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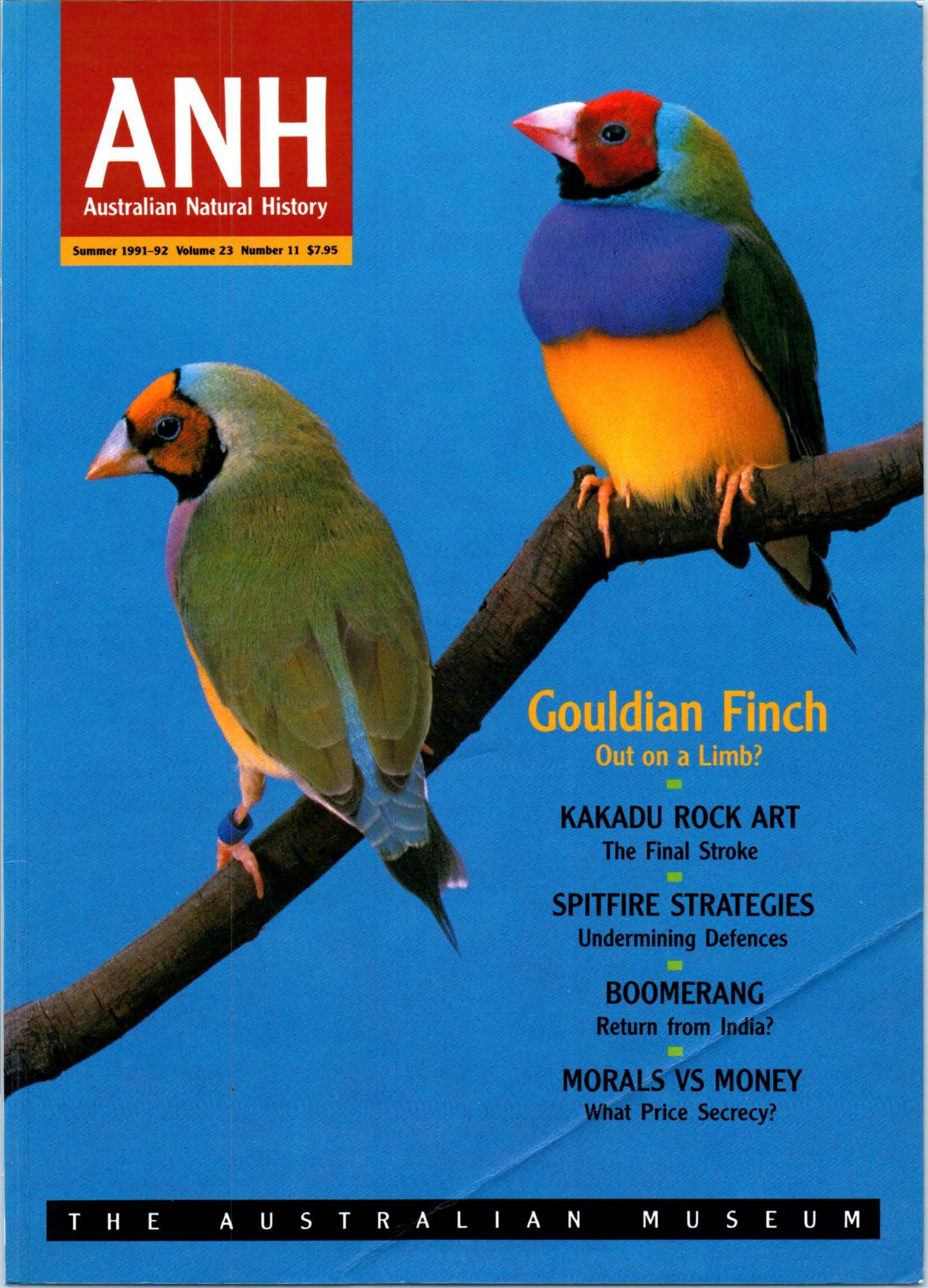


Gouldian Finch
Out on a Limb?

KAKADU ROCK ART
The Final Stroke

SPITFIRE STRATEGIES
Undermining Defences

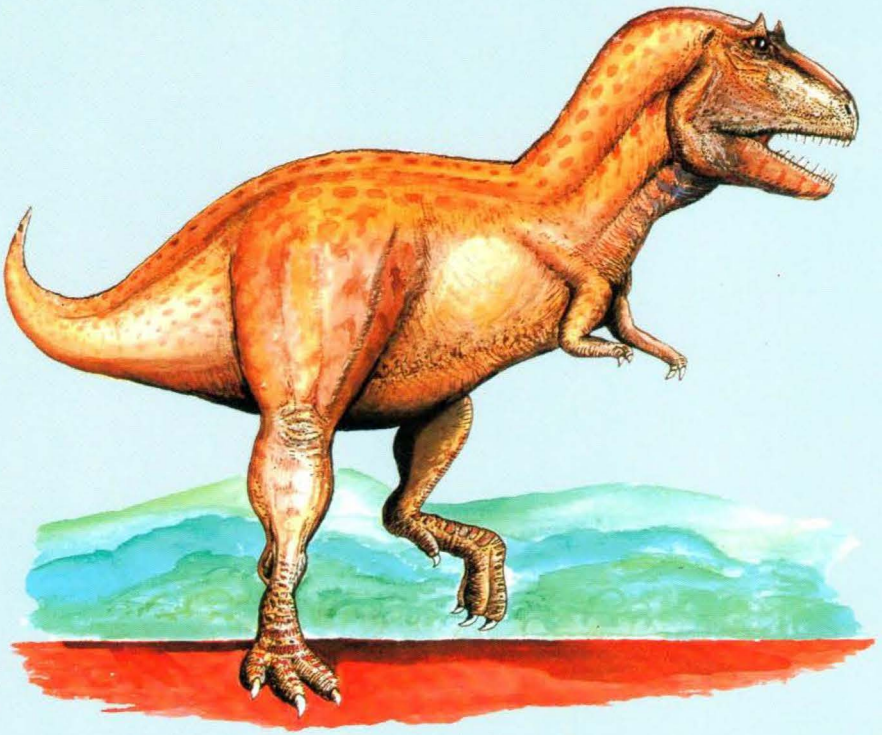
BOOMERANG
Return from India?

MORALS VS MONEY
What Price Secrecy?

THE AUSTRALIAN MUSEUM

THE DINOSAUR CLUB

(no, not something you use to hit dinosaurs with)



Scientists at the Western Australian Museum formed *THE DINOSAUR CLUB* to provide information on dinosaurs and other prehistoric creatures in an easy to read, enjoyable format. Through our magazine *DINONEWS*, you can read about latest discoveries from around the world, and help provide funds for scientists to continue researching our prehistoric past.

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Front Cover
The most brilliantly coloured of all finches, the Gouldian Finch has declined drastically over the last two decades. Many are affected by parasitic mites, which could be preventing the species' recovery. Photo: C. Andrew Henley, Auscape International.

E D I T O R I A L

DESIGNER GENES

BY FIONA DOIG
MANAGING EDITOR

SINCE THE FIRST GENE WAS SPLICED 20 years ago, genetic engineering has developed at a rapid rate. Farm animals have been genetically manipulated to produce human proteins in their milk to treat conditions like heart attacks and emphysema. Crops have been made frost-resistant, salt-tolerant or herbicide-resistant. This technology has been hailed as a saviour of the agricultural industry, medicine and the environment. Its potential is enormous.

A CSIRO genetics team has recently developed a cotton plant that produces its own insecticide. Since cotton farming normally requires vast quantities of pesticides, this new plant could reduce its impact on the environment as well as save money. But how will such plants cope when introduced into the environment?

While some exciting new developments are afoot in genetic engineering, there is great concern about the safety of releasing genetically engineered life forms into the environment. Until recently, most genetically engineered organisms were not intended to survive outside the laboratory. But many recent developments, like new crops, must be able to multiply to be of any benefit. They will be able to compete with natural flora and fauna.

In any new field of science, one must tread warily. Just as Faraday didn't expect the world to become polluted by dependence on fossil fuels, it is unlikely that Mendel's monkish mind contemplated how his experiments with beans might one day lead to the ability to design new species. Exciting as the new developments may seem, we are toying with a potentially lethal technology.

Biotechnologists reassure us of low risks, often on the assumption that genetically engineered organisms will be less fit than native species. But this is at best an educated guess. It really is not known how well they will adapt. We are more than careful with our biological control programs since the Cane Toad scare. Yet cavalier attitudes have been shown around the world where new genetically engineered organisms have been tested in field trials or released without approval.

Large profits can be made with genetically engineered products, so the private sector has invested heavily. Unfortunately this has led to a 'fastbucks' mentality, with many products being created for short-term profitability. Why, for example, would we *want* herbicide-resistant crops? Making crops more tolerant to weed killers is not going to solve any long-term problems. Bandaid applications of a technology with such vast potential are foolish and only diminish its value. Research and development priorities for Australia must be set.

The potential hazards of releasing genetically altered organisms into the environment are enormous – even more so than introducing an exotic species. A new life form that can multiply can't be recalled like a faulty vehicle. So once a new organism is released from the lab it is essential to monitor and control its dispersal.

But I am horrified to find that laws in Australia to regulate genetic engineering are still non-existent. An advisory committee exists but its guidelines are not mandatory. International companies could use Australia as a testing ground where strict regulations at home prevent experimentation. This contrasts absurdly with Australia's strict customs controls regarding the importation of exotic species.

No organism exists in isolation, whether it is natural or a genetic product. Any testing and introductions must be carefully controlled, monitored and understood or the industry itself could suffer unnecessarily. One badly monitored experiment would not only cause massive ecological destruction, it would also cripple what promises to be a significant industry in Australia. Mandatory, rigid guidelines controlling genetic engineering applications are vital.

A House of Representatives Standing Committee is currently conducting an inquiry into genetic engineering and is expected to recommend a system of appropriate laws. Such a move has been welcomed by scientists, ecologists and critics alike. But I fear a potential minefield for debate will erupt over the nature of the laws themselves. Whatever the criticisms, the final outcome must have some means of enforcing the new laws with severe penalties for breaches. And regulations must address priorities for research and development in Australia so that real long-term problems are covered. If we work out a sound, well-structured set of laws that recognises the priorities for genetic engineering, perhaps we can show the rest of the world that we are ahead not only in this new technology but also in its ethical applications and control. Now *that* would be a feather in Australia's scientific cap. ■

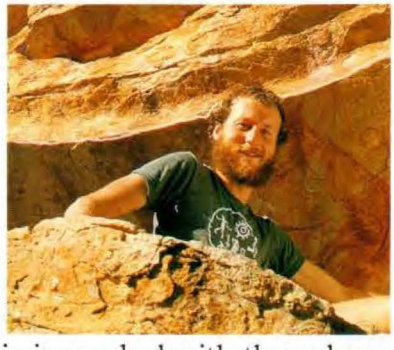
IN THIS ISSUE

BY GEORGINA HICKEY
SCIENTIFIC EDITOR

MARY WILLSON

THE SPOTTED PROFILE BELONGS to Monash University lecturer Dennis O'Dowd. And the itchy calling cards were left by mites while he was researching in a tropical Australian rainforest for the article on plant-mite mutualism. Fortunately for Dennis, and his colleague Mary Willson, the mites they are interested in do not have a penchant for parasitising people. Instead these tiny mites are involved in a mutually beneficial arrangement with plants whose leaves provide them with special shelters or 'mite houses'.

Also pictured is Australian Museum anthropologist Paul Tacon, who was fortunate enough to witness and record a traditional rock artist painting in Kakadu. What makes this painting so special is the fact that it will probably be the last for this area. In the article Paul describes the processes from go to whoa and discusses the significance of rock art in general.



COURTESY PAUL TACON

Other articles in this issue deal with those huge writhing masses of black sawfly larvae or 'spitfire grubs' seen on eucalyptus trees in spring, and we trace the development and refinement of methods used to date archaeological material. Tim Low presents food for thought about Aboriginal food lists; Robyn Williams sings the praises of a British green machine; and Ralph Molnar discusses arms races from an evolutionary view point, of course.

Also in this issue are stories about the plight of the Gouldian Finch (featured on the cover); morals versus money in scientific research; racism, romance and Indian/Australian relations; and lots more. The poster is an 18th-century illustration of a banksia.

Articles

A POCKETFUL OF MITES

If you look carefully on the undersurface of many leaves, you will find tiny pits, pouches, pockets or hair tufts that are home to even tinier mites. In return for shelter, the mites may protect the plants from fungal attack and other natural enemies.

BY DENNIS J. O'DOWD & MARY WILLSON

840

UNDERMINING SPITFIRE DEFENCE STRATEGIES

'Spitfire grubs' or sawfly larvae employ various defence strategies against predators, the most obvious one (and the reason for their name) being the spitting or regurgitating of eucalyptus oil. However one parasitic wasp has evolved the ability to overcome these strategies and so might well be worthy of consideration as a biological control agent.

BY PHILIP WEINSTEIN

848

THE TEST OF TIME: PHYSICAL DATING METHODS IN ARCHAEOLOGY

Often we are told the age of an ancient human skull or Aboriginal artefact and we accept it point-blank. But have you ever wondered just how such specimens are dated? Various dating techniques have been developed over the years and, as the methods are refined, so too are important archaeological dates, such as the age of human colonisation of Australia.

BY R.G. (BERT) ROBERTS & RHYS JONES

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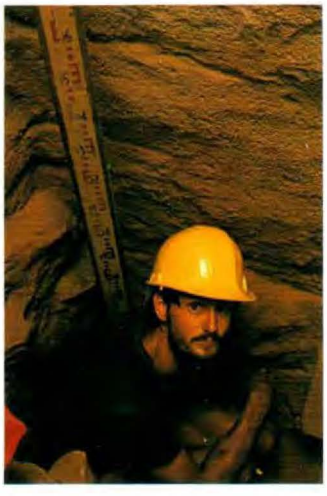

THE LAST ROCK PAINTERS OF KAKADU

Aborigines have been painting in Kakadu for over 18,000 years. However, with many of the traditional painters now dead, with Aborigines no longer camping in rock shelters, and with many of the sites now protected, rock art painting in Kakadu has become a thing of the past. This article bears witness to Kakadu's 'last stroke'.

BY PAUL S.C. TACON

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Regular Features

FROM THE ARCHIVES

THE INDIAN BOOMERANG

What do you call a boomerang that doesn't come back? A stick? This answer is not so silly as the riddle would have it. A curved stick or 'Indian boomerang', however, would be closer to the truth. The story of one such 'Indian boomerang' is related here. Reading a bit like a Harold Robbins novel, it involves politics, attempted murder, travel and romance.

BY CORALIE YOUNGER

832

RARE & ENDANGERED

THE GOULDIAN FINCH

The last 20 years have seen the drastic decline of Australia's most brilliantly coloured finch. And to make matters worse, the species has now been found to be heavily infected by a parasitic mite that affects the birds' breathing efficiency, preventing them from flying long distances in search of water and food.

BY SONIA TIDEMANN

834

WILD FOODS

A QUESTION OF METHODS

The technique used to reconstruct an Aboriginal food list assumes Aborigines ate all available food plants in a particular area. However if, like Western diets, traditional Aboriginal diets were culturally determined, then these food lists are misleading.

BY TIM LOW

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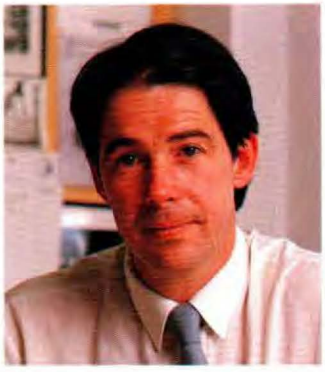

PROFILE

GREEN CHARIOTS

Jonathon Porritt: son of Olympic bronze medallist Arthur Porritt who most of us remember being portrayed in "Chariots of Fire" but, more importantly, Britain's outstanding and practical green politician.

BY ROBYN WILLIAMS

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PHOTOART

CORAL REEFS

Marvel at the beauty of coral reefs, including the Great Barrier Reef—one of the seven wonders of the natural world.

BY ROGER STEENE

874

STILL EVOLVING

THE RACE OF LIFE

The continued interaction between predator and prey may result in the predator enhancing the prey's ability to escape or defend itself, which in turn may enhance the predator's ability to catch prey. This process of adaptation and counteradaptation is known as an evolutionary arms race.

BY RALPH MOLNAR

880

THE LAST WORD

MORALS VERSUS MONEY

Since scientific research has become more dependent on private funding, a conflict of interest has arisen. Should Australian scientists publish their findings openly, for the sake of the global scientific community, or should they hold back their results in order to reduce the risk of large overseas companies beating us to the post in terms of commercial benefits?

BY IAN LOWE

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LETTERS

Comments, criticisms and congratulations from concerned correspondents. Readers are invited to air their views.

Hiawatha's Health

I was most interested in the article on Dr Hugh Sinclair (ANH vol. 23, no. 8, 1991); saddened also, as I had not heard of his death. Having been involved in lipid research for many years, I was aware of Dr Sinclair's work and of the foibles outlined by Robyn Williams. I regret that we were never together at the same symposia, so I never had the opportunity of meeting him. I am acquainted with another of his attributes: that of writing poetry. Here is an excerpt from his adaptation of Longfellow's Hiawatha, called "Hiawatha's Lipid" (first published in *The American Journal of Clinical Nutrition* in 1958):

Hiawatha, taking courage
Started on the Introduction
Giving first a brief description
On the Proto-Keysian period
When all fats in equal measure
Raised cholesterol in serum:
Butter, sardines, walrus liver,
Margarine, or safflower seed oil,
Or arachidonic acid,
Or the body fat of quokkas,
Or adrenals of the muskrat,
Or the milk of a female reindeer–
As these fats in equal measure
Raise cholesterol in serum,
As the rain in Minneapolis
Fills the ditches in the roadways
(So at least thought Hiawatha)
So these fats in equal measure
Raise cholesterol in serum.

Some of the technology is perhaps a little dated, but I think that his whimsical humour is still as fresh as ever. I hope that you will derive as much pleasure from this epistle as I have over the years.

—J.D. Craske
Longueville, NSW

Are Honeybees displacing native pollinators like this *Mythimna loreyimina* moth?

JIRI LOCHMAN / LOCHMAN TRANSPARENCIES

Backlash

Rob Manning's critique (see Letters, ANH vol. 23, no. 8, 1991) of Mr Graham Pyke's article ("Apiarists versus Scientists: A Bittersweet Case", ANH vol. 23, no. 5, 1990) deals with the semantics of the author's use of "*prima facie*" evidence and "deleterious effect", thus raising questions of objectivity and bias.

Perhaps Pyke could have chosen his words more carefully, although this should not prejudice Manning's view of the rest of the article. Firstly, Pyke has demonstrated one of the basic scientific principles – the application of high standards of objectivity in all observations. History demonstrates that those with vested interests rarely apply such standards and I suspect Manning has a vested interest in the Honeybee industry.

Secondly, ecologists specialising in pollination biology are, as Manning suggests, confronted with extremely complex natural systems. In order to assess properly the important role pollination plays in Australian terrestrial habitats it would be foolish of any scientist not to include widespread and abundant introduced pollinators into the equation. I cannot think of one introduced animal or plant that has not displaced, or had a deleterious effect on, Australian fauna and flora. The Honeybee problem is a prime example that exists in Manning's backyard.

The Western Australian Christmas Tree *(Nuytsia floribunda)* has abundant nectar-rich orange flowers that attract an equally abundant suite of potential pollinators, especially insects, during late spring and mid-summer. If Manning travelled to a decent patch of bushland near Perth during the flowering period, he would be confronted with trees buzzing with insect activity—mostly Honeybees. As he gazes at the 'hive of activity' above him, I wonder if he ponders as to whether Honeybees have displaced native pollinators?

Research increasingly supports the contention by scientists and naturalists that Honeybees negatively effect the ecology of the natural vegetation systems they occupy. If we perceive a potential threat to the integrity of such vital processes as pollination, it is in our own interest to spend research dollars in order to make informed decisions regarding an ecosystem's future. Do we support those who propose a knowledge-based future where biodiversity ensures a healthy land for all? Or do we support the views of a small special-interest group that is motivated by short-term gain and provides non-essential products?

Restrict Honeybees to agricultural land where they provide an essential service. Keep them out of our bushland!

—David G. Knowles

Cop This, George!

I was thrilled to see the photograph of Frank Talbot and George Seddon in Robyn William's column (ANH vol. 23, no. 9, 1991) because I took the photograph on a Macquarie University Environmental Studies field trip in 1978. The location is a small State forest (the name of which escapes me after this length of time) west of Bathurst. Frank at that time was Director of the Macquarie University Centre for Environmental Studies, and George had joined us for the field trip from his equivalent position at Melbourne University.

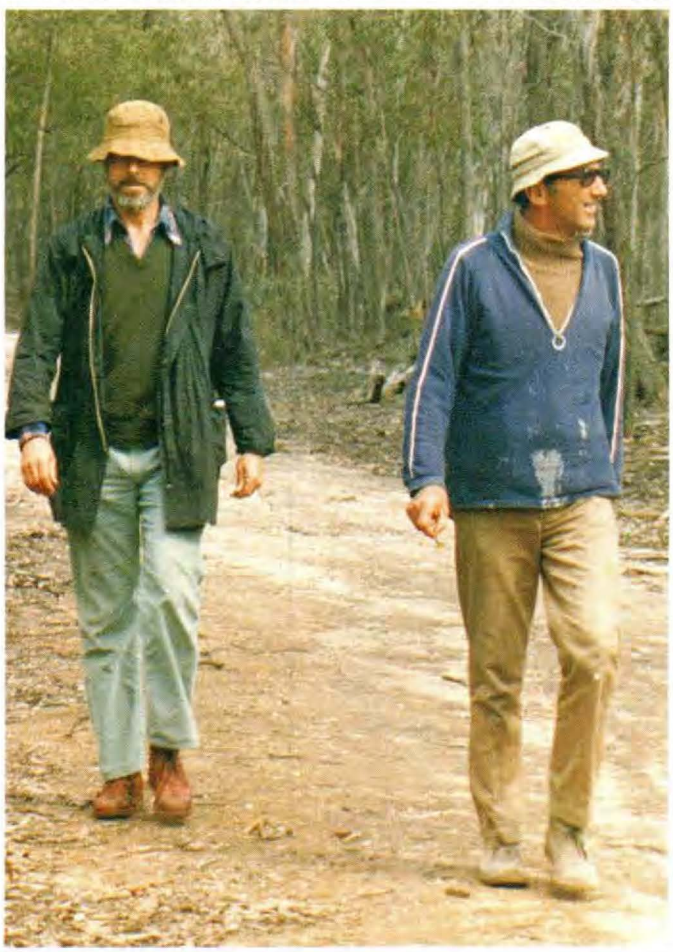
The Macquarie course is definitely one of the most challenging and enjoyable courses I have done. The field trips were the hands-on part of the course and were made more enjoyable by the inclusion of 'visiting' members like George.

Both men were an inspiration in different ways: Frank with his calm but concerned approach to environmental issues, George firing off ideas and questions. In fact, the difference can be seen in the photograph. Frank is ambling along, taking it easy, George looks around into the scrub, afraid of missing anything.

Many funny stories came out of the field trip but one of the best was about George after the trip finished. He had driven up from Melbourne to meet the rest of the group at Bathurst at the start of the trip, leaving his car in the Bathurst Police compound and the car keys with the Sergeant. When he went to pick it up eight days later, he was wearing the clothes in the photo and had not washed or changed during that time. The desk was staffed by a different officer, who was understandably suspicious when George presented himself asking for the keys. When George substantiated his story by claiming to be a university professor, the cop looked him up and down and said, "Yeah, you look like a professor" and gave him his keys.

I gave Frank two enlarged copies of the photo after the end of the trip, for him and George. It was a great surprise to see it turn up in ANH!

—Jack Haley
Randwick, NSW



Frank Talbot and George Seddon.

JACK HALEY

ISOBEL BENNETT

Halcyon Days

While going through my files I rediscovered this old photograph. All three men pictured (now dead) were closely related to the Australian Museum—Gilbert Whitley, as staff; Professor W.J. Dakin, a Trustee; and Mel Ward, a research associate. This is taken in Mel's museum on Lindeman Island, Queensland. This was in those wonderful days when interstate steamers anchored off the island and put one ashore—as they did for the Prof!

—Isobel Bennett
Newport, NSW

Which Museum?

With reference to the Editorial in ANH vol. 23, no. 9; as an ex-employee of the British Museum I feel I should draw your attention to the fact that the Museum of Mankind is the Ethnography Department of the British Museum. It is *not* part of the Natural History Museum (British Museum), which became independent of the rest of the British Museum some time last century.

—Margaret McCord
Australian Museum

Chimp's Chump

I was amazed to turn the last page of the Letters column (ANH vol. 23, no. 9, 1991) to see the little boy's expression on the face of the Chimpanzee!

—René Gantner
Beecroft, NSW

An Accolade

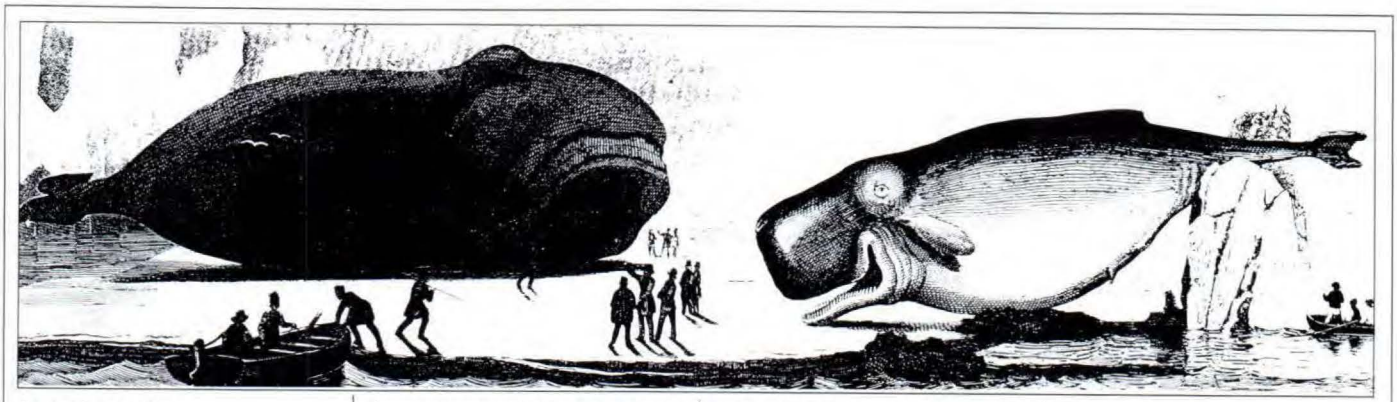
I do congratulate you on your magazine. I've been given a subscription, which I shall certainly renew when it runs out. I've seen it off and on for years and I am delighted that from now on I won't be missing an issue.

—David Attenborough
London, UK

Yen for Whaling

The need by the Japanese to catch whales extends deep into Japanese history (see Last Word, ANH vol. 23, no. 8, 1991). The introduction of Buddhism around the sixth century forbade the killing of land animals, although this teaching did not extend to fish.

Gilbert Whitely, Mel Ward and Prof. W.J. Dakin in Mel's lab on Lindeman Island, 1934.



A yen for whaling.

Whales were thus grouped with fish. Because of these tenets and the shortage of arable land, the sea became the chief source of protein for the Japanese.

Japan also has a deep suspicion of outside agencies. During the early part of this century Japan was highly suspicious of the European powers and the United States in attempting to obstruct Japanese power and influence.

In a modern context the International Whaling Commission is viewed in this light.

This letter by no means sets out to condone Japanese whaling but simply highlights some of the historical and psychological factors omitted by Kathy Glass and Kirsten Englund in their article.

—Ken Cotterill
Mareeba, Qld

Seeds of Tomorrow

In Mark Stafford-Smith's letter on land degradation (ANH vol. 23, no. 6, 1990), he states "Even today, native grass seed is not widely available and relatively little work has been done on harvesting techniques and establishment [of natural grasses]". This statement contains some apparent misconceptions.

Commercial supplies of native grass seeds have not been widely available through the seed trade but this situation is changing. However, much research on seed harvesting and establishment of native species is being carried out.

Many important native grasses produce chaffy seeds, which form light fluffy masses that do not flow freely. This causes problems at all stages, from harvest through to sowing. Our team (from the Queensland Department of Primary Industries) has developed brush harvesters that collect chaffy grass seeds. One is suitable for larger landholders and contractors in more intensive production districts. The second, currently being developed, is a simpler, yet efficient, harvester especially for individual users. We are testing the limitations of brush harvesting by identifying grasses and situations where this new harvesting concept could be used effectively.

Increasing supplies of native grass seeds are reaching the Australian market. This trend should grow as demand is generated by revegetation and recreation. One firm harvested 15 tonnes of Curly Mitchell Grass seed in 1988. One-third of this was withdrawn from sale because of naturally declining quality. Good storage facilities are therefore vital. Our early harvesting work produced around 700 kilograms of Queensland Bluegrass seed, which was marketed as far south as Melbourne. A commercial seed company is now interested in obtaining larger, regular supplies to develop this market further. This encouraged a commercial farmer, using a brush harvester built in his own workshop, to produce 700 kilograms of seed in 1991. Commercial seed supplies are also now available of a special strain of Wallaby Grass. Other native species are being developed for possible commercial release, such as Desert Bluegrass.

In our view, the future is a lot more optimistic than Dr Stafford-Smith's letter suggests, particularly as there is now money to be made from native grass seeds.

—Don Loch and
Brian Robotham
Queensland Department of Primary Industries

Seeds of native grasses like this Wallaby Grass are now commercially available.

CARL BENTO / AUSTRALIAN MUSEUM

ANH welcomes letters for publication and requests that they are 400 words maximum length and typed if possible. Please supply a daytime telephone number and type or print your name and address clearly on the letter.

QUIPS, QUOTES & CURIOS

COMPILED BY GEORGINA HICKEY

SCIENTIFIC EDITOR

Puffin Decoys

Atlantic Puffins (*Fratercula arctica*) are pigeon-sized seabirds with huge orange, blue and yellow-striped beaks. Their upright posture gives them the appearance of diminutive penguins, but they are actually members of the auk family, a northern ocean group with distant affinities to gulls and terns.

Young Puffins leave their nest after 40 days and spend their first two to three years at sea without returning to land. They usually return to their birth place to breed, but they do not attempt breeding until they are four or five years old. They are social birds that form monogamous pairs, and most use the same breeding site year after year. The male and female of the pair cooperate in rearing the single chick.

Because of their low reproductive rate, Puffins and other members of the family are particularly vulnerable to disturbance, taking a much longer time to recover from population reductions. Until the 1880s, Puffins nested on at least six islands along the Maine coast of the USA. However, intense hunting for food and feathers reduced the number of colonies to just two, one of which, in 1900, had only a single pair. The largest historic breeding colony of Puffins in the USA was on Seal Island off mid-coast Maine, where hundreds were extirpated by 1887.

In an effort to restore Puffins to some of their old nesting spots, biologists from the National Audubon Society transplanted 912 Puffin chicks from Great Island, Newfoundland, to the National Wildlife Refuge on Seal Island between 1984 and 1989. These were hand-reared in sod burrows, and then banded and released with the hope that they would return to Seal Island two or three years later to help found a new Puffin colony. In a bid to lure these social birds back to Seal Island, rather than their natal island, wooden decoys were set in place atop large rock formations.

The initial results were disappointing, with only six of 534 Puffins transplanted between 1984 and 1987 returning before the summer of 1990. Apparently chick survival at sea varies greatly year to year owing to such uncontrollable factors as weather, food abundance, predation, oil pollution etc. Efforts to restore the birds to Seal Island took an important positive turn in June 1990 when Puffin Project observers noticed a dramatic increase in two-year-old Puffins. Many of the young birds sighted at Seal Island and nearby Matinicus Rock wore yellow plastic bands with engraved black numerals that clearly identified them as returning transplanted Seal Island Puffins. Forty-seven of the Puffins had been transplanted from Newfoundland to Seal Island in 1988. These represent 25 per cent of the 190 Puffins transplanted that year. In addition to these, five Seal Island transplanted Puffins from 1987 were observed at Matinicus Rock and three of these visited Seal Island.

At Seal Island, the returning Puffins spent most of their time sitting among the decoys. Some of the birds also explored rock crevices, an important behaviour that suggests they are beginning to prospect for nesting burrows. Although nesting will probably not occur at Seal Island before 1992 or even later, the events of this summer give us optimism that, within a few more years, Puffins will soon reclaim this once important bird island.

—Stephen W. Kress
National Audubon Society
New York

A returning Puffin rests in the company of a wooden decoy on Seal Island off the coast of Maine, USA.

STEPHEN W. KRESS

A Beer a Day...

The saying is 'an apple a day keeps the doctor away' but perhaps it should be changed to 'a beer a day keeps the doctor away'. Recent work in the United States suggests that moderate consumption of beer reduces the prevalence of heart disease *(Amer. J. Clin. Nutr.* 51: 869–872; 1990).

Copper deficiency is thought to be a major cause of heart disease; many signs associated with heart disease (such as high blood cholesterol levels, high blood pressure and glucose intolerance) are also found in people on a diet low in copper. It has also been known for some time now that the risk of death from heart disease is lowered when moderate amounts of alcoholic beverages are consumed. Presuming that a large proportion of these beverages is beer, human nutritionists Leslie Klevay and Robert Moore, from the United States Department of Agriculture, set out to find whether drinking beer benefited rats fed a low-copper diet.

Rats were given a special diet that was low in copper.

Beer-drinking benefits rats on a low-copper diet.

CARL BENTO / AUSTRALIAN MUSEUM

One group was offered only water to drink; the other just beer. Budweiser beer was chosen (as it is apparently America's best-selling brew) and this was left to stand overnight at room temperature to reduce frothing.

The results of the experiments were unequivocal: beer drinkers lived nearly six times as long as water drinkers; they had up to three times as much copper in their livers, lower cholesterol levels, and smaller hearts. Lacing the diet with radioactive copper showed that beer drinkers absorbed a greater amount of copper from their food than their teetotalling mates.

The miniscule amount of copper in beer was insufficient to account for the differences observed. Alcohol also cannot be the cause, as experiments repeated using four per cent ethanol in water instead of beer did not increase longevity. Klevay and Moore believe that beer must contain an as yet unidentified chemical that decreases blood cholesterol levels and, at the same time, enhances copper metabolism. Already about a dozen of these 'reciprocal-action' chemicals are known, with perhaps the most familiar being aspirin.

The results of these experiments may also explain the seasonal cycle observed in human blood cholesterol levels, which are lower during summer than winter. Perhaps this is directly attributable to the fact that more beer is consumed in the hotter months.

—G.H.

Peacocks Show their Age

To the human eye, the peacock's train may appear to be no more than one of nature's indulgent whims. But what message does this ornamental extreme of evolution send to the peahen, and how does it contribute to the survival of the species?

There are several theories on the development of male ornaments as female sexual attractants. For example, a 'bright' and healthy ornament may suggest its owner has few parasites and, therefore, a favourable genetic resistance that could be passed on to offspring. Another theory predicts that the train contains age-dependent information, with females preferring older males. Presumably an older male demonstrates genetic fitness and suitability as a mate simply because he has survived.

To investigate the possibility that the train is a male age advertisement, John Manning, from the University of Liverpool, obtained feather counts from 28 Blue Peacocks, *Pavo cristatus (J. Evol. Biol.* 2: 379–384; 1989). These had been reared by aviculturists and thus were of known age – from three years old, when the first ocellus or eye feathers appear, to 14 years. The feathers of those birds kept alone in aviaries were collected and classified into one of three types (ocellus, fish-tail or curved). Free-range birds and those kept enclosed with other males were photographed while displaying and only the ocellus feathers counted from the photographs.

What did the peacock's train say to the peahen?

J.M. LA ROQUE / AUSCAPE INTERNATIONAL

As predicted, the number of ocelli appeared to increase with age. However, the feather collections revealed an even greater correlation between age and the *total number* of feathers in a train. Manning concluded that the peacock's train appears to be "an honest advertisement of his age".

More recently biologists Marion Petrie, Tim Halliday and Carolyn Saunders of Britain's Open University have shown that peacocks with the largest number of eye spots do indeed have the greatest mating success *(Anim. Behav.* 41: 323–331; 1991). However, it remains unclear whether peahens are choosing males with large numbers of ocelli or some other feature, such as symmetry, which is correlated with both ocellus number and age.

—K.McG.

Dr Suzanne Hand, a biologist at the University of NSW, and Karen McGhee, a freelance science writer living in Newcastle, are regular contributors to QQC.

MICHAEL FOGDEN / OXFORD SCIENTIFIC FILMS

Flambeau butterflies imbibing the eye and nasal secretions of the Yellow-spotted Side-necked Turtle (*Podocnemis unifilis*) in Peru.

A Taste for Tears

Tribesmen of the Rio Tapajos, Brazil, are said to be able to detect edible turtles just submerged below the surface of the river by the plume of Flambeau Butterflies *(Dryas iulia)* hovering above them. The butterfly, like the tribesman, pursues the turtles for food – but gains its nutrition by inserting its long tongue or proboscis into a basking turtle's eyes to drink its tears.

Crocodile tears are also on the Flambeau's menu. In western Brazil, it has been observed sitting on the eye turrets of basking or half-submerged Yellow-throated Caimans *(Caiman latirostris)*, drinking tears by inserting its tongue into the corners of the saurian's eyes.

The Flambeau's thirst for reptilian tears was reported by UK naturalists John Turner, Michael Andrews and Alan McGregor (*Antenna* 10: 119–120; 1986). The behaviour was initially observed and filmed independently by Andrews and McGregor at sites 1,500 kilometres apart in Brazil and Peru. When the films were broadcast on British TV in 1983 the similarity was noted by Turner and so the three jointly published. As the authors note, it was probably the first time a set of original natural history observations was coordinated through television broadcasting.

Eye secretions are also enjoyed by a handful of moth species but, as far as is known, they only drink mammal tears. Nectar and sap of fruit are more typical fare for moths, although quite a few take sweat and some even suck blood; for butterflies it is flower nectar, although fruit, pollen, bird droppings, carrion, water contaminated with mammalian droppings or urine, and sometimes sweat (John Turner, personal communication) are also eaten.

Hans Bänziger believes that the salt in tears could be one of the main attractions for tear drinkers (*New Sci.* 24 Nov. 1990: 38–41). Or perhaps it is the water in dry regions or seasons. He points out that tears also contain proteins (such as albumin and globulin) and diseased eyes yield an extra harvest of epithelial and white blood cells. Although moths generally subsist on sugars rather than proteins, tests confirm that some moths can digest proteins.

Tear drinkers are generally very specific in their tastes, restricting their attentions to certain species. Moths commonly choose as victims mild-mannered herbivores. Bänziger believes the South-East Asian *Lobocraspis griseifusa* is perhaps the most evolved of the tear-sucking moths. By repeatedly sweeping its proboscis across the eyeball of its bovid host, it irritates the eye and induces a copious flow of tears. It is capable of intruding its proboscis between the lids of a closed eye enabling it to feed even when its host sleeps.

In the case of the South American Flambeau Butterfly, reptilian tears appear to be providing a source of electrolytes in much the same way as mud-puddles do. The Flambeau is a species of the open ground and air above the tree canopy, and may find it difficult to find open patches of contaminated mud, static water or damp, salty ground to exploit in country covered by dense rainforest or, at times, on seasonally flooded river plains. The eyes of aquatic animals living along the river systems appear to have become a novel substitute; as Turner *et al.* put it, to the butterfly, the eyes are simply minute, salty puddles.

—S.H.

A.H. TOLHURST

Leaf-cutting ants.

Hitchhiker Ants

It can be hard to avoid leaf-cutting ants in tropical forests. Their colonies often contain more than a million workers that cut, harvest and carry to their nests many kilograms of leaves each year, which they use in the culture of a fungus for food. Often workers are seen providing their smaller offsiders, known as minims, with lifts back to the nest on the leaf they are carrying.

Biologists have speculated for more than a century over the reasons for the unusual hitchhiking behaviour observed in these ants. Two popular theories have emerged: minims defend the leaf-carriers from parasitic flies; and minims, which collect plant fluids, reduce their energy costs by hitchhiking.

Research on the hitchhiking behaviour of *Atta colombica* by Donald Feener and Karen Moss at the Smithsonian Tropical Research Institute, in Panama, strongly supports the first hypothesis—that of ant protection against parasitism (*Behav. Ecol. Sociobiol.* 26: 17–29; 1990).

They found that only the leaf-carriers were susceptible to attack from the parasitic fly *Apocephalus attophilus* because the females of this fly needed to stand on a leaf fragment to deposit their eggs in an ant worker's head. The presence of a minim hitchhiker significantly reduced the chance of a fly landing and, if it did land, staying on the worker long enough to deposit her eggs before being dislodged by the minim.

Feener and Moss noted the ability of colonies to respond to an increased number of parasites. After the controlled experimental introduction of extra parasitic flies to ant trails, they noted that colonies quickly increased the number of available hitchhikers.

—K.McG.

Ringing in the Corn

Since at least the Middle Ages popular imagination has been captured by the controversial phenomenon known widely as crop circles. The circles, which generally occur in fields of grain and are probably best known from examples in southern England and Wales, range in diameter from 0.3 metres to over 60 metres, but often have one or two outer rings and may form patterns that spread over as much as 95 metres. They are characterised by spirals of flattened grain. The spirals may be in either a clockwise or anticlockwise direction or a complicated mixture of the two, and the grain completely flattened like a carpet or merely brushed or skimmed. In addition, eyewitnesses to the formation of circles have reported hearing a distinctive humming noise, and reports of accompanying bright lights have come from Britain, France, Japan, Australia and the USA.

These are some of the observations made by British physicist Terence Meaden (*New Sci.* 23 June 1990: 25–27), who made the first scientific investigations into crop circles in 1980, and has since surveyed hundreds of circles and compiled statistics on nearly two thousand.

Meaden has traced the oldest report of a circle to the Middle Ages when 'mowing devils' were held responsible. As retold by Meaden, a farmer asked a workman what he would charge to mow his field. The mower's price was too high and the farmer told him that the devil himself could mow his oats before he should have anything to do with it. Next morning it looked as if the devil had taken the farmer at his word, for his crops were flattened in the familiar circle.

Many extraordinary explanations for crop circles have been proposed, ranging from hoaxers to fungi to extraterrestrials. Wendy Grossman in *The Skeptical Inquirer* (14: 117–118; 1990) lists some of the more bizarre, which include demented hedgehogs, giant hailstones, giant mushrooms, snared animals running in circles, mating deer, helicopters flying upside down and, recently, a hole in the ozone layer that allows ultraviolet rays to collapse the stalks.

Meaden, founder of the Circles Effect Research Group or CERES (in reference to the Roman goddess of tillage and corn!) believes, however, that the patterns are a product of natural forces in the atmosphere – specifically, an interaction between air flowing in the few hundred metres above the ground and the local topography.

He explains that, downwind of mountains and hillsides, the flow of air can become turbulent and form small-scale eddies or vortices. When one of these vortices breaks down, it can move close to the ground and sweep out a ring of damage as it expands, swirling a crop into the characteristic spiral pattern. The flow of air along the ground then may set up a concentric vortex rotating in the opposite direction. The second, counter-rotating vortex, together with its associated electrical effects, stops the swirling abruptly and accounts for the sharp edge of crop circles. This combination of directed airflows and their electrical properties also accounts for the complicated directions of swirling seen in some of the circles. Although circles are most commonly seen in crops, vortices also leave circular traces in earth, sand, snow and frost-covered grass. And, because the spinning air builds up a high electric charge, this neatly explains the accompanying humming noises and bright lights observed during circle formation.

—S.H.

Crop circles in Wiltshire, England.

FREDERICK C. TAYLOR / FORTEAN PICTURE LIBRARY

Biological Wool Harvesting

In 1972 CSIRO was asked to investigate the feasibility of using a biological agent to briefly inhibit wool growth, and so weaken or break the fibres, allowing the wool to be harvested without mechanical severance. The first step in achieving this goal was the discovery that murine epidermal growth factor (EGF)—a protein found most abundantly in the salivary glands of male mice—was a potent inhibitor of wool growth. This finding was particularly important because EGF can be manufactured using biotechnological methods, and thus substantial amounts can be produced at relatively low cost. Researchers examined the effects of the different doses of the protein in all classes of sheep, and concluded that the only occasion when dipilatory doses of EGF cannot be administered is during pregnancy.

Once the effects and limitations of the protein were known, the critical task was to examine how the findings could be incorporated into practical sheep management. Three husbandry options were investigated. The first involved weakening wool during the formation of fibres and then waiting for the weakened zone to emerge several millimetres above the surface of the skin before removing the fleece above the weakness. The others relied on causing complete shedding of wool fibres while retaining the cast fleece (with a fleece retention garment) until there was enough regrowth to protect the animal. These management options mimic the seasonal moult in animals such as Wiltshire Horn Sheep whose winter coat is shed in spring *after* a short and protective covering of new wool has emerged. This ensures they are never naked as a result of the moult.

The first option, the induction of a zone of weakened wool in the fleece, was very attractive because a fleece retention garment is unnecessary. By giving the sheep a small dose of EGF, big enough to weaken the wool fibres but not to break them, it was hoped that wool could be removed by gentle pulling after a protective layer had grown. The hitch was that, while fibres on the back could be broken easily, wool on the lower sides was too firm to break without discomforting the animals. Although this strategy was set aside, it should be studied further since it offers the best method of harvesting wool biologically.

Complete wool breaks achieved with higher doses of EGF are the basis of the present technology. The program for biological wool harvesting currently involves weighing the animal and, with a conventional shearing machine, removing wool from the head and limbs to avoid its loss at pasture, and also from the belly to prevent it from matting. The animal is then fitted with a fleece retention garment, injected with a depilatory dose of EGF on the basis of body weight, and returned to pasture. After four to six weeks the garment is removed and the fleece harvested.

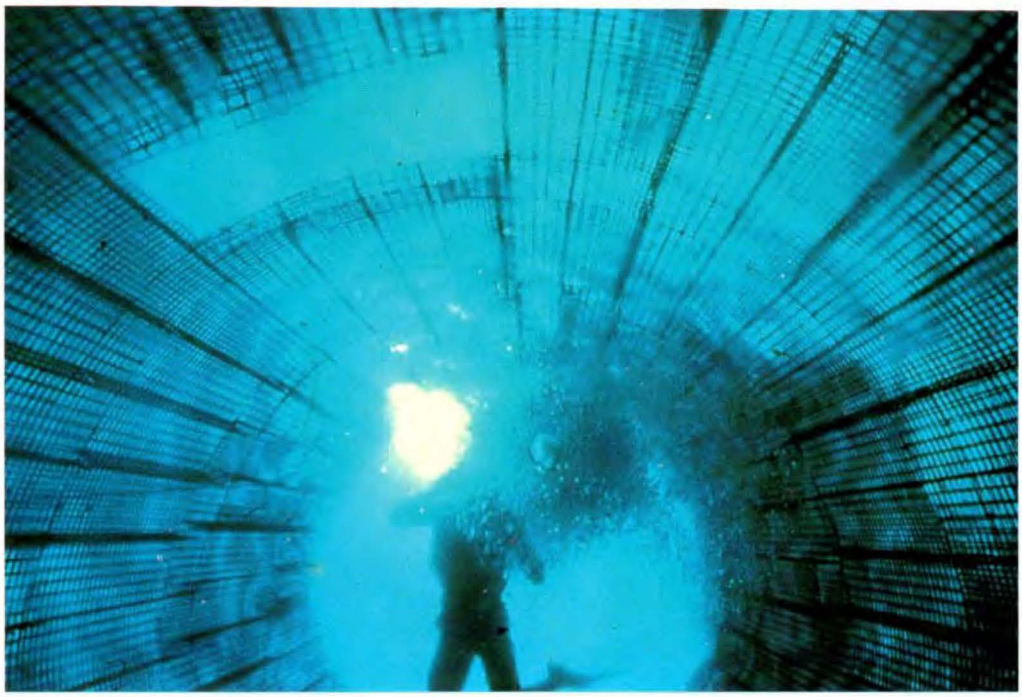
Another option—one that requires no sheep preparation or fleece retention—is available for housed sheep. The wool is simply removed about seven to 14 days after a depilatory dose of EGF. In winter, however, it may be necessary to provide these animals with further protection from the cold until the regrowth forms.

PHIL POTTE / CSIRO

Gently 'harvesting' the fleece from the sheep six weeks after a depilatory dose of EGF.

The obvious advantages of biological wool harvesting are that the fleece is of uniform length and free from wasteful short pieces of wool that result from overlapping blows made by a shearing machine, and the sheep themselves are not cut. Although work is still in progress refining the harvesting methods, our commercial partners expect farmers to be using the method within a couple of years.

—Bill Panaretto
CSIRO Division of Animal Production



WOLF HILBERTZ

Pass an electric current through an underwater cylindrical wire mesh and, hey presto! An underwater pipe.

Sea-grown Building Supplies

In an experiment off the coast of Colombia, engineers are making building supplies—by growing them under water. Using nothing more than wire mesh and a weak electric current, bricks, roofing tiles and pipes are being manufactured, for a fraction of the normal cost, as part of the United Nations Development Programme (*Discover* July 1990: 10).

The process is simplicity itself: it involves forming the mesh into shapes, which are placed under water, applying a 0.1-amp current to each square metre of mesh, and then waiting. Within the first week, electrons moving through the wire mesh attract calcium ions from the sea water, which combine with carbon dioxide to form a calcium carbonate veneer on the mesh. During the next few months, the tiny larvae of barnacles, small clams and other shell-bearing invertebrates, as well as small tube worms and corals, take up residence on the calcium veneer and thrive. The electrified mesh offers a plentiful source of electrons that can be used by the animals to extract calcium from the water to build up their protective shells. And because they have short life cycles, many layers of shells and animals soon accumulate and fuse to the mesh, forming a rock-hard layer of organic material that may be more than a centimetre thick.

The home-grown building materials are hoisted to the surface and are being used in local construction projects. Currently, attempts are being made in Cuba to 'grow' large pipes that will remain under water to carry sewage from coastal cities far out to sea. The process promises to be a boon for Third World countries that often cannot afford to import raw materials for such projects. **—S.H.**

Artificial Ivory

T. STODDART / AUSTRALIAN PICTURE LIBRARY

A new recipe for artificial ivory may prevent scenes such as this.

And in another technological good-news story, little more than eggs and milk are being used by workers at the Sakai Research Laboratories in Japan to produce a superior substitute for ivory that could help save the African Elephant (*Science and Technology in Japan* June 1990: 70–71). The artificial ivory is virtually indistinguishable from natural ivory and the researchers partly attribute this to the fact that all the raw materials are natural. Whole eggs containing calcium carbonate and proteins are crushed and mixed with milk, which contains the binder casein. Three kinds of lipase are then added to break down the fats, and titanium dioxide is added to adjust the weight.

The product ends up with natural capillaries that enable it to absorb water just like natural ivory. This is particularly important for piano keys. Plastic or synthetic resin keys tend to become slippery when played for a long time because they fail to absorb sweat from the pianist's fingertips. The same property is important in replacement roots for teeth and mouthpieces for wind instruments.

The newly developed artificial ivory is expected to satisfy Japan's enormous market for an ivory-like product. Before the total ban on the importation of elephant tusks from October 1989—as part of the international effort to save the African Elephant—Japan had been buying 130 tonnes of ivory annually, 80 tonnes of which had been used for name seals and piano keys alone.

—S.H.

Touching the Common Wall Cress stunts its growth. The plant on the left was touched twice a day for six weeks; the other was left alone.

Touchy Plants

The secret behind every good gardener may not be in the colour of the thumbs but the sensitivity of the touch. Recent work by biochemists Janet Braam and Ronald Davis at Stanford University, California, suggests that plants sense and respond to a wider range of physical stimulation than has previously been thought (*Cell* 60: 357–364; 1990). They found that routine and seemingly innocuous laboratory practices such as touch and water spraying were among stimuli that stunted growth in Wall Cress (*Arabidopsis thaliana*), the small weed popular for molecular and genetic research. It could thus be crucial for future experimental procedures to take into consideration the sensory capabilities of plants.

Braam and Davis identified five genes that were activated in response to tactile stimulation. One of these genes was found to be responsible for the production of calmodulin—a small protein known to have a crucial role in basic cellular processes (such as muscle contraction and the release of neurotransmitters) and that is under the control of calcium ions. Two of the other genes were found to be responsible for the production of similar proteins, reinforcing the idea that calcium ions are involved in the touch response.

The effects of touch-stimulated plants in the laboratory resemble the natural phenomenon known as thigmomorphogenesis whereby plants exposed to wind tend to be shorter and thicker than protected plants. Further study of these touch-induced genes may provide clues to the as yet largely unknown mechanisms by which plants perceive and react to environmental changes.

—K.McG.

"It is not capable of, nor was ever intended to, return."

THE INDIAN BOOMERANG

BY CORALIE YOUNGER

HISTORY DEPARTMENT, SYDNEY UNIVERSITY

IN JANUARY, 1911, A ROUTINE EXCHANGE of artefacts took place between the Australian Museum and India's Government Museum in Madras. Negotiations had begun in September 1910 to swap two Australian boomerangs for an 'Indian boomerang' known as a *valai tadi* or *valari*, meaning curved stick. Robert Etheridge, the Australian Museum's Curator, had become interested in the subcontinental boomerang through a description in Edgar Thurston's *Castes and tribes of southern India* (1909).

The Australian Museum archives record the boomerang's place of origin as Pudukkottai (Madras). *The Pudukkottai Gazette* describes it as integral to the material culture of its Kallar community. It notes "The Kallars and their sister community, the Maravars, are one of the rare, if not the only community in India, associated with a boomerang." The Kallars formed the largest community in Pudukkottai and Pudukkottai's ruler, the Rajah, was a Kallar by birth.

CARL BENTO / AUSTRALIAN MUSEUM

Indian 'boomerang' belonging to Pudukkottai, southern India.

In February 1911, shortly after receiving the Pudukkottai boomerang, the Australian Museum placed it on public display. The Curator expressed his satisfaction at the boomerang's acquisition in correspondence that read "A most welcome exchange – the first time the Australian Museum has possessed the so-called Indian boomerang."

The boomerang, crescent-shaped and generally made of a hard-grained wood, is heavier at one end than the other with the outer edge sharpened. It is not capable of, nor was ever intended to, return, and as such the *Pudukkottai Gazette* notes that the Kallar boomerang is very primitive compared to the Australian boomerang.

The boomerang was used by the Kallars to bring down game such as hare, jungle fowl and deer. Specimens of the *valai tadi* have also been found in Pudukkottai's megalithic burial sites and records show that, as early as the 14th and 15th centuries, the weapon was used to wound and kill humans. It was employed by Kallar warriors to deadly effect. Stuck in the tufts of hair on top of their heads it could be drawn out swiftly when an enemy approached. According to the then Prime Minister of Pudukkottai, as quoted by Thurston, "Men trained in the use of the weapon hold it by the lighter end, whirl it a few times over their shoulders to give it impetus, and then hurl it with great force against the object aimed at."

In 1886, the *Gazette* notes that a demonstration of these curved sticks was watched by Mounstuart Elphinstone Grant Duff, Governor of Madras, during his first visit to Pudukkottai. At the same time he had the opportunity to make the acquaintance of the soon-to-be Rajah Martanda Tondaiman and was also treated to a grand display of fireworks. He observed in a caustic note how "everywhere (throughout Pudukkottai town) it rained wreaths and nautch [Indian dancing] girls".

It was during my research on the contacts between Australia and India in the early 20th century that Zöe Wakelin-King,

Molly Fink (Rani of Pudukkottai) and Rajah Martanda Tondaiman in court dress, circa June 1920.

Molly: a portrait by Cecil Beaton that appeared in *Vogue* in 1932.

Asian Collections Manager for the Australian Museum, directed me to the Pudukkottai boomerang, one of many Indian artefacts lodged in the Museum's collections. Earlier, historian Dr Edward Duyker and I chanced upon a Pudukkottai–Australian connection of a different sort. It was the marriage of Melbourne-born Molly Fink to Martanda Tondaiman, Rajah of Pudukkottai. The marriage, celebrated in 1915, followed just four years after the exchange of boomerangs. It was to bring down the wrath of the British Government, opposed as it was to miscegenation (interbreeding between races).

Shortly after their wedding in the Victorian Registrar's Office (which the Governor-General Ronald Munro-Ferguson declined to attend) in November 1915, Molly, the new Rani of Pudukkottai, travelled to India where she was greeted by the Rajah's relatives and a bevy of nautch girls in the Old Pudukkottai Palace. (The British political agent had cabled the home government asking whether Molly was the sort of woman he could introduce to his wife!) There is no record whether Molly was entertained like Grant Duff was with an exhibition of boomerang throwing. However, it was in the palace armoury that Pudukkottai's most extensive collection of boomerangs existed. It is likely that the Australian Museum's Indian boomerang had originally resided there before making its way to the Madras Museum.

Sifting through official correspondence in the India Office Library, I discovered that Molly's visit to Pudukkottai was cut short by an attempt on her life: a poisonous concoction of crushed oleander leaves was secreted into her food. It was almost certainly administered by the Rajah's family. Molly and the Rajah fled to Double Bay in Sydney, Australia, where Molly subsequently gave birth to a son on 20 July 1916.

They then went to England to appeal to King George V for recognition of their son as heir to Pudukkottai's throne. However, so strong were the anti-miscegenetic sentiments that the Rajah and Molly's Sydney-born son were excluded from the succession and, in 1921, the Rajah was forced to abdicate in favour of a distant cousin. Molly and the Rajah went into self-imposed exile in France.

The only traces of Molly's association with Pudukkottai are a stack of faded photographs in the palace library and apocryphal stories that have been woven into Pudukkottai mythology.

As for the Pudukkottai boomerang in the Australian Museum, it sits in storage rarely sighted until a researcher or an exhibition resurrects it. ■

Suggested Reading

Duyker, E. & Younger, C., 1991. *Molly and the Rajah: race, romance and the Raj.* Australian Mauritian Press: Sylvania, NSW.

Thurston, E., 1909. *Castes and tribes of southern India.* Government Publications: Madras.

Coralie Younger is a postgraduate student in the History Department of Sydney University, where she is studying Australian contacts with India.

"Although the air-sac mite may not have led to the decline of the Gouldian Finch, it could be preventing the species' recovery to former numbers."

THE GOULDIAN FINCH

BY SONIA C. TIDEMANN

CONSERVATION COMMISSION OF THE NORTHERN TERRITORY

THE GOULDIAN FINCH (*ERYTHRURA gouldiae*) is the most brilliantly coloured of all the Australian finches. Together with eight other species of grass finch and mannikin, it is distributed throughout the woodland areas of northern Australia. Unlike the other species, however, the number of Gouldian Finches has declined drastically, particularly during the last two decades.

Early this century Gouldians were seen in large numbers at water holes where they came to drink daily, but observations have indicated that the range over which they once extended, as well as their numbers, has decreased. Perhaps the best evidence came from the number of finches caught during the years that finch trapping for the bird market was legal in Western Australia. The number of Gouldian Finches trapped, despite the best efforts of the trappers, declined by about 80 per cent.

Gouldian Finches feed mostly on native spear grass (*Sorghum* spp.), which grows widely across northern Australia. Towards the end of the wet season (December–March) the birds feed by alighting on a grass stalk and plucking the seeds from it. Usually by about April all the seed has dropped and from then on the birds feed on the ground, pecking amongst the stubble where it is not too thick, or feeding on the edges of tracks. Parents give their nestlings only *Sorghum* seeds to eat. The only finch to nest almost exclusively in hollows, the Gouldian Finch has more specialist requirements for breeding than the others. The preferred trees are Snappy Gums (*Eucalyptus brevifolia*) and Salmon Gums (*E. tintinnans*) that have been hollowed out by termite activity. Birds select hollows with openings about 50 millimetres in diameter and place the nest about 300 millimetres deep. Suitable breeding areas need to have trees with suitably sized hollows, ample supplies of *Sorghum*, and water within several kilometres of the nest.

The breeding season can extend from February to September, depending on the year. Four to eight eggs are laid. Both parents incubate the eggs for two weeks and feed the nestlings for about three. In the wild, an average of 4.5 eggs are laid and young fledge from nearly two-thirds of all nests. Nearly one-third of the nests are preyed on, probably by small goannas (*Varanus timorensis*) and the Brown Tree Snake (*Boiga irregularis*), and a few nests are abandoned.

The parasitic mite *Sternostoma tracheacolum* has been found in the respiratory pathways, lungs and air-sacs of wild Gouldian Finches. About 62 per cent of the population is affected. Other finches with which the Gouldian coexists are not affected or are only marginally affected (Masked Finch, 0.9 per cent; Pictorella Mannikin, 12.5 per cent). Although the air-sac mite may not have led to the decline of the Gouldian Finch, it could be preventing the species' recovery to former numbers. Heavy infection appears to affect breathing efficiency as the birds can be heard wheezing as though they had asthma. Towards the end of the dry season, when Gouldian Finches are sometimes required to fly long distances for food and water, heavily infected birds may die because they cannot breathe well enough to make these daily flights.

The Conservation Commission of the Northern Territory, assisted with funding from World Wide Fund for Nature, has been studying Gouldian Finch ecology since 1986. The aims are to draw up management plans, and monitor their progress, to secure the future of the bird. To this end, current research is focusing on several aspects.

There are only a few breeding areas known so far in northern Australia; these are 100–300 kilometres apart. A proposed gold mine will impinge on a small portion of one of these sites if mining is commenced. Efforts are being made to find new breeding sites. This involves selecting areas from a large-scale vegetation map where suitable species of eucalypts and *Sorghum* occur. The areas are then visited, large numbers of trees climbed and every hollow searched systematically.

Known breeding sites are being studied intensively to find nests, band birds and obtain a picture of the population dynamics of the species. A detailed study of air-sac mite biology is also being undertaken to determine how these are passed on from one bird to the next. A treatment that kills the mite and assists the survival of individuals is currently being tested in the laboratory and the field.

To ensure nest trees are protected from the large-scale, 'hot' fires that occur frequently at the end of the dry season, a fire management plan is being put into effect in suitable breeding habitat. The plan involves burning the area as soon as the *Sorghum* seed has dropped. This produces a low-intensity fire that reduces the grass fuel load and therefore the potential of large fires, without damaging the trees. It also minimises the chance of high-intensity fires later in the year.

Research on an endangered species is labour intensive and time consuming. Hopefully, though, the efforts of those who have contributed practically or financially to the project will be rewarded by an eventual increase in the number of Gouldian Finches in the wild. ■

"Heavy infection appears to affect breathing efficiency as the birds can be heard wheezing as though they had asthma."

Dr Sonia Tidemann is an ornithologist in the Wildlife Research Section of the Conservation Commission of the Northern Territory. She has been studying the Gouldian and other finches for about five years.

Gouldian Finch.

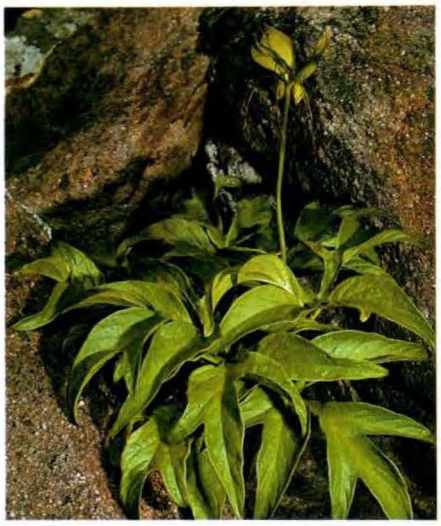
JEAN-PAUL FERRERO / AUSCAPE INTERNATIONAL

"Aboriginal diet, like Western diets, was culturally determined."

A QUESTION OF METHODS

BY TIM LOW

NATURE WRITER



Polynesian Arrowroot has poisonous potato-like tubers that need to be grated and soaked before eating. Some Aboriginal groups knew how to prepare and eat this plant, others considered it inedible. The fruits can be eaten raw, but on Groote Eylandt not even these were eaten.

HOW DID ABORIGINES ORIGINALLY LIVE? This question is of abiding interest to anthropologists and archaeologists. Anthropologists seek the answer by observing and questioning Aboriginies; archaeologists draw their evidence from the past—from cave and midden excavations, analysis of implements, and from surveys of the historical literature.

I am especially interested in Aboriginal food plants, and this interest has led me to look at how anthropologists and archaeologists learn about Aboriginal diet. In southern Australia, for example, where surviving Aborigines remember only fragments of their past, archaeologists have developed a technique for reconstructing the traditional vegetable diet. First they obtain a list of all the plants growing at their study site. Then, from papers written about Aboriginal diet elsewhere in Australia, they mark off all the edible species. This list, supplemented by the testimony of local Aborigines or pioneers, if any, becomes the diet list (see Flood 1980, and Hope and Coutts 1971 for examples).

Over the years I have become very sceptical of this technique. It assumes that Aborigines ate all of the available food plants. While this might seem a reasonable assumption (indeed, most anthropologists and archaeologists in Australia appear to hold this assumption), I am convinced it is wrong. I have gathered many lists of plant foods from around Australia, and a comparison of these indicates that Aborigines in most regions disregarded certain foods.

Nardoo (*Marsilea drummondii*), for example, the aquatic fern made famous by Burke and Wills, is recorded as a food only in the catchments of the Cooper, Diamantina and Darling Rivers. It does not appear on food lists elsewhere in Australia, despite its very wide distribution. Ethnobotanist Peter Latz, who has a life-

The Broad-leaved Native Cherry was a medicine plant on Groote Eylandt, used by the women to procure sterility. It was perhaps out of respect for the medicinal power of this plant that its fruits, although edible, were not eaten.

PHOTOS: TIM LOW

The baked beans of the Beach Bean are one of my favourite bush foods. Although eaten boiled as a vegetable in Asia, they are considered inedible by many Aboriginal groups because the raw beans are very poisonous. An Aboriginal boy was poisoned on Groote Eylandt in 1975.

time's experience of Central Australian Aborigines, has found no evidence that it was ever used in the Northern Territory.

Grey Mangrove (*Avicennia marina*), an important source of starch for some northern groups, appears on no food lists for temperate Australia, despite occurring as far south as Melbourne. The techniques for leaching its seeds apparently never spread south.

Beach Bean (*Canavalia rosea*), a vegetable of some Aboriginal groups, is apparently considered inedible by communities at Groote Eylandt, Kalumburu and Dampierland. Other examples can be found cited in Low (1988) and Latz (1982). The use of medicine plants shows much greater inconsistency.

Before drawing conclusions based upon food lists, it is important to ask whether the lists themselves are accurate. Are some species missing from lists just because their use has never been noted?

One of the most significant plant lists was published by Dulcie Levitt in her 1981 book *Plants and people: Aboriginal uses of plants on Groote Eylandt*. Levitt, now deceased, was a missionary on this Northern Territory island from 1951 to 1976. According to her, the Warnindilyakwa of Groote Eylandt do not eat Sandalwood fruits (*Santalum lanceolatum*), Broad-leaved Native Cherries (*Exocarpos latifolius*), Beach Beans, Grey Mangrove or Polynesian Arrowroot (*Tacca leontopetaloides*), although these are well-known foods of other tribes. Levitt states clearly that the Grey Mangrove and Polynesian Arrowroot were eaten on the adjacent mainland but not on Groote. Was she right?

Recently I made contact with Velma Leeding, a linguist who is working on the language at Groote Eylandt and who is checking over Levitt's work. I supplied her with a list of these and many other problem plants and asked if she could confirm the accuracy of Levitt's original research. The number of informants is dwindling, as the younger Aborigines are losing interest in their culture, but Leeding was able to confirm that Levitt's observations were substantially correct. Her informants in 1990 insisted that all of the above-mentioned plants, among others, were not local foods.

It may be that some plants vary in edibility and desirability between locations, and there are certainly omissions in all the lists, but I am sure that the large numbers of discrepancies between food lists cannot be accounted for in these ways. I am drawn to the conclusion that Aboriginal diet, like Western diets, was culturally determined.

Aboriginal life was bound by tradition, and experimentation with food was not encouraged. Aborigines migrating into new regions did not necessarily experiment with the new local foods, nor adopt the food-processing techniques of their neighbours. Some groups may have avoided certain foods as a mark of distinction from other groups. Minor snack foods like Sandalwood and Native Cherries may have been forgotten when temporary food taboos ended in a loss of local knowledge.

There is resistance to this kind of thinking from some anthropologists who, to counter the entrenched racism of Australian society, have portrayed Aborigines as the ultimate experts on natural resources. My readings leave no doubt that Aborigines were experts of the highest degree, but they were not omniscient. ■

Suggested Reading

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Low, T., 1988. *Wild foodplants of Australia.* Angus & Robertson: Sydney.

Tim Low is a full-time nature writer living in Brisbane. He is the author of four books about plant use, the most recent of which are Bush tucker *and* Bush medicine *(Angus & Robertson).*

"Porritt's approach to ecology is an interesting combination of traditional wisdom and 21st-century vision."

GREEN CHARIOTS

BY ROBYN WILLIAMS

ABC RADIO SCIENCE SHOW

"HE IS THE OUTSTANDING GREEN politician in Britain," said *The Times* of London about Jonathon Porritt. That was in 1990 when, at the age of 40, he stepped down as Director of Friends of the Earth. Porritt had just finished filming a six-part series for BBC TV called "Where on Earth are we Going?" and was continuing his regular broadcasts for the BBC World Service.

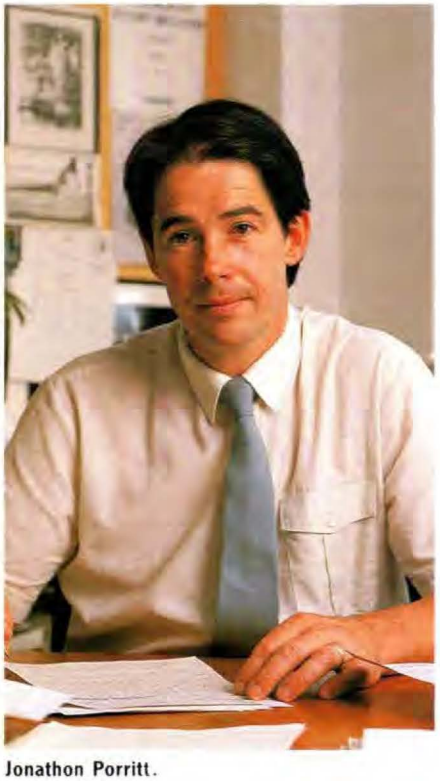
It was no surprise that *The Times* would note Porritt's career change with a full-page article. He is as well known in Britain as David Suzuki is in Canada. But in Australia? Not a household name. When I suggested he be invited as a speaker in the Australian Museum's Science Super Series, lots of folk looked at me blankly (this is not uncommon) and were obviously wondering "who on Earth is Williams trying to foist on us this time?"

I explained that he is one of the most compelling orators in the world, combining erudition with a beguiling reasonableness. I mentioned his unlikely background: Eton, Magdalen College, Oxford (where he gained a First in modern languages), ten years teaching English in a comprehensive school in London, leading to books on being green. I mentioned his father, Lord Porritt, whom many of us saw being portrayed by an actor winning the Olympic bronze medal in "Chariots of Fire". Arthur Porritt, as he then was, captained the New Zealand Olympic team in 1924 and went on to be Surgeon to the Queen and Governor General of New Zealand.

But there is nothing toffee about Jonathon Porritt. He is immensely charming and direct. He is able to command an audience of hundreds when speaking, but then will be jokey and restrained face to face, often unobtrusive in a group when it's someone else's turn to hold forth.

His reach and understanding of networks is, nonetheless, formidable. His new book *Save the Earth* has an introduction by Porritt's good friend Prince Charles and includes articles by Carl Sagan, Peter Ustinov, David Attenborough, David Suzuki, The Dalai Lama, Archbishop Desmond Tutu, John Fowles, Margaret Atwood, Yoko Ono, Robert Redford, Ted Turner, Jacques Cousteau and our own Peter Garrett . . . to name but a few! Little wonder there are orders for 350,000 copies worldwide.

Porritt's approach to ecology is an interesting combination of traditional wisdom and 21st-century vision. He urges us to dispense with the rapaciousness with which development has proceeded for most of the last two centuries. He wants us to consider the advantages of 'symbiosis' as a model for existence. This leads to an appreciation of Jim Lovelock's Gaia hypothesis, in which the Earth is conceived as acting like an integrated organism, controlling the balance of her own environment. He is not at all shy of the 'spiritual implications' of this metaphor and shows, like Peter Garrett, a strong religious influence in his thinking.



ROLAND KEMP

Jonathon Porritt.

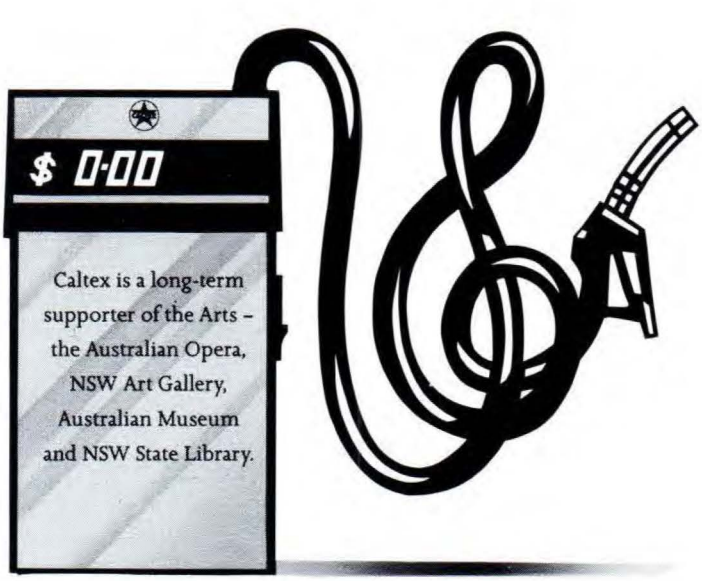
On the other hand, Porritt is a supremely practical politician. He wants results, not hand-waving. Change instead of posturing. His attitude to poor nations is typical. He deplores our inclination to lecture China or India or Brazil about their ecological indiscretions or disinclination to talk green. He is very much for the quota system, widely discussed, which would have nations such as USA or Australia, which produce large per capita volumes of greenhouse gases, owning few 'shares' for development or industrial activity, with Third World countries, being less polluting, owning most. We would then be forced to trade our shares with, say, India or China, so to allow us to get on with the job. The result? Developing countries would gain modern, clean technology without incurring crippling debt; we would be forced to restrain our dirty, wasteful ways; and the Earth's atmosphere would suffer far less pollution. Symbiosis.

Porritt says all this in the most persuasive, beguiling manner. His voice is rich and muscular, lyrical and yet urgent, and shows no signs of fraying even after two lectures and 18 interviews in one hectic day in Sydney. He stands solid at the podium, hefty shoulders and strong hips – like a rugby centre three-quarter. He is not a demagogue and lacks both Paul Ehrlich's apocalyptic flourishes and David Suzuki's uncompromising disdain for free enterprise.

Jonathon Porritt is, in short, an incrementalist, believing in the small but increasing progress achievable through the political process. He despises loonies and the self-centred viciousness of wild fringe groups. He is also understanding of the resentment of those workers who stand to be deprived of job and even home because of green limits to development. He is the environmental leader I would send first to a hostile union meeting about the closing of a mine or a logging licence.

But all this does not amount to a person willing to countenance the easy compromise. Here is what Porritt had to say at the conclusion of his book *Seeing green*: "To avoid writing the Earth's obituary we must cease to see the future simply as an extension of the present, and we must think as much about *should be* as about what actually *is*. We must think again of links between ourselves and the Earth, and of the way the Earth speaks to us through an ideal of life. We must seek ways creatively to disintegrate the economic and industrial constraints that are turning our world and our lives into a wasteland. Above all, we must learn to blend our concern for people with our respect for the Earth through the post-industrial politics of peace, liberation and ecology: the politics of life." ■

As Executive Producer of the ABC Radio Science Show, Robyn Williams has the opportunity to interview many interesting people in science.



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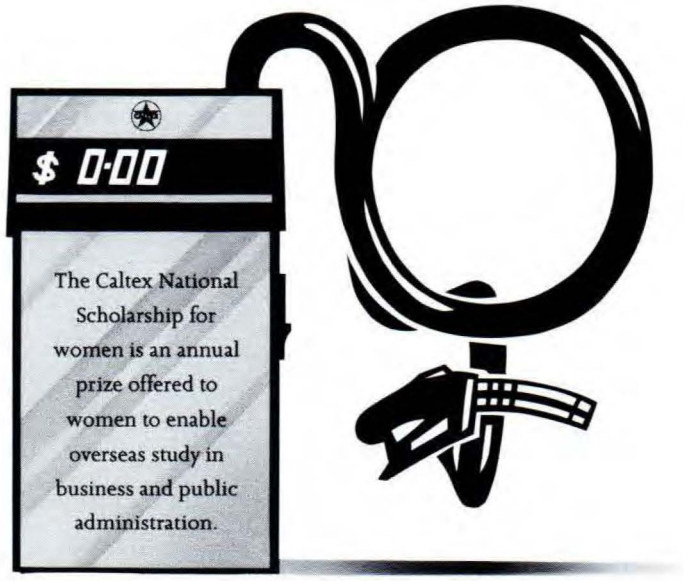

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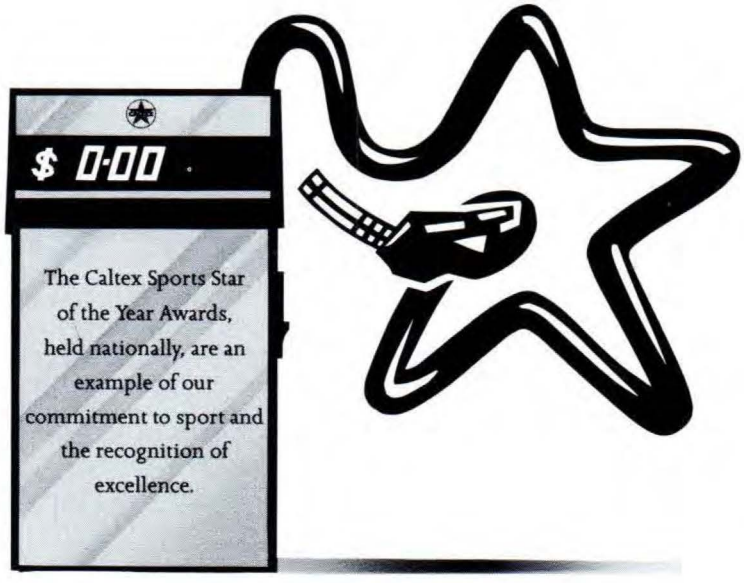

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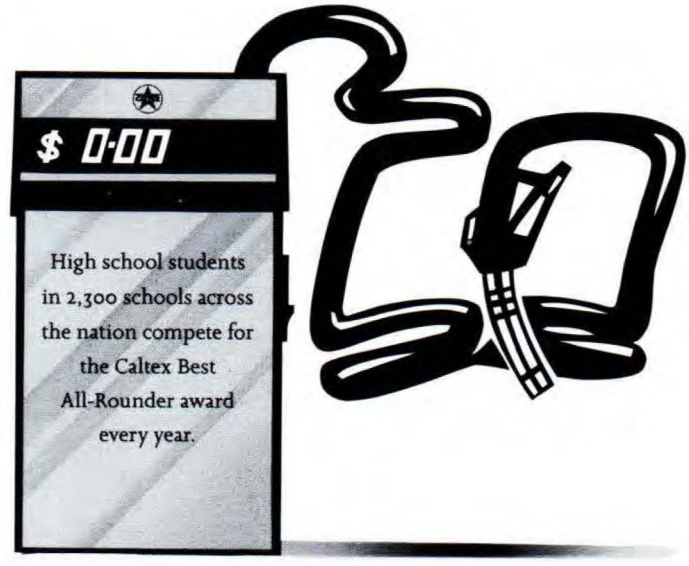

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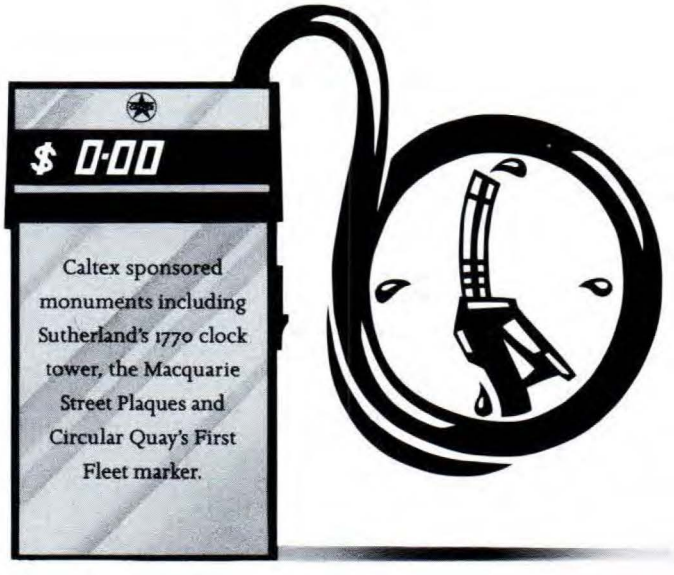

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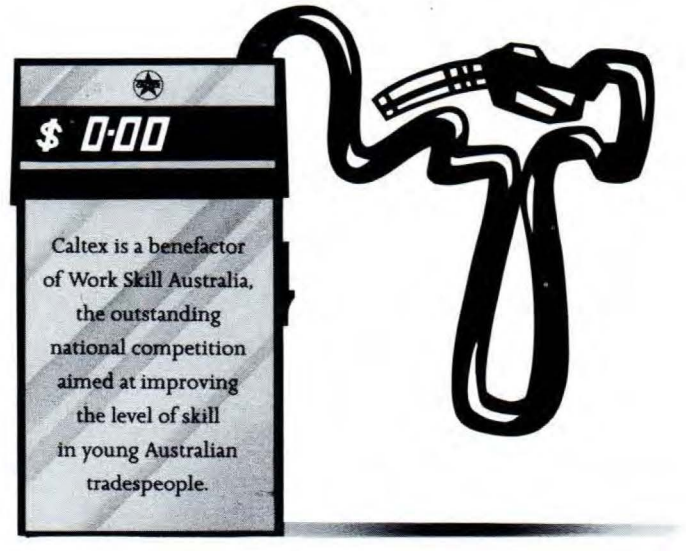

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"This was the last nail in the domatial coffin and the hypothesis of mite–plant mutualism was to spend a century in limbo."

A POCKETFUL OF MITES

BY DENNIS J. O'DOWD & MARY F. WILLSON

DEPARTMENT OF ECOLOGY & EVOLUTIONARY BIOLOGY, MONASH UNIVERSITY
US FOREST SERVICE, FORESTRY SCIENCES LABORATORY, JUNEAU, ALASKA, USA

OVER A CENTURY AGO, A SWEDISH botanist, Axel Lundströem, coined the term domatium (*domos* = house) for tiny pits, pouches, pockets, and hair tufts in major vein junctions on the leaf undersurfaces of many woody plants. After considering a number of possible functions for leaf domatia, Lundströem was left with a single puzzling feature that unified them—their association with mites. He went on to call these shelters 'acarodomatia' (mite houses) and argued that their denizens protected leaves from harmful arthropods and fungi, and checked the growth of microbes on the leaf surface. In essence, predatory and fungus-feeding mites received cosy shelters in exchange for guard and domestic duties on the leaves. This framework of mutual benefit stimulated our own interest in a possible relationship between plants with these enigmatic domatia and mites.

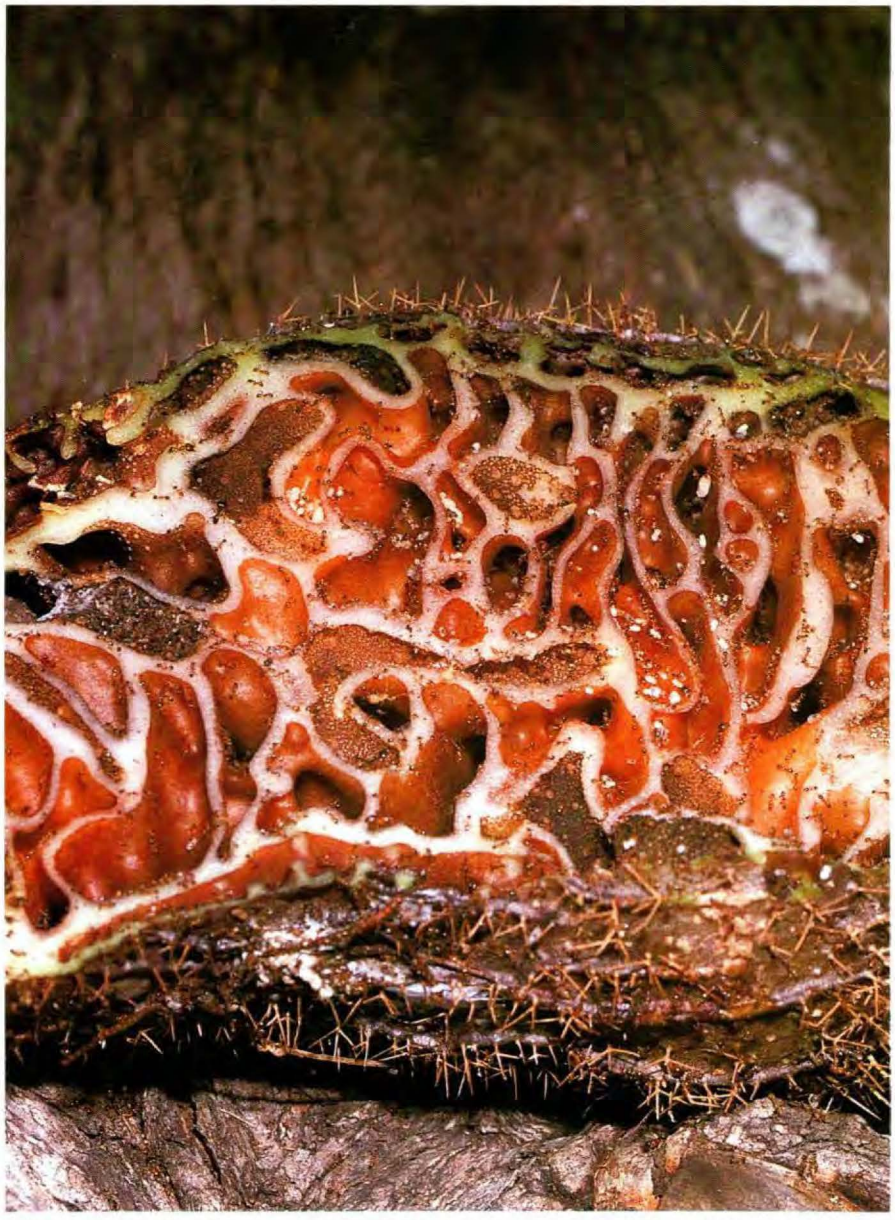
The name 'acarodomatia' became a fixture in the botanical literature, but the proposition that they form the basis of an evolved mutualism—a 'win-win' interaction in which participating species reap reciprocal benefits—between mites and plants has been hotly debated ever since. In late 19th-century Europe, Darwinian 'just-so' stories proliferated and, following Lundströem's proposal that domatia were sites for a protective mutualism with mites, domatia-bearing plants were even classified as 'acarophiles' or 'acarophytes' (mite-loving or mite plants). Yet naturalists, including Lundströem himself, provided no compelling evidence that associations between mites and domatia existed, much less that they resulted in mutualism.

One of the authors, Dennis O'Dowd, collecting leaves of the Glossy Tamarind (*Guioa acutifolia*) near Atherton, Queensland, to survey the association of mites with leaf domatia.

MARY WILLSON

An aggregation of eggs, juveniles and adults of a predaceous mite (*Euseius hibisci*) in the vein junction on the undersurface of an avocado leaf. Hairs in the junction, that do not occur in such concentrations elsewhere on the leaf, make these ideal 'mite houses', called domatia.

R. McMURTRY



Mutually beneficial relationships between plants and animals, such as occurs with ant-plants (*Myrmecodia spp.*), led researchers back to re-investigating an old theory about mite and leaf associations. This ant-plant has been cut away to reveal the nesting chambers of *Iridomyrmex* ants, which provide the plant with important nutrients.

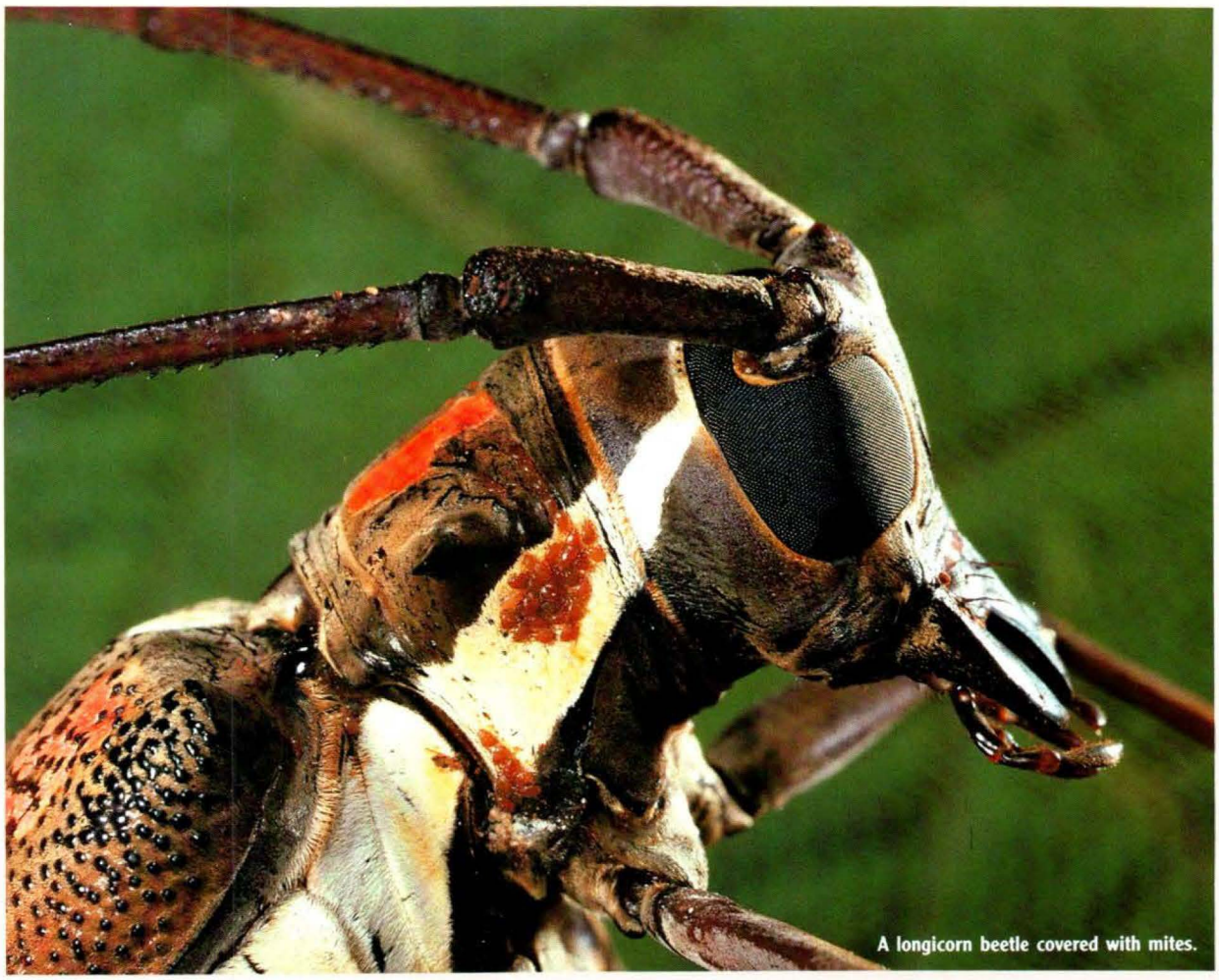
A.H. TOLHURST

In Australasia another perspective emerged. At the turn of the century, Alexander Hamilton, a botanist at Sydney Teacher's College, and N. Greensill in Christchurch, New Zealand, examined leaf domatia in their respective regions. Both rejected Lundströem's proposition of mite–plant mutualism: Greensill failed to find mites in domatia and Hamilton reported them only sporadically. Their anecdotal observations contributed to a rejection of mite–plant mutualism, and the notion of symbiosis (the living together of two of more different kinds of organisms) between mites and plants fell into disrepute. Equally important was a philosophical predisposition against a viewpoint that animals might influence the direction of the evolution of some plants. As summarised by the eminent Dutch botanist Max Jacobs in 1966: "The 'symbiological' way of approach...is defective because it starts from the unproven assumption that there is a functional relationship between plants and animals... We may count them [leaf domatia], locate them, dissect them, describe them, evaluate them as taxonomic characters. That is enough." This was the last nail in the domatial coffin and Lundströem's hypothesis of mite–plant mutualism was to spend a century in limbo.

WE DECIDED TO RESURRECT THE ISSUE OF mite association with leaf domatia for two reasons. First, although early naturalists reported that mites were or were not found in domatia, no-one had actually quantified it. Second, it has become clear over the last two decades that interactions between plants and animals *have* shaped many of their features. Take the mutualistic relationship between the 'bull's-horn' acacias and certain ants in Central America. Unlike Australian *Acacia* species, these acacias have swollen, hollow thorns that are occupied by only a few species of aggressive *Pseudomyrmex* ants that protect the plant from a variety of leaf-eating insects. A different benefit accrues in Australian tropical plants of the genus *Myrmecodia*, the so-called 'ant-plants'. Leanne Sommer from James Cook University has shown that the ant *Iridomyrmex cordatus* nests in special chambers in the swollen stem at the base of the plant and packs refuse into adjoining tunnels. The wastes decompose in the tunnels and nutrients are absorbed and incorporated into plant tissues. Plants with ants grow faster and have higher nitrogen levels in their leaves. Because *Myrmecodia* grows in the canopies of trees where little soil is available, association with ants may be especially important.

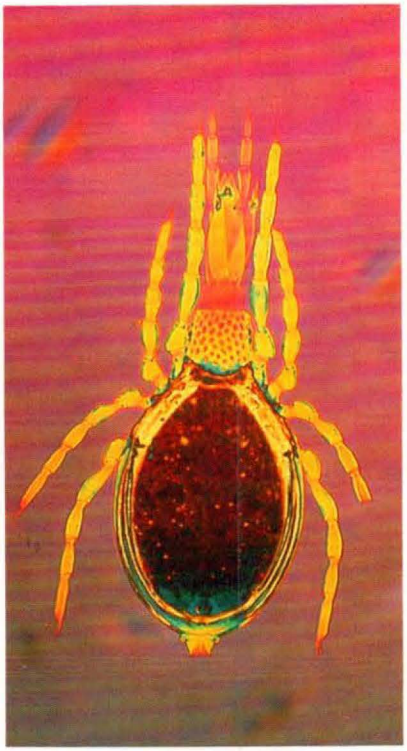
Ant–plant mutualism provides a seductive analogy for Lundströem's hypothesis of mite–plant mutualism. With this in mind we set out, with modest plans at first, to assay the pattern of association between mites and domatia on leaves of just three tree species in rainforests on the Atherton Tablelands in northern Queensland. But after our collaboration began, the project snowballed to the point where we and our co-workers have now surveyed mite–domatia associations in over 100 plant species from Papua New Guinea to the South Island of New Zealand in Australasia, and from Alaska to Florida in North America. We intentionally sampled many of the same plant species investigated by Hamilton and Greensill over 90 years ago in Australia and New Zealand and, unlike the old-timers, found bountiful evidence of mites in domatia of most plant species. In dissections of over 24,000 domatia on leaves of 37 plant species, over half of the domatia contained mites or their remains. Further, most mites came from predaceous or fungus-feeding groups, consistent with Lundströem's hypothesis. This pattern was repeated in our own work in deciduous forests in Wisconsin and Illinois in the United States, and in independent surveys by Bob Pemberton and Charley Turner of the United States Department of Agriculture, in California, Hawaii and Costa Rica. Domatia really are mite houses.

It turns out that these mite–plant associations are not unusual; plants with leaf domatia are broadly distributed, both taxonomically and geographically, and have an ancient history. Of approximately 290 families of dicotyledonous plants (those with branching veins), about a quarter have representatives with domatia. Plants with domatia occur from the tropics to the subarctic and to as far south as the limits of terrestrial flowering plants; they range in elevation from lowland to montane forests. Frequent in humid tropical and temperate vegetation, they sometimes comprise a sizeable fraction of all woody species. For example,



A longicorn beetle covered with mites.

P. GERMAN



A cryptognathid mite collected from soil. The lifestyle of these mites is poorly understood.

DAVID WALKER

Mites, Mites and More Mites

Mites, tiny eight-legged relatives of spiders, are usually less than the size of pepper grains and, as such, are literally on the edge of our perception. Yet they are one of the most diverse groups of creatures, perhaps rivalling insects in sheer numbers of species and in their variety of lifestyles. Although only 50,000 or so species have been described, acarologists ('acaro' = mite) estimate that there are at least 500,000 and probably closer to one million kinds of mites. Many are major parasites or commensals of vertebrates, including humans. For example, ticks—those blood-feeding parasites of mammals, birds and reptiles whose role in the transmission of human diseases is surpassed only by mosquitoes—are really just rather large mites. Many of us have first-hand experience with just two or three other kinds. Most people, even in polite company, have one or two species of a bizarre, spindle-shaped mite, *Demodex*, living in hair follicles in the nose, ears or eyebrows, and presumably feeding on skin cells and secretions from sebaceous glands; dust mites, such as *Dermatophagoides pteronyssinus*, are ubiquitous in our carpets and mattresses, and are responsible for allergies and asthma attacks; and trombiculid mites whose attempts to parasitise unwary bushwalkers or field biologists in the Australian tropics leave an itchy calling card and, albeit rarely, transmit scrub typhus.

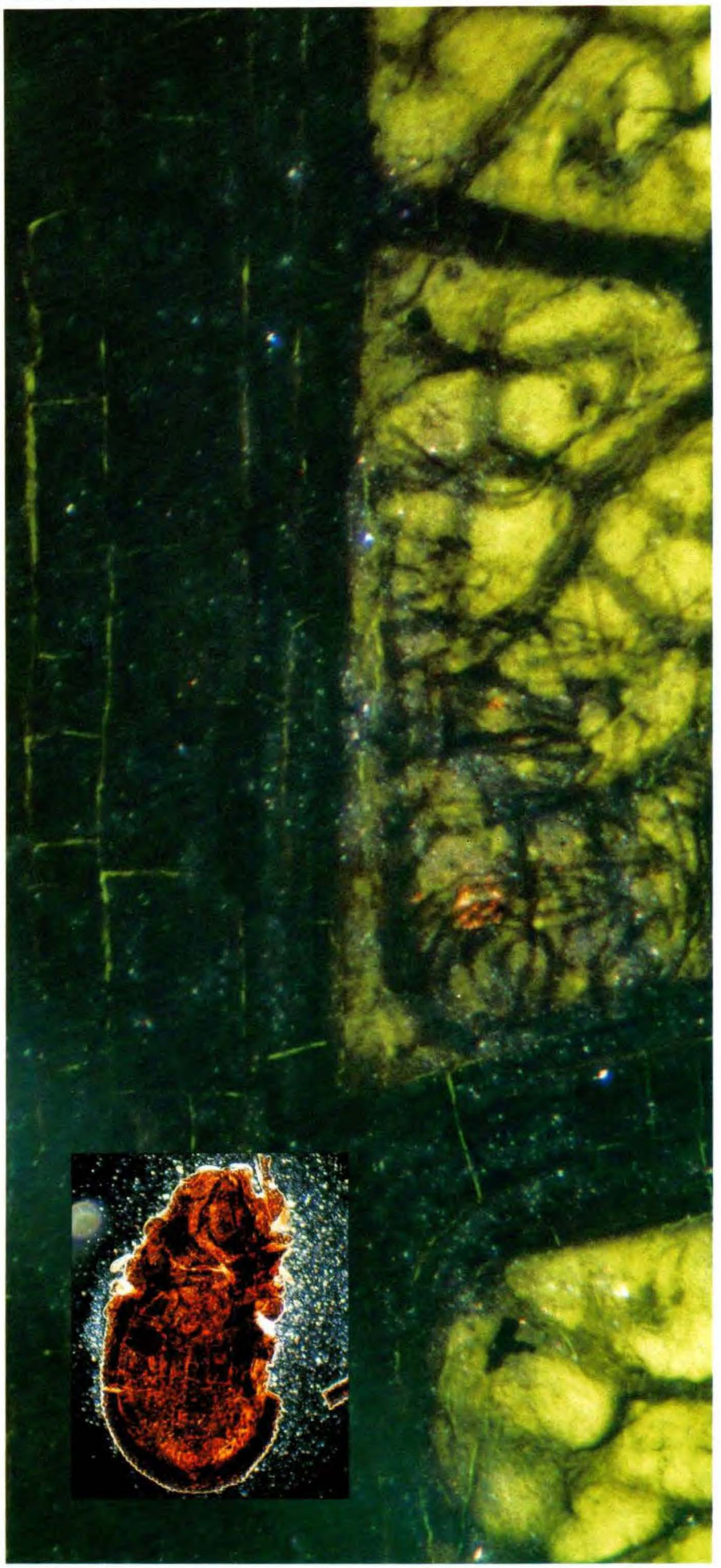
Although best known to most of us as troublesome and sometimes dangerous parasites and hangers-on, mites have adopted a vast array of alternative lifestyles. Some, like the tetranychids or spider mites, can be debilitating plant-feeders; others, like the oribatids or 'beetle mites' are extremely important as decomposers in the soil; and many, including the macrochelids and phytoseiids, are free-living predators foraging in soil or on plants. On plants with leaf domatia or 'mite houses', you can often find a microcosm of life and death among the mites. On the leaf blade, tetranychids and peculiar worm-like eriophyid mites—less than a fifth of a millimetre long—pierce plant cells and feed on their contents. In turn, these plant-feeding mites are eaten by many other mites, including phytoseiids and stigmaeids that actively stalk their prey and use domatia for shelter and egg-laying. Some of these predaceous mites, such as the phytoseiid *Typhlodromus occidentalis*, are so effective at consuming plant-feeding mites that they are reared and released in biological control programs on both crop and ornamental plants. Many other mites that use domatia, including saproglyphids, oribatids, tydeids and tarsonemids, are consumers of microbes, usually fungi and bacteria, that grow on the surfaces of leaves.

among trees in tropical wet forests of northern Queensland, they are represented in 36 per cent of plant families, 20 per cent of genera and 15 per cent of species. In broadleaf deciduous forests in North America, over 48 per cent of woody species have leaf domatia as do up to 31 per cent in some forests on the South Island of New Zealand. Furthermore, we have discovered domatia and plant-dwelling mites from 40-million-year-old fossil leaf deposits at Anglesea in Victoria and Golden Grove in South Australia, suggesting that these associations were widespread in ancient Australian rainforests.

We also explored alternative explanations for leaf domatia that have been proffered over the years (see table). Could domatia be architectural by-products of the coming together of two leaf veins—much like the triangular spandrels formed in cathedrals when a dome is mounted on two rounded arches—and any function, like sheltering mites, be incidental? While some developmental processes must account for domatia, they are not the necessary consequence of the intersection of two leaf veins: domatia are lacking in many major vein junctions and, on some leaves, of many domatia-bearing species we examined. Further, mites do not lurk in domatia simply by chance. If they did, mites would have been found randomly on the leaf surface or at least as often at vein junctions without domatia as with them. Rather, mites were concentrated in domatia above all other leaf locations we examined.

Could some physiological function for domatia, such as water uptake or gas exchange, be invoked? This is unlikely because special structural modifications, such as the presence of stomates for gas exchange or a reduction in the waxy layer on the inner surface of the domatium, occur only sporadically in domatia. Furthermore, because domatia are located on the underside of leaves and are sometimes lifted above the surface of the leaf blade, water uptake would be difficult. Perhaps domatia could be associated with symbionts other than mites, such as nitrogen-fixing bacteria? Although sometimes confused with bacterial leaf nodules, there is no evidence that domatia house symbiotic bacteria.

Can antagonistic interactions between mites and plants (such as competition, predation, parasitism etc.) explain leaf domatia? Again this is unlikely, as domatia form in the absence of mites and show none of the anatomical features of galls. Domatia could



CHRIS BREW

Mite–plant associations may be ancient. This close-up of a 'tuft' domatium on a 40-million-year old Quandong (*Elaeocarpus* sp.) leaf from a fossil deposit at Anglesea, Victoria, suggests so. Fossil mites (see inset) found in the leaf deposits are of the same kinds that inhabit domatia of modern Quandong trees in northern Queensland.

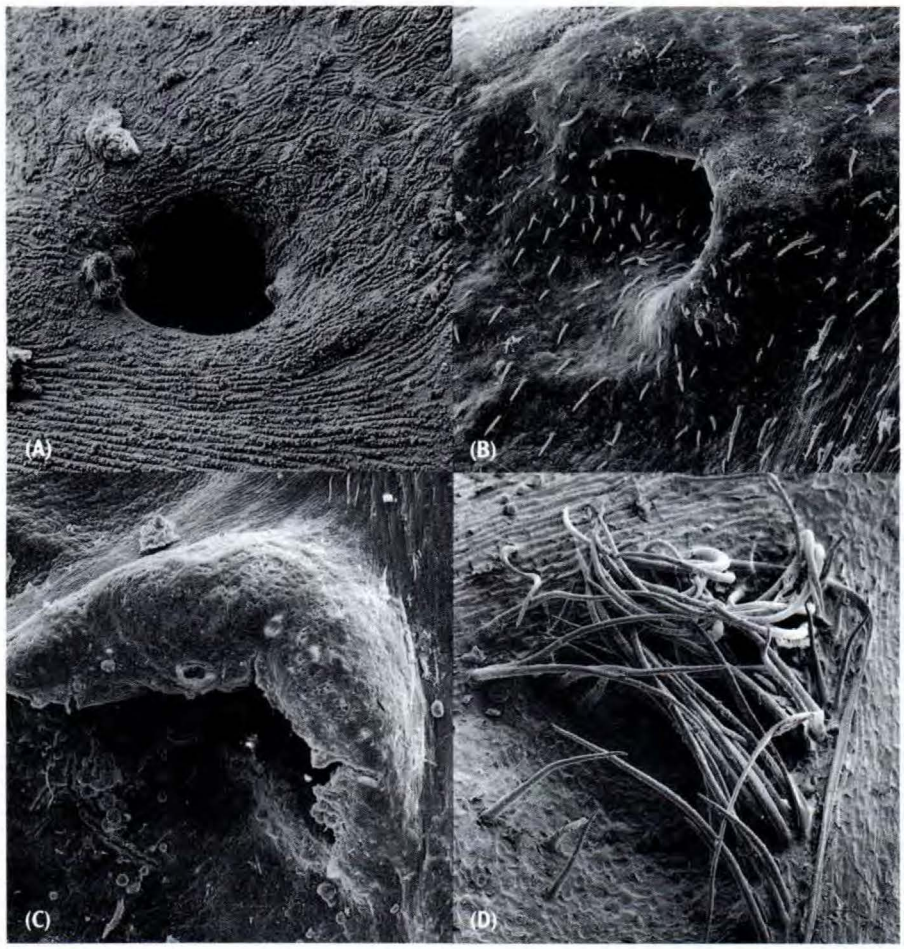
Explanations for leaf domatia

Hypothesis	Supporting Evidence
Nonfunctional hypotheses	
1. 'Spandrels'	No
2. Incidental associations with arthropods	No
Functional hypotheses not involving mites	
1. Organs of water uptake or gas exchange	No
2. Sites for nutritional mutualism with bacteria	No
Functional hypotheses involving mites	
1. Antagonistic relationships with mites	
a. Galls caused by mites	No
b. Restriction of damage by plant-feeding mites	No
2. Mutualistic relationships with mites	
a. Mites housed in exchange for provision of nutrients	No
b. Mites housed in exchange for plant protection from natural enemies	Yes

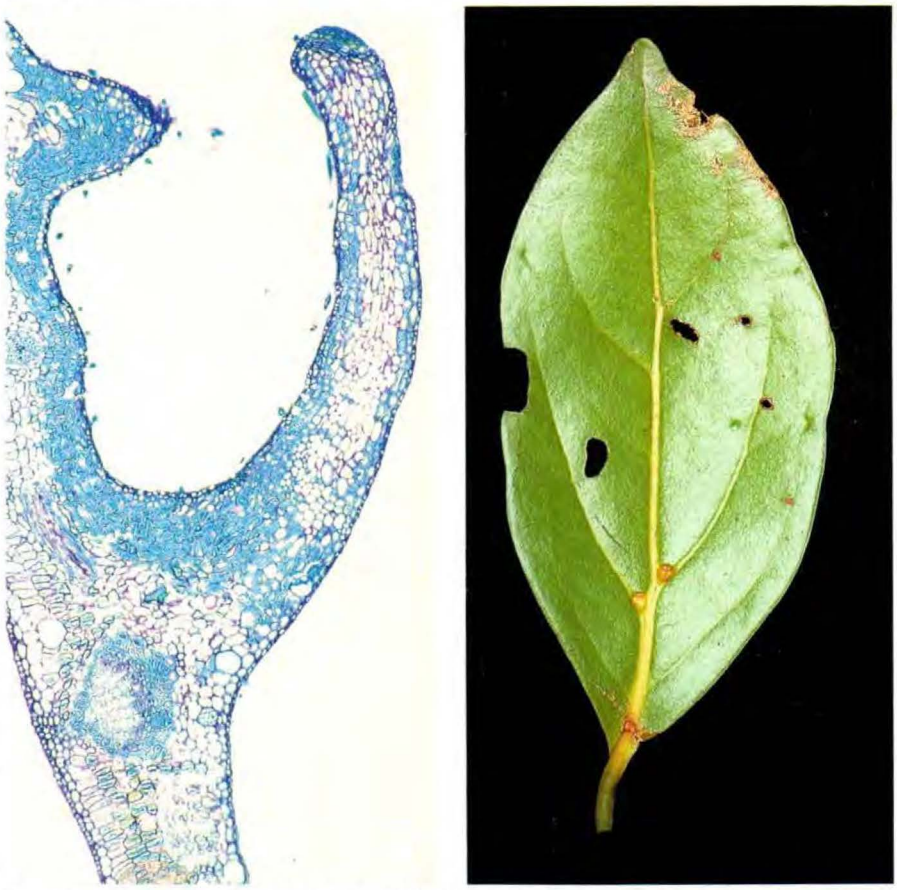
restrict leaf damage if plant-feeding mites congregate there, but plant-feeding mites were uncommon occupants of leaf domatia on almost all plants examined so far. Of mutualistic hypotheses, could refuse left in domatia by mites provide nutrition to the plant, as occurs in some ant–plant mutualisms? We found no evidence of specialised cellular structures or enzyme activity that would be expected if breakdown and uptake of nutrients were a principal function of domatia.

Protective mutualism appears to be the only hypothesis consistent with the predaceous or fungus-eating habits of most of the mites inhabiting domatia in all regions examined so far. Through their foraging activities on the leaf surface, domatia-occupying mites could decrease microbe cover, fungal parasitism and leaf damage by small plant-feeding arthropods. However, the hypothesis remains untested. No-one as yet has performed the critical experiments that demonstrate conclusively that mites in domatia benefit plants.

On the other side of the ledger, what benefits could mites gain from sheltering in leaf domatia? At Monash University, Dave Walter has shown that leaves of domatia-bearing plants have more beneficial mites than their counterparts without domatia. He did this by coupling experimental and comparative approaches. First, on some leaves of *Viburnum tinus*, a plant species with tuft domatia, he painstakingly shaved away the tiny plant hairs that make up each domatium and on others he left the domatia intact. When censused weeks later, mite numbers were much higher on domatia-bearing leaves. Second, he compared the numbers of mites on leaves of a variety of co-occurring plant species with and without domatia,

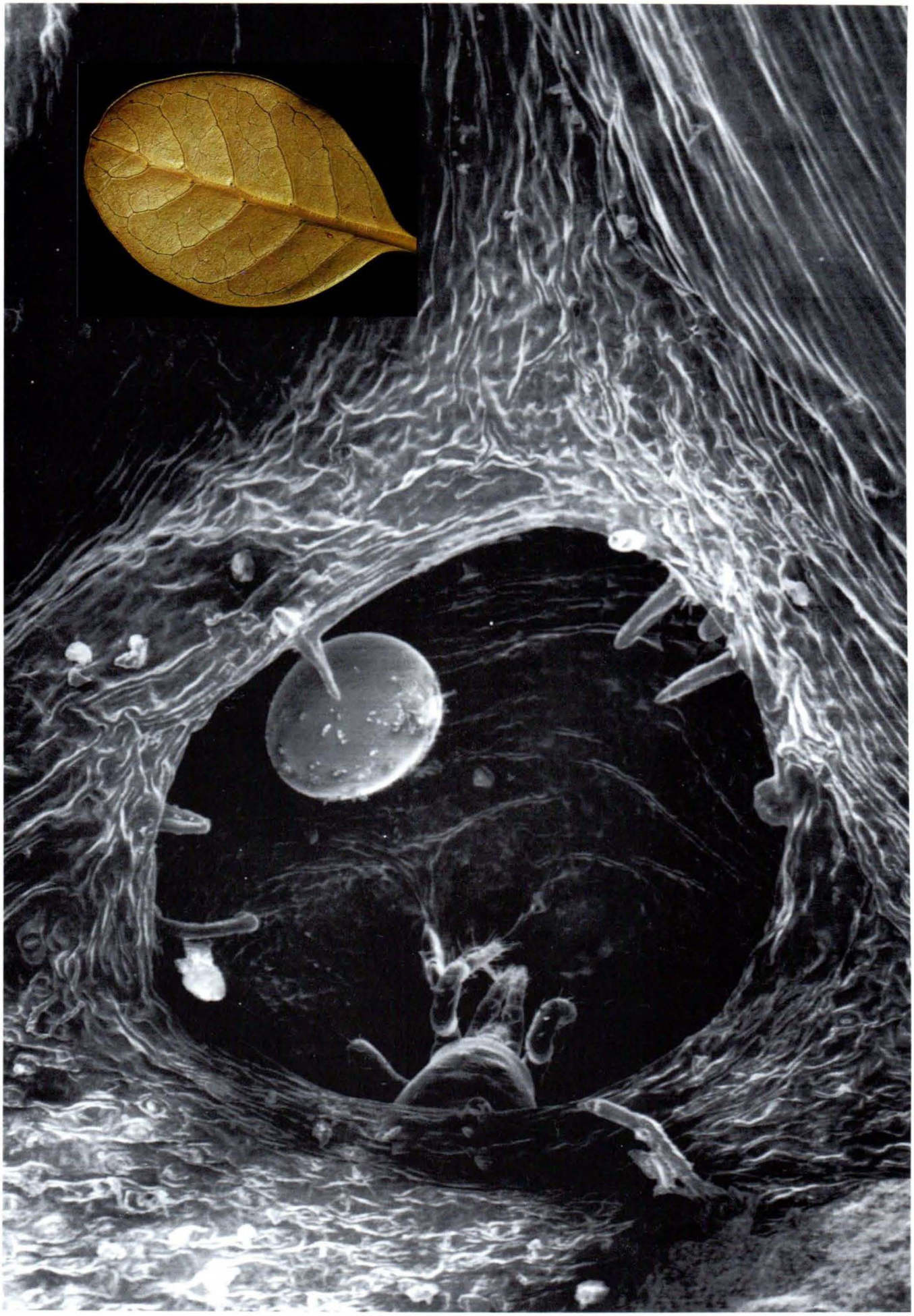


Leaf domatia can come in various shapes. Shown here are SEMs of the 'pit' (A), 'pouch' (B), 'pocket' (C) and 'tuft' (D) varieties.



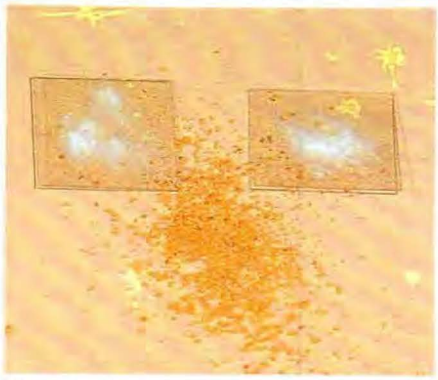
The undersurface of a Northern Rose Walnut leaf (*Endiandra cowleyana*), a canopy tree from montane tropical rainforest in northern Queensland, showing 'pouch' domatia (left shows cross-section).

DENNIS O'DOWD



BRUCE FURHRER

BOB PEMBERTON



R. McMURTRY

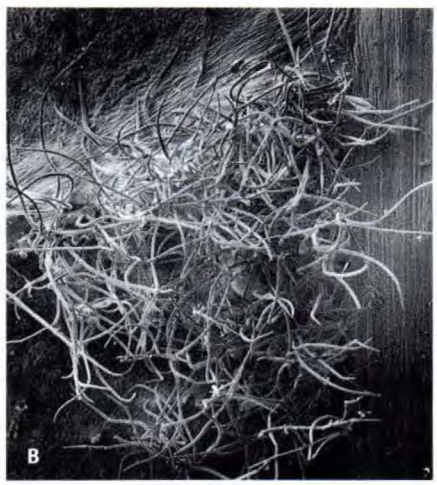
Artificial mite shelters have been made for decades by scientists unaware that they closely resemble the mite's natural shelters on leaf domatia. These artificial shelters or 'pseudo-domatia' contain cotton wool fibres where mites aggregate and lay their eggs. Some predatory mites are cultivated in this way for biological control of plant pests.

showing a strong relationship between domatia on leaves and greater numbers of potentially beneficial mites. The most plausible explanation for these increases in mite numbers is that mites are protected from physical stress and their own predators when using these shelters. Protection afforded by domatia may be especially important during inactive stages (such as the egg stage or during moulting) when mites may be more vulnerable to physical extremes or to predators and parasites.

PERHAPS ONE LESSON FROM THE HISTORY of the study of these associations is that the early schism between the disciplines of botany and zoology meant that most workers in each field failed to consider the implications of the other discipline. Most botanists did not consider seriously the possibility that minute, obscure animals, such as mites, could be a causal factor in the evolution of domatia. Acarologists, experts on mites, failed to recognise these plant structures and, to a large extent, neglected any role they might play in the lives of mites. On the face of this, it is ironic that those who routinely culture predatory mites for biological control of plant pests have for decades placed 'pseudo-domatia' on rearing surfaces for most of these mites. These shelters, usually a tiny tuft of cotton wool topped by a coverslip, or a miniscule 'A-frame' cut from a plastic sheet, appear essential for successful egg-laying by many kinds of leaf-inhabiting mites. By trial and error or the lore handed down from their mentors, these biologists have been producing artificial structures mimicking natural leaf shelters that have existed for at least 40 million years!

Scanning Electron Micrograph of a juvenile (with an egg) of the predaceous mite *Amblyseius limonicus*, lurking inside a pit domatium of the mirror plant *Coprosma repens*. Inset: undersurface of a whole mirror plant leaf. The pinprick holes are the miniscule pit domatia at the vein junctions where mites make their homes.

BRUCE FURHRER



DAVID WALTER

Experiments have shown that leaves with domatia support a much greater number of beneficial mites than leaves that have had their domatia shaved, suggesting domatia protect the mites from physical stress and predators. The hairy looking 'tuft' domatia can be seen in the vein axils on this Laurustinus (*Viburnum tinus*) leaf (A). The SEMs show a domatium before (B) and after (C) it was shaved.

After a century of debate, work on these associations is still in its infancy; many of the explanations for leaf domatia have been examined in only superficial ways or remain untested. Yet, given the patterns of association with mites described so far, the implications are exciting. If these mite–plant associations prove to be mutualistic, they would represent one of the most widespread and abundant of beneficial associations between plants and arthropods, rivalling the scope of pollination mutualisms between plants and insects. Further, they could have implications for agriculture and forestry in both tropical and temperate regions. Leaves of many agricultural species, including grapes, coffee, cashew, soursop, walnuts, rubber, currants and cherries, have domatia. Expression of leaf domatia, although sometimes variable, is under genetic control. If domatia do indeed increase the numbers and efficiency of natural biological control agents, their incorporation in plant varieties could prove valuable. ■

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Dennis O'Dowd is a Senior Lecturer in Ecology and Evolutionary Biology at Monash University in Melbourne. His special interest is in mutualisms between plants and animals. Mary Willson is a Research Ecologist with the United States Forest Service and an adjunct Professor at the University of Alaska and Washington State University. She is currently conducting a very careful study of seed dispersal by Grizzly Bears in Alaska.

Closeup of a larva of the sawfly *Perga dorsalis*. These larvae are known to most Australians as 'spitfire grubs' because they sometimes spit, but more often just regurgitate *Eucalyptus* oil. After pupating, the larvae develop into primitive thick-waisted wasps (sawflies).

JIRI LOCHMAN/LOCHMAN TRANSPARENCIES

UNDERMINING SPITFIRE DEFENCE STRATEGIES

BY PHILIP WEINSTEIN

NATIONAL CENTRE FOR EPIDEMIOLOGY AND POPULATION HEALTH
AUSTRALIAN NATIONAL UNIVERSITY

"An adult parasite eventually emerges from the sawfly cocoon, where only the spills of the banquet remain."

'SPITFIRE GRUBS', ALTHOUGH THEY look a bit like caterpillars, are actually the larvae of primitive stingless wasps known as sawflies. Sawflies belong to the suborder of wasps Symphyta, which is so named because symphytan larvae feed on plants (*sym* = with, *phyta* = plants). Of the Australian sawflies, the Pergidae is by far the largest family and also contains some of the largest wasps.

Within this family is the subfamily Perginae, which contains the familiar leaf-feeding 'spitfire grubs' (genus *Perga* and closely related genera). After pupation, spitfire grubs give rise to thick-waisted adults that are quite unlike the slender insects we usually think of as 'wasps'. The Perginae is a truly Australian subfamily, as more of its members are endemic (native) to Australia than to any other country. As if to drive this point home, most spitfires feed on *Eucalyptus* leaves. They are often most noticeable as large writhing masses of black larvae, clinging to the branches and trunks of eucalypts in early spring.

The larvae store *Eucalyptus* oils from the leaves that they eat, keeping the oils in a special part of their foregut. If the larvae are disturbed, for example by a predator (often human!), they regurgitate the oil in an attempt to drive the predator away. One predator, the parasitic wasp *Taeniogonalos venatoria*, avoids the regurgitate of spitfire grubs in a truly unique manner, as we shall see shortly. Because insects are cold-blooded, the regurgitated oil is cold and viscous in winter, and will often only exude slowly from a larva's mouth. In spring, however, the oil is warmer and more liquid, and can then be spat out in a truly projectile fashion. By raising its head and tail off the branch it is clinging to, a larva can bend its body into a 'U' shape; when done forcefully, this action compresses the oil sac in the foregut, and the liquid oil can be shot out almost 20 centimetres. It is undoubtedly this regurgitating behaviour that has earned these larvae both malignment and the common name 'spitfire grubs'. However, the *Eucalyptus* oil they regurgitate is the same oil that has been used in cough drops and chest rubs for decades, and should be no cause for alarm in the enlightened observer. At worst, the sticky oil could stain your clothing, but can easily be removed with turpentine or methylated spirits.

Apart from their spitting behaviour, there are many other intriguing aspects of the natural history of spitfire grubs. It is perhaps best to look at these in more detail as we follow the insect through its life cycle.

IN TEMPERATE REGIONS MOST SPECIES complete one generation per year, and the adults are on the wing in late summer or early autumn. They emerge from the soil in response to a complex combination of factors, including local temperature and rainfall. The exact timing of their emergence obviously also depends on the individual species, but the adults are always the predominant lifestage before winter. The winter-feeding larvae then take over as the predominant form.

Despite the fact that well over a quarter of adults are males, adult *Perga* have

Having scraped the wax off the leaf, *Perga dorsalis* uses her saw-like ovipositor to cut holes in the midrib of the leaf, through which she will then push her eggs.

DENSEY CLYNE/MANTIS WILDLIFE

DENSEY CLYNE/MANTIS WILDLIFE

In most species, the adult female flies off after completing an eggpod, but *Pseudoperga lewisii* remains on sentinel duty even after the larvae have emerged.

Newly emerged from their eggpod, *Perga affinis* larvae immediately adopt a circular defensive position. From this position, they can direct their defensive regurgitate at predators approaching from any direction.

never been observed to mate, and it is therefore assumed that individuals can develop parthenogenetically (from unfertilised eggs). The female lays her eggs into *Eucalyptus* leaves, often in groups of several dozen (eggpods), after preparing the leaf surface. With the ridges on the tip of her abdomen she scrapes off the wax and then inserts her ovipositor (egg-laying organ). The ovipositor is equipped with saw-like toothed blades (hence 'sawfly') that are pushed through the midrib of the leaf. The eggs are then laid in serial fashion along the midrib until a pod is complete.

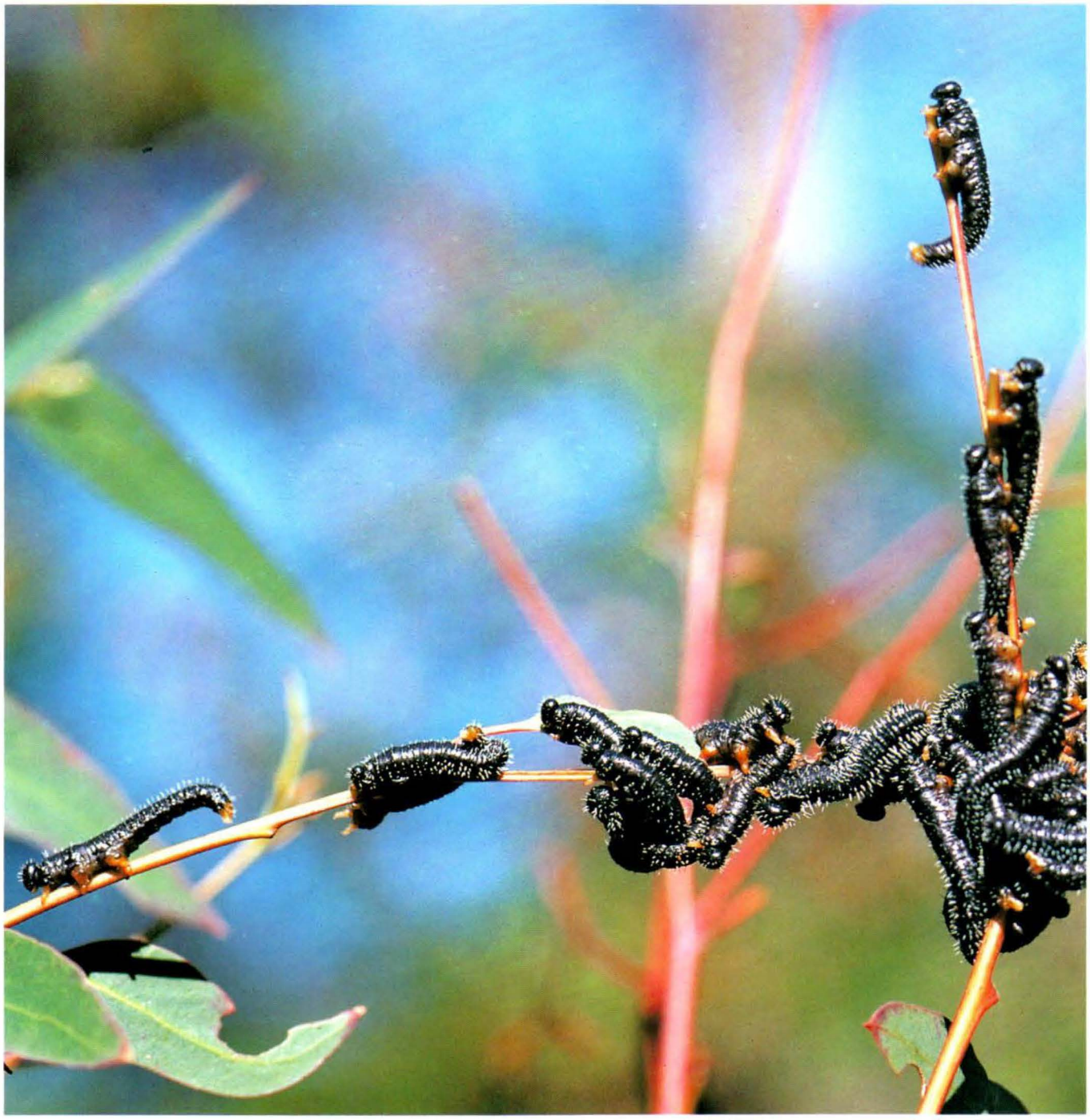
In most species, the female flies off after completing an eggpod, and may lay further eggpods if she still has eggs left over. In at least one species, *Pseudoperga lewisii*, the female takes up a guarding position on the leaf, protecting her eggs from parasites, predators and possibly even the sun. The young larvae continue to be protected after they have emerged, until the female finally dies. Unlike the adults of many other species, which are generally short lived, females of *Pseudoperga lewisii* can live (and remain on sentinel duty) for several weeks. This remarkable protective behaviour was the subject of one of the earliest reports of maternal care in insects, and was also among the first descriptions of insect behaviour in Australia. Mr R.H. Lewis, after whom the sawfly is named, observed *Pseudoperga lewisii* on the banks of the Derwent River, Tasmania, during April of 1835.

The eggs mature in the leaf for about four weeks in most species, and tiny (two to three millimetres) larvae then chew their way out of the pod to the leaf surface. In many (probably all) species of *Perga* and closely related genera, the young larvae immediately assemble into a circular defensive ring, with their heads pointing outwards. The larvae can thereby regurgitate *Eucalyptus* oil at a predator approaching from any direction. This defensive behaviour is known as cycloalexy (circular defence), and is also used by many other animals (including humans in Wild West wagon trains!). The larvae remain gregarious and feed as a colony throughout the winter months. They are nocturnal and rest in their defensive formation during the day.

Soon after dusk, a few 'leader larvae' take charge of the group, and lead the colony from its resting position to the leaves, where the larvae feed along the leaf margins throughout the night. The colony reassembles before dawn. Leaders leave the foliage, tapping the tips of their abdomens on the branch beneath them. The tapping causes mechanical vibrations throughout the branches and twigs, and these vibrations are detected by other members of the colony. These larvae move in turn towards the source of the vibrations, also tapping as they go. In this way, the whole colony is eventually reassembled. The tapping is audible to the human ear as series of slow, dull thuds, eerily reminiscent of Triffid noises. Interestingly, the last larva to leave a leaf always severs the remains of that leaf from the tree by chewing through the petiole (leafstalk); we will return to this behaviour shortly.

In spring the larvae become fully grown, measuring some five centimetres, and it is often only at this stage of development that they are noticed by the

JEAN-PAUL FERRERO / AUSCAPE INTERNATIONAL



DENSEY CLYNE / MANTIS WILDLIFE

A *Perga dorsalis* leader (on the left) taps the branch with its abdomen. Other larvae feel the vibrations and move to the source, thereby following the leader.

casual observer. The fully grown larvae move down the tree trunk to the ground beneath. Still as a cohesive colony, they search the soil for cracks or soft areas into which they can burrow. A few larvae at a time penetrate the soil, closely followed by those behind them, until the whole colony is some 40 centimetres or more beneath the surface. The larvae's task is made considerably easier by the presence of something they can push against, such as tree trunks, rocks, walls, even prize azaleas. The larvae will not eat or otherwise damage the garden plants under which they may be found, and can be safely left to their burrowing. It is likely that searching and burrowing is initiated by the same 'leader larvae' that previously led the colony on foraging expeditions.

Once underground, the larvae form a layer of closely packed cocoons. Each larva renders its cocoon watertight by lining it with a mixture of soil and *Eucalyptus* oil, which dries into a brown leathery skin. The larva then moults again, into a resting stage known as the eonymph. The eonymph constructs a fine sieve-like plate in the top of the cocoon to allow it to breathe, and then insulates the inside of its chamber with silk. The eonymphs remain in these cocoons throughout summer, entering a form of insect 'hibernation' called diapause. They thereby avoid the hot, dry summer weather, and some individuals remain in diapause for several years. The eonymphs pupate in late summer or autumn, and about two weeks after pupation the adult wasps finally emerge from the cocoons, dig their way to the surface, and fly away. The next generation of sawflies is then started as the newly emerged females again lay their eggs into gum leaves.

THE LARVAE OF THE MAJORITY OF species are found most commonly in the foliage of young or regrowing *Eucalyptus*. These include Blakely's Red Gum (*Eucalyptus blakelyi*), River Red Gum (*E. camaldulensis*), South Australian Blue Gum (*E. leucoxylon*), Yellow Box (*E. melliodora*), and Red Iron Bark

Mature sawfly larvae (*Perga affinis*) cling gregariously to a *Eucalyptus* tree, a familiar sight in late winter or early spring.

JEAN-PAUL FERRERO / AUSCAPE INTERNATIONAL

P. WEINSTEIN

The tiny eggs of *Taeniogonalos venatoria* have been laid into a leaf along its margin. One egg is shown by the point of a needle.

(*E. sideroxylon*). Because the insects and their eucalypt hosts have evolved together, eucalypts in natural woodlands are usually not badly damaged by the insects; the trees may, in fact, be invigorated by some defoliation, much as fruit trees benefit from pruning. Unfortunately, small ornamental eucalypts in gardens and even-aged young trees in woodlots sometimes suffer from excessive defoliation by sawfly larvae. Such trees may suffer growth retardation or even death, and only in these situations is it reasonable to kill sawfly larvae as 'pests'.

The astute gardener will find the larvae when they are still small, in late autumn or early winter, before they have eaten too many leaves. The leaf or twig with the larvae on it can then be cut off easily, and the larvae safely and humanely killed by dropping the twig into a pot of boiling water. In commercial plantations, either insecticides or biological control agents such as parasites can be used to control sawfly populations.

Of the several parasitic wasps and flies that attack *Perga*, one parasite is behaviourally unique. It is a trigonalyid wasp, *Taeniogonalos venatoria* (family Trigonalyidae), and I have studied it in depth for a number of years. By rearing *Taeniogonalos venatoria* on the larvae of *Perga* in the laboratory, I was able to analyse the lifecycle and behaviour of the parasite.

Taeniogonalos venatoria is unique in that it lays its tiny eggs on *Eucalyptus* leaves. All other parasitic wasps first locate their host larvae (or host eggs or pupae), and lay their eggs directly into the tissues of the host. *Taeniogonalos venatoria*, by contrast, depends on the host larvae eating the tiny eggs inadvertently when they eat *Eucalyptus* leaves.

Once eaten, the eggs hatch in the gut of a sawfly larva, and parasite larvae pene-

The parasitic wasp *Taeniogonalos venatoria* laying its eggs on a *Eucalyptus* leaf, thus avoiding the defensive strategies of the sawfly larvae.

trate through the gut into the host's tissues. Here a parasite larva may develop further, consuming the sawfly host larva from within, just like an insect version of 'Alien'. An adult parasite eventually emerges from the sawfly cocoon, where only the spills of the banquet remain.

Many eggs will, of course, never be eaten, but *Taeniogonalos venatoria* lays over 10,000 eggs, many more than other parasitic wasps. In addition, *Taeniogonalos venatoria* can develop in a variety of insects other than sawfly larvae, such as in the caterpillars of large moths. The parasite lays its eggs apparently at random on a variety of plant species, and the chances of at least some eggs being consumed by a leaf-eating caterpillar or sawfly larva are therefore reasonably high.

It is possible that the unique egg-laying strategy of *Taeniogonalos venatoria* has evolved, in part, to overcome the defensive behaviours of host larvae. The circular defence strategy of sawfly larvae, for example, is not effective against trigonalyid parasites because the adult parasites never confront the sawfly larvae themselves.

Petiole chewing by pergid larvae appears to be another defensive behaviour that *Taeniogonalos venatoria* has overcome by ovipositing on foliage. Petiole chewing, as mentioned previously, is the process by which the last larva to leave a chewed leaf removes that leaf from the branch. Several theories have attempted to explain this behaviour, but the most likely one holds that the larvae remove the evidence of their feeding in order to 'hide' from parasites and predators. Many parasitic wasps and flies are known to search for their hosts by the sight and smell of the feeding damage the hosts cause to plants. In a similar way, ivory-poachers can follow elephant trails through the forest. By removing damaged leaves (and hence their smell) from the tree they are in, sawfly larvae are believed to make it more difficult for parasites to find the tree and, therefore, also the sawfly larvae themselves. However, because *Taeniogonalos venatoria* oviposits on leaves regardless of the presence of feeding damage or hosts, petiole chewing does not help the sawfly larvae to 'hide' from their trigonalyid parasites.

The ability to overcome some of the host defensive behaviours with which other parasites are confronted makes *Taeniogonalos venatoria* a very successful parasite. In some areas of south-eastern Australia, *Taeniogonalos venatoria* is in fact known to be the single, most important mortality factor in populations of the Steelblue Sawfly (*Perga affinis*). In these areas, over 50 per cent of host larvae are parasitised. *Taeniogonalos venatoria* may therefore be worthy of consideration for use as a biological control agent, particularly in young, even-aged eucalypt plantations where sawfly larvae can otherwise reach plague proportions. With the importance of hardwood plantations in Australia on the rise and the acceptability of insecticide use falling, the control of pest populations of sawfly larvae may become increasingly reliant on the use of biological control agents such as *Taeniogonalos venatoria*. ■

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Dr Philip Weinstein is a medical graduate with a longstanding interest in natural history. He holds degrees in zoology and in national park and wildlife management, and has recently completed his doctoral thesis in entomology at the University of Adelaide. Philip currently works for the National Centre for Epidemiology and Population Health, Australian National University; he is studying the epidemiology of insect-vectored diseases at the Communicable Disease Control Unit, South Australian Health Commission.

The author wishes to acknowledge the guidance and inspiration provided by Andrew Austin and Derek Maelzer in conducting much of the research presented in this paper. The research was generously sponsored by the Australian Special Rural Research Council (now the RIRDC).

"Australian archaeologists now have a powerful tool to investigate the age range beyond the effective limits of radiocarbon."

THE TEST OF TIME: PHYSICAL DATING METHODS IN ARCHAEOLOGY

BY R.G. (BERT) ROBERTS & RHYS JONES

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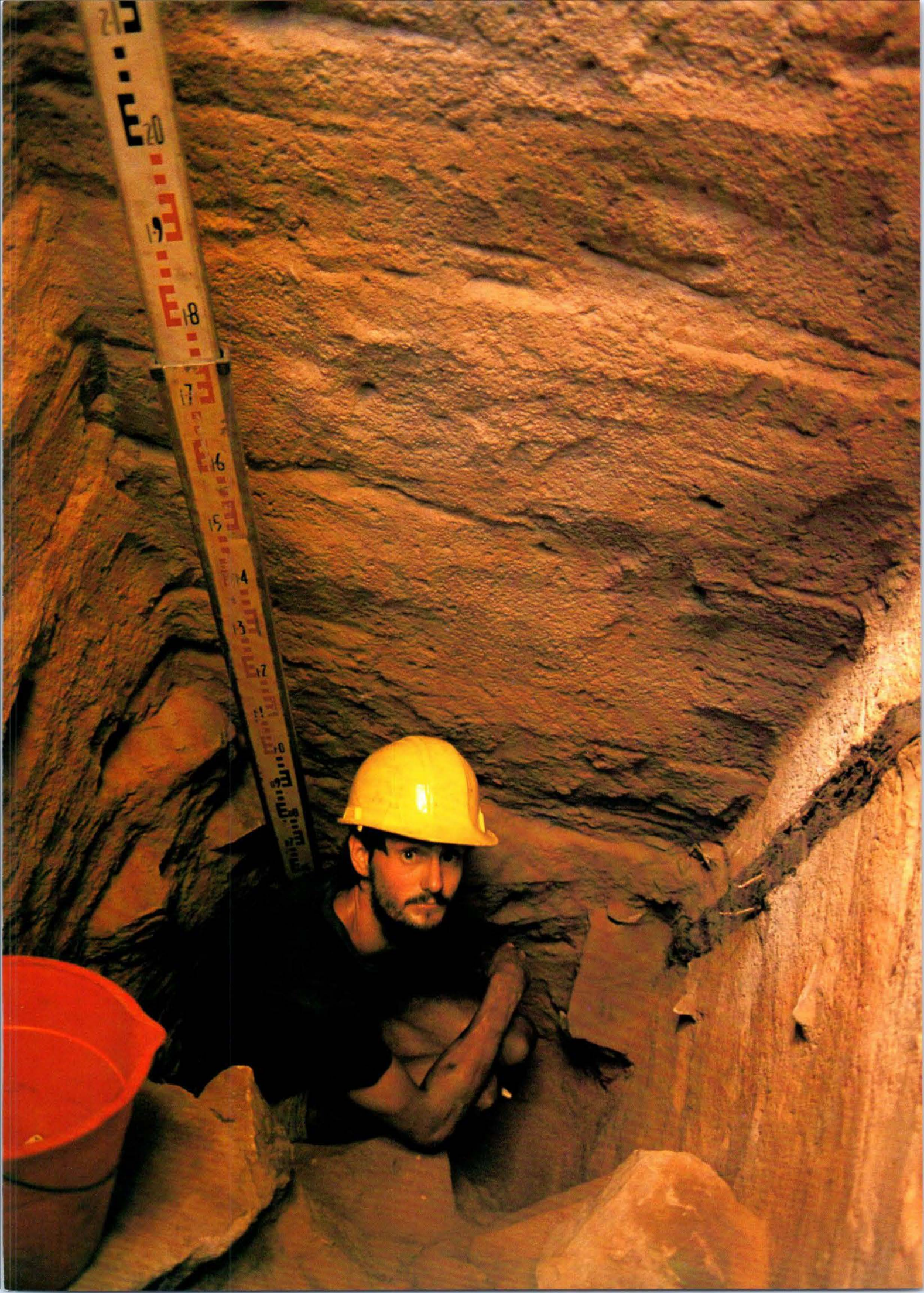
APPRECIATION OF THE GREAT ANTIQUITY of the Earth and of biological and human history has been a surprisingly late development in scientific thinking. Isaac Newton, in the late 17th century, could conceive of an infinity in space, but his ideas as to the age of the universe were still constrained by a literal interpretation of the Book of Genesis. Count Buffon, daringly skirting the edges of official ecclesiastical sanction a few decades before the French Revolution, tried to calculate the age of the Earth from cooling experiments conducted on a large sphere of brass. His conclusion was that the Earth may have been no older than 60,000 years.

The theories associated with the names of Charles Darwin and Alfred Russel Wallace required a vastly expanded time scale to accommodate their evolutionary biological processes and, so too, a much greater antiquity for human origins than had previously been imagined. The concept of 'deep time' was also embodied in the writings of the foremost geologist of the time, Charles Lyell, who assented to an ancient origin for mankind in his 1863 treatise *On the geological evidences of the antiquity of man*. By the beginning of the 20th century, serious scientific opinion considered an antiquity for humans and their direct ancestors that extended back several hundred thousand years. The problem lay in the lack of any independent means of proving such ages. All methods rested on informed guesswork, based partly on inferences, drawn

The author, Bert Roberts, collects samples of sediment from an excavated sandstone-floored pit known as Malakunanja II in Kakadu. A sophisticated dating method known as thermoluminescence reveals that this site was occupied by humans at least 50,000 years ago.

RHYS JONES

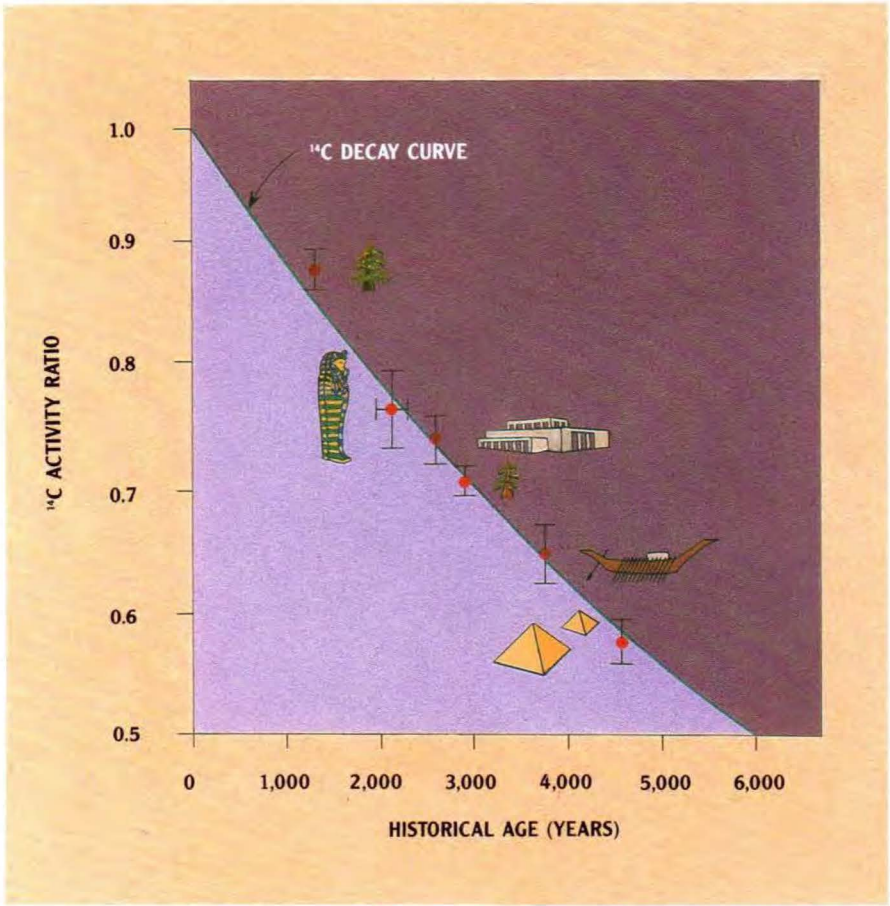


from observable rates of geological processes, such as the rates of erosion or formation of deposits.

Archaeometry, a term coined by the British Iron Age specialist Christopher Hawkes in 1958, can be broadly defined as the study of physical and chemical methods of analysis of archaeologically related material. The earliest archaeometric dating methods involved counting the annual growth rings of fossil trees and the annual spring-melt clay layers (varves) laid down in glacier-edge lake beds. But the study of tree rings and varves provides absolute chronologies for only the past few millennia.

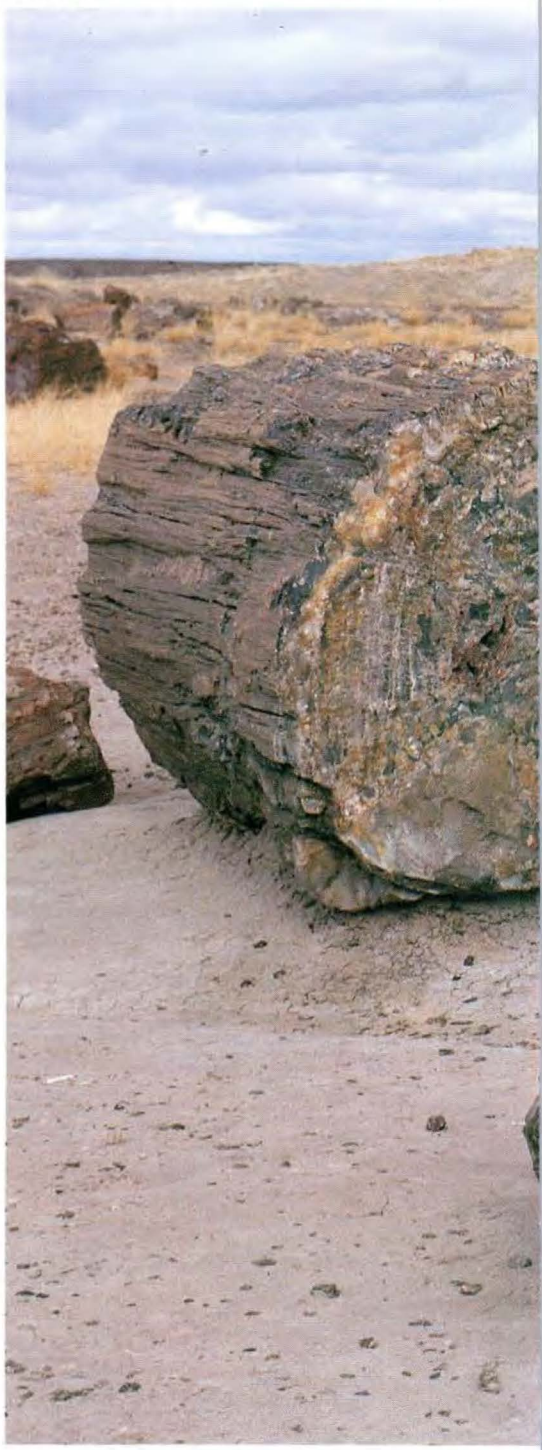
The beginning of a revolution in our understanding of human prehistory, through the development and application of physical dating methods, began immediately after World War 2 with the advent of radiocarbon dating at the University of Chicago. A team led by the Nobel laureate Willard Libby proposed a technique based on an isotope of carbon, ^{14}C, which is produced by cosmic ray bombardment in the upper atmosphere. This isotope becomes dispersed throughout the atmosphere and oceans, and is subsequently incorporated into plant and animal tissue during metabolism. This exchange ceases at death, after which the ^{14}C content decays at a constant rate. The age of organic material, most commonly wood or shell, is determined by measuring the remaining ^{14}C activity and comparing this with its presumed activity at the time of formation (see diagram). Conventional counting of the emissions of beta particles during decay permits materials as old as 40,000 years or so to be dated. The recent utilisation of accelerator mass spectrometry (AMS), which directly measures the abundance of ^{14}C atoms, has extended this range to a theoretical limit of 70,000 years. More significantly, AMS dating requires only minute quantities of sample, so that materials as exotic as wheat seeds, proteins in rock art pigment (see ANH vol. 23, no. 3, 1989–90) and even threads of the Turin Shroud have been dated.

Application of the radiocarbon method to archaeological sites in Australia has transformed our knowledge of the prehistory of the continent. The first direct date older than 10,000 years was obtained by John Mulvaney (Australian National University) from Kenniff Cave, south-eastern Queensland, in 1962. The same site later yielded material dated to 19,000 years. By the late 1960s, ages of 20,000 years were obtained from rock shelters on the southern coast of New South Wales, from Koonalda Cave on the Nullarbor Plain, and from Malangangerr and other sandstone shelters in what later became Kakadu National Park. In 1969, a human cremation and associated camp site were discovered near the southern tip of an eroded sand dune on the shore of Lake Mungo in western New South Wales. These remains were dated to about 26,000 years ago, but subsequent work on the sand dunes has demonstrated that some stone artefacts and shell midden deposits are 35,000 to 37,000



The earliest comprehensive comparison of carbon-14 (^{14}C radioactivity) with samples of known age. The solid curve depicts the decay of ^{14}C activity with the passage of time, based on a ^{14}C half-life of 5,720 years. The vertical scale shows the ratio between the ^{14}C activity of an ancient sample to that of a modern one. The samples of ancient wood were collected from (in order of increasing antiquity): a Douglas Fir Tree; an Egyptian mummiform coffin; the floor of a Syrian palace; a Californian Redwood; an Egyptian funerary boat; and the tombs of two Egyptian kings. The age of the tree samples are known independently from their annual growth rings and the archaeological samples are dated from historical and stylistic evidence. (Redrawn from Arnold and Libby 1949.)

One of the earliest archaeometric dating methods involved counting the annual growth rings of fossil trees.



IAN FAULKNER

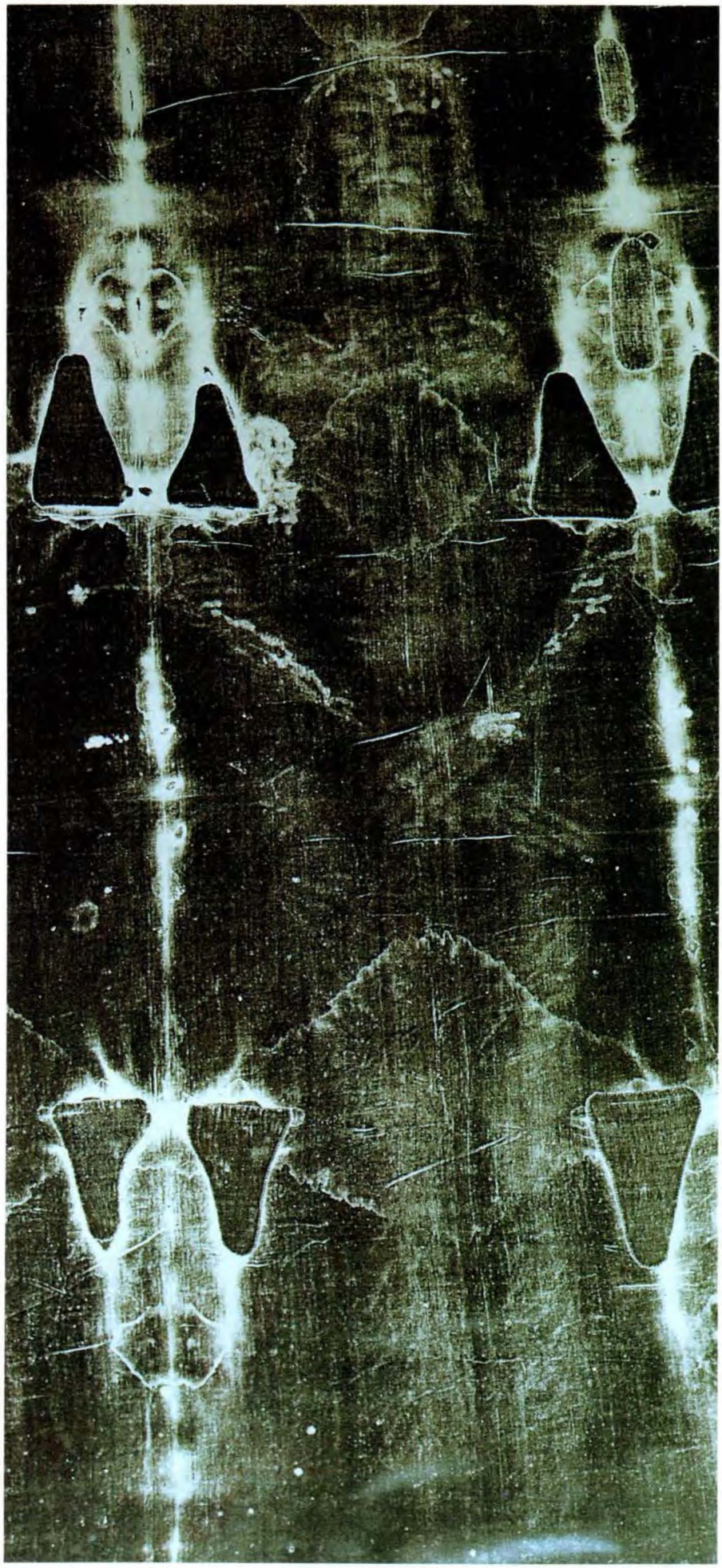
years old or even more. Radiocarbon ages of similar antiquities have been reported from river terrace deposits near Perth in Western Australia.

The interpretation of these oldest radiocarbon dates is a contentious issue. At the very least, they are around 3,500 years too young because the level of atmospheric ^{14}C has not been constant during the past 50,000 years. There is also the insidious but far greater problem of contamination of an old sample by modern carbon: it requires only one per cent modern ^{14}C to give an infinitely old sample an apparent age of 38,000 years. As a result of these uncertainties, the oldest radiocarbon ages should not be taken at face value and the time of arrival of the first Australians must be sought from other dating methods.

ARCHAEOMETRY IN THE 1950s AND 1960s was dominated by advances in radiocarbon dating but the immutable half-life of radioisotopes provided the basis for other dating techniques. The most notable of these are potassium–argon (K–Ar) and uranium-series (U-series) dating. The K–Ar method utilises the fact that a naturally occurring isotope of potassium, ^{40}K, decays radioactively into two 'daughters', one of which is argon gas, ^{40}Ar. In molten rocks, the argon gas is lost, but begins to accumulate quantitatively when the rock crystallises. Once the rock has solidified, ^{40}Ar will gradually build up with time in potassium-rich minerals and the ^{40}Ar:^{40}K ratio can be used as a 'clock'. A more sophisticated approach is to convert first some ^{39}K to ^{39}Ar by neutron bombardment and then measure the ^{40}Ar:^{39}Ar ratio. This dating method is most suited to rocks hundreds of thousands or millions of years old and was at the centre of a controversy involving the dating of volcanic tuffs associated with early hominid remains in East Africa. A decade of acrimonious debate eventually ended in the early 1980s when Ian McDougall, a geochronologist at the Australian National University, produced firm K–Ar and Ar–Ar dates of just under two million years for the hominid-bearing tuffs.

Uranium-series dating refers to one of the primordial radioisotopes, ^{238}U, and its

AUSTRALIAN PICTURE LIBRARY



A. H. TOLHURST

On 14 October 1988 the Archbishop of Turin announced to the world that the Turin Shroud was not the burial cloth of Christ as was believed by many for more than 600 years. Radiocarbon dating by three independent laboratories in Arizona, Zurich and Oxford revealed that the cloth was made between AD 1260 and AD 1390.

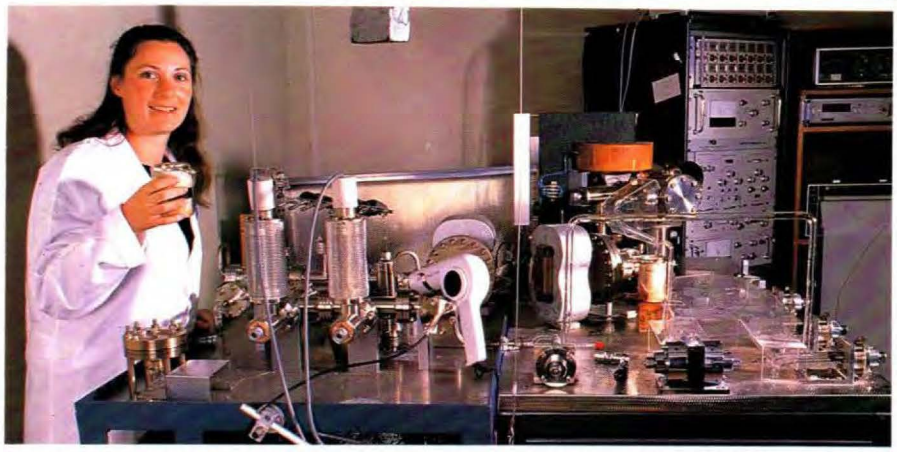
subsequent radioactive decay series. For archaeological purposes, materials such as cave stalagmites, coral, shell, bone and teeth can be dated by measuring the ratio between two isotopes from this decay series, namely ^{234}U and its thorium daughter, ^{230}Th. As ^{234}U undergoes radioactive decay, there is a gradual accumulation of ^{230}Th with time. By measuring the ^{230}Th:^{234}U ratio, it is possible to obtain an age for materials formed between 5,000 and 350,000 years ago. The U-series, method has been used to date stalagmites from Palaeolithic sites in Europe, hominid fossil remains in China, and bone fragments associated with the anatomically archaic Solo people in southern Java.

Fission-track dating was initiated in the early 1960s and it has been applied to volcanic glasses, such as obsidian, and some minerals (for example zircon). The technique is based on the small amount of ^{238}U that decays into two fission fragments, which recoil from each other leaving tracks of damage in the crystal structure. These tracks are only around 0.01 millimetre in length but become visible under a microscope after being chemically treated. The 'clock' is reset by the most recent heating event, which erases any tracks in the glass or mineral. The number of tracks increase subsequently in response to the fission of ^{238}U, which occurs at a constant rate. Thus, the age is a function of the number of fission tracks and the amount of ^{238}U present in the material being dated. The technique has the potential to date materials that were last heated only a few centuries ago and can extend as far back as one billion years. The fission-track method has been used to date obsidian tools of Holocene antiquity and to unravel the early Pleistocene geological and associated hominid chronologies in East Africa, China and Java.

But perhaps the greatest leap forward in archaeometry since the radiocarbon revolution occurred during the 1970s and 1980s with the dating of natural deposits using trapped-electron based techniques, such as thermoluminescence (TL) and electron spin resonance (ESR). Both methods rely on the steady accumulation through time of displaced charges (electrons) within minerals. Electrons are displaced as a result of bombardment by natural radiation and become trapped at defects in the crystal lattice. In the case of TL, grains of quartz or feldspar are used for dating, whereas ESR can date tooth, bone and shell. In TL dating, the sample is heated at a steady rate to a red-hot glow and its stored charge is determined from the quantity of faint light emitted as the trapped electrons are

evicted (see diagram). For ESR dating, the sample is subjected to a slowly changing magnetic field and its stored charge is determined from the strength of the signal at the particular microwave frequency at which the electrons resonate. The age of a sample is calculated by dividing the magnitude of the stored TL or ESR charge by its annual rate of supply from cosmic rays and naturally occurring radioisotopes in the soil. The latter include the previously mentioned ^{238}U decay series and ^{40}K, as well as the thorium decay series and rubidium. Although the experimental errors associated with TL and ESR ages are typically larger than those cited for ^{14}C ages, the trapped-electron methods can provide ages as far back as 200,000 years, which covers the critical period for first human colonisation of Australia.

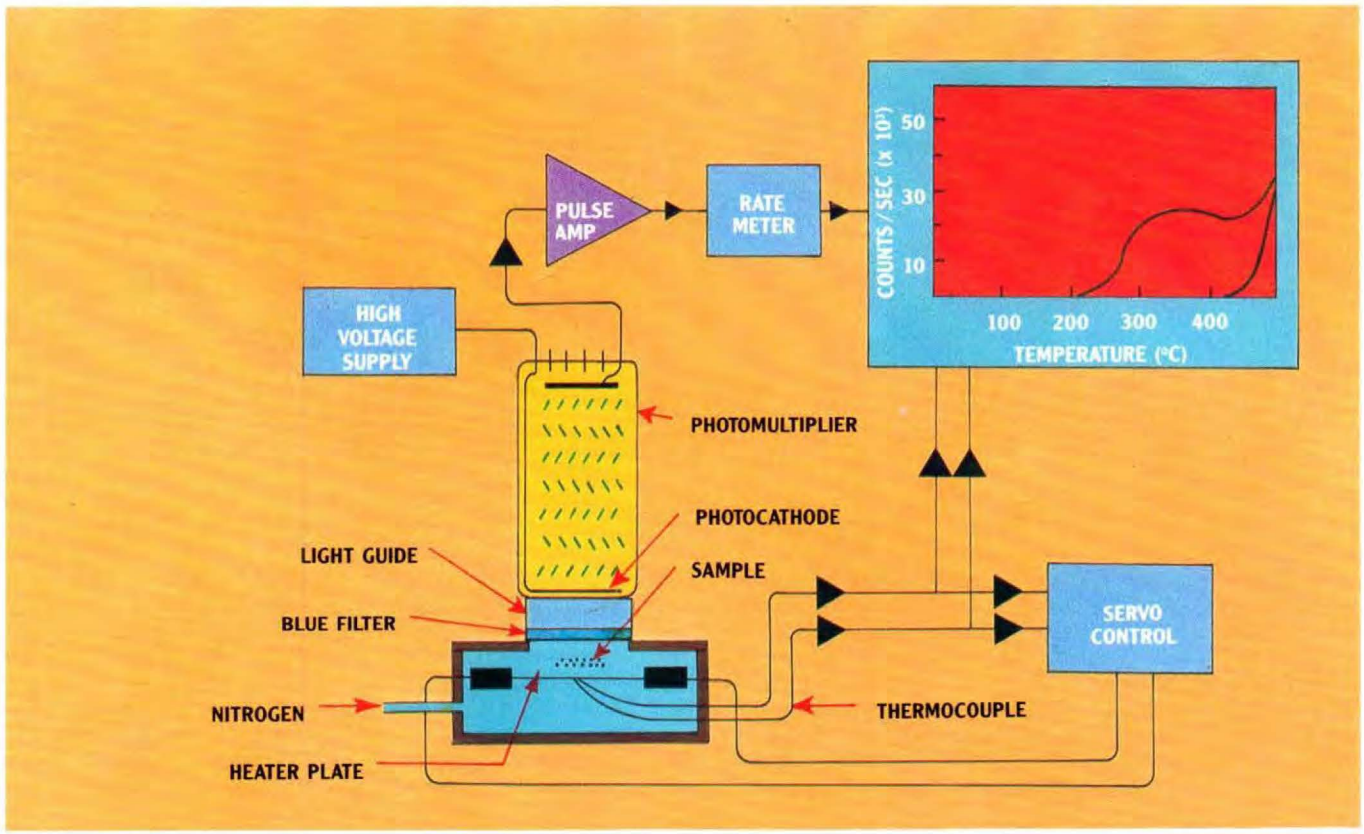
Applications of TL in archaeology have progressed rapidly since fired pottery, ceramics and, in the late 1970s, prehistoric Aboriginal hearth-baked clay from Lake Mungo were first dated at the University of Oxford. Burnt flint, volcanic ash and unheated sediment (exposed only to sunlight immediately prior to burial) have been used since to yield ages of archaeological significance. In the past few years, for example, burnt flints associated with Neanderthal and Cro-Magnon remains in western Europe and the Middle East have been dated by French scientist Helene Valladas and colleagues. They have shown that morphologically modern *Homo sapiens* were present in the Middle East by about 90,000 years ago and may have overlapped with Neanderthals in the region up until 50,000 years ago. This outcome ran counter to prevailing palaeoanthropological expectations, but there is evidence now also for the occurrence of anatomically modern humans in South Africa by 70,000 years ago, based on ESR dating, of animal teeth recovered from hominid-bearing sediment layers.



The argon dating facilities at ANU's Research School of Earth Sciences, being operated by Dr Caroline Perkins. The equipment immediately to her right is the ultra-high vacuum system for extraction of argon from samples. This dating method is suitable for dating rocks hundreds of thousands—or even millions—of years old.

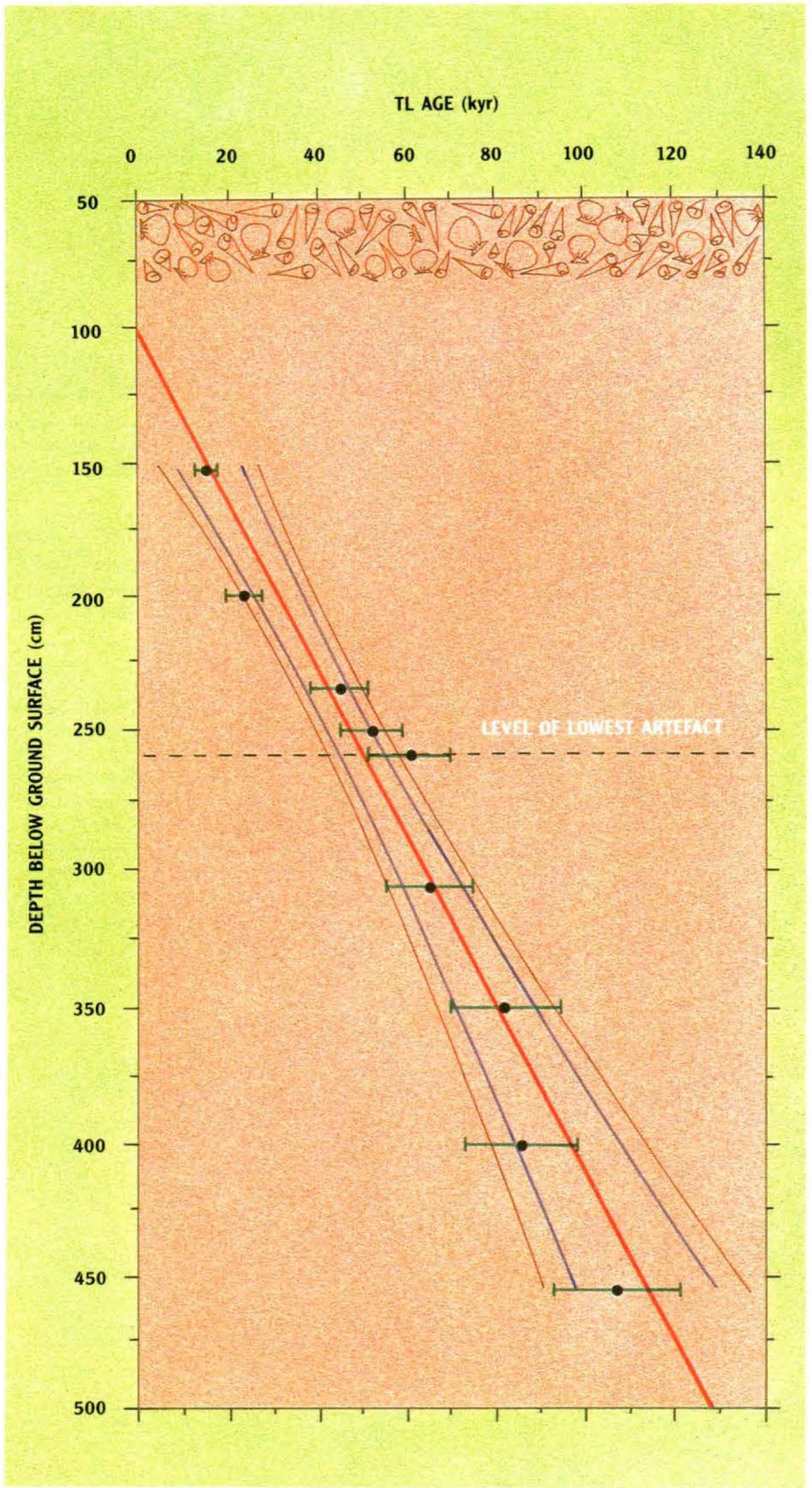
IAN McDOUGALL

BY COMPARISON WITH THE HOMINID chronologies revealed in Europe and Africa, the time taken for modern humans to reach the Australasian region has remained elusive. In 1988, Dutch scientist Gert-Jan Bartstra and co-workers reported U-series ages from fossil-bearing deposits in southern Java that suggest the morphologically archaic Solo people, themselves late descendants of the Javanese *erectus* lineage, may have persisted in the region until as recently as 100,000 to 75,000 years ago. In Papua New Guinea and Australia, which in the



IAN FAULKNER

Schematic diagram of the apparatus used in thermoluminescence (TL) dating. The sample is placed on a metal plate that is heated at a steady rate to 500° in a nitrogen atmosphere. The photons emitted during heating pass through a light filter to be detected and multiplied by the photomultiplier tube. The resulting signal is stored on computer for subsequent analysis and a plot is produced of TL output against temperature. The two 'glow curves' shown on the inset figure are the TL emitted by the sample on its first heating (upper curve) and the background thermal radiation emitted on the second heating (lower curve). The background curve is subtracted from the first-glow curve to determine the TL signal that the sample acquired in antiquity. (Redrawn from Aitken 1990.)



At Malakunanja II, a sandstone rock shelter in Kakadu, a series of nine thermoluminescence (TL) age samples was collected from the five-metre profile, showing the progressive increase in age of the sand deposit with increasing depth. The age scale is graduated in thousands of years (kyr). The precision associated with each of the nine dates is shown as a horizontal bar. The thick red line is the regression line fitted to these dates, assuming a constant rate of sand accumulation. The thinner lines are the 95 per cent (blue) and 99 per cent (brown) confidence limits for this regression: there is one chance in 20 that the true date lies outside the 95 per cent limits and only one chance in 100 that it lies outside the 99 per cent limits. The top 80 centimetres of this deposit is shell midden and the depth of the lowest stone artefact is shown. The diagram therefore illustrates that there is less than one chance in 20 that the lowest artefact is younger than 40,000 years. (Redrawn from Roberts *et al.* 1990.)

IAN FAULKNER

past have been linked by a land bridge, archaeologists have been restricted largely by the effective 40,000-year age limit of conventional ^{14}C dating and its attendant problems of age calibration and sample contamination. However, by using techniques with longer age ranges, two independent studies have suggested that the real antiquity of human occupation of the Greater Australian continent is considerably older than this methodological limit.

The Huon Peninsula in north-eastern Papua New Guinea is a coastal region undergoing rapid tectonic uplift, where a flight of terraces can be found rising from the sea. Each terrace comprises a fossil coral reef of different antiquity. In the mid 1980s, a team led by Les Groube from the University of Papua New Guinea discovered stone tools, including a distinctive ground-edge axe with side grooves, in volcanic ash deposits that mantle one such raised reef. The reef has been dated by U-series techniques to between 45,000 and 53,000 years, while TL dating of the overlying ash indicated an age of at least 40,000 years for the artefacts.

In 1973, during an archaeological survey of the Kakadu region of northern Australia, Sydney University researcher Johan Kamminga excavated a sandstone rock shelter known as Malakunanja II. He obtained a ^{14}C age of 18,000 years from charcoal pieces associated with stone artefacts. In 1989, we and colleague Michael Smith re-excavated the site. We dug down five metres, to the very base of the sand column, and obtained a vertical sequence of nine TL dates from the sandy sediments (see diagram). The bottom half of the deposit was totally sterile of any cultural materials and gave ages of between about 65,000 and 110,000 years. However, numerous stone artefacts were contained throughout the top 2.5 metres of sand. We attempted to pinpoint the time of appearance of the first artefacts, which we bracketed with three TL dates: the youngest at about 45,000 years provided a minimum age for first human arrival at the site, the oldest at 61,000 years gave the age of the most deeply buried artefact, and the middle date of about 52,000 years indicated that the site almost certainly had been occupied by 50,000 years ago. All of these TL samples were collected from stratigraphic levels containing artefacts. The low level of precision of the TL dates (typically ± 10–20 per cent of the age) remains a problem, as does the question of whether or not artefacts could have been pushed down the column into older sands. We are confident, however, that our stated date of 50,000 years for the first human occupation of this site will stand the test of further enquiries.

With recent advances in TL dating, Australian archaeologists now have a powerful tool to investigate the age range beyond the effective limits of radiocarbon. Establishing the age of the human colonisation of Australia will remain a high research priority. ■

L. M. GROUBE

A 'waisted blade', dated to more than 40,000 years, from a raised coral reef deposit, Huon Peninsula, Papua New Guinea.

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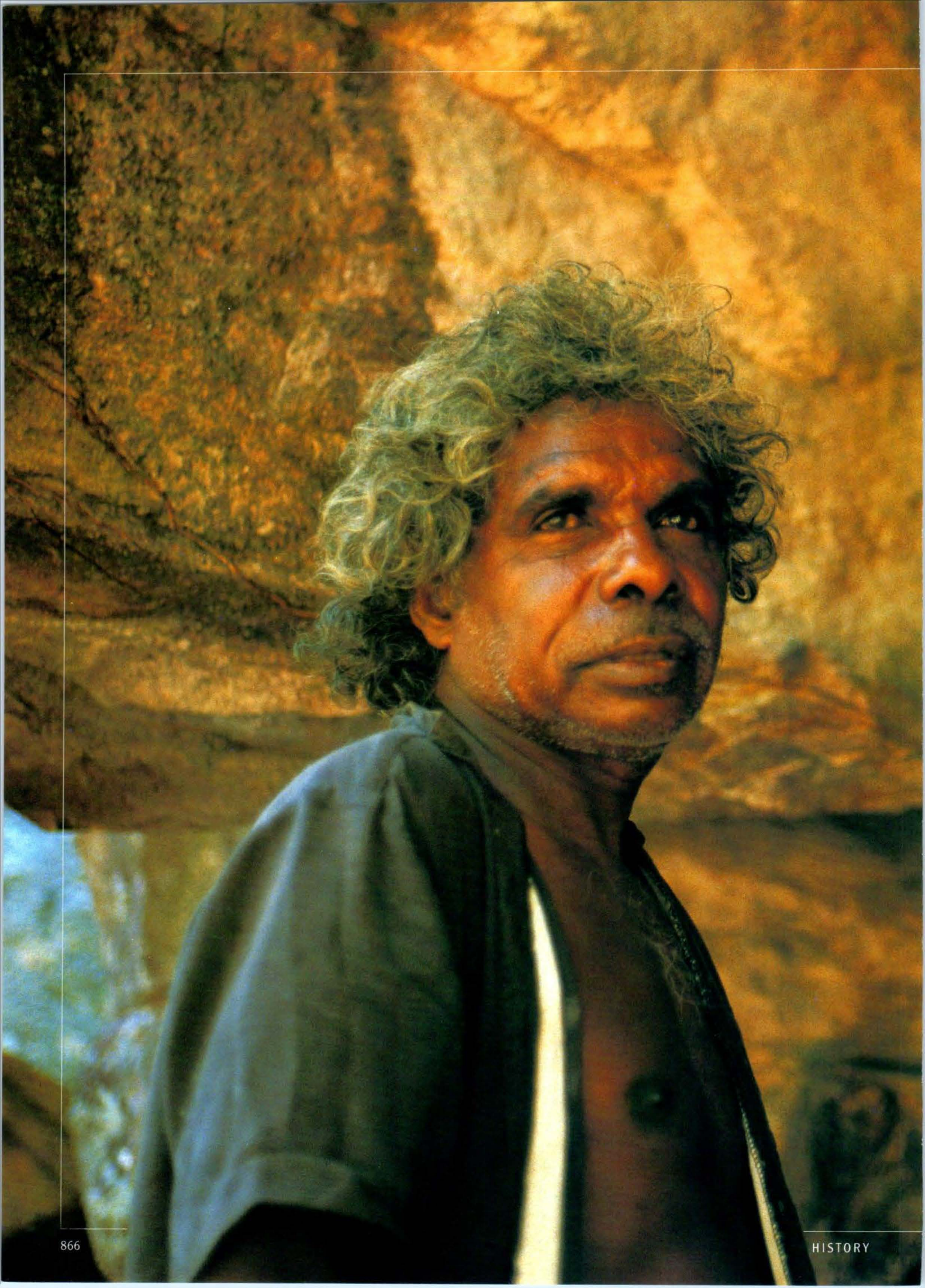
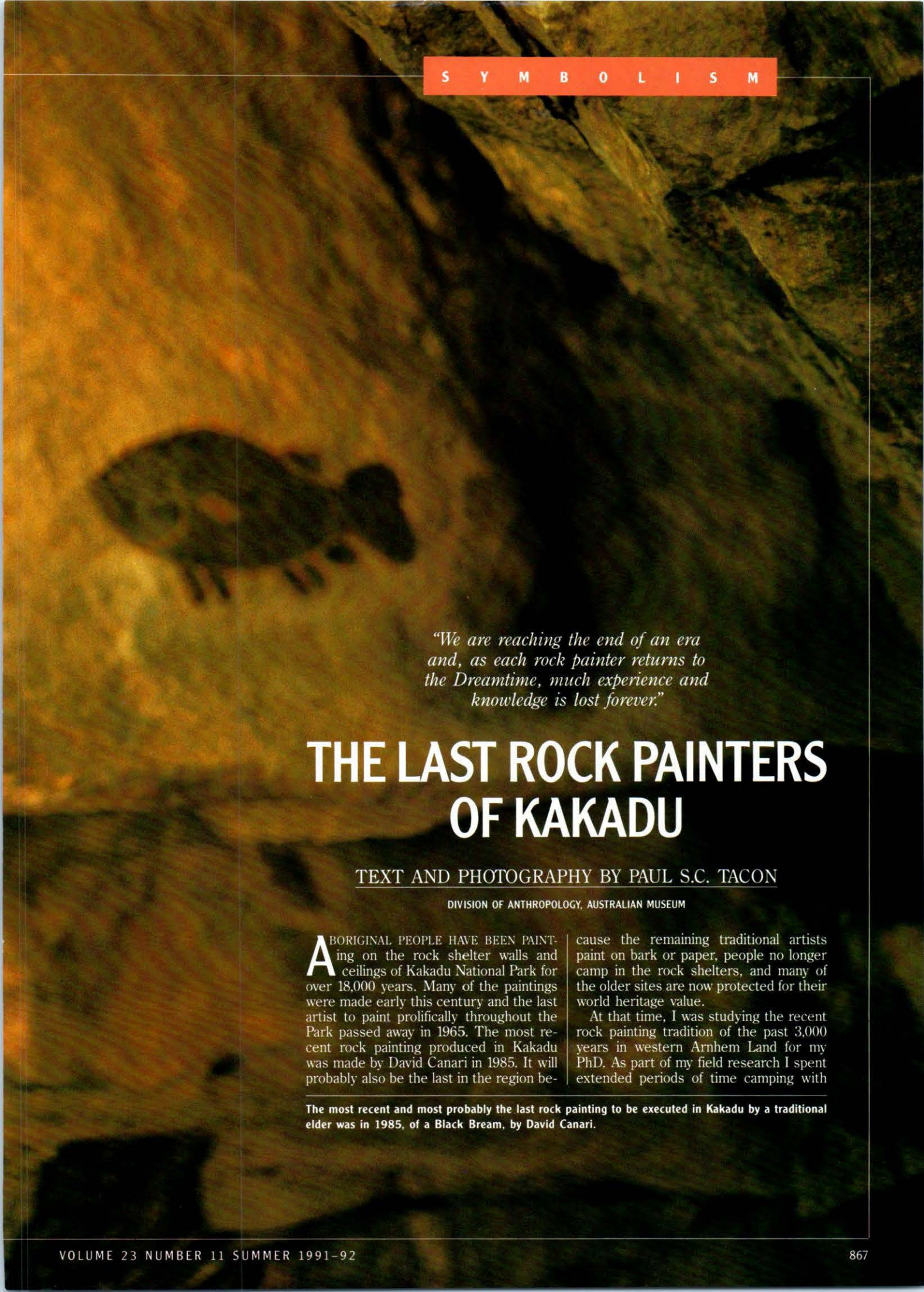
Richard (Bert) Roberts is a doctoral student in the Department of Geography at the University of Wollongong. He is currently completing his thesis on the age and mobility of sediments in the Kakadu region, and has strong research interests in the archaeological application of TL dating methods. Dr Rhys Jones is Senior Fellow in the Department of Prehistory at the Research School of Pacific Studies, Australian National University. A quarter century of his research has focused on the initial human colonisation of Australia and the subsequent peopling of the continent, with particular interests in Lake Mungo, Tasmania and Kakadu.





"We are reaching the end of an era and, as each rock painter returns to the Dreamtime, much experience and knowledge is lost forever."

THE LAST ROCK PAINTERS OF KAKADU

TEXT AND PHOTOGRAPHY BY PAUL S.C. TACON

DIVISION OF ANTHROPOLOGY, AUSTRALIAN MUSEUM

ABORIGINAL PEOPLE HAVE BEEN PAINTing on the rock shelter walls and ceilings of Kakadu National Park for over 18,000 years. Many of the paintings were made early this century and the last artist to paint prolifically throughout the Park passed away in 1965. The most recent rock painting produced in Kakadu was made by David Canari in 1985. It will probably also be the last in the region because the remaining traditional artists paint on bark or paper, people no longer camp in the rock shelters, and many of the older sites are now protected for their world heritage value.

At that time, I was studying the recent rock painting tradition of the past 3,000 years in western Arnhem Land for my PhD. As part of my field research I spent extended periods of time camping with

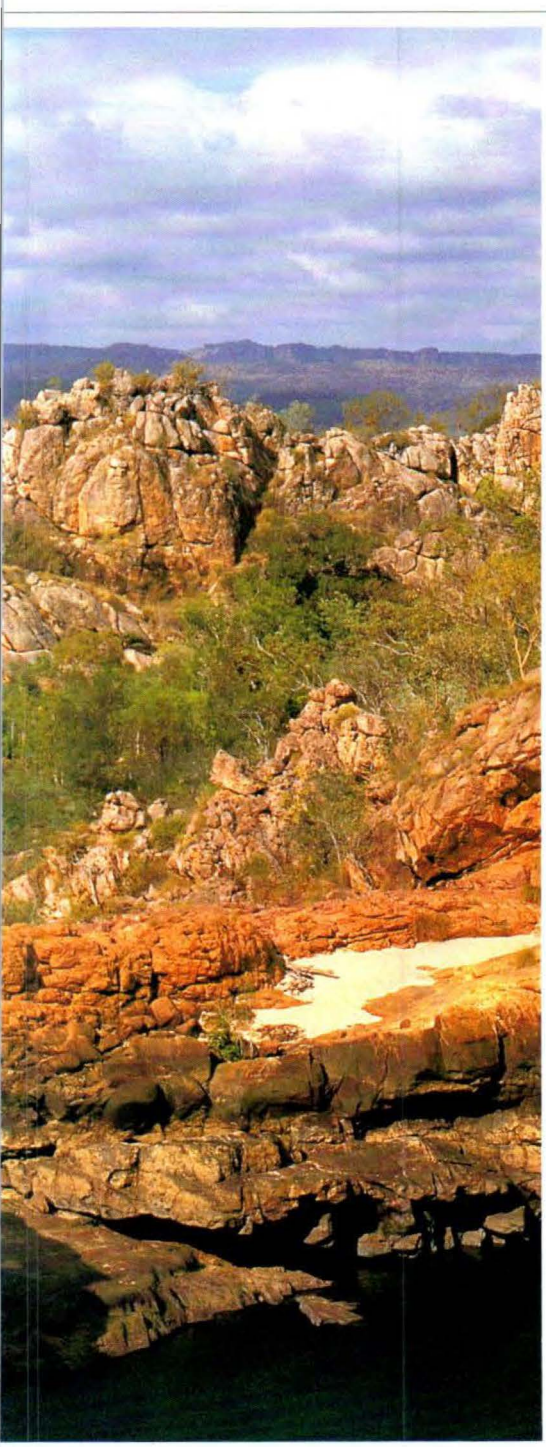
The most recent and most probably the last rock painting to be executed in Kakadu by a traditional elder was in 1985, of a Black Bream, by David Canari.

Aboriginal elders at various locations within the Park. It was on one of these occasions, while camping with David and his wife Nancy* in a waterfall-fed gorge, that David painted a Black Bream *(Hephaestus fuliginosus)*, a common and tasty freshwater fish found in the creeks and waterholes near the escarpment. He placed it in a small shelter not previously painted so as not to obscure older works. I photographed the whole procedure and, in the process, witnessed what may have been the last rock painting by an Aboriginal person in Kakadu; the last flicker of one of the longest continuous art traditions in the world.

As an outsider some people would argue that my presence directly contributed to the production of the painting. However I neither encouraged nor discouraged David to paint it; it was purely his decision. Furthermore, he had painted at other sites in the 1960s, is an elder with traditional links to the landscape, and continues to produce bark paintings and painted didjeridus; he certainly is not a novice. In keeping with earlier artists, fish and goannas are his most common subjects and all pigments are obtained from the landscape. My research took us to this particular location but it was his independent decision to mark our visit in a way that had been repeated by others thousands of times before, through the act of painting.

On the first day of our visit to the gorge I hiked above and around the falls but didn't have time to go much further. When I returned David had already caught a large water goanna and Nancy had a Black Bream. While we were talking about their good luck, and I was photographing the large lizard, Nancy pulled another Black Bream from the water. They were both thrilled with the catch and David said he would paint a Black Bream on some nearby rocks so we could remember Nancy's good luck. Other people would hear of our visit and when they saw the painted fish they would know where we had camped. He then chose two spots that

**David's wife passed away in 1986. Her name has been changed for this article so as not to upset friends and relatives. Traditionally, a person's name was not repeated to close relatives after death until a considerable period of time had elapsed.*



Rock pools in Koolpin Gorge. Recent rock paintings are most often found near permanent sources of freshwater in Kakadu National Park.

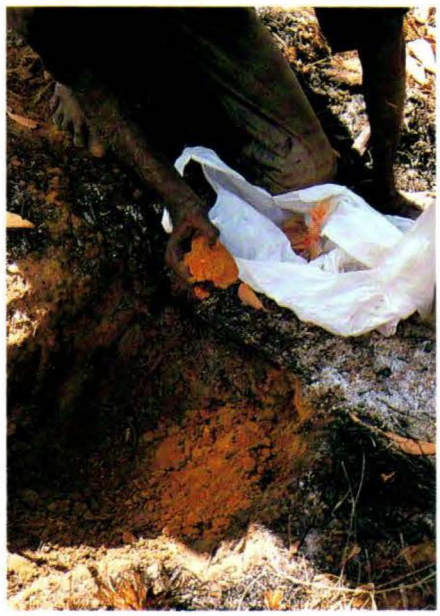
were relatively well protected from water wash and insects and, after discussing the merits of each, he decided on the one that would best safeguard his painting for the future.

The next morning we got up at seven. We ate the goanna and the rest of the previous day's catch for breakfast. Then Nancy packed up their swag and belongings while I put my gear in the truck. David gathered up his painting and carving tools. Once we finished clearing our camp site Nancy wandered down to the spot where she caught the Black Bream with the intention of catching more to take back to her outstation. David and I walked a little further and started work on his painting.

The Black Bream caught by David's wife and the inspiration behind his painting.

He got me to help him prepare the pigments and, in the process, I learnt something about the use of ochres. First we crushed some yellow ochre (limonite) in an old tobacco tin, added a bit of water and a few drops of white wood glue, and stirred and shook the mixture. Using a sharp knife, I then scraped off some red ochre from a large lump of haematite and added water and glue to it. An orange–red pigment can also be made by heating limonite over a fire. In earlier times orchid pseudo-bulb juice *(Dendrobium dicuphum)* might have been mixed with the ochre, and sometimes 'bush gum', obtained from the bark of green trees, was used. When this was done the bark was ground on a flat stone and boiled in water. Once it became sticky it could be spread over surfaces to be painted or mixed with pigment. Today it is much easier to use commercial glue. Finally, I ground up some charcoal from a large piece retrieved from the fire and added glue and water to it. When we had finished we had three tins of paint ready to be used on the rock wall.

David climbed up to a protected panel just above the walking path to the falls, on the eastern side. He began to paint and said he would like to return next year to see how his work survived. He also said that, when I return to the area 10, 20, or 30 years from now with a wife and children, long after he is dead, I can look at the painting and say 'my good friend David did this' and in that way remember the good time the three of us had camping at the gorge.



David removes yellow ochre (limonite) from a dried creek bed. Later some of it was roasted over a fire to change it to a rich orange-red colour.

These detailed paintings with internal features were made in the 1950s by Najombolmi, the last artist to paint prolifically throughout Kakadu.

David started by painting a solid black fish body complete with tail and fins. He then waited for the paint to dry, but this didn't take long as it was quickly absorbed by the porous rock surface. He next painted the outline of the fish in red. Slowly, carefully and meticulously he worked so as not to drip the paint or to overlap it on the black body. I watched with great interest as I had presumed most rock painting had been started with an outline, only to have the body and internal features added later. I was soon to learn this was not peculiar to his own style and that most rock and bark painters work this way.

After the red had dried, David picked up the tin of yellow and applied tail division marks, an eye, spikes and a yellow gill flap. He said he didn't want to illustrate the backbone and guts. Taking one last admiring look at his work he said he wouldn't sign his name below this one, as he has done with some of his other paintings elsewhere, but that it was enough I should know he had done it.

We hurried back to the truck before arriving tourists could spot us, collecting Nancy on the way. On the way back to their outstation we passed lots of packed vehicles heading towards the camping area and were thankful they hadn't arrived two days earlier.

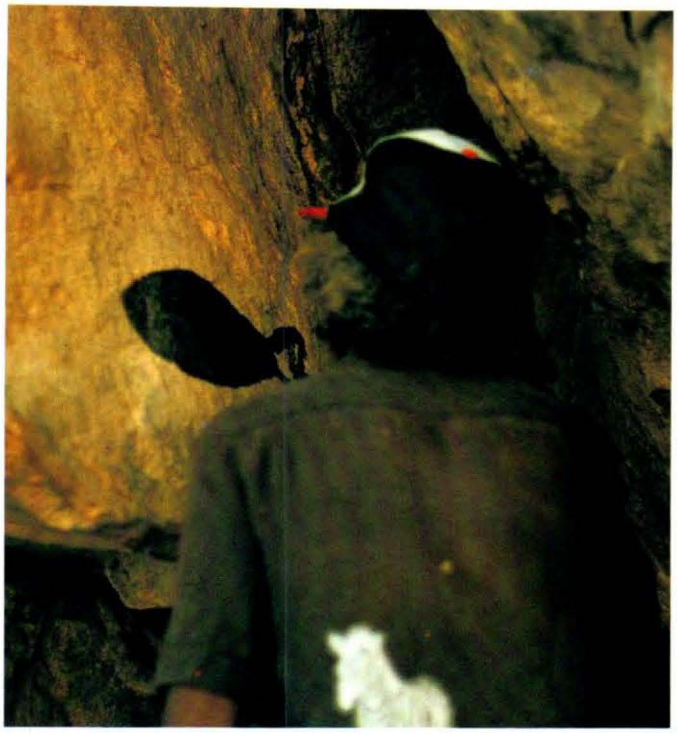
One of David's motivations was to record Nancy's catch and to commemorate the good time we shared camping in the gorge. According to other Aboriginal elders, many paintings spark similar memories for them and this was always one of the many functions of rock art. In this sense, some of the rock art in western Arnhem Land can be considered a form of recorded history. However, without someone to explain the personal associations, this aspect of the art is lost to the outsider.

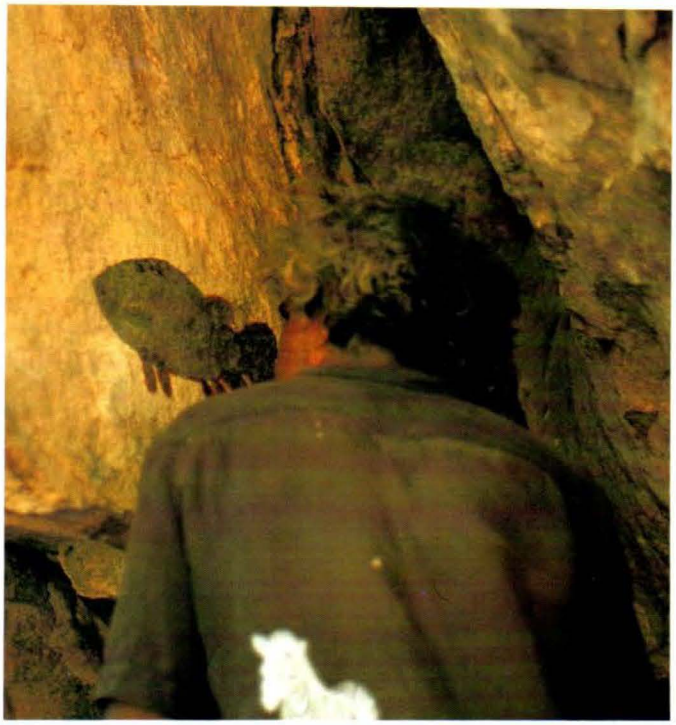
For the Aboriginal people of western Arnhem Land oral traditions, including story-telling and the passing down of knowledge and experience, were exceedingly important. Just as important were visual traditions, and the two are components of a larger form of cultural expression. Today, with change occurring at an ever-quickening pace and with many knowledgeable elders having died, the art has taken on an increased importance. It is something that many non-Aborigines are attracted to and so has become a vehicle for passing on and preserving Aboriginal knowledge, traditions, culture and belief, not only to Aborigines but also to others. For instance, at Ubirr, one of the main complex of rock art sites frequented by interstate and overseas tourists, Bill Neidjie (a Bunitj clan elder known to some as 'Kakadu Man') said that this place, like other art sites, was very important and the paintings must not be touched or defaced by anyone. He said that when he comes here it makes him think about the past, and the paintings give him all sorts of feelings and memories. For him they are Aboriginal 'history'. All the paintings, caves and shelters like these have a story and tell of the past.

Accumulated knowledge was always important so many of the experiences, 'laws', lessons, important events and changes in the recent or more ancient past, as well as more esoteric aspects of the Dreamtime, have been retained and passed on to succeeding generations in symbolic form. Much of the recent body of rock painting in western Arnhem Land records and expresses aspects of this legacy. However, particular pieces or forms of art do not always have set meanings or interpretations. Individual works often have many levels of meaning encoded into them, and they may mean different things to different people or groups within the community. Some works have both sacred and secular meanings, but the nature of the design protects the more secret information from the uninitiated. Usually, however, each work encompasses only a set range of symbolic meanings pertinent to the society that produced it. This is true not only of Aboriginal art but also of our own.

The last rock painting of Kakadu also records our experience in symbolic form by focusing on the significant animal species we interacted with during the visit, that is the Black Bream. Our trip to the

First the solid black fish body was painted. Then a red outline was added. And finally other features, such as an eye and tail markings, were painted in yellow on top of the black body.



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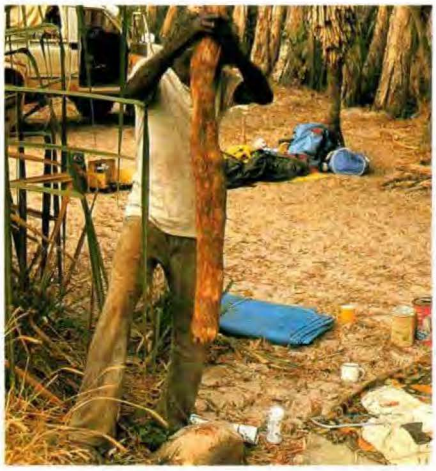

David Canari prepares a section of bloodwood trunk to make a didjeridu, which was later painted with images of the Black Bream and goanna caught during the trip.

gorge was further recorded with a painted didjeridu begun at the time and later painted with Black Bream and the goanna we had for our meals. Rock painting in Kakadu has occurred only two other times since the mid-1960s, at Nourlangie in 1972 and north of Ubirr in the early 1980s. As well, some painting was done at Oenpelli but all of these events appear to have been initiated by Europeans.

Today there are few rock painters left in western Arnhem Land and David is the last with traditional land ties in Kakadu. Rock art sites are protected by legislation and repainting is discouraged. David's Black Bream is the last rock painting of Kakadu as he now restricts his work to portable objects. One of the reasons is that recent painting and repainting is often met with much controversy. In 1987, for instance, when ten Wandjina sites were repainted by Aboriginal people in the Kimberleys, outsiders protested across the country, claiming older paintings had been irresponsibly defaced. However, for some of the Aboriginal elders who supervised, it was necessary to renew the images as they contain energies that help keep Aborigines alive; in addition, repainting is thought by some to be an important learning experience that helps bond Aborigines with the landscape. Much of the controversy is directly attributable to differing cultural perceptions. For example, in more traditional Aboriginal societies the painting process itself is highly valued, while in Western societies it is more often the product that is important and so great protection measures are taken.

In Arnhem Land today, the tradition and process of painting continues with motifs similar to recent rock paintings reproduced on sheets of bark, paper or plywood. Many of the elders who painted in rock shelters this century have died in the last five years and those that survive are elderly and frail. We are reaching the end of an era and, as each rock painter returns to the Dreamtime, much experience and knowledge is lost forever. This is one of the reasons we should listen to and record what the elderly have to offer, but also it highlights the need to preserve, protect and respect rock art sites when we encounter them. They are not only an important part of history but also have contemporary significance for many people. Valuable lessons can be offered to us all by their systematic study and interpretation but this, too, should be done with care and caution so as not to distort a site's true significance.

In my study, for instance, I found fish to be one of the most common and important subjects in the rock art produced over the past 3,000 years, even though they had been dismissed by previous scholars who focused their work on larger animals and outstanding examples of Dreamtime Beings. Besides being a staple food, fish also are symbolic of regeneration, human souls, spirit children that reside in permanent water holes, and life in general. It was no coincidence that David chose to paint a fish. His last painted statement, among other things, is an expression of hope for the future. It is a hope that knowledge and traditions will not be lost and that the young will continue to realise their connection to the land, its species and sites. This is a dream shared by many Aboriginal elders and is one of the most important lessons they have to offer. Only by having a firm sense of roots and association with the landscape will we care for its future. In the process our own future is provided for. ■

Brothers Nipper Kapirigi and David Canari with the author in front of one of Kakadu's largest painted rock shelters. Nipper and David's father painted the large Barramundi early this century and Nipper was born in the shelter.

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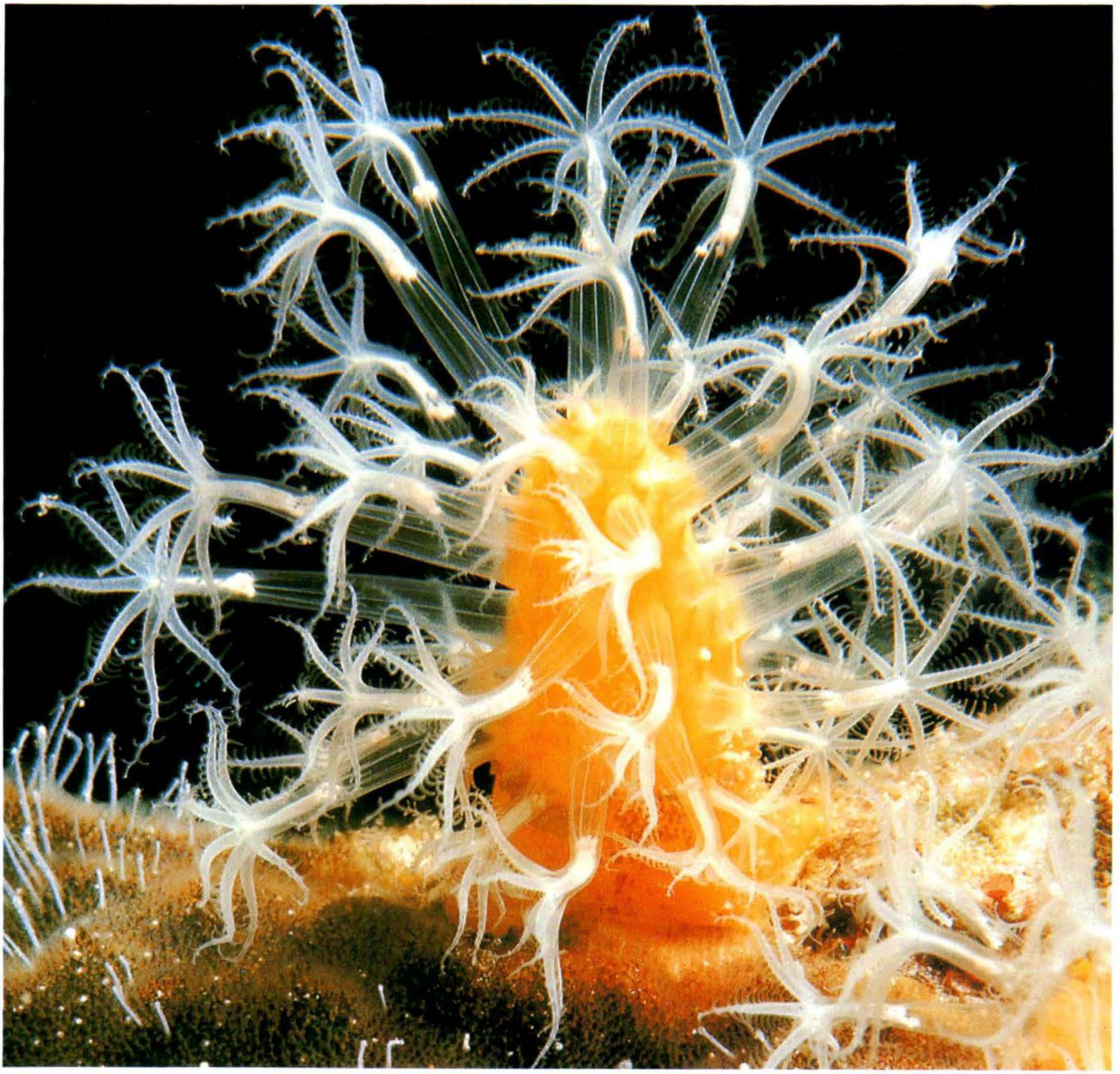
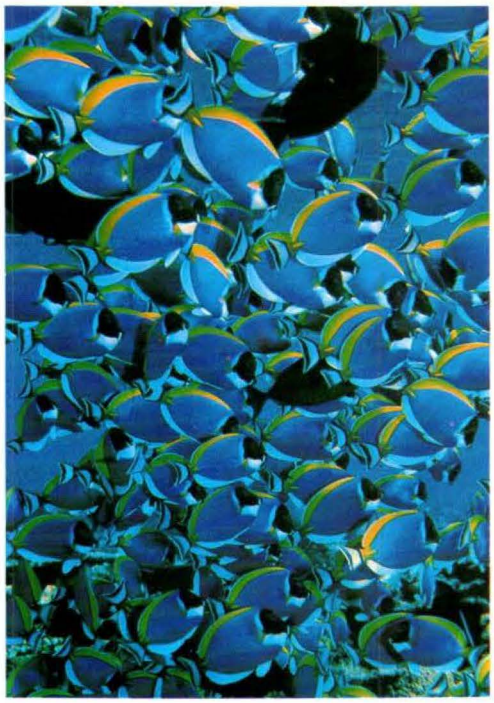
Dr Paul Tacon is a Scientific Officer in the Division of Anthropology at the Australian Museum. His research focuses on the material culture of indigenous peoples in Australia and Canada, with field work concentrated in the far north of both countries. He is particularly interested in the relationship between art, identity and the landscape.



A beehive coral, *Eleutherobia* sp.

Surgeonfishes (*Acanthurus leucosternon*) utilise schooling strategies to decrease the chance of predation.

The spectacular Randall's Basslet Fish (*Pseudanthias randalli*).

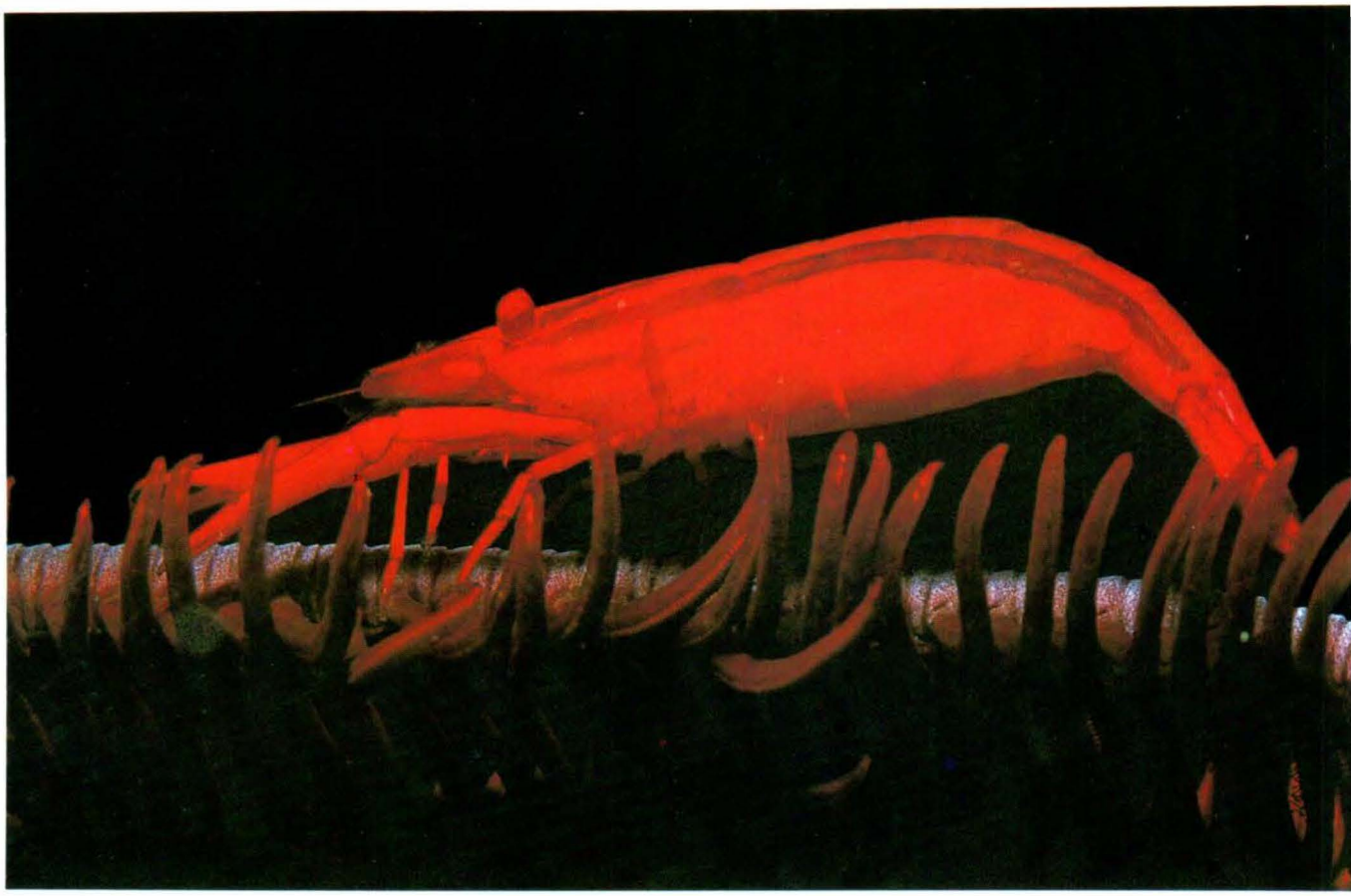


CORAL REEFS

BY ROGER STEENE
UNDERWATER PHOTOGRAPHER

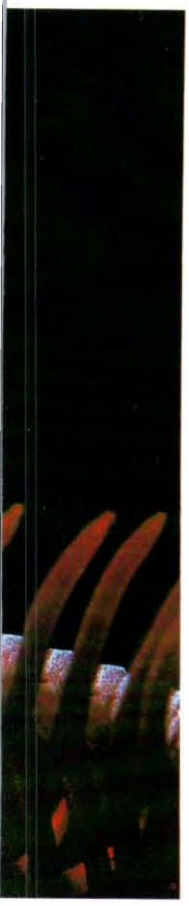
Coral reefs are among the oldest and richest natural communities on Earth. Nowhere else can so many diverse creatures be found living so closely together. Complementing and enhancing this abundance is the exquisite beauty of form, colour and motion. Roger Steene, an Associate of the Australian Museum, has spent 20 years photographing coral reefs, and the photos shown here represent only a taste of the 300 superb colour plates that can be found in his new book *Coral reefs: nature's richest realm* (Crawford House Press, 1991).

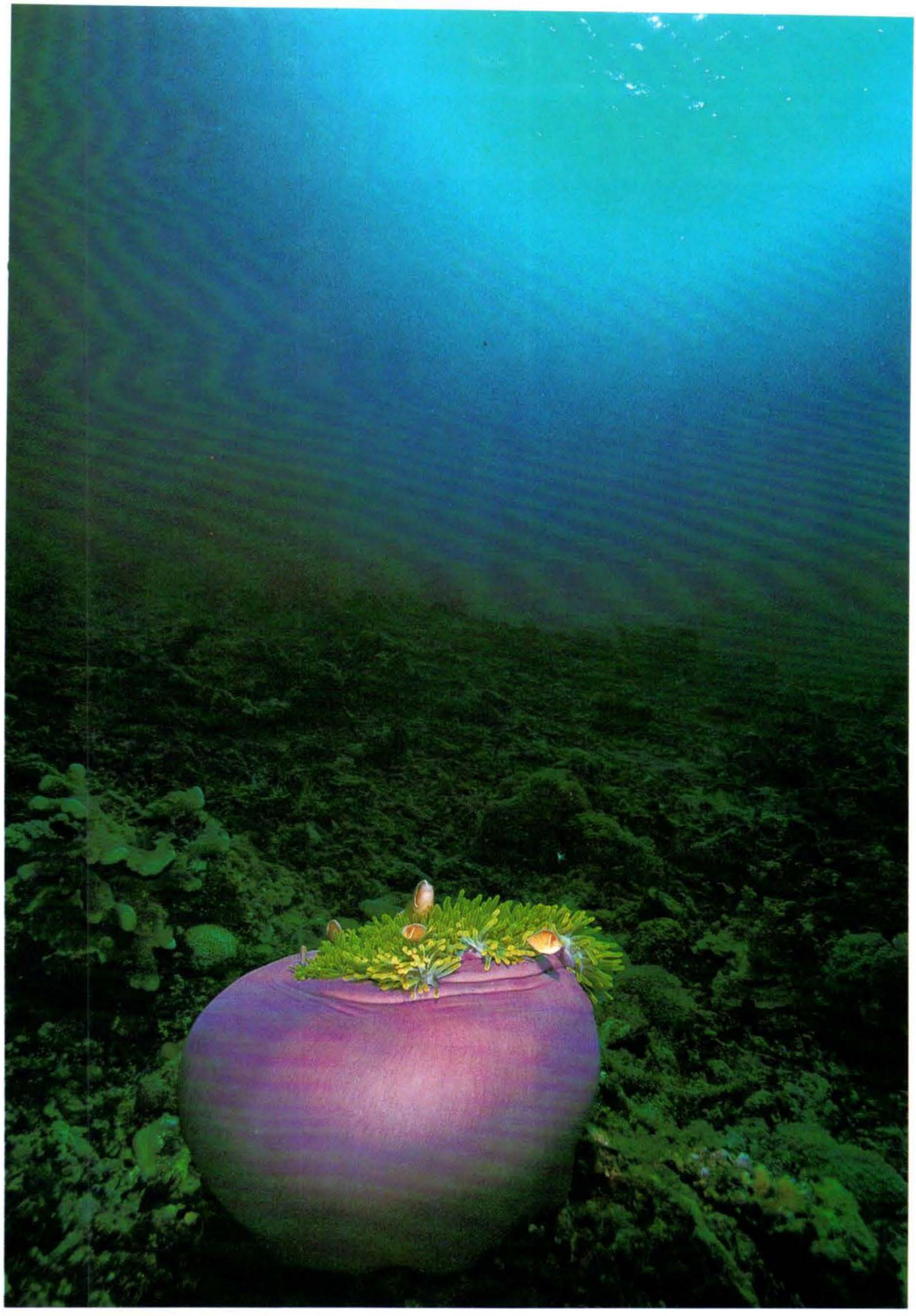
Commensal snapping shrimp (*Paraportia nudirostris*) on a featherstar (*Himerometra robustipinna*).



CORAL REEFS

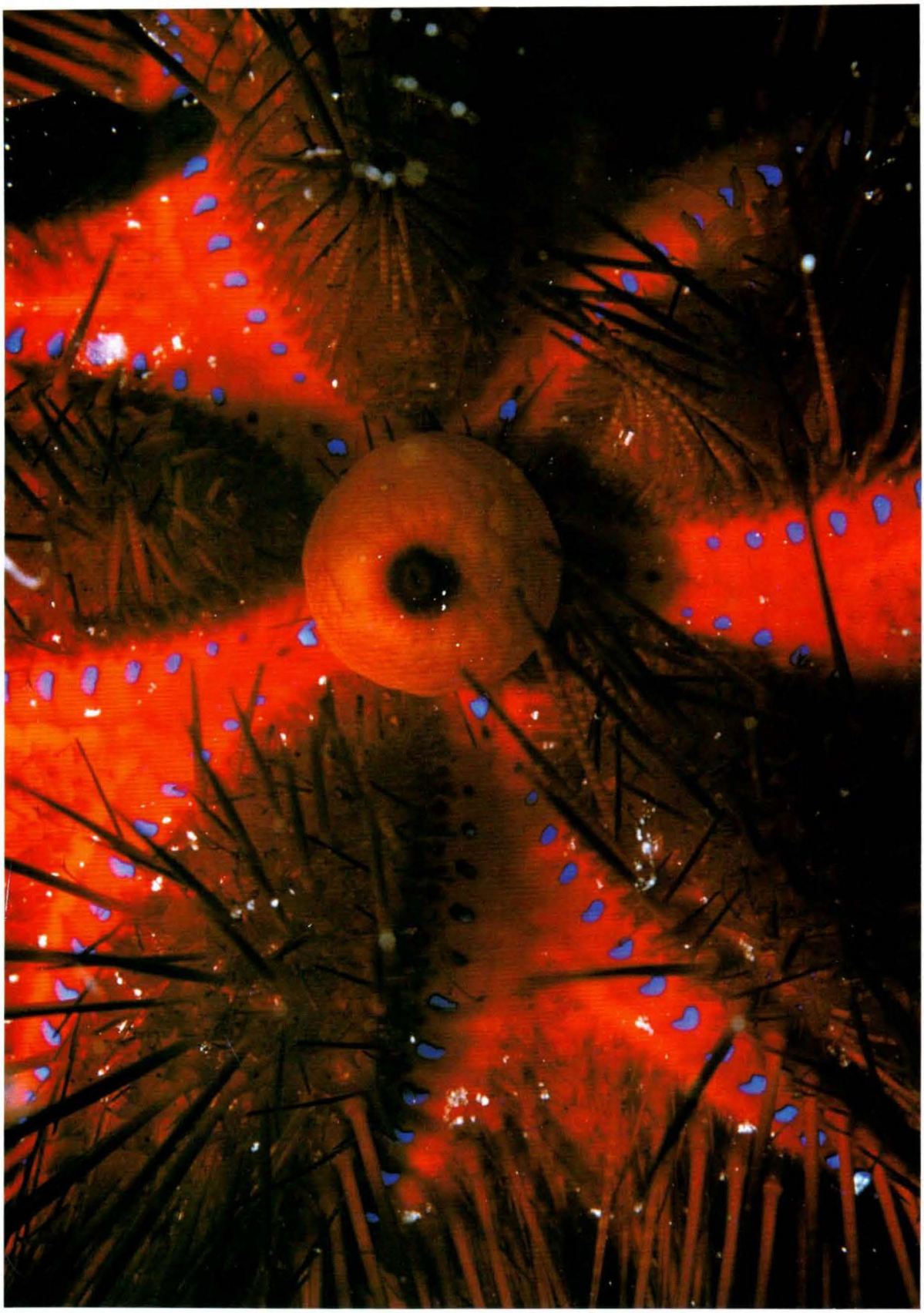
The birth of a coral; a close-up of a *Goniastrea* sp. spawning.

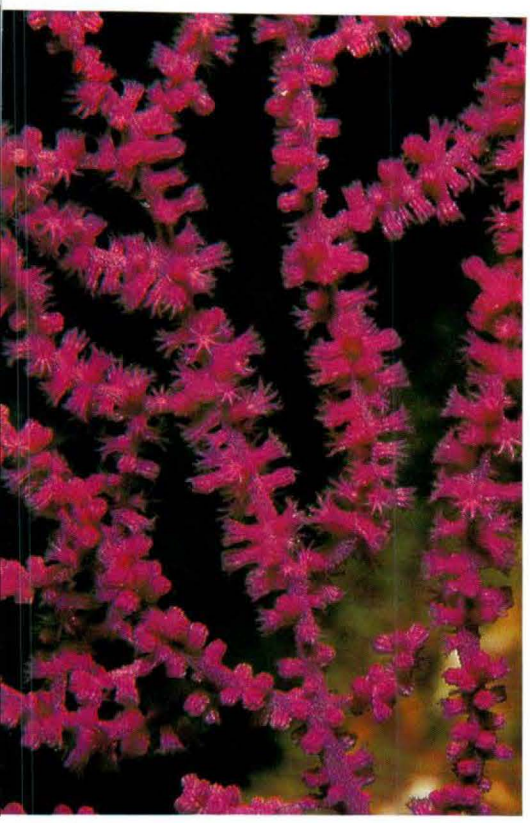




Pink Anemone Fish (*Amphiprion perideraion*) and a *Heteractis magnifica* anemone: a commensal classic.

A living pincushion: needle-like spines protect the Radiant Star Urchin, (*Astropyga radiata*).





Close-up of lavender gorgonian polyps (*Acalycigorgia* sp.).

CORAL REEFS

The Spotted Box Fish, (*Ostracion meleagris*), a colourful poison container.

"As predators got better at digging out prey, prey got better at digging in deeper."

THE RACE OF LIFE

BY RALPH MOLNAR

VERTEBRATE FOSSILS, QUEENSLAND MUSEUM

I DIDN'T BUY THE BOOK IMMEDIATELY: I looked at it and wondered if I really wanted to spend $47.50. I moved off, looked at other books, balancing those I wanted against how much money I had. But I was drawn by the evocative, even presumptuous, theme of the book and finally gave in. On the flight across the Pacific to Brisbane I found I had that almost mythical object: a book I couldn't put down.

The subject of the book was several thousand metres below, on the floor of the Pacific. The book deals with many things: gastropods' shells and those taken over by hermit crabs, the eyes of scallops, the sensitive tentacles of lima clams, and the stinging cells (nematocysts) of sea anemones and box jellyfish. All are concerned with attack or defence, attack occurring during the catching of prey and defence while trying to avoid becoming prey. *Evolution and escalation*, by Geerat Vermeij of the University of California at Davis, is about the implications of predatory behaviour in marine animals. The ramifications of predation shape much of the form and behaviour of marine organisms.

Predators are the agents of natural selection and, in consequence, the faster, better-armoured, less appetising, or craftier prey animals will escape being eaten; these individuals are selected. Vermeij relates predation to the other major agents of selection. Competition, although probably the most prevalent agent of selection, is also one of the less severe. Rarely does it result in death, more often 'just' reducing an organism's fitness. Predation and the weather more often kill. However, the weather is chancy; the predator is not.

The continued interaction of a predator and its prey during their evolution can become an arms race. In an arms race, selection by the predator may enhance the prey's ability to escape or defend itself. This, in turn, selects the individual predators that are more effective at catching prey. Each improvement in the predator's ability to catch prey increases the selection pressure on prey to develop adaptations for escape, and *vice versa*—a deadly dance of adaptation and counter-adaptation.

The relationship between cuckoos and their hosts can be likened to an evolutionary arms race. The better the hosts get at recognising cuckoos' eggs, the better the cuckoos get at mimicking hosts' eggs. Shown here from left to right are clutches of the Grey Fantail (*Rhipidura fuliginosa*), Restless Flycatcher (*Mylagra inquieta*), Leaden Flycatcher (*M. rubecula*), Scarlet Robin (*Petroica multicolor*), Brown-backed Honeyeater (*Ramsayornis modesta*) and Bar-breasted honeyeater (*R. fasciata*), all containing an egg from the Brush Cuckoo (*Cuculus variolosus*).

CARL BENTO/AUSTRALIAN MUSEUM

Parasites are a kind of predator, and recent work on the European Cuckoo (*Cuculus canorus*), by Nicholas Davies and Michael Brooke from Cambridge, has sketched the outlines of an arms race between these birds and their prey. This work has shown the reciprocal nature of an arms race. Initially cuckoos laid eggs in the hosts' nest, then the hosts developed the ability to recognise cuckoos' eggs and reject them. This ability selected those cuckoos' eggs that better mimicked the hosts' eggs, while the hosts refined their discrimination of (and against) cuckoo eggs.

It has been argued that such relationships between predator and prey are not arms races because, if the predator fails to catch the prey, it usually can hunt again but, if the prey fails to escape, it dies. The selection on the prey is greater than that on the predator. So it was thought that, although the prey might adapt to the predator, there would be little pressure for the hunter to respond to the prey. However, this is not always true, as was recently shown in a study of the Common Garter Snake (*Thamnophis sirtalis*) and the poisonous Rough-skinned Newt (*Taricha granulosa*). Edwin D. Brodie, Jr (University of Chicago) and Edwin D. Brodie, III (University of Texas) found that on the Canadian mainland, garter snakes are resistant to the poison and eat the newts, but on Vancouver Island, the newts have become much less toxic—for reasons yet unknown—and the snakes that eat them have lost much of their resistance to the poison. So it is clear that predators can and do respond to the evolutionary changes in their prey.

However, arms races are not inevitable. Although Vermeij persuasively argues they are common, arms races require certain conditions that are not always met. For an example, John Thompson from Washington State University points to the unicellular *Trypanosoma*, a parasite in the blood of African cattle. If the cattle's immune systems recognise its surface protein, they can attack it. But *Trypanosoma* has well over 1,000 different possible surface proteins, seemingly well beyond the range of any individual beast's response. So, instead of an arms race with successive generations of cattle developing antibodies against successive generations of *Trypanosoma*, each individual cow develops a different range of antibodies that protects it against some of the parasites—a kind of shotgun approach.

Escalation is the cumulative result of arms races. Hence modern organisms are no better adapted to their fellow organisms, relatively speaking, than their ancestors were in ancient times, because in turn these fellow organisms have become more dangerous than their own ancestors. Although the prey has improved its ability to withstand predators, this improvement has been offset by the predators' improvement at catching prey. Both sides have become better at the struggle,

but they have not made their own lives any less risky.

The first obvious stage of escalation in the fossil record appears to have been at the beginning of the Cambrian (560 million years ago), when the shell-less multicellular animals of the Precambrian disappeared and organisms with shells appeared. Presumably shells developed to protect their 'owners' and, if true, we might reasonably expect the evolution of other protective structures or behaviours at the same time. Behaviours such as hiding in burrows. The diversity of burrows increased significantly near the beginning of the Cambrian and their depth increased progressively until the Devonian (about 400 million years ago). The evidence is consistent with the hypothesis of escalation: as predators got better at digging out prey, prey got better at digging in deeper.

Vermeij explores the general consequences of escalation, noting that some geographical locations have less intense predation than others. Such locations he calls 'safe places'. In fact, geography itself has nothing to do with this, and safe places seem to be related to the climate being too severe for many predators. Polar regions are safe places in the sea, and probably on the land too. In safe places relict animals survive; these are animals whose close relatives have elsewhere become extinct. A complement of animals, including primitive amphibians (temnospondyls) and some kinds of dinosaurs, inhabited Mesozoic Australia long after they became extinct elsewhere. Perhaps 100 million years ago Australia, then near the south pole, was a safe place.

Predation has greatly influenced the living world. But arms races have a deeper importance because they exemplify cases of selection where the agents are organisms. This is different from the blind selection of the weather or falling asteroids. Cuckoos' eggs mimic those of their hosts so well because, ironically, they were chosen by their hosts to do so. ■

Suggested Reading

Brodie, E.D., III & Brodie, E.D., Jr, 1991. Evolutionary response of predators to dangerous prey: reduction of toxicity of newts and resistance of garter snakes in island populations. *Evolution* 45: 221–224.

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Dr Ralph Molnar is Curator of Palaeontology at the Queensland Museum. His research has been directed towards filling the vast gap in knowledge of Australian vertebrate history between the Devonian and Miocene.

QUESTIONS & ANSWERS

COMPILED BY JENNIFER SAUNDERS

EDITORIAL ASSISTANT

Natural *vs* Artificial Pesticides

Q. I recently saw a program of "Beyond 2000" where it was revealed that the plants we consume often contain significant amounts of naturally produced pesticides. The program went on to infer that our ingestion of artificial pesticides is of little concern as they do not significantly change the amount that exists naturally in the plants. It seems to me that this would only be a valid conclusion if the artificial pesticides have essentially the same toxicity as the naturally produced pesticides. Are you aware of any comparative study into this issue?

—Dennis L. Murray
Queanbeyan, NSW

A. Plants produce toxins to protect themselves against fungi, and insect and animal predation. Every species of plant seems to contain its own set of toxins; for example, 49 natural pesticides are ingested when a cabbage is eaten and 23 completely different ones are consumed when lima beans are consumed.

Although several scientists have studied the toxicity of artificial pesticides, Professor Bruce Ames from the University of California, Berkeley is one of the first to compare the toxicology of natural and artificial pesticides. He concludes that 99.99 per cent (by weight) of the pesticides consumed in the American diet are naturally produced chemicals (the range of naturally occurring pesticides far exceeds that of synthetic ones), and that both natural and synthetic chemicals are equally likely to give positive results in animal tests for carcinogens (cancer causing agents), clastogens (agents that break down the genetic material of the cell), teratogens (agents that cause birth defects) and mutagens (agents that induce mutation). Professor Ames also believes that, because humans are exposed to such low doses of synthetic pesticide residues, the comparative hazards of these pesticides are insignificant. In fact, many modern pesticides are developed from natural plant toxins that are less toxic to humans.

In response to natural pesticides, animals have a broad array of defences that combat the changing toxic chemicals in plants. The surface cells lining the mouth, oesophagus and stomach are replaced frequently and Professor Ames argues that these defences are effective against both natural and synthetic toxins at the levels consumed by humans.

Professor Ames' work indicates that there may be a disproportionate concern in the community about synthetic pesticide residues. In America, breeders are developing plants that have greater amounts of natural pesticides and are thus 'naturally' insect-resistant in order to reduce the use of synthetic ones. But there have been problems; a new type of potato developed at vast cost had to be withdrawn from the market because the higher levels of two natural toxins,

Do artificial pesticide residues on crops pose a threat to human health?

S. STRICKLAND/APL

solamine and chaconine, were found to cause birth defects in humans.

There is a tendency to think of hazardous chemicals as being only synthetic, but every natural chemical can also become toxic if the dose is high enough. The first rule of toxicology is to remember all chemicals are 'toxic'; it is just the dose that can make it poisonous.

—Michelle Neal

Appetising Mussels

Q. In the river near my place I find many mussels (pippies). I have been told by some people that they are poisonous, yet my family and I collected and ate much larger mussels in a river not far from Dubbo. I wanted to know if the smaller mussels (approximately seven centimetres long) around my place are edible. This question came from reading the 'quip' about mussels in ANH vol. 23, no. 7, 1990–91.

—David Battishall
Hannam Vale, NSW

A. There are only 17 species of freshwater mussels in Australia but they form a dominant percentage of artefacts in many Aboriginal middens dotted over the continent. This indicates their food value, a fact appreciated by many 'new' Australians since 1788. A dish of freshwater mussels simmered in their own water in the shell over a corrugated iron hotplate is a gastronomic memory I'll never forget. They are certainly not poisonous in nature. However, like oysters and other filter-feeding molluscs, they can take up and store toxic particles (heavy metals, bacteria etc.) in the water. For this reason it is perhaps worthwhile checking what is upstream before you hoe into your next meal of mussels.

By the way, be wary of the common name 'pippie' (more correctly pipi). Common names are terribly inefficient ways of getting messages across because they can be so ambiguous. *Donax deltoides* is known in New South Wales as a pipi, in Queensland as the ugari, and in South Australia as the goolwa cockle. If our six-year-old kids can remember *Tyrannosaurus rex*, why can't we remember *Donus deltoides*, which in New South Wales, Costa Rica, Tashkent or Tierra del Fuego can *only* mean the common marine bivalve inhabiting the surf beaches of eastern and south-eastern Australia.

CARL BENTO / AUSTRALIAN MUSEUM

To avoid confusion, this common NSW marine bivalve is better known as *Donax deltoides* than a pipi.

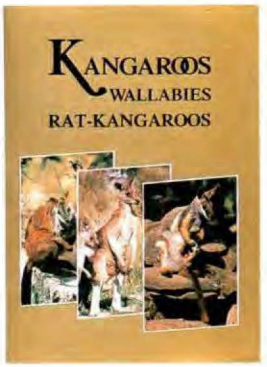
—Phil Colman
Australian Museum

Questions for this column may be sent to Jennifer Saunders, Australian Natural History, P.O. Box A285, Sydney South NSW 2000.

REVIEWS

COMPILED BY JENNIFER SAUNDERS

EDITORIAL COORDINATOR



Kangaroos, Wallabies Rat-kangaroos
Ed. by G. Grigg, P. Jarman and I. Hume. Surrey Beatty & Sons, NSW, 1990, 835pp. $148.00.

This two-volume epic is easily the most authoritative and comprehensive review of the biology of kangaroos and their numerous small relatives. It is the result of the Australian Mammal Society's Bicentennial Symposium and consists of 59 research papers, 43 of which are major reviews. Together these papers represent a broad coverage of the ecology and conservation of this significant group.

Although kangaroos are among the most conspicuous of our mammal fauna, it is not well known that there are some 50 different species (and about a dozen more in New Guinea). These encompass a great range of sizes and appearances, and are found in habitats as diverse as grasslands of the arid zone and rainforests. In addition to the large kangaroos familiar to most people, there are a variety of wallabies, and the small and secretive rat-kangaroos, potoroos and bettongs. It is a terrible shame that more people are not aware of this diversity and of the striking beauty of many of the species, some of which are illustrated by a number of colour plates scattered throughout the text.

A major aim of the editors, as stated in the introduction, is to provide a broad coverage of the biology and conservation of all species of macropods, not just the commercially important or conspicuous species; hence the title *Kangaroos, wallabies and rat-kangaroos*. This has clearly been achieved.

Individual articles are grouped under seven topics. In volume one, these are evolution, zoogeography and community ecology; diet, feeding and digestion; energy, water and temperature; reproduction; and development, growth and sexual dimorphism; and in volume two, social organisation and behavioural ecology; and population ecology and management. While some articles are necessarily somewhat technical or specialised, there are many that contain a great deal of valuable information that is readily accessible to a wide audience. Some graziers, for example, might be interested in Glenn Edwards' review of the interaction between kangaroos and sheep.

Of all the fields of research covered, the most crucial is the conservation status and future of the various macropod species. So, what is the status of macropods after 200 years of European settlement? Evidence suggests that the smaller species, particularly those from arid habitats, have not fared well. There is general agreement that the current research emphasis should be refocused from the more common and conspicuous species to these smaller, little known animals as they have suffered most. (They also comprise about two-thirds of the 44 extant Australian macropod species.) Some authors predict that unless positive steps are taken, the status of many more species will continue to decline. In the southern regions of Australia, for example, about half of the macropod species has already declined or become extinct and, while the north and north-east of Australia has had relatively few species decline, this situation could rapidly change. The Northern Territory Government, for example, has recently commenced an extraordinary scheme to log one million hectares of lancewood forest in its northern end, without even an Environmental Impact Study! This is not good news for the small Spectacled Hare-wallaby as this region represents one of its few remaining strongholds.

The 835 pages of text is saturated with information, numerous diagrams, tables, black-and-white and colour photographs. Students and professionals will find these volumes good value at $148.00, while many others will find it a useful reference on a wide range of interesting issues.

—Harry Parnaby
Australian Museum

Australian Rainforests in New South Wales Volumes 1 & 2
By Alex Floyd. Surrey Beatty & Sons, Sydney, 1990. Volume 1, 135pp. $48.00. Volume 2, 179pp. (plus micofiche) $65.00.

Alex Floyd is one of the finest field botanists in New South Wales. Trained as a forester, he worked briefly in Papua New Guinea attached to the Botany Division of the Forests Department, before coming to New South Wales where he had a distinguished career in silvicultural research on the north coast. One of his tasks here was to prepare field descriptions and keys for the State's rainforest trees. In 1976 he was seconded to the National Parks and Wildlife Service (NPWS) to undertake a survey of the remaining rainforest stands in New South Wales—a topic of interest to both the NPWS and the Forestry Commission. Later, he transferred to the NPWS, where he remained until his retirement several years ago.

These excellent books detail the results of his survey, and provide the most comprehensive account ever to have been produced of these extraordinarily interesting communities.

Floyd recognises four major rainforest subformations in New South Wales: subtropical, dry, warm-temperate and cool-temperate. These in turn are divided into 13 alliances and 57 suballiances; and in Volume 2, the suballiances are described in some detail, with discussions of their occurrence and variation in specific sites. Species lists for typical localities are also included on microfiche. In a way, it is this volume that represents the real outcome of Floyd's survey.

To most readers, however, Volume 1 will prove the more interesting. In this volume, which can be purchased separately, the reader is provided with a comprehensive overview of rainforest in New South Wales. After the inevitable, and fortunately realistic, definitions of rainforest and its four local subforms, the structural features of the local rainforests are discussed in some detail. This is followed by an outline of the author's suballiance classification and its basis; a rather brief review of the main environmental factors influencing the occurrence of rainforest in New South Wales; and a description of this occurrence, related where relevant to the occurrence of similar rainforest subforms both within Australia and overseas.

The next two chapters are perhaps the most interesting in the whole work. The first looks at the origins of rainforest in New South Wales

from its Gondwanan beginnings, through Australia's northern drift and climatic changes, to the present. Floyd states that "the four rainforest subformations have been selected by the various major events in the geological history", and he provides convincing arguments, based primarily around species and family occurrences, to support his case.

The following chapter is entitled "Natural Regeneration Principles and Methods" and it comprises about a third of the text in Volume 1. The particular strength of this chapter lies in the detailed accounts of the mechanisms adopted by various local rainforest plants for their regeneration. This includes seed production, dispersal, dormancy, germination and coppicing, and it is here that Floyd's encyclopaedic knowledge of the New South Wales rainforest flora is especially evident. For anyone involved in rainforest management, this should be compulsory reading.

The book then goes on to look at different patterns of rainforest regeneration, artificial restoration, and the conservation of rainforest communities and species in New South Wales.

Both volumes contain the same seven appendices, and both are liberally illustrated by excellent colour photos of features discussed in the text.

Unfortunately, the work is not faultless. It would have benefited from tighter editing to eliminate ambiguously worded statements and to ensure that subheadings agree with the succeeding text. To this reviewer the brief treatment of logging was rather facile, while the discussion of regeneration patterns was simplistic. However, these are minor quibbles about what is undoubtedly an outstanding production on Australian rainforest in the mid-latitudes—perhaps a better title than the tautological one it bears!

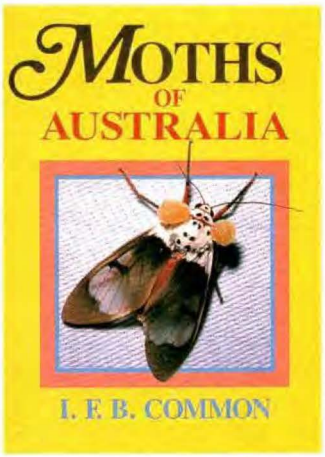
—George N. Baur

Moths of Australia
By I.F.B. Common. Melbourne University Press, Melbourne, 1990, 535pp. $125.00.

This book is a milestone in the study of Australian moths. It is certainly the most comprehensive ever published in this field and there is no doubt that it will remain the authoritative text for many years to come.

The first six chapters give comprehensive overviews of structure and life history, biology, population control, economic significance, evolution and geographical distribution, and family classification. I found these chapters particularly valuable, especially the superb illustrations concerning structure.

The major part of the book (over 350 pages) provides detailed accounts of the moth families, with family characteristics summarised in some detail—a valuable feature for the serious lepidopterist. For naturalists, and lovers of moths in general, the accounts of family biology are particularly interesting. Many of the



common and more interesting species are mentioned by name, their foodplants listed, and their distributions given. Most significant, in this regard, is the amount of new information that has been included.

Perhaps the most important section of the book for those wishing to identify moths are the colour plates. There are 32 colour and 40 black-and-white plates that illustrate over 1,000 species and a number of their larvae. While this number covers only a fraction of our total moth fauna, it far exceeds any other book on Australian moths ever published. The quality of the plates is very good and I found no difficulty in identifying specimens, even when using the black-and-white plates. In addition, there are some 900 superb line drawings illustrating pupae, wing venation, and genital structures associated with each family.

Another of the book's main

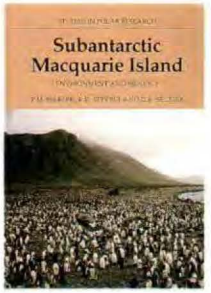
features is its modern classification and updated nomenclature. Many of the problems of the past have been resolved and a reader familiar with moth Latin names will soon discover a number of unfamiliar combinations. Amongst these necessary changes, I was rather saddened to see the replacement of *Antheraea eucalypti* (the Emperor Gum Moth) by *Opodiphtera eucalypti*, but then I guess I will eventually become used to it.

Throughout the book there is constant mention of primary literature sources. These direct the reader to major taxonomic revisions and biological studies enabling those who wish to do so to investigate particular subjects in more detail.

The book concludes with a chapter on the collection and study of moths, and a useful food plant and larval host list. The former would have been considerably enriched had it been illustrated.

Moths of Australia must rank among the most significant books ever written on moths anywhere in the world, and its excellence was recently recognised when it was awarded the 1991 Whitley Medal by the Royal Zoological Society of New South Wales. We are so fortunate that it is based on Australian moths. For the student of moths and the serious naturalist I cannot recommend it strongly enough, but it is a pity it is so expensive.

—M.S. Moulds
Australian Museum



Subantarctic Macquarie Island: Environment and Biology
By P.M. Selkirk, R.D. Seppelt and D.R. Selkirk. Cambridge University Press, Cambridge, 1990, 285pp. $75.00.

Macquarie Island, one of two Australian subantarctic island groups, is a wild and beautiful place, with weather that has to be experienced to be believed. Steeped in history, and once savagely exploited by humans, it provides an ideal laboratory for studying the special characteristics of an isolated southern island ecosystem.

For many years now, Macquarie Island has been continuously manned by scientists and support staff, and a plethora of papers has been published on its geology and natural history. Consequently, there has been a real need to have this information brought together, not only for scientists, but for all those who are interested in the antarctic region, and island habitats and environments. *Subantarctic Macquarie Island* fills this gap most suitably, and represents another contribution to the well-known and respected *Studies in polar research*, published by Cambridge University Press. This series reflects the growth of research activities in and about the polar regions, and provides an outlet for synthesising the results.

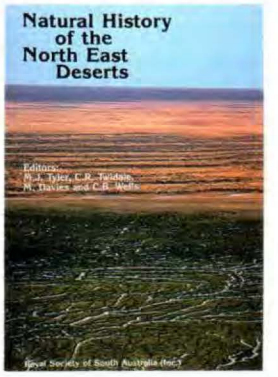
There are 12 chapters in *Subantarctic Macquarie Island*, ranging from discovery and human occupation, physiography and climate, origin and geology, vegetation, birds, mammals, microbiology, and freshwater and nearshore marine environments. The last chapter, "Human Effects: From Mismanagement to Management Strategies", is a most useful and timely addition. Macquarie Island has seen a recent upsurge in tourist activities and this chapter should be read by those responsible for leading tourist expeditions, not only to Macquarie Island, but to any antarctic or subantarctic region. Also included are about 60 black-and-white photographs to give the reader a feel for the island, and the figures and tables are of a high quality and add to the value of this work.

Following the chapters are 20 pages of references that will provide a very adequate entry into most areas of the geology and natural history of this island group. There are 12 appendices that list organisms, including vegetation, terrestrial vertebrates, marine invertebrates, fishes, birds, marine mammals and introduced mammals. There are also two indices of genus and species names mentioned in the text and a comprehensive subject index.

There is, however, a bias toward the botanical and geological aspects of Macquarie Island that reflects the interests of the authors. The vertebrates are treated reasonably well, although the statement on page 157 in reference to Killer Whales is misleading – Killer Whales belong to the dolphin family. The terrestrial and marine invertebrates are treated in a cursory manner but this is largely due to the lack of knowledge of these groups on Macquarie Island.

Nevertheless, I heartily recommend this book for biologists, geologists, conservationists, teachers and anyone who is interested in island habitats and environments. Although the main thrust of this book is Macquarie Island, there is a lot of useful information about other subantarctic islands as well. A copy of *Subantarctic Macquarie Island* combined with Cumpston's 1968 historical treatise *Macquarie Island* will give anyone a very good overview of this most fascinating island group.

—D.S. Horning
Macleay Museum



Natural History of the North East Deserts
Edited by M.J. Tyler, C.R. Twidale, M. Davies and C.B. Wells. Royal Society of South Australia, South Australia, 1990, 226pp. $28.00.

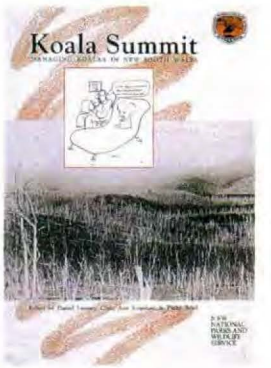
This is one of a series of books put out by the Royal Society of South Australia that deals with the natural history of various regions of the State. Unfortunately, it is not immediately clear how the 'north east' of the State has been delimited. Perhaps this is common knowledge among those to whom the book is targeted, but it left me feeling initially confused.

There are 20 chapters, covering everything from geology and various topographic features such as mound springs, through to fauna and zoogeography. I found the section on geology to be highly informative. The chapter dealing with mammals, although giving a good overview, contains little detailed information, and is thus somewhat disatisfying. Those on soils, the Coongie Lakes and Aboriginal people are all informative and well written.

One thing that the volume does lack is a chapter giving a summary of the region. It would be nice to have such an overview, which could perhaps contrast the area with other parts of the Australian arid zone.

Overall, however, the volume will be highly useful to anyone visiting north-east South Australia. Indeed, I'm sure that travelling the region with this volume in hand would be a truly wonderful experience. It is, of course, essential reading for anyone researching the natural history of the area.

—Tim Flannery
Australian Museum



Koala Summit: Managing Koalas in NSW
Ed. by D. Lunney, C.A. Urquhart and P. Reed. National Parks and Wildlife Service, NSW, 1990, 256pp. $19.95.

The future of the Koala in New South Wales has again been at the fore of public domain, with the widespread response generally being sympathetic. But what is the status of the Koala, and how is it threatened?

A conference, convened in November 1988, brought together researchers, town planners, politicians, officers of both State and local governments, scientists, and conservationists to discuss the plight of the Koala in New South Wales. They were told that, based on the results of a

State-wide survey during 1986–87, the Koala is a rare and vulnerable species.

It is a common misconception that reduced Koala numbers are the sole result of the spread of *Chlamydia psittaci*. This disease, however, is merely a symptom of the stress under which Koalas are currently placed. This stress arises primarily from the loss of habitat, although pressures from cars, dogs, eucalypt dieback, forestry, urbanisation and bushfires also play a part.

With recognition of habitat loss as the main threat to the Koala population, the next step is to investigate what is being done to protect the remaining habitat, most of which lies outside the National Park estate.

This was the central question posed to participants of the Koala Summit, along with a request to formulate a set of guidelines for the National Parks and Wildlife Service and the Minister for the Environment to use when allocating funds and resources for Koala conservation.

Koala Summit: Managing Koalas in NSW reflects the diversity of topics covered at the two-day conference, including research, local studies, captive management, the role of government, viewpoints, and a report of the discussion from the workshops and plenary session.

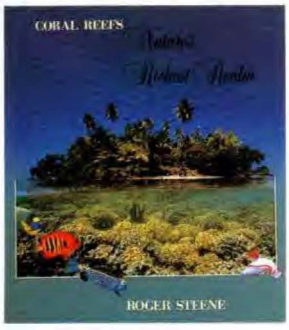
The papers presented in the research, local studies and captive management sections represent a summary of the knowledge relating to the management of Koalas both in the wild and captivity. How to implement that knowledge to ensure the long-term survival of the Koala requires the reconciliation of a basic dilemma—who is ultimately responsible for the protection of the remaining habitat?

Currently the Australian National Parks and Wildlife Service places responsibility at the feet of various State governments. However, as reported in *Koala Summit*, perhaps the responsibility should be that of local governments through regional and local environmental plans. (This was disputed by conservationists who pointed to instances in which the New South Wales Government overrode local government planning decisions.) The workshop on the State governments' role proposed a number of recommendations that involve both the local and State governments. Therefore, there is an obvious need for increased cooperation between State and local governments to manage and conserve areas of prime habitat, and for a review to simplify, clarify and disseminate the applicable legislation. Both of these recommendations need to be adopted and acted upon immediately.

As this publication is aimed at various levels of government, I feel that the final recommendations should have been highlighted. Instead, they are simply contained within the body of the workshop discussion, and the reader can easily miss them (I had to read and re-read the relevant section a number of times before I found all of the recommendations).

With the inclusion of the occasional cartoon to offer a light touch to an emotional topic, *Koala Summit* provides a wealth of information on Koalas. It should appeal to members of the general public who are interested in Koalas, while providing a valuable resource base (including a management-orientated bibliography) to those students and researchers who require more detailed information on the Koala in New South Wales today.

—Elizabeth Telford
Illawarra Environmental Centre



Coral Reefs:
Nature's Richest Realm
By Roger Steene. Crawford House Press, Bathurst, 1990. 335pp, $70.00.

With the increasing popularity of scuba diving and underwater photography, many have tried to capture the magic and beauty of the underwater world—in particular, the more colourful and diverse reef environment. *Coral reefs: nature's richest realm* is a sample of the culmination of over 20 years of one man's passion for coral reef photography.

Roger Steene has selected photographs encompassing reefs of the tropical Atlantic and Indo-pacific. No less than 300 superb colour plates illustrate the uniqueness and variety of nature, including pictures of marine animals never before published and some new to science.

The introduction by Walter A. Starck II gives a brief but lucid overview of coral reefs from their history and evolution through their geology, geography and biology. He then moves on to "the reef experience, which is what this book is all about" and, with a vivid narrative, takes you on a journey from the tropical glare into the turquoise blue water for a dive over a patch reef. Then, with the aid of a diver propulsion vehicle, he travels across the lagoon to the reef crest and finally to the outer edge where you drop off into the seemingly bottomless precipice of the open ocean. All this complements the magnificent pictures that follow, as you step into the world of the creatures that live in and around the coral reef.

The book is divided into a number of chapters, including "Reef Gardens", "Sand Community" and "Colours and Adaptations" to name a few. Each chapter has a short introduction, which in some cases seems to promise more than the pictures illustrate. The captions are simple and unobtrusive, mostly with common names but sometimes lacking detail. The more informative captions are found in the "Commentary" at the back of the book. This section supplies scientific names, details of locations and extra interesting snippets of information. Some may find having to flip backwards and forwards to read about the pictures frustrating, while others may find enough satisfaction in the beauty and art of the photos alone. However, as you turn the pages it becomes obvious that Roger Steene has developed a great understanding and intimacy with the coral reef environment.

—Sally Reader
Australian Museum

"The recent CSIRO experience with the gene-shears innovation was depressingly predictable and predictably depressing."

MORALS VERSUS MONEY

BY IAN LOWE

DIVISION OF SCIENCE AND TECHNOLOGY,
GRIFFITH UNIVERSITY, QUEENSLAND

THE TRADITIONAL PRINCIPLES ON which the scientific process is built include the open sharing of new knowledge. Scientists are expected to submit their work to peer review and publish the conclusions in the open literature. There is concern when these normal processes are not followed as, for example, when the chemists Pons and Fleischman announced their 'cold fusion' results at a press conference before submitting the work for peer review. As in that case, the suspicion of the scientific community is aroused if the normal procedures are neglected.

Commercial organisations that conduct research do so in the hope of developing products or services that will produce profitable sales. As a result, scientists who work for private companies are usually expected to direct their work toward the commercial objectives of their employers as a higher priority than publishing in learned journals. On the other hand, the traditional priority of university staff is the advancement of knowledge as an end in itself. Funding of research in universities has been seen as part of their normal operating budget, allowing academics to keep at the forefront of knowledge. Since Australian universities had their functions and resources brought up to world standards in the 1960s, it has been the normal expectation that each academic would pursue research. This principle has been eroded by the policies of the Commonwealth Government in recent years; before that the public purse funded this research, albeit at parsimonious levels by comparison with research in government laboratories and the private sector.

In recent times the Canberra theocracy has systematically cut the funding of research in the university system, urging the universities to concentrate their resources. The decline in funding has had the effect, as one of my colleagues put it, of "starving us out of the ivory tower". With funding from the public purse no longer adequate to maintain research momentum, many researchers have sought support from the private sector. Many fruitful partnerships have sprung up, leading to useful developments and real commercial benefits. There has been a price to pay, however. There is at best a tension and at worst a conflict between the scientist's loyalty to the firm funding the research and commitment to the scientific community as a whole. To maintain the respect of peers and gain promotion in the university system, publication in the open literature is mandatory. On the other hand, the commercial sponsor of research reasonably expects to have the opportunity to obtain commercial benefits from the work before it is in the public domain.

"...a cure for the flu may be on the horizon..."

A recent controversy has raised the wider issue of the opportunity for Australian enterprise to benefit from local research and development. A considerable effort on the influenza virus shows promising signs of progress. Some of the researchers in the field believe that a cure for the flu may be on the horizon. Should the work be published?

On the one hand, the norms of the scientific community favour open publication. If this is not done, there is no prospect of the work being of benefit to the scientific community. On the other hand, there is a school of thought that the potential economic benefit from a cure for influenza is less likely to be kept in Australia if the progress is openly revealed. As the large international corporations based in the Northern Hemisphere are much better equipped than any local firms in Australia, the argument goes, any commercial benefit is likely to be lost by frank disclosure of our scientists' discoveries.

I have little sympathy with this view, for four reasons. The detail in the scientific literature is often not sufficient to allow the work to be replicated. Some experimenters don't reveal the 'trade secrets' that allow them to collect their data; I have even known scientists to engage in the reprehensible act of phrasing their reports so as to mislead competitors!

Second, there is usually a long delay between the scientific work being carried out and the appearance of the results in the published literature. The experience is not always as bad as one I suffered recently with a co-author; an international journal took over three years to get our manuscript into print for the waiting world. Delays of over a year are far from unusual when work is published in major international journals, especially for Antipodean authors, so the work is often about two years old when it appears in print.

Third, I am not convinced that our scientists should see their first loyalty to local commerce rather than the global scientific community. When research is funded by the public purse rather than private corporations, there is no obvious reason why the possibility of local exploitation should hold up the normal process of communication to other scientists. While all scientists gain more than they lose from open communication, those in a small country such as Australia are particular beneficiaries of the free exchange of information. We produce about two per cent of the papers in the literature, and gain access to the other 98 per cent of new knowledge through the process of open publication.

That raises the final point. The track record of Australian commercial organisations in utilising the results of local research and development is far from inspiring. For decades the performance of our scientists in producing publishable work has been good by international standards, whereas the innovative performance of our industry has been abysmal. The recent CSIRO experience with the gene-shears innovation was depressingly predictable and predictably depressing. Until we have a reward structure to build up a local tradition of technological development, we will continue to be renowned internationally for such unproductive activities as company takeovers, tax avoidance, defamation actions and cosmetic surgery. There is little convincing evidence that holding back publication of research on the flu virus would spark a surge of high-technology industry in Australia. ■

Associate Professor Ian Lowe is Director of the Science Policy Research Centre at Griffith University, where he is also Deputy Dean of Science and Technology. His research interests are in the broad area of policy issues affecting science and technology.

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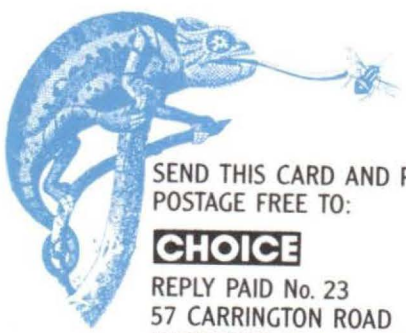

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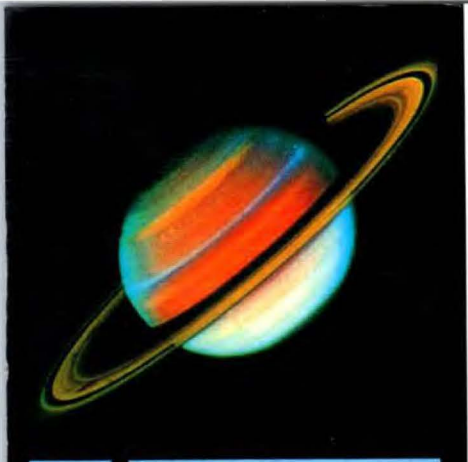

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