, though not always, as single cells. However, this is about as far as the similarity to bacteria goes. Bacteria have cells described as procaryotic and are relatively simple in their internal organization. Yeasts, in common with all the higher organisms, have complex eucaryotic cells which are essentially as internally complex as those of man himself.

Yeasts can multiply by two methods. The more usual is a simple vegetative division into two essentially identical cells. In most of the commercially valuable yeasts this occurs by a process called budding in which the parent cell forms a small bulge called a bud with which its cell contents are shared by internal reorganization. The bud increases in size, becomes separated from the parent by a complete cell wall, and eventually detaches to live as a new individual. Budding is a unique process, as virtually all other living organisms form new cells by a division into two equal halves which both then grow to mature size.

The other process by which yeasts can multiply is a form of sexual reproduction in which the genetic material of the cell is extensively rearranged. In common with other organisms this process gives rise to new individuals which are not necessarily identical to the parent. All yeasts chosen for commercial application must have negligible tendency to undergo spontaneous sexual reproduction, as the chosen characteristics could be lost.

Yeasts occur naturally in almost all types of environment, but they are found typically in places where sugars are freely available. They occur as films over the skins of most fruits, in the nectar of flowers, and in sugary exudates from trees and smaller plants.

In addition to sugars, yeasts need for their growth the usual trace elements required by all living things, a number of vitamins, and simple compounds of nitrogen and phosphorus. Most yeasts will grow equally well in the presence or absence of oxygen,



The initial stage in sexual reproduction in a typical yeast. The parent cell has divided internally to form four spores. (x 1,800).

but their proper commercial utilization is frequently entirely dependent on the extent to which oxygen is limited or made available.

Industrial uses of yeasts

It should be stressed that yeasts are a broad and highly diverse group with greatly differing properties and requirements. For any particular type of fermentation involving a yeast it is necessary to choose a strain which will carry out the required conversion with the greatest efficiency.

The two most significant industrial uses for yeast have been the manufacture of fermented drinks and the manufacture of bread from leavened dough.

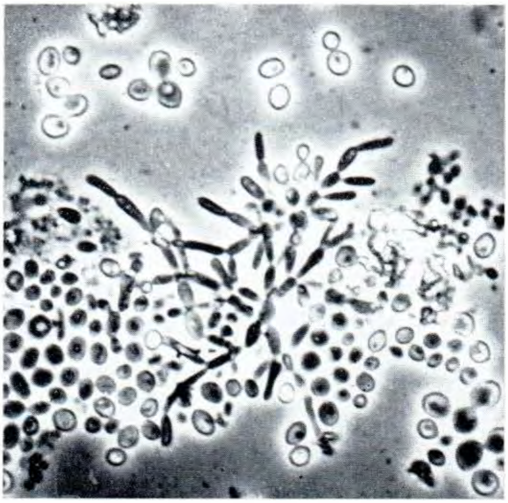
The production of beer, wines, and other similar products involves, primarily, the conversion of sugar to alcohol. While it is evident that yeast can carry out this conversion, two most significant facts must be considered for this conversion to be commercially sound. Firstly, more alcohol will be produced if oxygen is not made available to the yeast, as oxygen facilitates the complete conversion of sugar to carbon dioxide and yeast cells. Secondly, more alcohol will be produced if actual yeast growth can be kept to a fairly low level, as the less sugar that is converted to yeast cell matter the more sugar the yeast may be encouraged to convert to alcohol. Alcohol-producing fermentation processes, therefore, involve the addition of small amounts of yeast to solutions of sugary materials which are not aerated and which are kept in closed vessels. The availability of yeast nutrients other than the sugar is restricted. The carbon dioxide produced in these fermentations may be wasted, or some may be deliberately retained in the product as is the case with beer and sparkling wines. In earlier times yeasts found their own way into the fermentations from the raw materials and the air, but in modern practice the correct quantity of a selected yeast strain is added deliberately. The raw materials for this type of fermentation are fruit juices for wine and cider, etc.; malted grain and sugar for beer; and various malted and unmalted grains, and other farinaceous materials, for a variety of other beverages. Where starchy raw materials are used the starch is usually converted to sugar by the enzymes normally found in such materials. Industrial alcohol is frequently produced by the fermentation of molasses.

When yeast is used to leaven bread dough it ferments the naturally occurring traces of sugar in the flour, or some of the added sugar in the case of sweet products. Any alcohol produced is unimportant as it is lost in the baking, so that the important aspect of the fermentation is the production of a large volume of carbon dioxide gas which raises the dough.

There is another group of industries interested not in what changes small quantities of yeast may cause in other materials, but rather in the production of large quantities of the yeast cells themselves. The largest of these is the industry which supplies the bakers with their yeast. The others produce yeast for high-grade animal fodder, food flavourings from processed yeast, and, more recently, basic yeast protein as an economical dietary supplement for human consumption. In all these industries the basic underlying concept is the production of a minimum of alcohol and a maximum quantity of yeast cells from the sugar sources used. By contrast with those in the alcohol-producing industries, these fermentations are violently aerated and contain adequate additional nutrients to enable maximum conversion of the sugar to yeast. As the flavour of the raw materials in this type of process is unimportant, a large variety of sugar sources is available. The most usual are molasses, waste liquors from paper mills, and suitably treated starchy washes from factories processing cereals and potatoes. Thus these processes are not only producing valuable products but in many cases are using undesirable industrial wastes which would otherwise have caused a considerable disposal problem.

Yeasts as undesirables

While the fermentation of sugars is a process which is commercially valuable when intentional it can be a serious problem when unintentional. Much spoilage of acid and sugary foods and drinks is caused by the development of yeasts which have remained viable due to inadequate processing, or to a lack of adequate preservative levels. Some yeasts can grow at very high sugar levels such as are found in honey and jams, and, as mentioned previously, most can grow freely in the total absence of oxygen.



Some yeasts may form branched chains of cells. (x 500).

There are also yeasts which will attack fatty foods and some which are so specialized that they can grow on petroleum fractions in the presence of traces of water. These latter can cause corrosion problems in the petroleum industry, though recently it has actually been found economic to put these problem organisms to use by growing them as fodder yeast on some of the less valuable petroleum fractions.

Another group of yeasts and yeast-like organisms cause diseases in plants and animals, including man. While there are some uncommon but serious infections, most of these diseases are mild. They are typically infections of the mucous membranes and skin. The common mouth infection in infants known as "thrush" is a yeast infection, and, similarly, yeasts frequently occur as secondary invaders in sore throat conditions.

The future

Far from the likelihood of the useful activities of these small organisms becoming replaced in this modern technological age it seems highly probable that we will find more and more ways of utilizing their frequently unique abilities. We may well become dependent on them as a means of converting low-grade non-nutritious substances into first-class protein to help alleviate the serious food shortage which threatens the world.

Note: The diffuse pale areas surrounding the cells in the photos are an optical effect associated with the microscope.

[The illustrations in this article are reproduced with the permission of Mauri Brothers and Thomson, Limited.]

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This extremely large starfish was taken off Noumea, New Caledonia, by two skindivers, Mr George Bargibant, an employee of the Aquarium of Noumea, and his friend Mr B. Conseil. It lived successfully in the Aquarium for more than 4 months, and was killed, preserved and sent to the Australian Museum after being severely attacked by a fish newly introduced into the tank. The starfish was about 25 inches wide in life, but has shrunk since preservation. It is pink, with brown tips to the arms, and is as yet nameless. It has been placed in the Museum's research collections.—*Elizabeth C. Pope, Australian Museum.* [*Photo by courtesy of "The Sydney Morning Herald".*]

An aerial view looking north along the Laidlaw Range, a Devonian atoll. The circular patch of limestone on the left (middle distance) is Lloyd Hill; it represents a smaller atoll. Note the small patch reef below the "tail" of the Laidlaw Range atoll. These remarkably well-preserved fossil reefs are 350 million years old.

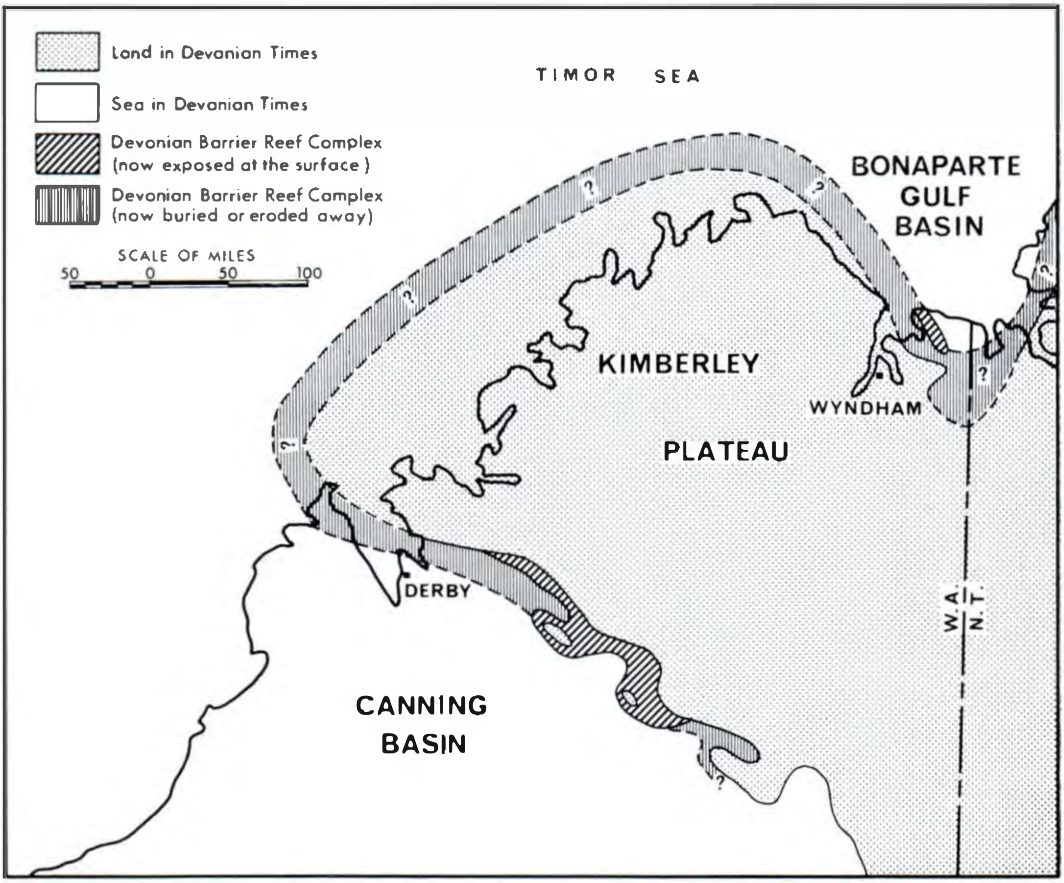
The Devonian "Great Barrier Reef" of Western Australia

By PHILLIP E. PLAYFORD
Supervising Geologist, Geological Survey of Western Australia

WESTERN Australia's "Great Barrier Reef" forms a belt of rugged limestone ranges in the West Kimberley district, extending for 180 miles along the northern margin of the Canning Basin, east of Derby. These ranges consist of algal, stromatoporoid, and coral reefs that developed during the Devonian Period, some 350 million years ago, when sea covered the Canning Basin. They are regarded by geologists as being among the best-preserved fossil reefs in the world.

The excellence of exposures and the comparatively small amount of deformation and alteration of the limestones make these reefs ideal for detailed study. There is a sound economic reason for such research, as buried reefs of similar types have produced large quantities of oil in various parts of the world. During the past 7 years the Geological Survey of Western Australia has carried out an extensive programme of research in this area, concentrating on the origin and inter-relationships of the various reefal deposits, and on the animals and plants that have contributed to their development.

The limestone reefs making up the barrier-reef complex wind across the countryside some 150 to 350 feet above the adjoining plain, so that the present-day topography



This map shows the occurrence of the Devonian "Great Barrier Reef" fringing the Kimberley Plateau. The reef complex is well exposed east of Derby along the northern margin of the Canning Basin.

approximately reproduces that of the Devonian sea floor, the reefs rising from the plain in much the same way as they rose above the ancient ocean basin. From the air it seems almost as though they are modern reefs that have only recently emerged from the sea. The reason for the clear topographic expression of such ancient reefs is that the shales and other soft sediments that were laid down in the ocean basin and in channels between the reefs are readily eroded away to form valleys, whereas the reefs and their associated limestones are resistant to erosion and consequently stand out as ranges.

Spectacular gorges

The best exposures of the reefs and their associated deposits occur in a number of spectacular gorges cut through the ranges, notably in Windjana, Geikie, and Brooking Gorges. Apart from their great geological interest these gorges provide some of the most attractive scenery in the State, and one of them, Geikie Gorge, was recently declared a National Park. This gorge has been cut by the Fitzroy River through the Geikie Range. It is 8 miles long and is accessible by boat throughout its length. The limestone walls are polished clean by floods to a height of some 30 to 40 feet above the normal river-level. Such exposures are ideal for detailed examination of limestones. The polished surfaces show algae, stromatoporoids, and other organisms making up the reef complex beautifully preserved in their original growth positions. The modern fauna of the water in this gorge is also very interesting, as it includes sharks, sawfish, and stingrays.

These fish, which normally live in the sea, have apparently adapted completely to the freshwater environment of the gorge. Their ancestors must have moved up the Fitzroy River from the sea, progressing from one permanent pool to another, until they reached Geikie Gorge, which is about 200 miles from the sea via the river.

Windjana Gorge must rank among the world's classic geological localities. Nowhere else are the relationships between the various deposits of an ancient reef complex so well displayed as they are here. The gorge has been cut by the Lennard River through the Napier Range; it is $2\frac{1}{2}$ miles long and has near-vertical walls from 200 to 250 feet high. The gorge has an awe-inspiring grandeur which cannot fail to impress any visitor. Until very recently it was well off the beaten track, but it is now visited by increasing numbers of tourists, and its reservation as a National Park should be delayed no longer. The gorge contains permanent pools which are stocked with freshwater crocodiles and fish, including small sharks. Limestone caves in the area were used by the *Unggumi* and *Bunaba* Aborigines to store the skeletons of their departed tribesmen, and some caves are decorated with remarkable paintings of men and animals, especially *Wandjina* figures.

Well-preserved fossils

It is possible to obtain a clear picture of the environments in which these Devonian reefs developed by studying the rock outcrops in detail. The limestones are rich in well-preserved fossils which testify to the types of animal and plant life that lived in and around the reefs 350 million years ago. Thus we find that the organisms of the reefs themselves are quite different from those of the lagoons behind the reefs or those of the deep oceanic waters in front. The types of limestone and other rocks that developed in the different environments are also very distinctive, and can be mapped as separate units, to give a clear picture of the shape and structure of the reef complex.

The reefs were built up by various lime-secreting algae and animals that had the ability to build wave-resistant reef frameworks close to sea-level. The main contributors were calcareous algae (especially blue-green forms), stromatoporoids, and corals, in that order. Modern reefs have been constructed mainly by corals and calcareous algae, but in these Devonian reefs corals were less important than stromatoporoids, a group of colonial organisms, now extinct, which resemble corals in their growth forms, but differ in their skeletal structure.

The wave-resistant reefs formed a relatively small part of the total volume of the barrier-reef complex. The reefs were commonly only 100 to 1,000 feet wide, each forming a narrow rim around a broad lagoon in which back-reef organic limestones were deposited. In front of the reef extensive talus deposits were laid down, largely derived by wave erosion of the growing reef. It is similarly true of modern reef complexes that the reef rim normally forms only a small part of the reefal deposits as a whole, although of course the reef is the controlling feature of each complex. In the Canning Basin, the reefs and their associated lagoonal deposits together formed limestone platforms that rose to 600 feet or more above the surrounding sea floor. They ranged from small atolls a few acres in extent to extensive bodies covering hundreds of square miles. Small patch reefs lacking central lagoons also developed in some areas. The reefs commonly grew upward and outward, advancing over their own fore-reef talus deposits, although in some cases the reef retreated over the back-reef lagoonal deposits. During the Devonian the area was slowly subsiding, and the reef-building organisms were able to keep up with this subsidence, thus building up very thick deposits of limestone. The maximum thickness of these reefal deposits in the Canning Basin is believed to exceed 5,000 feet.

The Canning Basin "Great Barrier Reef" fringed a Devonian landmass that is occupied today by the Kimberley Plateau. In Devonian times this land area had a mountainous topography that resulted from a period of block faulting shortly before reef growth began. Torrential conglomerates were shed from the active fault scarps, and some of these interfinger with the reefs, especially in the Sparke, Burramundi, and Van Emmerick Ranges. The barrier-reef complex is believed to have extended right around the Kimberley landmass beneath the present continental shelf, to join up with closely similar reef limestones that are now exposed in the Bonaparte Gulf Basin.

Above: An aerial view looking northwest along the Napier Range at Windjana Gorge. The gorge has been cut by the Lennard River, exposing a classic section through the barrier-reef complex (which can be seen winding off into the distance). *Below:* The southwestern wall of Windjana Gorge, three-quarters of a mile from the gorge's eastern entrance. This wall is the one at the bend in the left foreground of the photo above. The massive limestone in the centre of the photo below is the reef; it is flanked on the left by steeply dipping fore-reef talus deposits (the dip of which is depositional) and on the right by flat-lying limestones laid down in the lagoon behind the reef.

Lagoonal environment

The back-reef lagoons protected by the reef rims were generally rather shallow, and in some areas they included mud flats that emerged at low tide. However, certain lagoons were up to 200 feet deep. The types of limestone laid down in the lagoonal environment are quite distinctive. They are well bedded, and were generally laid down nearly horizontally. Limestones that were bound or precipitated by algal mats are common, as are those composed of *Amphipora*, a distinctive spaghetti-like stromatoporoid. Patch reefs grew in some lagoons, but they seldom make up a major part of the lagoonal deposits. The lagoonal fauna is dominated by a few species, and generally lacks forms that are typical of normal open-ocean conditions. The water of the lagoons probably had salinities significantly greater than that of normal sea-water, owing to the restriction of circulation caused by the reef rims and to the high rate of evaporation in the shallow water.

Talus slopes descended steeply from the front of the reefs to meet the ocean floor at depths that probably exceeded 600 feet in some areas. These slopes were mantled with debris broken from the growing reefs by wave action. From time to time large landslides occurred down these steep slopes, and enormous blocks were broken away from the reefs. The fore-reef deposits thus show steep depositional slopes (commonly as high as 35 degrees) marking successive talus slopes, and they include a great deal of reef debris, ranging from small fragments to huge blocks the size of multi-storey buildings. Various organisms lived on the fore-reef slopes, brachiopods being especially abundant in some areas. Algae, sponges, corals, and stromatoporoids commonly grew on the upper parts of the slopes, close to the reefs. Depositional dips of up to 55 degrees occur in some areas where the fore-reef deposits were bound together by algae.

Ocean-floor deposits

The deposits of the ocean floor and of deep channels between reefs consist largely of sands, silts, and clays carried in from the land areas, together with beds of limestone and limestone concretions. They include little or no debris from the reefs, and were laid down nearly horizontally. The fossil fauna is dominated by pelagic organisms (i.e., free-swimming or floating open-ocean forms), and is commonly beautifully preserved. The fossil ammonoids, conodonts, fish, and crustaceans from these deposits are world famous. They show close similarities to forms that occur in the Devonian strata of Europe. The ammonoids and conodonts, which evolved rapidly, have been used to determine the relative ages of the strata very precisely.

Part of the Devonian barrier-reef complex is buried beneath younger sedimentary rocks in the northwestern area of the Canning Basin, and it is regarded as a prime objective for oil exploration. Devonian reefs are also possible objectives in the offshore areas around the Kimberleys. The Canning Basin reefs show some clear similarities to those of western Canada, which have produced the bulk of that country's oil, and consequently there are strong hopes that the Western Australian examples will one day prove to be similarly productive.

[*The photos and map in this article are by the author.*]

FURTHER READING

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PREHISTORIC PAPUAN ENGRAVING

THE engraved shell above was dug up at Rainu, Collingwood Bay, southeastern Papua, in 1904. No other similar objects are known from Melanesia from either prehistoric or modern times, and it is therefore one of the mysteries in the prehistory of Papua-New Guinea.

The design is made up of a bird with a vertical row of three tight anti-clockwise spirals on each side. It was first engraved and then the background around it was reduced, leaving the figures in low relief. The reduction may have been done by pecking and grinding. In working on the body of the bird the artist originally incised a line too far up the shell. This mistake, and the later correction which flattened the bird's back slightly, can be clearly seen in the illustration.

The design on the shell is similar to "Massim" art, which was made in European times in this area of southern Papua. However, it is clearly not a recent form of this art, in which scroll-work, circles, and highly stylised bird motifs, usually said by ethnographers to be the frigate bird (*Fregata* species), predominate. It is important to remember that the artist was almost certainly not attempting to produce a photographic likeness of a particular bird, but was working within his own cultural tradition, so it may be difficult for us to interpret the end result.

The engraving (No. E.15597 in the Australian Museum's collection) was found in an old village mound by the Rev. P. J. Money, an Anglican missionary who was an honorary collector for the Australian Museum. In the mound he found at least ten other engraved shells with incised or relief decoration. Two of the shells bear a human face motif, but the most common designs are spirals and ellipses like that forming the bird's body.

In the same mound he also found many potsherds, decorated with concentric circles, spirals, and grooved arcs, unlike pottery made in the area in 1904. In addition, stone axe-adzes, conus shell arm rings, as well as pig and human bones, were found. Of special interest were fragments of a stone mortar and a stone club-head: although club-heads were in use until very recently, stone mortars have never before or since been found in association with pottery.

We cannot now date this shell. The evidence was destroyed when it was dug up under uncontrolled conditions, and no carbon or other organic remains definitely associated with it were retained. The shell itself could be dated by the radio-carbon method, but it is too small to give a good date and it would be destroyed in the process. We know that it is prehistoric and, because of its stylistic affinities and associated finds, expect it to be less than 1,000 years old.

The shell itself is a three-quarter section of the outer whorl of a large, heavy cone, which appears to be *Conus leopardus* (sometimes called *Conus millepunctatus* or confused with *Conus litteratus*). This cone shell is known from the area and occurs widely in the Indo-Pacific. The engraved section is 10·5 cm high and 8·5 cm wide at the base. It appears to have been sawn off at top, base, and sides, presumably prior to the engraving of the design.

Firm identification of the bird portrayed in the engraving is not possible. However, the following points are considered important in any attempted identification: the straight, short bill without any indication of a hooked tip; the rounded, high head outline with a series of short lines incised at right angles to the crown and back of the head (crest?); the simple curve of the neck, not sinuous as in a heron; the engraved groove down the line of the neck (wattle?); the weakly curved dorsal outline of the back, not hunched as in a heron or a jabiru; the engraved longitudinal lines of the body (artistic tradition or wing feathers?), and the dorsally placed spiral at the tail end, reminiscent of the up-curled tail feathers of a mallard. The lack of legs does not necessarily indicate that the bird is floating or sitting.

The attitude and general appearance of the bird suggest a stork, but none are known from this area of New Guinea. The Jabiru or Black-necked Stork (*Xenorhynchus asiaticus*) occurs in the southern lowlands of the island, but is apparently not known east of Port Moresby; bill length and body features also appear to exclude it from further consideration. Other birds suggested by the engraving include cassowaries (the Double-wattled Cassowary and the Dwarf Cassowary both occur in the area), cranes (only the brolga, *Grus rubicunda*, occurs in New Guinea, but it is not recorded east of the Sepik and Fly Rivers), ducks, shags or cormorants, and grebes (all with species known from the area).

Whatever its date and cultural context, however, the superb craftsmanship of the Rainu specimen appears to be unique to this area—and to prehistoric times there.—*J. P. White and H. J. de S. Disney, Australian Museum, and J. C. Yaldwyn, Dominion Museum, Wellington, New Zealand.* [*Photo by C. V. Turner.*]

MOTH EGGS!

By NOEL McFARLAND
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INSECT eggs, so frequently overlooked (even by entomologists), show an incredible variation in shape, surface texture, and colours. A few of the countless interesting forms and adaptations to be encountered in Australia are illustrated here by greatly enlarged photographs of the eggs of nineteen species of moths.

If some butterfly eggs had been included a considerably different series of shapes would be seen, even though butterflies and moths are very close relatives within the same major insect group—the order Lepidoptera. If representative eggs of certain other insect orders were also included (such as Hemiptera, Coleoptera, Hymenoptera, Neuroptera, or Diptera) the variety of egg forms would be increased still further. That, of course, would be far beyond the scope of a short article. Therefore, I decided to limit this article to eggs selected from twelve families, using only moths as examples. To put this small effort into the correct perspective, it is important to realize that there are over 100 families of moths in the world, and that 75 of these families are represented in Australia. Some of these families contain thousands of species. *Perhaps these photographs will alert Australian entomologists and naturalists to an intriguing area of study that has hardly been touched in this country.*

Moths, butterflies, and some other insects can often be readily identified as to genus, and sometimes as to species, by differences in their eggs. Some species are, in fact, more easily separated from their close relatives by their eggs than by the adult insects themselves. The egg should never be overlooked by taxonomists, or by others interested in accurate identification of species. There are, however, many closely related species whose eggs are hard to separate without careful study of all details, including the micropylar region, using high magnification. The micropyle is a minute opening through which spermatozoa enter during fertilization. (See fig. 10). Other entomological terms used here are: ovipositing or oviposition (the act of depositing eggs by the female moth); ovipositor (a tubular structure, in the tip of the adult female moth's abdomen, by means of which the eggs are deposited); foodplant (the specific plant, or plants, upon which the larvae of a moth feed). The use of the term "glue", to describe the adhesive with which eggs are attached to the plant, is a term of convenience, quite clear in its meaning. (There is no need to disguise the meaning with a longer word!).

The glue is usually a colourless fluid, which hardens upon contact with the air as the eggs are being deposited. It is more-or-less waterproof once set. This is imperative in the case of species whose larvae feed upon trees, tall shrubs, or high-climbing vines: otherwise, the eggs could be washed from their points of attachment on the foodplant leaves or stems during rainstorms, and the minute, newly-hatched larvae (caterpillars) would then have little chance of returning to the correct leaves during the short period, after hatching, when they are able to exist without food. Exceptions are found among some of the moths whose larvae are "general feeders" upon many kinds of plants, or upon weeds, grasses, or other low plants that densely cover the ground, or upon the roots of plants. These moths often deposit their eggs free (unattached—no glue), or the glue, when present, may be quite weak and the eggs readily become dislodged, which does not matter under these conditions. Such eggs frequently approach a spherical shape. Young larvae of these species rarely have any trouble finding their food near at hand when they hatch.

The time required for moth eggs to hatch varies greatly, depending on the season and temperatures, the species, its life-cycle, the growth-cycle of its foodplant, and the part of the plant eaten. A large number of species will hatch within an average period of 5 to 15 days. But many others, especially autumn or winter moths of cool or temperate regions, are known to spend from 3 weeks to several months in the egg stage.

Some pass the winter in the egg stage; others may pass the dry season of deserts or semi-arid regions as eggs. Eggs of such species are often protectively coated in some way, or deposited in crevices, or the shell is hard and tough.

Methods for inducing moths to oviposit in captivity and techniques of egg photography cannot be covered in this article, but these topics are partially covered by some of the publications listed at the end.

Comments on the illustrations

Most of the eggs illustrated in this article were deposited by moths in captivity. Many of the moths were attracted to ultraviolet lights in my garden at Blackwood, South Australia. [The ultraviolet lights were G.E. F15T8.BL (a "black light"); substitutes are not recommended if the best results are desired.] All the eggs illustrated (except fig. 9) can be found in the State of South Australia, and some of them eastward to New South Wales; of the remaining eighteen species, fifteen can be found in the Blackwood-Belair region of the Mount Lofty Range, south of Adelaide, South Australia. When no locality is given below the name the eggs were deposited by moths captured at Blackwood.

The figures in this article were selected from available egg photographs of over 100 species, primarily to illustrate some of the amazing *differences* that exist between the eggs of moths in various families, and sometimes even within one family. (Eggs of birds seem quite uniform by comparison!) Basic *similarities* between species of different genera, within the same family, are illustrated by figs 10 and 11, while figs 7 and 8 show the easily-distinguished eggs of two closely related species of anthelid moths, far less readily separated in the adult stage. All photographs are by the author, and all show living, unhatched eggs.

In the study of insect eggs, some important differences to look for (and record) are: (1) The manner in which eggs are deposited by the moth—dropped on the ground and in no way attached to anything, or attached or glued to a certain part of the foodplant (note which part); strength of the adhesive (heavily or lightly glued); attached singly, in twos or threes, in rows, flat or heaped masses, in stacks, or in other formations, which may be regular or irregular; (2) naked as against covered with hairs, scales, or some other substance (e.g., dried frothy covering, soil particles, etc.); (3) basic shape or outline of the egg, and its various profiles as viewed from different positions; (4) type and extent of surface sculpturing (ribs, granulations, pits, etc.); (5) general hardness or softness of the shells; (6) transparent as against opaque or partly-opaque shells, and degree of surface-shine; (7) *all* colour changes that are observed during incubation; (8) measurements of all dimensions in a sequence of *diminishing maximums;* (9) mode of exit by hatching larva, and from which part of egg (side or end); is shell devoured (entirely, partially, or not at all)?

Many moths can be found flying only during certain months of the year. (Dates given are the months during which adults may be collected at the locality indicated.) Some of the spring and summer species have more than one generation during a year, but many others do not. The majority of autumn and winter species are single-brooded. As a matter of interest to readers in the Northern Hemisphere, it should be mentioned that in southern Australia the four seasons are as follows: September–November = Spring (moist grading to dry); December–February = Summer (mostly dry and warm to hot); March–May = Autumn (dry grading to wet); June–August = Winter (mostly wet and cool to cold). October in coastal South Australia corresponds roughly to April in coastal southern California. Annual average rainfall is 28 inches at Blackwood, S.A.; most of this falls between May and September. Occasional heavy summer rains can also occur.

Because the magnifications used in many series of photographs are not necessarily indicative of the relative sizes of the various eggs, the actual measurements should always be recorded for each species to an accuracy of at least 0·05 millimetres. (This can be easily done with metric dial calipers). Anything more exact than 0·05 millimetres is not necessary or meaningful with larger moths, because the eggs of many species can vary by as much as 0·10 millimetres (in length and/or width) within a batch obtained from one female. Great variation in egg size is sometimes the case within certain species of the family Geometridae, for example.

The eggs illustrated here (along with numerous others), usually accompanied by the associated larvae, pupae, and adult moths, are preserved under specific code-numbers for each species. These preserved specimens (as well as corresponding field notes and photographs, etc.) will become available to qualified specialists for future study.

THE ILLUSTRATIONS

Superfamily Hepialoidea

Family Hepialidae (Ghost Moths)

Fig. 1: *Aenetus blackburni* (late March to early April). These eggs are dropped free by the female moth (in no way attached to any surface). This is the typical mode of oviposition among the Hepialidae. Some hepialid eggs are more or less perfect spheres, and the shell is usually rather soft and easily dented. Some collapse of the shell takes place during development. When freshly deposited the eggs of this species are pure white, but they soon become opaque black.

Superfamily Zygaenoidea

Family Zygaenidae (Foresters, Burnet Moths)

Fig. 2: *Hestiochora rufiventris* (late November to December), 43 miles west of Eucla, Western Australia. As in many (perhaps all) other zygaenoids, the eggs are notably soft-shelled. They are attached in long series up and down the leaves and stems of the foodplant, closely end-to-end, but rarely in actual contact. Colour, pale yellowish.

Family Limacodidae (Slug Moths, Cup Moths)

Fig. 3: *Doratifera oxleyi* (mid-March to mid-April). The shells are very soft and easily broken; it is almost impossible to separate these eggs without damaging them. They are extruded by the resting female in long and sinuous chains, rather like toothpaste being squeezed slowly from a tube. Colour, translucent yellowish; surface shiny.

Fig. 4: *Pseudanapaea trigona* (October to mid-May). The photograph shows two eggs, close to hatching, as seen from the underside. (They were deposited on a thin sheet of clear plastic.) The small larvae are clearly visible through the colourless and transparent shells. The shells are exceedingly thin, pliable, and easily ruptured. In nature, they are attached singly to the foodplant leaves, appearing (at first) like tiny, clear, flattened droplets or water, barely visible when viewed from above; later, they could be mistaken for flat, shiny scale insects adhering to the leaves. When being deposited by the moth, they are so soft and flexible that individual eggs often have entirely different shapes, depending upon the angle of contact of the moth's abdomen with the leaf surface (and the pressure exerted) at the moment of oviposition. Thus, only "average" measurements of egg length and width can be made for this species. *Of all species I have seen to date, this one would seem the ideal subject for anyone wishing to study larval development as it takes place inside an insect egg.*

Superfamily Pyraloidea

Family Pyralidae (Pyralids), Subfamily Epipaschiinae

Fig. 5: *Epipaschia pyrastis* (November–April). These are very much flattened, soft-shelled, and "scale-like", with a finely-pitted surface which results in a sparkling surface shine. They are deposited in distinctive flattened masses, like shingles on a roof, each one partly overlapping those in front of it. The photograph shows only a part of one mass, as attached to the foodplant leaf.

Superfamily Bombycoidea

Family Lasiocampidae (Lappets)

Fig. 6: *Digglesia rufescens* (December–February; May–July). Typical of most bombycoid eggs, the shells are tough and firm. The eggs are securely glued to the surface—in this case a piece of stiffened muslin, which is ideal for causing many moths to oviposit in captivity. The white areas of the shell are opaque. When the eggs hatch, the dark areas will show as transparent on the empty shell, and the opaque white markings will remain (on the empty shells) exactly as seen in the photograph. The general appearance of these eggs is typical of many other lasiocampid eggs.

Family Anthelidae (Anthelids)

Fig. 7: *Pterolocera* species (April–May). Ten miles west of Vivonne Bay, Kangaroo Is., South Australia. These are very tightly glued to each other, wherever they contact along the sides. The shells are opaque. See the dry rings of colourless adhesive (glue) on the two eggs that have been broken off the main mass (upper right). This species occurs in scrub areas away from the immediate coast around Adelaide, and on Kangaroo Island. A related species in southwestern Western Australia has strikingly different eggs, although similar to these in shape.

Fig. 8: *Pterolocera* species (April). Halletts Cove, South Australia. The egg in the upper right corner shows the end view. The shells are opaque. The adult female moths of this genus are wingless. The adult males of this and the preceding species look quite similar at first glance, but clear-cut differences in the eggs of these two species are immediately obvious (both in shape and markings). This species occurs along the coast in certain areas near Adelaide, and on Kangaroo Island.

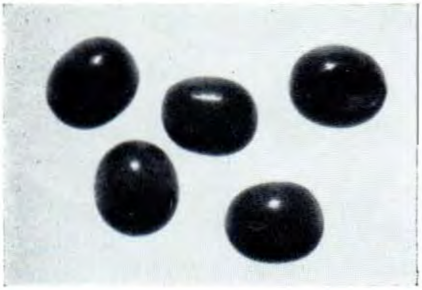
Family Carthaeidae

Fig. 9: *Carthaea saturnioides* (late September to early December). Stirling Range, near Toolbrunup Peak, Western Australia. For details on the larval, pupal, and adult stages of this superb moth, see Common (as in "Further Reading" list at the end of this article). The eggs are at first a uniform light yellowish with a bright surface shine. They are normally glued in irregular small groups (twos or threes, etc.) on the new leaves of the foodplant.

Superfamily Notodontoidea

Family Notodontidae (Prominents)

Fig. 10: *Danima banksiae* (March–October). Ten miles west of Vivonne Bay, Kangaroo Is.,



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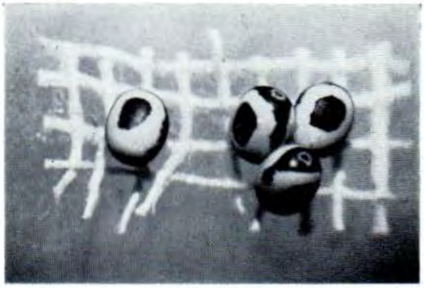

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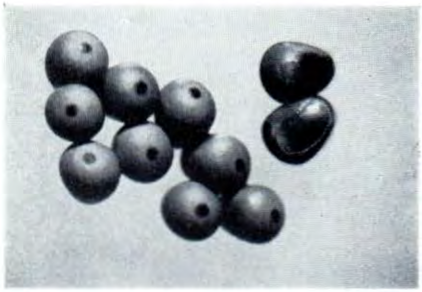

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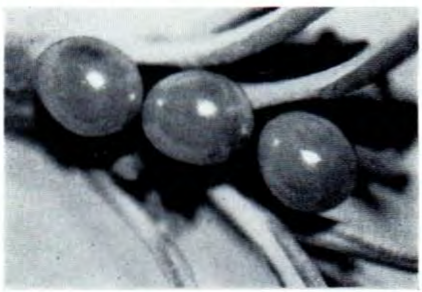

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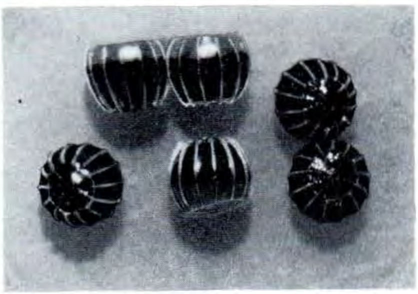

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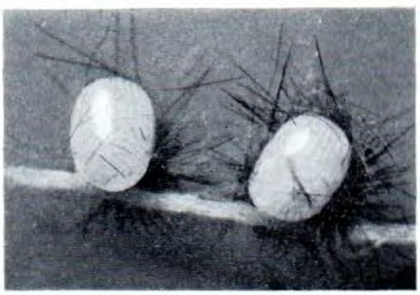

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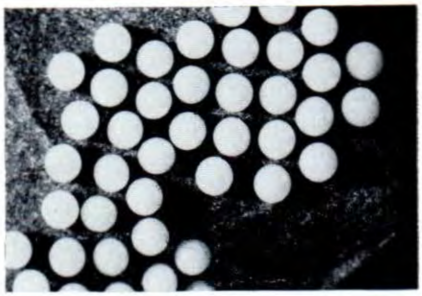

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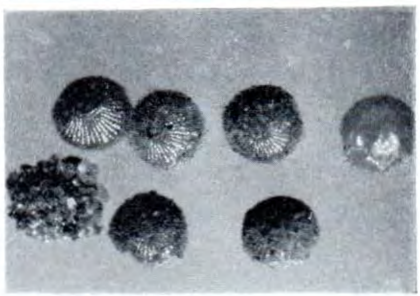

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South Australia. These large, intensely chalk-white eggs are so conspicuous on the dark green linear leaves of certain species of *Hakea* that they are quite easily seen with the naked eye from distances of 10 feet and more! They are usually deposited singly. Field-collected eggs of this species (from Kangaroo Is.) were found to be commonly parasitized by a minute black wasp. The small dark spot, on top of the egg, covers the micropylar area. The inset shows a partially-eaten shell from which the larva has recently emerged. Note that the shell is uniformly opaque, not a common feature among moth eggs except in the Bombycoidea and a few other groups. With opaque eggs it is not possible to see colour changes as the larvae develop inside.

Fig. 11: ***Hyleora*** species (March to early May). These eggs illustrate the commonest notodontid egg profile—quite flat on the bottom and evenly dome-shaped above, without ridges or other major surface sculpturing. (Similar eggs are seen in many Northern Hemisphere notodontids). The shell is very tough in this species, but not opaque; the colour changes are spectacular.

Family Thaumetopoeidae (Processionary Caterpillars and relatives)

Fig. 12: *Epicoma melanosticta* (November–May). These eggs are evenly-curving over the top, with flat bottoms, but the lower rim is not sharp. During oviposition they are covered and interwoven with pale golden-tan "hairs" from the tip of the female's abdomen, which bind them together into a somewhat flexible cluster. In the photograph the egg mass is shown lighted from beneath.

Fig. 13: *Discophlebia catocalina* (mid-November to early February). These are securely glued upright, in short irregular rows and smaller groups (sides usually stuck together), never with any attached scales or hairs. They are prominently ribbed and shiny, with a peculiar two-tone (internal) colour pattern. The lower one-third or one-quarter of the egg is milky-whitish, while the remaining upper area is dark sooty-brown. The two uppermost eggs, and one in the middle, are seen lying on their sides; the other three are standing upright as they are deposited.

Figs 14, 15: *Oenosanda boisduvalii* (mid-March to mid-May). The two eggs in fig. 15 were removed from the densely-covered egg mass shown in fig. 14. Some of the dark "hairs" (from the tip of the female's abdomen) are still adhering, and the eggs remain standing end-up, as they were attached to one of the strands of muslin upon which this mass of twenty-five eggs was deposited. The elongate-cylindrical egg shape, with weak longitudinal ribs, is unusual in the Notodontoidea.

Superfamily Noctuoidea

Family Arctiidae (Tiger Moths and relatives), Subfamily Lithosiinae (Lichen Moths)

Fig. 16: *Xanthodule ombrophanes* (October–November; February–June). This photograph is a rather poor copy from a colour slide, but was included because it shows a most unusual form of oviposition among the Arctiidae. The flightless female moth waits on her cocoon until the winged male locates her; after mating she rapidly deposits her eggs all over the surface of the cocoon, then falls to the ground and dies. A shrivelled moth (about to die), having laid all her eggs, is seen clinging to the right end of the cocoon; the thin, shiny and nearly colourless empty pupal shell, from which she emerged a day or two earlier (with a huge abdomen full of eggs), can be vaguely seen inside the cocoon. The egg shape could almost be described as a blunt pyramid.

Fig. 17: *Scoliacma bicolora* (October–November; January to mid-April). Aldgate, Mt Lofty Range, South Australia; collected by Andrew Smith. A unique feature of these small eggs, which are glued in groups close together but not touching (much like those in fig. 18), is their almost water-clear translucence when freshly deposited. The uppermost egg is turned over, showing the more flattened underside, which has been slightly dented. The second egg from the left, in the lower row, is standing on its edge, to show the lateral profile (its bottom faces to the right). The newly-hatched larvae eat their egg shells entirely before dispersing.

Subfamily Nyctemerinae

Fig. 18: *Nyctemera amica* (December–June). These rounded, smooth, shiny eggs are, in general appearance, typical of many arctiid eggs the world over. They are slightly flattened on the bottom (where attached), and so are not perfectly round, although they seem to be when viewed from above. It is interesting to note that this species does not deposit its eggs in actual contact with each other; even though they are very close together in a mass formation, the precise spacing is always maintained. Part of a mass is here shown as attached to the surface of the foodplant leaf.

Family Noctuidae (Owlet Moths, Cutworms, etc.)

Fig. 19: *Cosmodes elegans* (October–June). Here is an egg shape typical of many noctuids. Also, note the ribs. When first deposited the eggs are pure white. After a day or two, an irregular dark-brown band-pattern can be seen developing through the shell as changes take place inside. The eggs are deposited weakly glued and unattached.

Family Agaristidae (Day Moths)

Fig. 20: *Apina callisto* (mid-April to mid-May). Walkerville, Adelaide, South Australia; very localized distribution in open grassy-weedy areas, but usually abundant where it is present. This species is amazing for the habit of the female moth during oviposition: she deposits her eggs on the ground, attached to bits of litter or soil particles, or even to dry pieces of horse manure! (At this time the foodplant is not present on the dry ground). Just prior to oviposition the female crawls along, "dabbling" the tip of her abdomen in dusty-dry soil, picking up fine particles. A few eggs are then deposited, and the first of these will be heavily coated with soil (see one in lower left corner). The soil-dabbling is then repeated during a short walk by the moth, and a few more eggs are deposited. Most of those in the photo have been brushed partially clean, to show the distinctive sculpturing on the upper surface of the shell, but the one at the lower left represents the natural condition of a first egg deposited after soil-dabbling. The one at the

far right shows the smooth and shiny underside, rubbed clean of soil particles.

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PHILLIP E. PLAYFORD was born in Perth and graduated with Honours in Geology at the University of Western Australia in 1952. He attended Stanford University, U.S.A., as a Fulbright Scholar (1959 to 1961) and was awarded a Ph.D. in Geology. He is now Supervising Geologist with the Geological Survey of Western Australia, and is President of the Royal Society of that State and an Honorary Associate of the Western Australian Museum. Dr Playford has published widely on geology, specializing in reefs, stratigraphy, and petroleum geology. He has also published papers on history and anthropology.

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