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ANH
Australian Natural History

AUTUMN 1991 VOLUME 23 NUMBER 8

SLIME MOULDS
A Reflection of Ourselves?

WHALING
The Cultural Gulf

VANISHING FROGS
Mysterious Global Phenomenon

EMPEROR, KING & LITTLE PIG
Search for Solomon's Rats

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MANAGING EDITOR
Fiona Doig
SCIENTIFIC EDITOR
Georgina Hickey, B.Sc.
CIRCULATION MANAGER
Cathy McGahey
ART DIRECTION
Run Run Run Design Pty Ltd
EDITORIAL ASSISTANT
Jennifer Saunders
TYPESETTING
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Front Cover

Is it animal, plant or fungus? Slime mould cells can adhere, control their shape and communicate with each other, making them a popular model for studying how more complex organisms like people are constructed. Here a *Dictyostelium discoideum* slime mould slug moves across an agar plate. Photo: Ron Oldfield.

E D I T O R I A L

THE TOURISM TRAP

BY FIONA DOIG
MANAGING EDITOR

EXOTIC HOLIDAYS ARE MOVING AWAY from the traditional beachside resorts—the appeal of catching a crocodile's eyes by torchlight is taking over from neon lights of nightclubs. Discovering animals—especially endangered species—in the wild has become fashionable. Educational tours sighting rare animals have sprung up offering everything from half-day whale watching trips to seasonal Antarctic expeditions.

In developing countries, tourism may be a wise means towards conservation, particularly of a species threatened by habitat destruction. By making an endangered species more financially viable than its habitat, its habitat (and therefore the species) might stand a chance of being maintained. Sadly, few governments have wised up to this. In Borneo, where extensive clearing of land for logging and agriculture may threaten Orang-utans, it really is a case of not seeing the forest for the trees. Clearing trees also makes Orangs easier for tourists to sight—but doing so could lead to their extinction. It's a no-win situation.

The Malaysian Government would be wise to look at Central Africa, where Gorilla-trekking tours have boomed. The major threats to highland Gorillas have been from poaching and deforestation. Both problems are being tackled with money coming from a fruitful source: the tourist. Gorilla-trekking tours in Rwanda are well set up and expensive—but, if the cost provides the means to keep the national park boundaries intact and the Gorillas safe, then it is worthwhile.

Gorilla-trekking tours in Africa have contributed towards the survival of the species.

FIONA DOIG

In many countries, natural history is for sale. Allowing sales of rare shells and coral in the South Pacific may bring about instant profits but, once again, it can also destroy the natural beauty that brings the tourist in the first place.

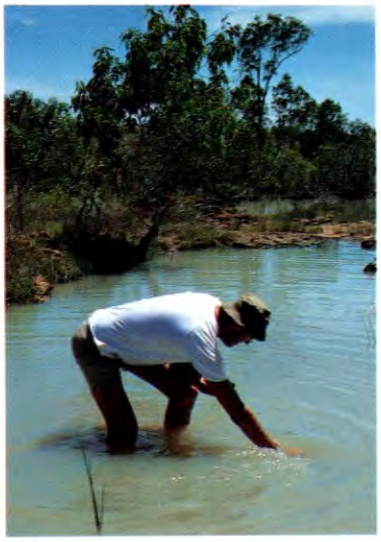
In developed nations, with their comparatively better economic climates, one would be forgiven for thinking that environmental costs can easily be offset with income. Unfortunately this is rarely true. Visitors to the Great Barrier Reef, for example, may leave behind cash, but travel by boat that discharges reef-threatening effluent and damages the reef every time it anchors. Whale-watching tours (a $100-million-a-year activity in the USA) have become so popular in Hervey Bay, Queensland, that the whales can be 'mobbed' by tourist boats. Fears have been expressed that the animals could be physically harmed by such activity or harassed enough that they leave. (There are legal limits to approaching whales that are overlooked in the excitement of spotting a Humpback.) In New South Wales, toxins from car exhaust could be significantly contributing to the decline of a rare spider species in the Jenolan Caves. Without restricting access, we can endanger a species by 'loving it to death'.

Uneducated tour operators can damage the reputation or undercut costs of those dedicated to running legitimate educational tours with genuine conservation commitments. An overseeing authority could restrict numbers, and ensure that rangers guide the tour groups and give accurate information. Fees could fund local conservation. Such is the case with the Fairy or Little Penguins (*Eudyptula minor*) on Philip Island, Victoria, which ranks third on the list of Australia's natural tourist attractions. The birds are fully protected and rangers guide tourists on the daily sightings at dusk. Entrance fees fund the educational centre, staff and research, as well as the pest eradication program.

It makes sense that, as tourists, we should have to pay to see an endangered species in its natural state. If a high cost is what it takes to provide appropriate tourism management to ensure that a rare species doesn't become any rarer, then many fascinating creatures could be around much longer. ■

IN THIS ISSUE

BY GEORGINA HICKEY
SCIENTIFIC EDITOR



M. DAVIES

THE DISCOVERY IN 1973 OF QUEENSland's Gastric Brooding Frog, and its extraordinary practice of giving birth to live young through the mouth, attracted worldwide interest. Less than ten years later, however, this species disappeared without trace. And the phenomenon is by no means restricted to this peculiar frog. It has been repeated for many different species from several different countries. Frogophile Mike Tyler from the University of Adelaide (pictured searching for his elusive quarry) discusses the possible causes and the significance of this disturbing global event.

Our cover story this issue is about cellular slime moulds—those strange plant–animal–fungus-like creatures found in soil. Macquarie University's Susannah Eliott and Keith Williams concentrate on the animal-like nature of these slime moulds and explain how they can be used to study the way more complex multicellular animals, such as ourselves, work.

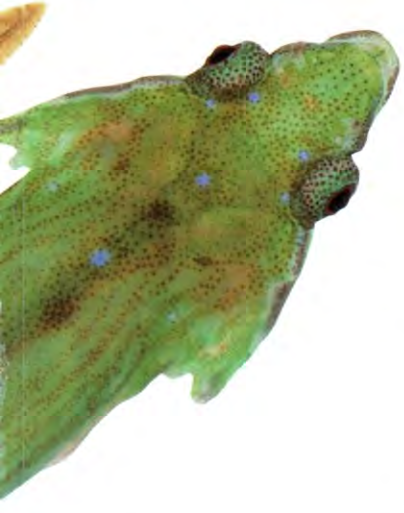
Tim Flannery is back, this time taking on the role of eccentric rat-catcher. He relates his gruelling and often frustrating experiences in the high mountains of Guadalcanal (Solomon Islands).

Other articles in this issue deal with clingfishes, particularly the cleaning variety, and 'virgin birth' in Bynoe's Gecko. We are also told about one early curator of the Australian Museum who acquired a specimen of a Giant Sperm Whale, literally by following his nose; the dilemma of the conservationist when both predator and prey are endangered species; and the need to understand the cultural basis of stubborn commercial whaling attitudes.

Our regular writers describe how to get a meal from a eucalypt, how to read the warnings in the fossil record, the two opposing theories of how species came about, and some dusty domestic delights of a celebrated nutritionist.

Articles

Regular Features



Columns

LETTERS

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

A.H. TOLHURST

The humble bumble.

Insects in Rhyme

John Brackenbury ("Insects in Flight", ANH vol. 23, no. 5, 1990) reminds us that "...it was possible to theoretically conclude that the Honeybee could not fly...". In my book *Animal Action* (unpublished)—a volume of light verse dedicated to animal conservation and welfare—I pondered upon this:

The Plight of the Bumblebee

Aerodynamical theory has stated
That Bumblebees certainly never could fly,
Some Bright aeronautical experts related
That wind tunnel testings precisely tell why.

The size and the weight and the shape of the body
Related to total wing spread so they say,
Has been so designed—rather shabby and shoddy
To stop the poor bumbler from getting away.

But quite unaware of this physical data
The Bumblebee takes off and wings in to flight,
To leave the abode of his queen amorata
Denying the scientists fear for his plight.

Each day with his nectar he'll buzz to his honey
To top up her honeycombs stores in the hive,
Though Boffins may think that it's awfully funny
I ask you how else could the poor B. survive?

—**Len Green**
Vaucluse, NSW

Beyond Comparison

Is Michael Brooker (Letters, ANH vol. 23, no. 5, 1990) serious? There is just no comparison between ANH and the implied glossy adventure magazine. As a subscriber of 11 years, ANH is leaps and bounds ahead with concise and detailed scientific articles into which my enquiring mind can sink its intellectual teeth.

—**Sandra Worrall-Hart**
Newman, WA

Caley's Birds

Subsequent research on history relating to George Caley (From the Archives, ANH vol. 23, no. 5, 1990) indicated that Gregory Matthews (*The Birds of Australia*, 1925) had made an error that I repeated in this article. Dr Latham had borrowed the paintings of Australian birds in 1800—not from the Earl of Derby as the article stated but from A.B. Lambert. On the latter's death in 1842, the Earl of Derby acquired the paintings for his private collection.

—**Joan Webb**
University of Technology, Sydney, NSW

Stinging Article!

I cannot agree with Graham Pyke's assessment of the current controversy (ANH vol. 23, no. 5, 1990) about Honeybees. Surely the situation is "...there is *prima facie* evidence that Honeybees have an effect..." and not that there is a "deleterious effect"—as the author continually states. If you are proposing to look at the evidence objectively, then by stating that "Honeybees have a deleterious effect on native plants and animals" the author has signified his intent to give a biased view of the present controversy and related research.

This question is so complex that it would be unlikely for research to conclude that Honeybees have a significant and harmful effect upon native fauna. After all, 180 years have lapsed since the introduction of Honeybees and one would expect some signs of conclusive evidence to have been recorded to date—or has this been masked by land clearing, mining, clear-felling of timber, prescribed burning, wildfires, salination, drought, cyclones, pollution or a combination of any of these?

Dramatic changes to plant and animal systems do occur naturally over time without any human-induced external influence. In Western Australia, nectar flows since 1896 have shown huge annual fluctuations, which indicate both insects and birds must be able to naturally regulate their own population densities each year.

The supposition that native animals like gliders and moths could be directly affected by Honeybees is misleading. Both animals are generally nocturnal and have adequate time to feed on the available nectar supply (when in season). Many of the *Eucalyptus* and *Banksia* species produce pre-dawn nectar. The major competitor for these animals are ants as they are known to consume considerable quantities of nectar before dawn.

The availability of hollows for nesting by many parrot and cockatoo species must be plentiful despite the small percentage that is used by feral bees. Several parrot species are declared pests over many areas of Western Australia that have high annual use by beekeepers. This suggests the local populations are limited not by nesting sites (despite logging) or feral bees but by the availability of food.

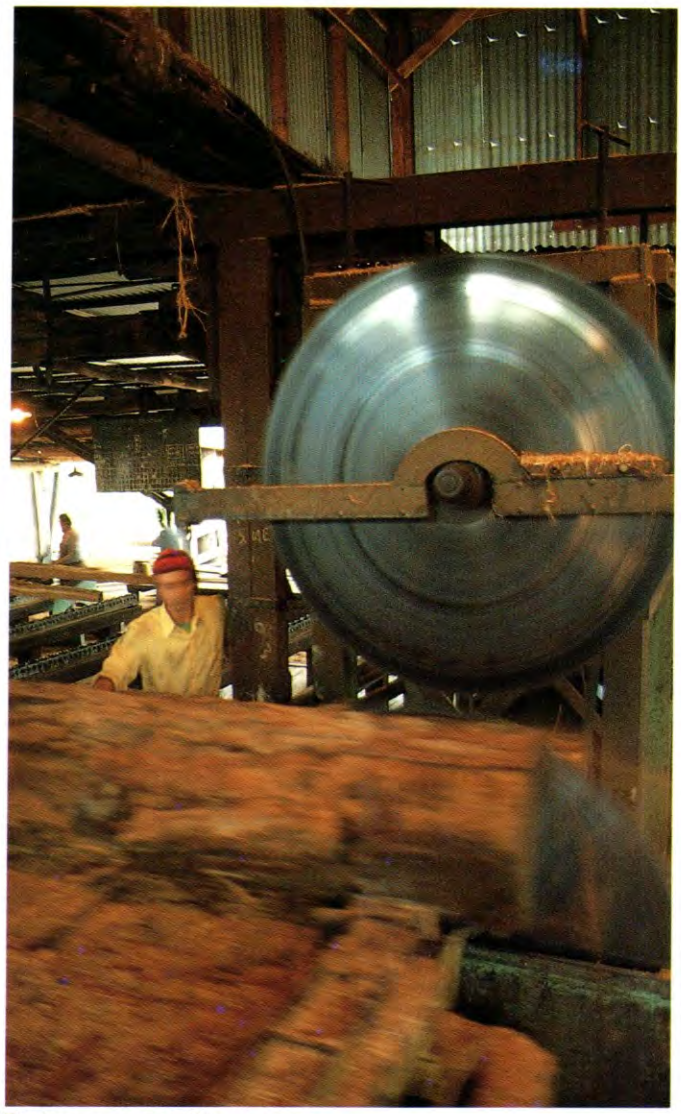
Many research papers give an alternative view to that presented by Graham Pyke. Unfortunately, because scientists become specialised, their views become polarised. Some beekeepers are like this too but, because they are unqualified or lack research facilities, are dependent on the scientist, who can influence the decision-makers in our society. Many government draft proposals rely solely on this type of biased view, which can affect peoples' livelihoods.

—**Rob Manning**
WA Dept Agriculture
Perth, WA

Take Trees

An ANH reader wrote seeking advice on how to be environmentally sound in the home (ANH vol. 23, no. 5, 1990). David Mills suggested support for sustainable organic agriculture. It does not necessarily follow that organic and sustainable are interchangeable. For example, the terraced rice paddies of Bali are certainly organic and they *appear* to be sustainable, having produced three crops a year without, apparently, a decline in productivity over thousands of years (perhaps 10,000).

But there is a big question mark over the matter of sustainability. How long can the Earth's atmosphere sustain the constant addition of methane produced by rice paddies? Paddy-grown rice is the staple food of about half the world's population. David Mills also addresses the matter of energy efficiency in the home, advising us to "include home modifications to improve passive solar usage". One assumes (this is risky!) he is referring to trapping solar energy (heat) in a concrete slab flooring system during the day via uncovered, north-facing windows so the floor acts as a huge heat bank, releasing its trapped energy at night when curtains are pulled across the windows. This is beautiful if you happen to already have a concrete slab



MALCOLM RICKETTS

Timber: a renewable resource.

floor. But if you haven't built the house yet, can I suggest you look at timber instead of concrete?

Given that timber grows on solar energy and that concrete manufacture swallows up great volumes of energy derived from fossil fuels, I calculate you'd have to 'save' as much energy each day as Midnight Oil blows out of its system in a night, every day for the remainder of time. Or thereabouts. These are very rough calculations.

In all seriousness, I am absolutely staggered at the *absence* of discussion of the energy consumption of the various alternative housing construction materials. Timber is far and away the most energy-efficient building material. Bricks, cement, steel and aluminium eat up energy like nobody's business in their manufacture.

Timber is also a renewable resource. It is biodegradable—it composts itself a lot quicker than steel oxidises. It lends itself to recycling to a degree unmatched by any of its competitors. Its use is greenhouse-positive in that it stores carbon in wood fibre.

We must acknowledge the role of the green movement in raising public *awareness* of environmental issues. But it stands condemned, in my view, for being mainly responsible for a mind set against the use of timber.

According to the World Bank, Australia is in the top ten per cent of the world's nations in terms of area of forest per capita—but in the bottom ten per cent in the rate of forest utilisation. We have nearly as much forest as the whole of Europe and more than Laos, Cambodia, Malaysia, the Philippines and the two Koreas combined. Yet we still import the product of other peoples' forests.

You want an energy-efficient, greenhouse-positive home? Build it out of timber. Australian timber. There's enough there for all...if only we had the collective intelligence to use it.

I can almost hear the cries of "what about biodiversity?" from greens who insist on believing that Australia's timber industry has done dozens of whole species in the eye. There have been at least 118 known species extinctions in Australia over the past 200 years. To the best of my knowledge, not a single one can be attributed to the timber industry.

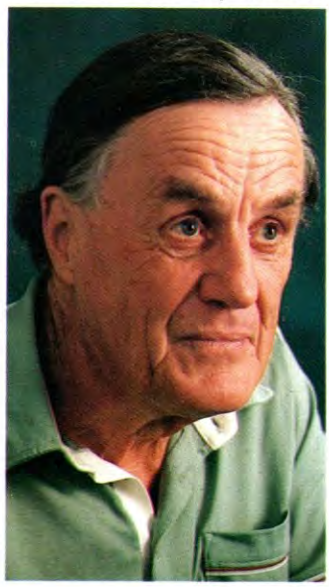
—Stephen Guest
Vic. (Assoc.) of Forest Industries

The Final Act?

"We are scientific in our gadgets but not in our ideas" is a version of a quote from Professor Hanbury Brown (Profile, ANH vol. 23, no. 5, 1990). As the millennium drains ingloriously down the plug hole, there must be quite a few of us puzzling over what went wrong. From Occam through Newton to Asimov, science seemed to be a one-way track. A few temporary set backs were, for sure, to be expected. But these were soon corrected and inevitable progress resumed, so we supposed.

It hasn't worked out like that, and Professor Hanbury Brown may well have put his finger on why. Humans are smart enough to make gadgets but they aren't smart enough to deploy them intelligently.

Professor Hanbury Brown.



There have been hints of this. In 1931, Goedel showed that in numbers we can say things we can neither prove nor disprove. About 1986, topologists Freedman and Donaldson received prizes for demonstrating (implicitly) that the human mind can't handle four dimensions. Nearly anything we're interested in has more dimensions than that, so we've got a problem. Happily, life has been going on in defiance of Boltzmann entropy for quite a while. It isn't in any way necessary that its products understand its processes.

There's little doubt that human languages and gadgets have been of some use. But whether that will continue, or whether a new species altogether will have to arise to maintain advance, is far from sure. Dr David Suzuki suggests that it will be easier to guess about that in ten years time, when the human act either has or hasn't come together. I think he's right.

If present human numbers are, indeed, a penultimate plague before extinction, it won't matter if lots of other species go with us. Extinction periods are fairly common. Whatever the processes by which life advances may be, they are no strangers to periodic clean-ups.

—**Peter Fannin**
Yulara, NT

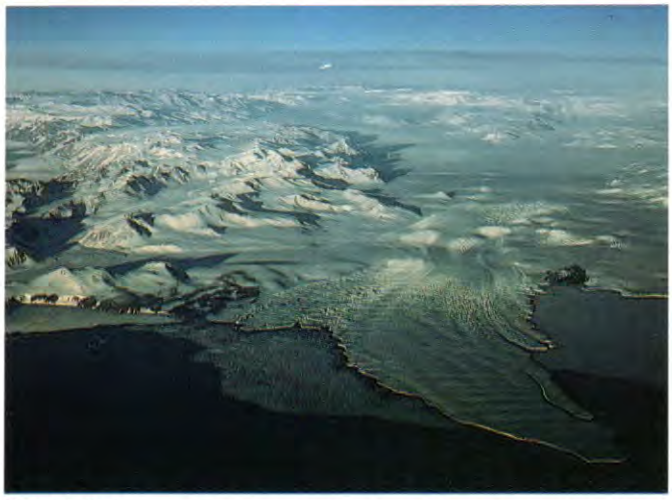
Dinosaur Club

The Western Australian Museum has formed a dinosaur club to promote interest in dinosaurs, provide educational material and inform members about new discoveries. All proceeds go into funding our new 'Diamonds to Dinosaurs' gallery and for palaeontological field work in Western Australia. In 1991, the Western Australian Museum celebrates its centenary and is running 'The Great Australian Dinosaur Hunt' in the remote Kimberley district to find Western Australia's first dinosaur bone. Six lucky members will get the chance to join our expedition for one week in July. Anyone can join the club for $10.00 per year and receive a full kit of information as well as our dinosaur newsletter. For details write to the Western Australian Museum Dinosaur Club, Francis Street, Perth, WA 6000.

—**John Long**
Western Australian Museum
Perth, WA

Members are needed to find Western Australia's first dinosaur.

ALEX RITCHIE



Should all Antarctic Treaty nations take part in conservation of Antarctica?

Argument for Antarctica

The article by Phillip Law on Antarctica (ANH vol. 23, no. 4, 1990) deserves the most careful consideration. The key point he makes is that "...at present there is no way of preventing a nation or a company from prospecting or mining in Antarctica...". To this I would add there is no way of stopping them harvesting fish, whales or krill in the waters surrounding it. In my book *Saving Australia* (1988), I outlined the way we should go:

"We should do what we can to ensure the conservation safety of the area while accepting that this vast land and its seas are part of the common heritage of humankind...the de facto controllers are the signatories to the Antarctic Treaty of 1959...The treaty nations have agreed on a number of useful conservation measures. These include using the land for peaceful purposes only, a free exchange of scientific information, and the banning of all nuclear material...It is often claimed that this co-operation is a diplomatic wonder. The explanation is that so far there has been no economic reason for disagreement. Where whales were concerned the organisation proved a paper tiger, just as it is in the case of krill and fish harvesting. When one acquisitive nation wants to start drilling for oil or mining in Antarctica, the treaty will prove powerless.

"Immediate action should be to draw the rest of the world into the management of this region, at least in consultative terms. The World Conservation Strategy has already outlined the objectives needed for this area...In accepting these goals the Australian Government should push for the whole of the marine ecosystem to be managed along the lines of the Great Barrier Reef Marine Park. This means that some economic activities can continue, although only after management guidelines have been prepared. Some areas need to be zoned as national parks, both on land and at sea. The Antarctic Treaty organisation is already in place and working reasonably well so it should continue as the present de facto authority...all nations could take part in the debate and recommend amendments...The United Nations should set up a watchdog committee...[that] would step in only if any dangerous conservation action was planned."

—**Vincent Serventy**
Hunters Hill, NSW

Ex-editor's Praise

Many thanks for ANH volume 23 number 5! In every aspect of print publishing it deserves praise for its better-than-professionalism, while the content is just about as perfect as an amateur naturalist such as myself could want of a serial publication. I do not imply that this is the only issue deserving praise; most other issues in this volume series have been of excellent standard. As an ex-editor of ANH I know something of the effort required to get such a praiseworthy result. Best wishes, and a long life to ANH!

—**Barbara Purse**

Wilderness: Not Just a Wild Idea

In his argument that wilderness in Australia is impossible, Flannery (The Last Word, ANH vol. 23, no. 2, 1989) makes many unjustified assumptions and presents limited evidence. He argues that Australia's natural environment ideally requires megafauna and carnivores or, in their present absence, fire and culling. He claims that wilderness precludes ecological use of fire and culling, and therefore Australia cannot have wilderness.

This argument assumes, without justification, that a megafauna is essential to maintaining biological diversity; that Aborigines exterminated the megafauna; and that Aboriginal use of fire had a similar effect to the megafauna. Neither evidence nor explanation is presented of what the 'real damage' caused by megafaunal extinction was; why it is considered worse than the last 200 years damage; how Aboriginal firing had an ecologically equivalent effect to the megafauna; and where or how 'vast numbers' of Red Kangaroos are further threatening Australia's environment. Flannery also ignores the dramatic climatic and corresponding vegetation changes in the last 40,000 years; the fact that some environments such as rainforests do not need fire to maintain species diversity; our incomplete knowledge of the role and extent of fire in pre-European Australia; the fact that Aboriginal use of fire probably was not uniform across the whole country or over time; and that factors

other than fire regimes (such as foxes, cats and clearing) may have caused post-European species extinctions.

Wilderness conservation—managing areas so as to minimise the impact caused by modern technological society—brings many benefits for nature conservation and society. Wilderness management can involve active management, including the use of fire as an ecological tool and control of particular species if warranted. The massive changes to Australia's environment in the last 200 years have been much greater in both scale and rate than any brought about by megafaunal extinction or reduced Aboriginal burning. Protecting remnants of natural Australia and managing them to minimise the impact of modern technological society will play an increasingly vital role in nature conservation. Australia needs wilderness.

—Jamie Pittock
Vic. Natl Parks Assoc.
Melbourne, Vic.

Wingham Brush Off

The article on rainforest regeneration at Wingham Brush (ANH vol. 23, no. 5, 1990) contained a number of incorrect claims. The authors stated that the Wingham project 'triggered' the regeneration of a string of rainforest remnants in New South Wales and Queensland. To the contrary, a host of community and individual-inspired regeneration projects on the far north coast, in the Tweed and Richmond Valleys and elsewhere pre-dated the program at Wingham.

These continue and, if anything, can claim that they inspired the council and departmentally funded projects that were to follow. Wingham Brush contains a complex of invasive weeds and vines that are not generally replicated in other north coast rainforests. This limits the application of the technique used. The heavy reliance on herbicide spraying at Wingham has drawn widespread contention—the chemical company Monsanto has recently given a major endowment to the Wingham project.

There has been a number of occasions where attempts have been made to impose the Wingham technique on other regeneration projects in much the same dogmatic way that the Bradley Method was originally applied at Wingham. Each area is unique and therefore should be approached with that in mind.

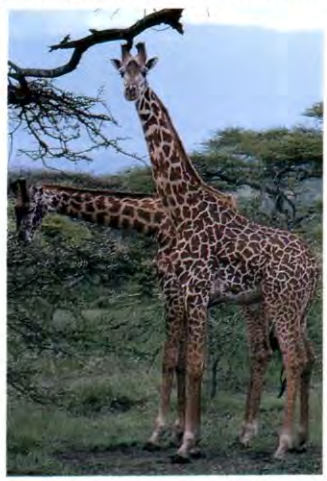
Congratulations to ANH for its great format.

—Brenda Stacey
Mt Warning, NSW

Neckless

Michael Archer speculated on the origin of the neck in vertebrate animals (ANH vol. 23, no. 5, 1990). In his view, "the primary, original *raison d'etre*. . .was an enhanced ability to gyrate the front-fixed senses without having to turn the whole body", that is, to look over the shoulder. With all respect to my friend and colleague, I disagree.

He was referring to sight, but the nose and ears are also 'front-fixed' sense organs. The direction of a source of a scent may be determined by the strength of the stimulus reaching each nostril but location can be improved by waving the head from side to side. Eyes, however, can detect only what is 'in line of sight'. The nub of Archer's argument is that, by permitting the head to turn, the neck allows a vertebrate animal to see what is going on all around it. *But this is what most vertebrates can do, whether or not they have a neck.* The eyes are usually situated on the sides of the head and provide a field of view that extends above, ahead, to the sides and, with the exception of a narrow central sector, *behind* the animal. Very slight movements of the head suffice to scan this 'blind' sector, as demonstrated to anyone who tries to sneak up on a frog, skink, sparrow or rat from behind.



FIONA DOIG

It is perhaps more likely that the vertebrate neck evolved to aid eating and drinking rather than for vision.

So what benefit was provided by the evolution of a neck? Surely it was to do with drinking and eating. As reptiles evolved and came to stand up on their legs, it became necessary to have some means of bringing the head down to the level of the feet in order to drink or to take food from the ground—unless they were provided with a trunk or a very long tongue.

Returning to the main point, I suggest that it is irrelevant for Archer to complain that we humans cannot see what is going on behind us. We could have had a more flexible neck but this option was not taken up by early primates. We must assume that the benefits of forward-facing eyes and a short, rather stiff neck outweighed the alternatives.

What, then, of eyes on top of the head? The pineal and parapineal (parietal) eyes are very ancient sense organs that, after more than 500 million years of being outperformed by 'true' eyes, still turn up in some contemporary lampreys and reptiles as a well-developed organ equipped with lens and retina. Although this feature has been available throughout the known history of the vertebrates for improvement into the sort of turret eye that Archer longs for, there appears to have been no evolutionary demand for such a periscope.

Light-heartedly, Archer suggests that humans with rear vision would not need a neck and could have a bullet-shaped head and body (presumably with 'ordinary' arms and legs). As a follower of "Dr Who", I find it easy to envisage such a Humpty Dumpty alien but I have great difficulty in imagining a rabbit or horse built on the same principles.

My difference with Archer must be regarded as amiable discussion between zoologists. It will be interesting to see how long it takes for it to be cited by creationists as evidence that, because scientists sometimes disagree, Genesis must be true.

—Ronald Strahan
NPIAW, Australian Museum

QUIPS, QUOTES & CURIOS

COMPILED BY GEORGINA HICKEY
SCIENTIFIC EDITOR

Yellow Rain

Between the late 1970s and mid 1980s reports of chemical warfare emerged from areas of South-East Asia. Witnesses alleged that a chemical-warfare agent they called 'yellow rain' had been sprayed by aircraft, helicopters, rockets and bombs in attacks against insurgents and civilians in Laos and Kampuchea, causing sickness and death. The various medical symptoms recorded suggested that several chemical agents had been used, including a nerve gas, a riot-control agent and a chemical that causes internal bleeding.

The yellow rain was said to form sticky yellow spots, two to six millimetres across, that quickly dried to a powder. Samples of the alleged chemical agent were analysed by, among others, a university contractor engaged by the US Defense Intelligence Agency and the US Army. According to the US State Department, several samples analysed by the contractor contained abnormally high levels of three potent mycotoxins, poisonous substances not indigenous to the region and highly toxic to humans and other animals; and in 1981 the US State Department accused the USSR of waging or abetting chemical warfare in Laos and Kampuchea. The US Army, however, found no evidence of toxic chemicals in the samples. What the Army did find in the yellow samples, as did several others, was a high level of pollen grains (about a million grains per milligram).

Intrigued by the description of the controversial yellow substance, Matthew Meselson (Harvard University), Joan Nowicke (Smithsonian Institute) and Thomas Seeley (now at Cornell University) began their own investigations into the substance. They found that the plants represented by the pollen were all common in South-East Asia and their flowers were frequently visited by indigenous honeybees (*Sci. Amer.* 253: 122–131; 1985). Their study also showed that the pollen had been predigested by honeybees. Lacking was a plausible military explanation for the addition of predigested pollen to a chemical-warfare agent!

Further study by Meselson, Nowicke and Seeley showed yellow rain to be indistinguishable from the spots produced by defecation during massed flights of the Giant Honeybee (*Apis dorsata*) in South-East Asia. The spots were the same size, had the same pollen load and both contained bee hairs and bits of fungus. They also found a wide variation of pollen types in adjacent spots, something that might be expected from a substance produced by honeybees and not from a man-made mixture.

Reanalysis of the records of interview with refugees by Jeanne Guillemin (Boston College) found the reports of air attacks and sickness inconsistent, and it was also noted that no chemical munition or fragment had ever been recovered from the areas allegedly attacked. Further interviews conducted with Laotian refugees by Meselson, Seeley and a Thai Colleague indicated they did not generally recognise honeybee faeces for what they are, and some refugees identified bee faeces as the alleged agent of chemical warfare. The researchers concluded that yellow rain was a phenomenon of nature, not of man.

In tropical forests of Asia, *Apis dorsata* lives in colonies averaging 40,000 bees. Often there is more than one nest in a single tree, occasionally as many as 100 nests. In Asia, Seeley and colleagues observed showers of bee faeces during which they could neither see nor hear the hundreds of thousands of bees defecating high above them. Some showers fell over an estimated area of 6,000 square metres.

Makhdzir Mardan and Peter Kevan believe they have found the reason for mass defecatory flight in South-East Asian honeybees. In *Nature* (341: 191; 1989) they report observations of 19 such flights by *Apis dorsata*, during which, in each case, at least half the colony's bees flew in gentle arcs up to around 20 metres from the comb, about five minutes before returning and defecated *en masse*. Mardan and Kevan believe the phenomenon is a means of preventing the temperature of bees' nests becoming so hot as to endanger the larvae. By defecating in mass flights the bees are able to dissipate heat; a typical colony dumps around 7,750 kilojoules during mass defecatory flights at ambient temperatures of 28–31° C. Thus, the lightened bees are more efficiently able to dissipate heat by repeatedly evaporating liquid from their mouthparts and reingesting the cooled droplets, a behavioural process called 'gobbetting'. These mass defecatory flights occur when thermal stress is greatest, which in the tropics is between 9 o'clock in the morning and 12 noon (when temperatures rise rapidly) and between four and six o'clock in the evening (when it is often windless).

So yellow rain, it seems, is no sinister agent of war but a means of helping Asian bees avoid nests reaching a lethal 37° C under still, hot and humid conditions when heat is not easily lost to the air and when ambient temperature is high.

—S.H.

Yellow rain: natural or chemical warfare agent?

MATTHEW MESELSON/HARVARD UNIVERSITY

Snakes that Know When to Rise from the 'Dead'

Most North American kids have seen the non-venomous Hognose Snake (*Heterodon platirhinos*) threaten an aggressor (by puffing, hissing, coiling and striking) and then feign death if the potential predator seems undeterred. It's a very striking, smelly (they evert their cloaca) and determined display, even to the seemingly counter-productive point of the 'dead' snake (with mouth open, tongue extruded and showing no overt signs of breathing) continually turning onto its back if rolled onto its belly. Eventually, after several minutes, the snake relaxes, turns over and slithers away, the whole instinctive business appearing to be a very stereotypic performance.

But recent studies by Gordon Burghardt (University of Tennessee) and Harry Greene (University of California at Berkeley) of the duration of the 'I'm-dead-go-away' stage suggest that newly hatched Hognose Snakes are monitoring the presence and degree of interest of the potential predator (*Anim. Behav.* 36: 1842–1844; 1988). 'Predators' used in the experiments were humans and stuffed owls. It was found that the presence of a stuffed owl will induce a longer state of 'rigor mortis' in young Hognose Snakes than in its absence, and that humans watching a 'dead' snake will delay its miraculous resurrection longer than if they gaze away from the snake.

Clearly, in challenge to the common perception that reptiles are somewhat 'dim-witted', these Lazarus-like snakes are carefully modifying a complex behaviour in response to variations in their environment—a capacity too often thought to be the hallmark of mammals.

—**Michael Archer**
Univ. of New South Wales

A.H. TOLHURST

The Hognose Snake feigns death to avoid predation.

Risky Business

In a paper entitled "Man bites dog—glider bites owl!", Monash University postgraduate student Paul Peake has recently reported some unusual behaviour in an Australian marsupial (*Aust. Mammal Soc. Newsl.* Autumn 1990). During a study of the Powerful Owl (*Ninox strenua*) in south-eastern New South Wales, Peake observed Yellow-bellied Gliders (*Petaurus australis*) 'mobbing' a tape-recorder emitting the mournful 'woo-hoo' calls of Powerful Owls. It is the first time mobbing behaviour has been reported in a marsupial species. Peake reports that several gliders would typically approach the tape-recorder from as far away as 200 metres, to as close as three metres, calling loudly and frequently (a loud, high-pitched, somewhat unnerving shriek followed by a throaty rattle), and on one occasion chased away an owl that was also present. (Despite the catchy title, at no time did a glider actually bite an owl!)

Although the harassment of a predator by members of a prey species has been reported in a number of animals, benefits to the prey species have been assumed rather than demonstrated. In this case, however, mobbing appears to offer a direct benefit to Yellow-bellied Gliders. Peake reports that these gliders are rarely taken as prey by Powerful Owls despite their abundance in the study area. Instead, the larger Greater Glider (*Petauroides volans*) and smaller Common Ringtail Possum (*Pseudocheirus peregrinus*) and Sugar Glider (*Petaurus breviceps*) are the three most commonly recorded species in the Powerful Owl's diet.

—**S.H.**

PETER O'HALLORAN

P. PEAKE

The mobbing behaviour of Yellow-bellied Gliders prevents them ending up as prey for the Powerful Owl (photo shows juveniles). Right: Yellow-bellied Gliders mobbing a tape recorder emitting Powerful Owl calls.

Dr Suzanne Hand, Biological Science, University of NSW is a regular contributor to QQC.

ANTHONY FARR/AUSTRALIAN MUSEUM

A handful of Crown-of-thorns Starfish skeletal elements showing mauve colouration.

Thorns from the Past

Over the last 30 years, predation by large aggregations of Crown-of-thorns Starfish (*Acanthaster planci*) has been responsible for the destruction of corals throughout the Indo-Pacific region. Since 1962, two outbreaks have caused extensive damage to the central section of the Great Barrier Reef, leading some researchers to question the long-term viability of the reef.

Opinion has been sharply divided over the cause(s) of these outbreaks. Some scientists believe that the fluctuations in Crown-of-thorns populations are a recurrent, natural phenomenon that is regulated by environmental pressures. Others consider the outbreaks to be the result of direct or indirect human interference on the reef ecology, by means such as predator removal, physical modification of the environment, or the influx of pollutants or nutrients into the ocean.

Resolution of this conflict of opinion may be facilitated by an understanding of ancient Crown-of-thorns population patterns. The skeleton of each starfish comprises several thousand calcium carbonate elements or bones. Following death or predation, the animal undergoes disintegration and the elements are rapidly dispersed. If Crown-of-thorns outbreaks are an enduring feature of coral reef ecology in the Great Barrier Reef, then analysis of subsurface sediment should provide evidence of past populations in the form of skeletal elements. Surface and subsurface (cored) sediment was therefore collected from Green Island Reef (east of Cairns) and John Brewer Reef (north-east of Townsville), the recent histories of which are particularly well documented, both having experienced two devastating Crown-of-thorns outbreaks since 1962. The sediment samples were exhaustively processed for Crown-of-thorns skeletal elements. This laborious and time-consuming task was simplified by the distinctive skeletal morphology and characteristic mauve colouration of the elements.

Large numbers of elements were recovered from the surface sediment of Green Island and John Brewer Reefs, with averages of 22 and 17 elements per one-kilogram sediment sample respectively (*Coral Reefs* 8: 67–78; 1989). A comparable abundance of elements was also recovered from the ancient subsurface sediment of each reef. By contrast, element recovery for surface sediment from Heron Island Reef (east of Gladstone), which has maintained a 'normal', low-density Crown-of-thorns population for more than 30 years, yielded only two elements from the 55 sediment samples processed.

Carbon-14 dating of Crown-of-thorns elements suggested that elements contained in the surface sediment were derived from recent (contemporary) outbreaks, while those buried within the sediment were up to several thousand years old (*Science* 245: 847–850; 1989).

Interpretation of these results is complicated by the substantial physical and biological reworking to which reef detritus, including Crown-of-thorns elements, is subjected prior to final burial. In particular, the burrowing activities of certain shrimps (family Callianassidae) in shallow coral reef sediment effectively mix the sediment pile down to a depth of at least 50–60 centimetres below the sediment surface. Evidence of major events, such as Crown-of-thorns outbreaks, is therefore not preserved as discrete intervals or horizons within the sediment record. Subsurface element density and distribution well beyond the influence of modern callianassid shrimps, however, reflect the presence of very large numbers of Crown-of-thorns on Green Island and John Brewer Reefs for several thousand years, and possibly since the initiation of modern reef growth in the central Great Barrier Reef, approximately 9,000 years ago.

Due to the intensive sediment reworking, it is not possible to establish if the high numbers of subsurface elements represent recurring Crown-of-thorns outbreaks or stable, long-term, medium-density starfish populations on these two reefs. When not in outbreaking proportions, the Crown-of-thorns Starfish is considered to be an uncommon and cryptic member of the reef community; a persistent, medium-density population of starfish has not been recorded in the Great Barrier Reef. The abundance and distribution of elements in subsurface sediment is, therefore, consistent with the view that population outbreaks typify Crown-of-thorns Starfish behaviour.

So far the Great Barrier Reef Marine Park Authority has been reluctant to instigate control measures. Reasons include the prohibitive cost involved in containing the starfish on just one reef, let alone all those affected; the ineffectiveness of the controls so far used; and the lack of desire to interfere in what may well be a natural and recurring ecological phenomenon. This research demonstrates that the Crown-of-thorns Starfish is an important and integral part of reef ecology in the central Great Barrier Reef. The dramatic population fluctuations may play a critical role in reef evolution and in the promotion of species diversity.

—Peter D. Walbran
Environmental Geologist
R.W. Corkery & Co.
Orange, NSW

Millipedes, Marigolds and Mothballs

Anting is a behaviour well known in birds, whereby the bird may squat on an ant nest with its feathers spread and the ants swarm all over it. Sometimes the bird will pick up an individual ant gently in its beak and jab its skin and stroke the feathers with it. Generally, anting has been interpreted as a maintenance behaviour, in which the metabolic products of ants, such as formic acid, may soothe skin irritated by rapid feather replacement. Other hypotheses include the suggestion that the antibacterial and fungicidal substances (such as *B* hydroxy fatty acids) found in ants may help control pathogens found on birds.

If birds are using the soothing or antimicrobial properties of ants, birds should also recognise these properties in other organisms or objects. Consistent with this chemical recognition hypothesis are the observations that birds use millipedes and marigolds, which contain antiarthropod and antibacterial properties respectively; and Charles, Linda and Larry Clark from Pennsylvania have recently reported 'anting' by Common Grackles (*Quiscalus quiscula*) and European Starlings (*Sturnus vulgaris*) using napthalene mothballs (*Wilson Bull.* 102: 167–169: 1990). The birds were observed picking up individual mothballs in their beak and rubbing their wing feathers, after which they dropped the mothball and flew away.

The Clarks also noted that napthalene is registered by the United States Environmental Protection Agency as not only an arthropod repellent but also a bird repellent. It is clear from these observations, however, that napthalene is not repellent to at least two species of birds!

—G.H.

CARL BENTO/AUSTRALIAN MUSEUM

Marigolds and mothballs: two of the unusual things birds have used for 'anting'.

The Fungus, the Forest and the Potoroo

The study of our planet's infinitely complex web of life is one of the most interesting and important areas of biological research to gain popularity in recent years. In Australia, particularly, there has been a rapidly growing recognition of the interdependence of organisms and the roles they play in maintaining our unique ecosystems. One such case identified recently is that of the fungus, the forest and the potoroo.

A study of the diet of the Long-nosed Potoroo (*Potorous tridactylus*) in dry, open forest at Naringal in south-western Victoria by Andrew Bennett and Barbara Baxter of the Arthur Rylah Institute for Environmental Research in Melbourne has found that these potoroos rely far more on fungi for food than previously thought and that the role of small, fungus-eating mammals, such as the Long-nosed Potoroo, may be very important in the health of forest ecosystems (*Aust. Wildl. Res.* 16: 263–271; 1989).

Unlike grazing and browsing kangaroos, potoroids (potoroos, bettongs and rat-kangaroos) tend to eat low-fibre plant foods such as bulbs, tubers, roots and fungi obtained underground by digging shallow excavations. In Bennett and Baxter's study, fungi were found to comprise at least 25 per cent of food eaten by the Long-nosed Potoroo, and in autumn and winter over 50 per cent. At least 42 species of hypogeal (underground fruiting) fungi were eaten (far more species than an experienced collector could find), most with underground fruits ranging from one to five centimetres in diameter.

For the Long-nosed Potoroo, the fungal fruiting bodies appear to be a nutritious and reliable food source. They are a good source of water; they compare well with many fruits and vegetables in terms of calories; they are, compared with nut kernels, a good source of protein, carbohydrates and minerals; and they not only survive after conditions suitable for their growth and production have ceased (such as dry summer conditions) but also survive bushfires. Other potoroids that depend on fungi include the Brush-tailed Bettong and Long-footed Potoroo, and to a lesser extent the Rufous Bettong and Tasmanian Bettong.

Fungi form associations with forest trees in which a close physical, mutually beneficial relationship exists between the fungus and the roots of a plant (a fungus-infected root takes up nutrients more efficiently than does an uninfected root), and thus play an important role in productivity in forest ecosystems. The fungi concentrate biologically important elements such as nitrogen and phosphorous from dilute substrates, a capacity that may be important in Australia where soils are relatively poor in nutrients.

Fungi with underground fruiting bodies, however, lack active mechanisms for dispersal of their spores and for this are dependent upon the animals that eat them. In small mammals, fungal spores are not digested during passage through the gut, but are concentrated in their droppings and distributed as the animal moves through its home range. When conditions are suitable, these spores germinate producing new fungi that form new associations with forest trees and the cycle is repeated. Ensured is a food source for potoroos, an agent of dispersal for the fungi and healthy, productive forests for all.

—S.H.

HANS & JUDY BESTE/AUSCAPE INTERNATIONAL

The Long-nosed Potoroo's habit of eating fungi plays a vital role in forest ecosystems.

Africa: Evolutionary Hotspot for Hominids

Not all parts of the geological record are equally exciting in terms of evolutionary activity. There are long periods stretching millions of years when nothing much seemed to happen, and other periods when vast numbers of species disappeared and other lineages proliferated. These active periods were clearly hotspots in geological time. Indeed the competing explanations for them form the basis for the debate about punctuated equilibrium and gradualist models of evolution.

If there are hotspots of evolution in time, what about in space? Could it be that certain geographical regions are more likely to be the focus of evolutionary activity than others? Are certain environments promoters of speciation or extinction, or capable of supporting greater levels of biological diversity? These questions are particularly pertinent in the study of human evolution.

Most palaeoanthropologists now accept that the hominids (humans and their ancestors) had their origins in Africa. This is indirectly testified by the recent research in molecular biology that shows that humans' closest relatives are the African apes, and that they diverged from the chimpanzees and Gorilla some six to eight million years ago. It is also directly indicated by the fact that the earliest hominoid fossils come from Africa, and that the fossil record within Africa is far richer than anywhere else. Not only did the hominids have their origins in Africa, but they also underwent an adaptive radiation (that is, diversified into a series of related species) there between three and two million years ago, and that at a much later date—between 100,000 and 200,000 years ago—the first anatomically modern humans appeared. Africa, in other words, appears to have been an evolutionary hotspot for hominids.

Most of the hominoid fossils we know of come from two very restricted areas in Africa: the limestone plateaux of the Transvaal and the Great Eastern Rift Valley. It is the latter area that has yielded the earliest and most abundant finds. The Rift Valley is a 5,600-kilometre-long tectonic gash, the result of the rising of eastern Africa and the subsequent stretching of the Earth's crust. Along these stretch lines faults occurred, producing a series of escarpments and cliffs. Scattered among them are volcanoes, and much of the landscape is covered with the larvas and ashes of their eruptions during the last 15 million years.

This geological context is critical to the discovery of hominoid fossils. The effect of these major earth movements and volcanoes was to create a string of closed lake basins. The gentle deposition of the lakes was ideal for preserving animals that died at their edges, while the subsequent faulting and erosion meant that these fossils were exposed for palaeontologists to discover rather than being buried hundreds of metres below the surface. Outside the Rift Valley such ideal conditions seldom occur, and so it might be assumed that this geological freak, rather than any biological imperative, lies at the heart of our understanding of human evolution. But first we must ask what promotes evolutionary novelty and maintains biological diversity.

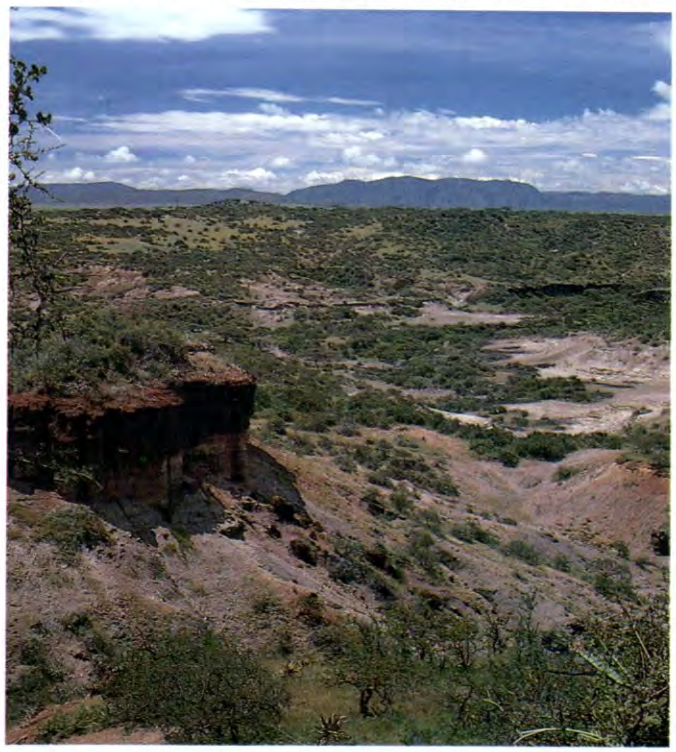
Where environments are rich in energy and nutrients there is often more diversity. There is thus a gradient in biological diversity with latitude, with the richest environments being in the tropics and the poorest in the highest latitudes. Where environments are subject to major fluctuations in conditions there is often little indigenous evolutionary change. Conversely where there is no environmental change or variability there is little diversity. What this seems to suggest is that a little environmental variation and disruption is a good thing from an evolutionary standpoint. Furthermore, where landscapes are broken up into smaller units—each isolated and distinctive—then evolutionary novelty is likely to occur.

When we look at the Rift Valley we find that all these conditions are fulfilled. The environment is relatively rich in energy and its seasonality leads to marked but relatively predictable fluctuations in conditions. The faulting and volcanic activity leads to the formation of local lake basins and riverine systems, separated by barriers that may have inhibited movements of individuals and populations. And through the last ten million years or so the climate and environment have fluctuated considerably, but not to the extent found in higher latitudes that were ravaged by the depredations of the glaciations. In other words, The Rift Valley provided all the conditions under which we would expect a lot of evolutionary activity—a geographical hotspot generating new species and communities.

Geological and hence environmental conditions provide only the necessary, but not sufficient, causes of evolutionary change. The formation of the Rift Valley, in conjunction with the changing climates of the time, provided the context in which hominids were successful. Those circumstances were the expansion of seasonal environments in the tropics, the radiation of many groups of other mammals that provided the tight competitive conditions in which evolutionary change is likely to occur, and sufficient long-term climatic change to prevent the establishment of a simple ecological equilibrium. The result was not the hominids but an extremely diverse and rich community of mammals that themselves underwent major evolutionary change. One group of animals subjected to this new environment and ecological community was the African apes, widely distributed across the central and forested parts of Africa. The eastern parts of these populations would have faced major environmental change as the stable forests of the Miocene gave way to the drier and more seasonal environments of the Pliocene and Pleistocene. It is the juxtaposition of the right environmental conditions with the appropriate evolutionary raw material that lies at the heart of most of the evolutionary record, and the hominids are no exception.

We are still a long way from saying that the Rift Valley is the cradle of humanity, but it is perhaps suggestive that the area, which for geological reasons has yielded the most exciting fossils, may also, for ecological reasons, be the one that promoted such a unique species. Humans are not an inevitable outcome of a linear evolutionary process leading to greater and greater complexity; rather, it is a question of being in the right place at the right time—an evolutionary hotspot.

—Robert Foley
Dept of Biological Anthropology Univ. of Cambridge, UK



FIONA DOIG

Olduvai Gorge, Tanzania, part of the Great Eastern Rift Valley in Africa: critical location for hominid fossils.

ANIBAL RAFAEL MELGAREJO GIMENEZ

Brazil's Fruit-eating Frog: a World First

First-known incidence of fruit-eating in frogs has been reported in the South American species *Hyla truncata*.

Not far from Rio de Janeiro, among the shrub thickets, cacti and bromeliads of the sand dunes between the Pacific Ocean and a coastal lagoon, lives a little hylid tree frog that, of late, has made quite a splash (*Copeia* 1989: 781–783). Not content to chase arthropods for food like most frogs, the 39-millimetre-long *Hyla truncata* also eats fruits and seeds, and appears to fill a role not previously known to be played by amphibians—that of seed disperser.

Although reports of frogs consuming plant material are not uncommon, generally plants are not regarded as an important part of the diet and are often interpreted to be incidentally eaten when frogs are foraging for creepy crawlies. So, when Helio da Silva, Monica de Brittopereira and Ulisses Caramaschi of Brazil's National Museum noticed during a field study of *Hyla truncata* that individuals brought into the laboratory often defecated seeds, their appetite was whetted. Could *H. truncata* be deliberately eating fruits?

To find out, the researchers collected 81 frogs at sunrise, over a period of six months, from their daytime refuges in the water-filled axils of the terrestrial bromeliad *Neoregelia cruenta*, and analysed their stomach and intestinal contents. Excluding stomachs that were empty, 42 per cent contained fruits and sometimes seeds of four plant species (including *Anthurium harrisii* and *Erythroxylum ovalifolium*), along with ants, grasshoppers, beetles, spiders, cockroaches, dragonfly naiads, beetle and butterfly larvae—the major diet of the frogs.

To test the hypothesis that the fruits were intentionally eaten, ten frogs were fed in the laboratory on a fruit-only diet for a week. The frogs survived without ill effect, and two were maintained thus for a further four months. Field studies also supported the theory (a frog was observed in the wild eating one of the four identified fruits) and laboratory analysis indicated that the fruits were swallowed whole and were indeed digested, with only the naked seeds being found in the rectum waiting to be voided. The fruits were indeed part of this species' diet.

Hyla truncata is believed to be an agent for the dispersal of these seeds because those that passed through its digestive tract were found to be viable. Da Silva and colleagues suggest that, because *H. truncata* probably defecates seeds in the water-filled axils of the bromeliads in which they take daytime refuge, the chances of germination are greater than in seeds dropped on the sandy soil of the dunes. The next step in the study will be the evaluation of actual seed dispersal and the nutritional value of fruits in the diet of the little frog from Rio.

—S.H.

Sterile Red Fungus Takes Over Take-all

Ever since pioneer farmers started growing wheat in Australia, a significant proportion of crops have been lost to parasitic fungi that destroy the roots of plants. One disease, take-all (also known as hay-die or whitehead), is caused by the fungus *Gaumannomyces graminis* var. *tritici* (Ggt) and can cost Australia up to $400 million annually in lost wheat yield. Now a recent discovery by researchers at the University of Western Australia may soon change our ability to control take-all and other rootrot in cereals.

Dr K. Sivasithamparam's group in the Department of Soil Science and Plant Nutrition has been looking at the problem of take-all disease for many years. As part of the research program, Ph.D. student Majeed Dewan isolated a pinkish red fungus with rather unusual properties on the roots of wheat on a farm in Western Australia. Wheat plants that had been colonised by the fungus were immune to infection by the take-all fungus, and they were shown to grow faster, larger and stronger than wheat plants not colonised by the fungus. Dr Sivasithamparam recognised this fungus as a natural competitor of Ggt that could become the basis of biological control of take-all disease. He and Dewan set about to study the fungus in detail.

In the next few years they examined its effect on almost all commercially important crop plants including cereals, legumes, oilseed and other rotation plants. It appeared able to colonise the roots and promote growth in virtually all plants tested. And, not only did it protect susceptible plants from Ggt but from a wide range of root-rotting fungi such as *Phytophthora* (the cause of die-back in Jarrah) and *Rhizoctonia* (the cause of bare-patch disease).

Sterile Red Fungus recovery from wheat roots. Roots were surface sterilised and placed onto petri dishes in sections. Sterile Red Fungus is recovered most frequently from crown segments.

PETER KEATING/BIOTECH INTERNATIONAL

The researchers were, however, unable to make the new fungus form spores or fruiting bodies. As the taxonomy of fungi is largely determined by the fruiting body, no name could be ascribed to the new organism, so it has the tentative title Sterile Red Fungus (SRF).

By this time the researchers had formed a collaborative association with a local biotechnology company, Biotech International Ltd, with the view to sponsor further research and commence commercial development of SRF. To overcome the problem of producing enough SRF cheaply for the many millions of hectares of Australian wheat, Biotech developed and patented a completely new inoculum delivery system based on perlite, a porous mineral commonly used in the horticulture industry. In 1989, with the Western Australian Department of Agriculture, wheat field trials were able to commence on a large scale. Unfortunately, however, 1989 proved to be a poor year for field trials. Very little spring rain fell and there was virtually no finishing rain. Under such climatic conditions take-all does not have much effect, so disease protection could not be determined. But Biotech and the Department of Agriculture were sufficiently impressed by growth promotion early in the season to expand the field trials program and in 1990 SRF was sown in seven research station sites across the State and with a number of interested farmers. If success continues, within two years farmers will be able for the first time to protect their crops from rootrot and simultaneously get a boost (about 40 per cent) in yield.

But now SRF is destined for even bigger things. Because of SRF's ability to colonise the roots of all plants and because, like many endophytic fungi, it secretes proteins into the host plant, it should be possible using genetic engineering to redirect the fungus into making different proteins, such as natural insecticides, nematocides, or those that make the host plant drought-resistant or salt-tolerant.

Many scientists have tried to produce genetically engineered plants but, because of the complexity of plant genetics, it is a notoriously difficult task. Fungi, however, have a much simpler genetic organisation and have proved to be readily amenable to genetic manipulation. With a recombinant (genetically modified) fungus living within its roots, the host plant should get exactly the same benefits as if it had been genetically engineered.

The advantages of this approach would be enormous. Fungi grow clonally like bacteria so it is possible to produce large amounts relatively quickly, compared to plants where years of breeding are required to produce commercial quantities of seed. Also, because of SRF's wide host range, the same recombinant SRF would be able to treat all sorts of crops.

But the most impressive advantage is the environmental implications of this technology. SRF is a sterile fungus that appears unable to form spores or to spread away from where it is deliberately released; indeed it can only survive for a short time in soil, and when the host plant dies, the fungus progressively declines. So, if SRF was genetically modified to produce a bio-insecticide, for example, the plant would continually receive a dose of insecticide, but none would be lost by wind drift or end up on non-target plants and, when the plant is harvested, the insecticide would degrade naturally. If we can successfully develop the technology to make this concept work, then we could eventually do away with many poisonous and environmentally hazardous agrochemicals.

The Federal Government has recognised the worldwide potential of this research and recently awarded Biotech International and the University of Western Australia a substantial grant to continue their work together for the next three years.

—Peter Keating
Director of Research & Development
Biotech International Ltd

Trading Places: Reverse Mounting in Grebes

A method commonly used to sex birds of species in which males and females look very similar (that is, are monomorphic) is to colour-mark individual birds and then to sex them by noting which bird mounts during copulation. The assumption is that, in birds, males mount females and not *vice versa*. A study of Silvery and Hooded Grebes (*Podiceps occipitalis* and *P. gallardoi*) in snow-melt lakes in the foothills of the Andes in southern Patagonia has found that this assumption may lead ornithologists astray. United States zoologists Gary Nuechterlein and Robert Storer report that 27 per cent of mountings observed in Silvery Grebes and 15 per cent of those in Hooded Grebes, were actually by females (*Condor* 91: 341–346; 1989).

Reverse mounting (females mounting males) has been reported in many bird species, but is usually regarded to represent unusual or aberrant behaviour. Nuechterlein and Storer's study indicates that, in grebes at least, it constitutes a regular and integral part of their courtship behaviour, occurring most frequently early in the season during pair formation. The researchers found that copulatory movements (for example, everting the cloaca, tail-thrusting and ejaculation) were all significantly less frequent in reverse mountings than in normal mountings, and at least some details of the behaviour appeared cursory or ritualised.

Interestingly, reverse mounting occurs in a number of non-passerine birds but may be of a different context. For example, in pre-roosting Acorn Woodpeckers (*Melanerpes formicivorus*) mounting is related to neither age nor sex, but may be related to reducing aggression prior to the group roosting in holes (where birds are crowded together). Nuechterlein and Storer suggest that reverse mounting may be far more widespread than usually recognised and warn bird-watchers to beware of misidentifying sexes in monomorphic species in which the male and female commonly engage in reciprocal or mutual courtship displays.

The observation of reverse mounting in Silvery Grebes means traditional methods of sexing may be unreliable. Reverse mounting is usually regarded as aberrant behaviour in birds.

—S.H.

"With his precious grisly heap in tow, Wall's reeking load was dispatched to Pinchgut Island where his difficulties should have evaporated with the stench."

THE TALE OF WILLIAM WALL'S WHALE

BY STEVE VAN DYCK
MAMMAL SECTION, QUEENSLAND MUSEUM

EVERYTHING FISHY HAS A DARK SIDE. For every prawn cocktail, a parcel of heads throbs in a garbage bin somewhere. For every bucket of oysters, a fetid one waits to turn the peristaltic tide, but tipping their scales on maritime emetics comes the stranded whale. One day a dying idol, the next an unimaginable mountain of biological warfare. For, in spite of all the pathos and noble human sentiment associated with whale strandings, our warm humid climate has no conscience about turning the awe into nausea almost overnight.

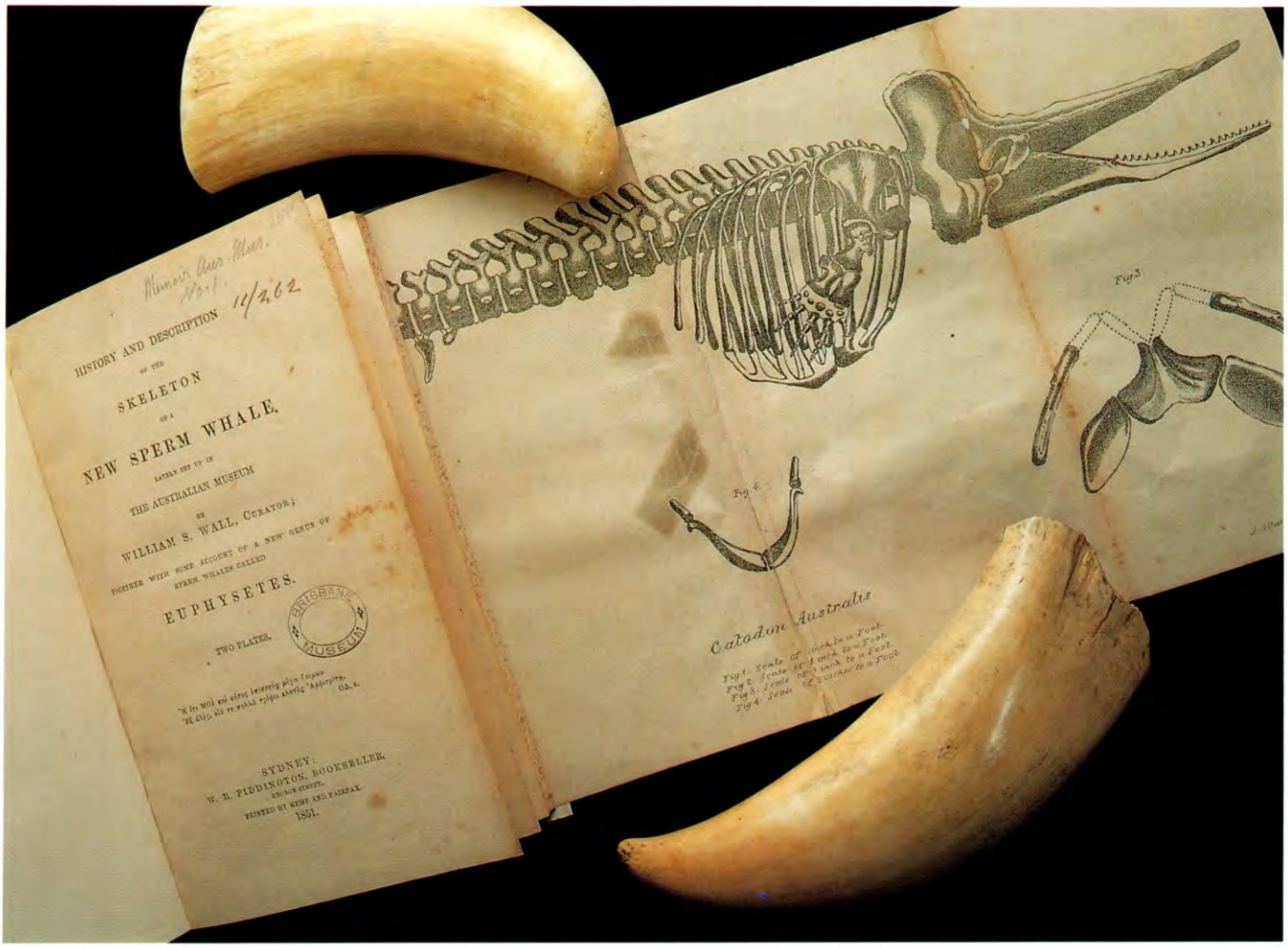
It is then that the old saying "'fish' and company stink in three days" finds its ultimate expression. Moreover, the odour associated with the rapid conversion of a single dead sperm whale into 30 tonnes of rancid Anchovette, has only to be encountered once to be tattooed on the sinuses for life.

Such a heady summer fragrance drifted toward Sydney on 5 December 1849 when, according to surgeon and distinguished naturalist Dr George Bennett, the *Sydney Herald* announced that a dead sperm whale had been spotted at sea bobbing around like a stricken blimp, and had been towed into Port Jackson by the schooner *Thistle*.

Mr William Wall, then Curator of the Australian Museum, envisaging the gigantic beast's skeleton slung from the gallery rafters, took upon himself the formidable task of negotiating for the whale's remains.

The vessel's skipper, Mr Williamson, was prepared to be more than accommodating with Wall's desire for the bones, but took some convincing that he should part with the lower jaw, whose rich load of teeth he was most anxious to retain. But, after the blubber had been stripped off the whale for boiling, and after some well-chosen words by the persuasive Wall, Williamson evidently softened and presented the Curator with the entire carcass, meat, bones and much maw.

Wall's leverage was opening a can of worms he could hardly have anticipated: "There was considerable difficulty in obtaining men willing to undertake so unpleasant, and, as they considered,



Teeth of the Giant Sperm Whale *(Physeter macrocephalus)* with Wall's original paper published in the first edition of *Memoirs of the Australian Museum* (1851).

BRUCE COWELL/QUEENSLAND MUSEUM

unhealthy an employment during the heat of summer. On the following day, however, four [Portuguese] sailors were hired who had been in the whale-fishery: after engaging them on their own terms, he found that, owing to previous employment, they would not be able to commence their work for four days: this was to be regretted as decomposition takes place rapidly in the hot month of December in Australia; but as these were the only men willing to undertake it, he was compelled to submit."

Meanwhile Wall received an order from the water-police magistrate to remove the putrifying carcass from Neutral Bay as the local residents could not operate under certain shifts in wind direction.

"The head was still doomed to more troubles: the sharks had performed on their part a beneficial operation, but the huge jaws, lying out of the water, had attracted some of those creatures (mischievous all over the world) called 'small boys', who were caught labouring hard at the lower jaw, endeavouring to extract the teeth"

Not wanting to put any noses out of joint, Wall complied with the direction but, as the carcass was being relocated in a secluded bay, he noticed that a portion of the tail, containing ten of the caudal vertebrae, was missing, presumably having been sent to Sydney along with the blubber. The single-minded Wall made exhaustive enquiries all over Sydney until he eventually found the wayward tail lying on Hughes' Wharf in Sussex Street. "This was fortunate; for on return of the men from dinner, in half an hour, it had been ordered that the whale's tail, the object of so much anxiety and search, was to be sunk in the harbour to get rid of the disagreeable effluvium arising from it."

With his precious grisly heap in tow, Wall's reeking load was dispatched to Pinchgut Island where his difficulties should have evaporated with the stench. But the head of the monster gave him the slip and went missing from the rock it had been lashed to. It had floated back around to Neutral Bay and stranded itself outside the residence of the Collector of Customs who, finding the smell so disagreeable, had ordered the coxswain of the Custom House boat to tow it out of the harbour.

As luck would have it, Dr George Bennett (the Australian Museum's first Curator and Secretary between 1835 and 1841) happened to be on the boat the very day the run-a-muck skull was heading for deep water, and he managed to persuade the coxswain to spare the head for the Museum by leaving it lashed to a rock where it would not annoy anyone.

Wall was beside himself with joy on the discovery of his missing treasure. But his rapture was short lived. "The head was still doomed to more troubles: the sharks had performed on their part a beneficial operation, but the huge jaws, lying out of the water, had attracted some of those creatures (mischievous all over the world) called 'small boys', who were caught labouring hard at the lower jaw, endeavouring to extract the teeth; fortunately they were discovered before any material damage had been affected."

The disagreeable task of cleaning the mess was then begun, the putrid beast taking four days to flense. The bones were then treated with lime and other preparations, and left for two months while they bleached. The skeleton was complete except for a missing flipper.

To his ultimate good luck and judgment, Wall followed up a report given by two boys that a strange fish was lying on the rocks near the baths at Woolloomooloo Bay. In so doing he found the mystery fish to be his missing flipper, and retrieved it with considerable celebration.

Wall finally got his specimen up on display, and was undoubtedly relieved to be able to wash his hands of the entire matter.

But the story does not end with the bones swinging from the Museum's ceiling. Wall's rapture led to the description of his specimen as a new species of sperm whale, *Catodon australis*, and its lengthy scientific description was published as the first of the *Memoirs of the Australian Museum* in 1851. It has since been synonymised with the Giant Sperm Whale (*Physeter macrocephalus*).

Wall, of course, has long since gone but, his cachalot, bearing its original registration number J326–30, is still to be found among the many hard-earned treasures of the Australian Museum. ■

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Steve Van Dyck is a curatorial officer in charge of the mammal section of the Queensland Museum. He has been there since 1975.

"Beyond protecting the island from unwelcome invaders, the real challenge for conservation is in the balance of interest between wetas and the Mercury Island Tuataras."

THE 'ELEPHANT WETA'

BY MARY E. MCINTYRE
SCHOOL OF BIOLOGICAL SCIENCES,
VICTORIA UNIVERSITY OF WELLINGTON, NZ

THE SPECTACULAR 'ELEPHANT WETA' or 'Tusked Weta' of Middle Mercury Island, New Zealand, is a giant 'ground' weta (flightless cricket-like insect) found only on one small (ten-hectare) uninhabited and rodent-free island off the north-eastern coast of the North Island. It appears to represent a relict population that has survived in long isolation from the outside world. The popular names refer to large size (males can reach nine to ten centimetres to the tip of the jaw, both sexes up to 28 grams) combined with an enlarged head and elephant-like 'tusks' in males. The female, in contrast, lacks the large head and tusks and is rather plain and retiring by comparison. A scientific name awaits publication.

Despite their size and ground-living habits, these wetas are a relatively recent discovery. One small male was originally found in 1970. The species was not seen again until 1983 when a university student studying skinks on the island made further sightings. In 1989 three adult wetas were obtained for study by scientists surveying Tuataras in the Mercury Islands. They have since provided a few surprises and a challenge for conservation!

Initial attention has centred on the tusks. These are used as jousting weapons in what may become prolonged and energetic head-butting contests. Despite appearances, however, this behaviour is almost 'gentlemanly', with the potential, but apparently not the intent, to injure. It seems to be associated with the defence of resources (probably a nest or hole in the ground) used by females. At other times the tusks seem to get in the way.

Little is known about these wetas in their natural surroundings. But planning is underway, as part of a research program to assist conservation, for round-the-clock surveillance of adult wetas using radiotransmitters.

Middle Island supports unusually high numbers of invertebrates and reptiles, made possible in part by the manuring effect of nesting seabirds. 'King' of the island and top terrestrial predator is the ancient and inscrutable Tuatara (*Sphenodon punctatus*), itself a threatened species.

Any weta is top of the Tuatara menu when available, and an adult 'Elephant weta' is almost certainly a delicacy. But predator and prey play by some rules! Both emerge at night in search of food and both become less active in cool weather. But Tuataras 'sit and wait' for their prey, rather than hunting it out, and prefer open areas where they can see likely prey approaching, while also observing their territorial neighbours. The wetas, in contrast, have been found only where there is some ground cover or leaf litter. Perhaps it is mainly the least cautious of wetas that are fair game for Tuataras!

MARY E. McINTYRE

Male 'Elephant Wetas' jousting. These insects can grow up to ten centimetres in total length.

A balance has undoubtedly been achieved over aeons of coexistence with the Tuataras. This is in stark contrast to the threat posed to all island inhabitants by warm-blooded predators such as rats that don't play by the same 'rules'. Rats are active at night in all weather conditions, range widely and seek out prey. Although the island is a protected site and permits are needed to land there, the possibility of rodents hitchhiking on a small boat is a continuous threat.

Beyond protecting the island from unwelcome invaders, the real challenge for conservation is in the balance of interests between wetas and the Mercury Island Tuataras, as well as some endangered lizard species that are also found on Middle Mercury Island. This is best done by ensuring there are further free-ranging populations as insurance against ecological misfortune (fire, vegetation change, rodent invasion, rising sea-level etc.). For the wetas, which occur only on Middle Mercury Island, this could be achieved by re-introducing juveniles to a neighbouring island cleared of introduced predators and preferably also free of Tuataras. The new site must also offer a suitable food source for these unexpectedly carnivorous wetas (other 'giant' wetas are primarily vegetarian), which apparently prefer insect larvae and other small invertebrates.

The only available host islands (two at present) in the Mercury Group have, until recent eradication, had populations of the Kiore or Polynesian Rat (*Rattus exulans*), which was originally introduced to New Zealand by Polynesian settlers. Islands with Kiore seem 'dead' at night (apart from seabirds in the nesting season), whereas nearby Middle Mercury Island teems with life. Detailed comparisons show almost complete annihilation of flightless ground-living invertebrate species and nocturnal forest-dwelling lizard faunas. There are no Tuataras, although the survival of a few ageing individuals on two larger nearby islands that still support Kiore suggests they were once present.

Now that the Kiore are removed, the restoration of these islands as wildlife refuges will rest on building up the invertebrate populations as a food source for species higher in the food chain. However, we do not yet understand enough about such 'small island' communities as systems, or about the wetas, to confidently predict how such an unusual species will fare in new circumstances, with or without Tuataras. Although this is an immediate dilemma for the weta, it is also a challenge for conservation since it offers the opportunity to monitor community development and obtain guidelines for other conservation projects. It might also provide some fundamental insights into community dynamics. ■

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Dr McIntyre is a research fellow in the School of Biological Sciences at Victoria University of Wellington, New Zealand. Over the past two years she has been part of a research team involved in the conservation of both Tuataras and wetas.

You can learn a lot about the history of Macquarie Street just by looking at the pavement.

Macquarie Street's Sydney Hospital hasn't always enjoyed such an established and conservative title.

Last century, the site was occupied by a hospital which was named after the preferred liquor of the day, namely, Rum.

In 1810, three Sydney businessmen built the city a magnificent hospital in exchange for the coveted monopoly over the city's Rum trade.

This became the Rum Hospital, and stood complete until 1876, when the central block was demolished to build the present Sydney Hospital.

Further down the street you'll find the site where the Female School of Industry once stood.

In 1826, before anybody had even heard of 'Feminism,' the colony ran short of servants.

Accordingly, the ladies of the colony set up the Female School of Industry in order to teach their lesser sisters "every branch of household work." The site is more appropriately occupied now by the Mitchell Library.

The fact is, Macquarie Street is more than just another city street.

It is Sydney's, if not Australia's, most interesting thoroughfare.

In an effort to pay tribute to this, Caltex, in association with the NSW Public Works Department, has laid twenty commemorative footpath plaques along Macquarie Street, each marking a historical site.

So if you want to find out what Sydney was really like in the early days, look out for the Caltex Commemorative Plaques on your next stroll down Macquarie Street.

You could learn a lot simply by watching where you walk.

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"If left for any length of time, it fermented into an alcoholic 'cider' on which Aborigines (and later settlers) regaled themselves."

EUCALYPTS AS FOODS

BY TIM LOW
NATURE WRITER

IF EUCALYPTS WERE EDIBLE, HOW EASY IT would be to live off the land. They are the dominant forest cover of Australia's moister regions (or they were, before clearing) but, unfortunately, they supply almost nothing by way of food. None of the 500 plus species has edible fruits or tubers, and their aromatic leaves are too tough and toxic for us to eat. Eucalypts were more important to Aborigines for the animal foods they harboured (Koalas, possums, birds' eggs, honey, lerp) than as food themselves.

But in a genus so large there are inevitably a handful of food-producers, including species that supply edible seeds, nectar and 'apples'. One remarkable eucalypt may even provide a marketable substitute for maple syrup.

In central and northern Australia Aborigines harvested the seeds of several eucalypts. In north-western Queensland, the tiny seeds of the Black Box (*Eucalyptus largiflorens*) were soaked in several changes of water—to remove an unpleasant taste—then ground between stones and eaten raw.

In the Kakadu region, Aborigines ate the seeds of the Darwin Woollybutt (*E. miniata*) and Swamp Bloodwood (*E. ptychocarpa*). These seeds are worth gathering because of their size. Indeed, the Darwin Woollybutt produces its seed bounty in gumnuts as big as eggcups (up to six centimetres long and five centimetres wide).

Some eucalypts, especially the bloodwoods, secrete so much nectar that Aborigines could suck it straight from the flowers, or dunk sprays of the flowers in water-filled containers to produce a sweet drink. The nectar has a tangy, dark-honey taste.

The Western Bloodwood (*E. terminalis*), a common outback tree, produces an unusual food known as the bush coconut or desert apple. It is a nobbly, apple-sized gall produced on the stems by a coccid bug larva (*Apiomorpha pomiformis*) that lives inside. Aborigines relish the inner layer of the gall, which tastes like sweet coconut, and also eat the sweet grub. The Western Bloodwood is also a source of edible lerp, 'sugar-bag' (native bee honey), medicinal gum-like kino, and water, which can be drained from the roots. No wonder this tree often featured in Aboriginal mythology.

But the most extraordinary eucalypt foods are the sticky-sweet saps secreted by two gum trees, one in south-western Australia and the other in Tasmania. Settler Ethel Hassell, who lived north-east of the Stirling Range in Western Australia, told of how Aborigines obtained a "thick, purplish syrup" by stripping and scraping the bark of yate trees (*E. cornuta* or *E. occidentalis*): "They often eat this syrup like honey, and said it was very nourish-

Darwin Woollybutt was an Aboriginal calender tree; on Groote Eylandt its flowering signalled that honey would be plentiful in wild bees' nests.

PHOTOS: TIM LOW

Swamp Bloodwood has become a very popular garden tree, thanks to its showy red, pink or white flowers, and large shiny leaves.

ing. I have frequently eaten it and it tastes like a mixture of treacle and honey."

The other syrup producer is the Cider Gum (*E. gunnii*), found on the hills and plains of Tasmania's cold Central Plateau. There are remarkable old accounts of how Aborigines incised the trunks of this tree and made holes at the base into which the sap flowed. A flat stone was kept over the holes to stop birds and mammals from drinking the syrup. If left for any length of time, it fermented into an alcoholic 'cider' on which Aborigines (and later settlers) regaled themselves. According to the colonial doctor John Macpherson: "At Christmas time, in 1826, the Lake Arthur blacks indulged in a great eucalyptus cider orgy". Bottles of this curious brew were sent to British botanist W.J. Hooker in 1884.

Stephen Harris, of the Tasmanian Department of Parks, Wildlife and Heritage, has proposed the harvesting of this sap as a flavouring essence or maple syrup substitute. In a fascinating paper to the Fifth Symposium of Australian Gastronomy held in Adelaide in 1990, he reported that a preliminary assessment indicated a potential annual production of at least 15 litres from one tree. If 1,000 yielding trees could produce 15,000 litres, then the indicated retail value would be around $300,000, using the retail price of maple syrup as a guide. He suggested the eventual establishment of plantations to ensure the conservation of wild stands of the tree. Biological work is required to determine whether the production of the cider is environmentally controlled (that is, only produced in slow growth conditions in the cold uplands) or genetically controlled and therefore subject to selection for high yield, and also whether young trees are capable of producing the same quantity of sap as old trees.

Harris concluded: "The syrup may provide a distinct alternative to maple syrup, the production of which is declining drastically in the northern hemisphere due to the death of trees from the effects of acid rain". Cider Gum has the potential to become a food crop as significant as the macadamia nuts (*Macadamia integrifolia* and *M. tetraphylla*), currently Australia's only contribution to international cuisine. ■

This Western Bloodwood is growing in Palm Valley, south-west of Alice Springs.

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Tim Low, B.Sc. is a full-time nature writer. He is the author of four books, the most recent of which, Bush Tucker *(1989) and* Bush Medicine *(1990) include articles reprinted from ANH.*

"But what about the Institute, I asked myself, as I followed this tanned, name-dropping don through the shambles of his old pile."

DR SINCLAIR'S INDULGENCE

BY ROBYN WILLIAMS
ABC RADIO SCIENCE SHOW

THE 'INSTITUTE' IS A LITTLE WAY FROM Oxford. You drive along a few of those fast grey highways that surround the old city, then turn off to pleasant Abingdon and on to Sutton Courtnay. When I got a little lost the villagers knew immediately whom I was after. "Oh, you want Dr Sinclair. He's down the main road till you see the great big gates. Then it's along the drive to the old mansion."

And, indeed, that's where he turned out to be, although I had to trudge in bewilderment through the vast grounds, past the splendid marquee where there were still signs of yesterday's champagne and strawberries, in between the rows of marble statues of smooth Greek boys, to the quietly festering swimming pool where Dr Sinclair lay on a stone bench, completely naked.

"Oh, you really should have come to the garden party" he said hurriedly as he pulled on some pants. "We had all the members of the Council, Lord Thing came from London, and there was the Professor of Whatsit from Cambridge and. . .would you like to see the plans for the Institute?"

He led me through the gardens and the hidden surprises of elaborate fountains and Japanese grottoes. We came to the main building. "It's got 19 bedrooms and lots of space, but it really isn't terribly old." It turned out to be a 19th-century folly dressed up as Tudor, impressive nonetheless. But it was the inside that proved to be astonishing.

Everything was covered in ancient dust and cobwebs. There were ancestral portraits, towering bookshelves, velvet curtains, even suits of armour, all bedecked in fine layers of filaments and filth, like the Hollywood set for a ghost movie. "You must look at these" enthused my guide. Although well into his 80s, he was a lively robust man with little twinkly eyes. "They're the plans."

They certainly were plans, a model of laboratories, buildings, even little plastic trees stuck about to make it realistic. It did seem to be impressive. But the model, too, was deep in dust. Nearby, a large billiard table was laid out with testimonials and pictures: Dr Sinclair with the Queen Mother, Dr Sinclair with various Nobel Prize winners, Dr Sinclair at Oxford.

There was no doubting his academic record. He'd been educated at Winchester, one of England's most formidable intellectual hothouses, where he'd won the Senior Science Prize. Then to Oriel College, Oxford, and a first-class Honours degree in animal physiology. By 1937, after a clutch of prizes and medals, he was installed as a Fellow of Magdalen College, where he was to remain for the next 53 years. During that time he tutored hundreds of young men who went on to become the medical and biological elite around the world, including Australia.

The late Dr Hugh Macdonald Sinclair.

It was Dr Sinclair who pointed to saturated fat as the villain in the piece of Western diet. In his most notorious experiment, having had his interest primed by contact with the Inuit in North America, he put himself on an Eskimo diet—nothing but fish and seal for 100 days. He kept the seal carcass in the fridge and carved bits off; the fish wasn't so hard to manage. "But I had to abandon the experiment after that because I began to smell so very badly!"

It was long enough, though, to show that the nature of his blood had changed—its tendency to clot had been remarkably reduced. This was, perhaps, what lay behind the Eskimos' ability to resist cardiovascular disease when on a traditional all-meat diet, in complete contrast to Western people. There was something different in the meat they consumed. It was polyunsaturated.

Since that experiment (which Dr Sinclair, characteristically, never got around to writing up properly) every household knows something about the perils of cholesterol and dietary sludge. It's like eating Araldite. He became established as an internationally respected authority on nutrition. He edited the *International Encyclopedia of Food and Nutrition*, won the United States Medal of Freedom (with Silver Palm), and established the International Institute of Human Nutrition, becoming its director in 1972.

But what about the Institute, I asked myself, as I followed this tanned, name-dropping don through the shambles of his old pile—the remains of his garden party where the medical establishment of England had just met once more to advise on the 'Institute's' progress—out into the timeless summer light that always graces Oxford, and has done, according to those who belong, since the beginning of time.

I was still wondering when I reached Oxford itself, having said goodbye to Dr Hugh Macdonald Sinclair and his trees and statues. The next day I saw Colin Blakemore, whom I know quite well. He's Professor of Physiology at Oxford and well known for his work on vision and his films on science, such as "The Mind Machine", which won him the Faraday Prize of the Royal Society.

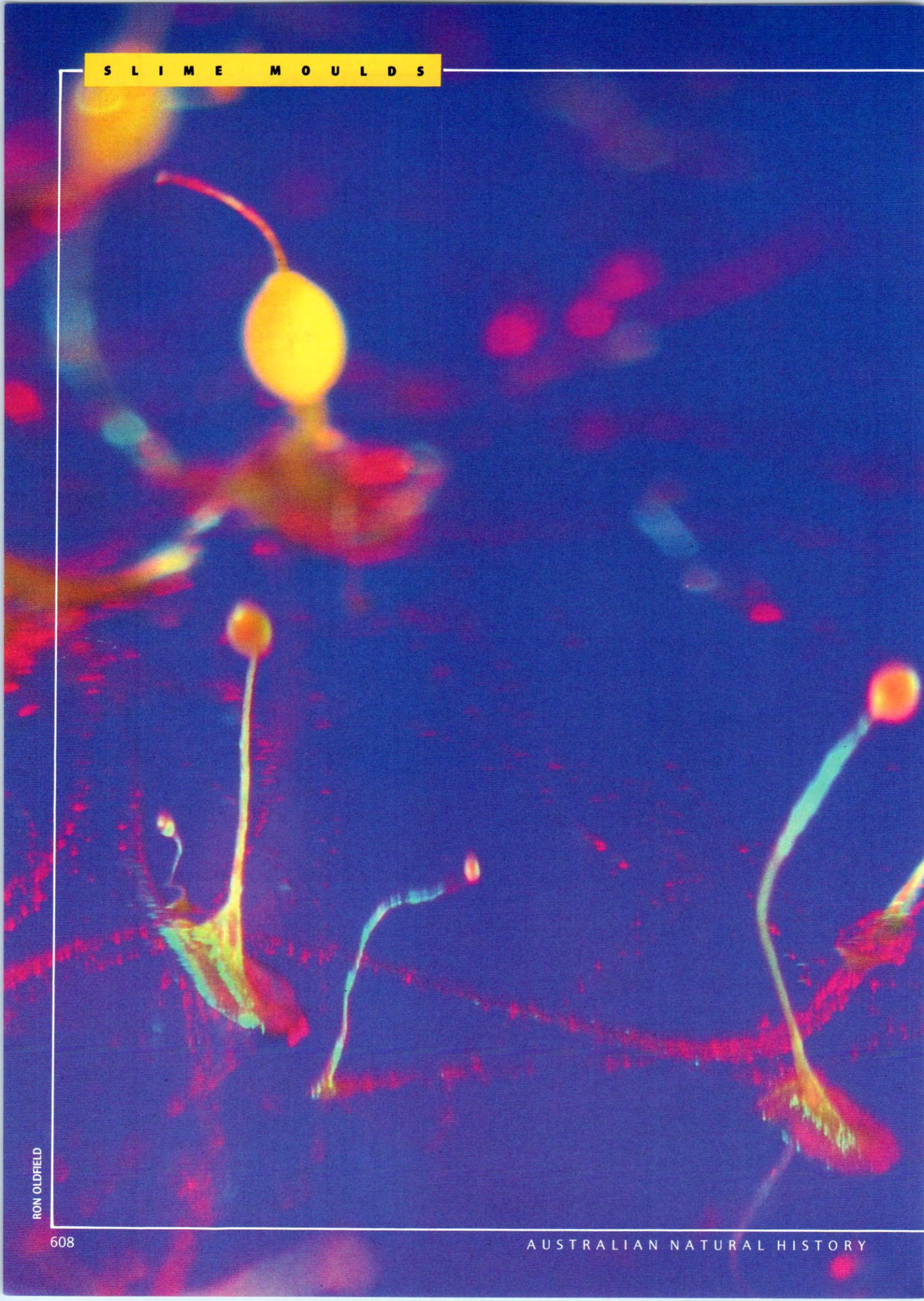
"The International Institute?" he smiled. "Why that's Hugh's indulgence, and they all go along with it."

"Do you mean" I asked in amazement "that, year after year, all these renowned scientists turn up, have a lunch, pretend to sit on a council to run an institute, and it's all sham?"

"Well, at least Hugh seems to believe in it" he said. "And I suppose that the others are too polite to show their doubts until he goes."

Hugh Sinclair died in late June, 1990. I can't imagine what will happen to his 'Institute' nor who will have the job of fossicking through the secrets of the strange old man who lived alone for so long. But then it could only happen in Oxford! (Don't you believe it!) ■

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



RON OLDFIELD

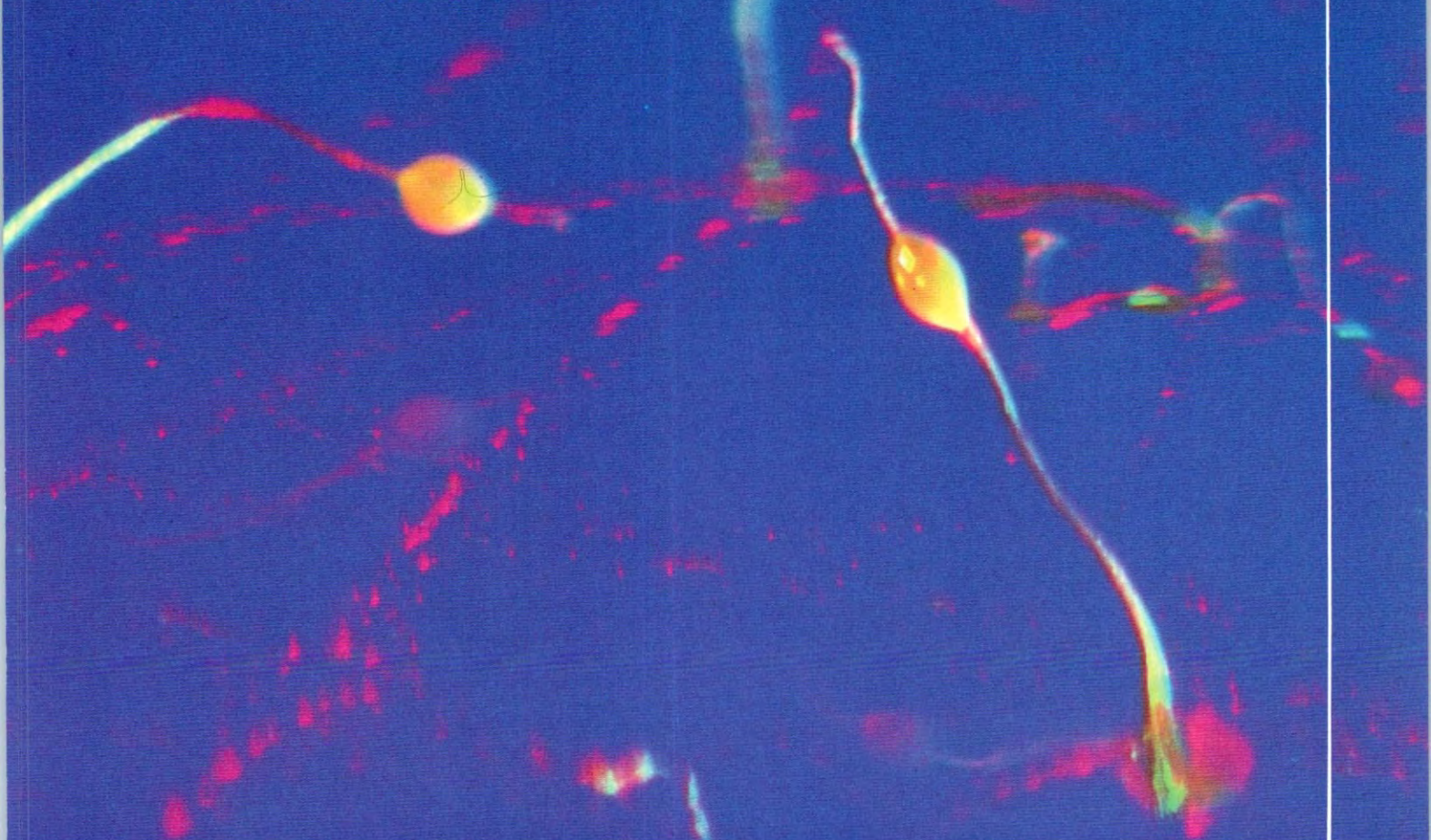
"The study of slime moulds has led to important findings in animal cell and developmental biology, and is helping us understand just what makes multicellular organisms tick."

MODELLING PEOPLE USING CELLULAR SLIME MOULDS

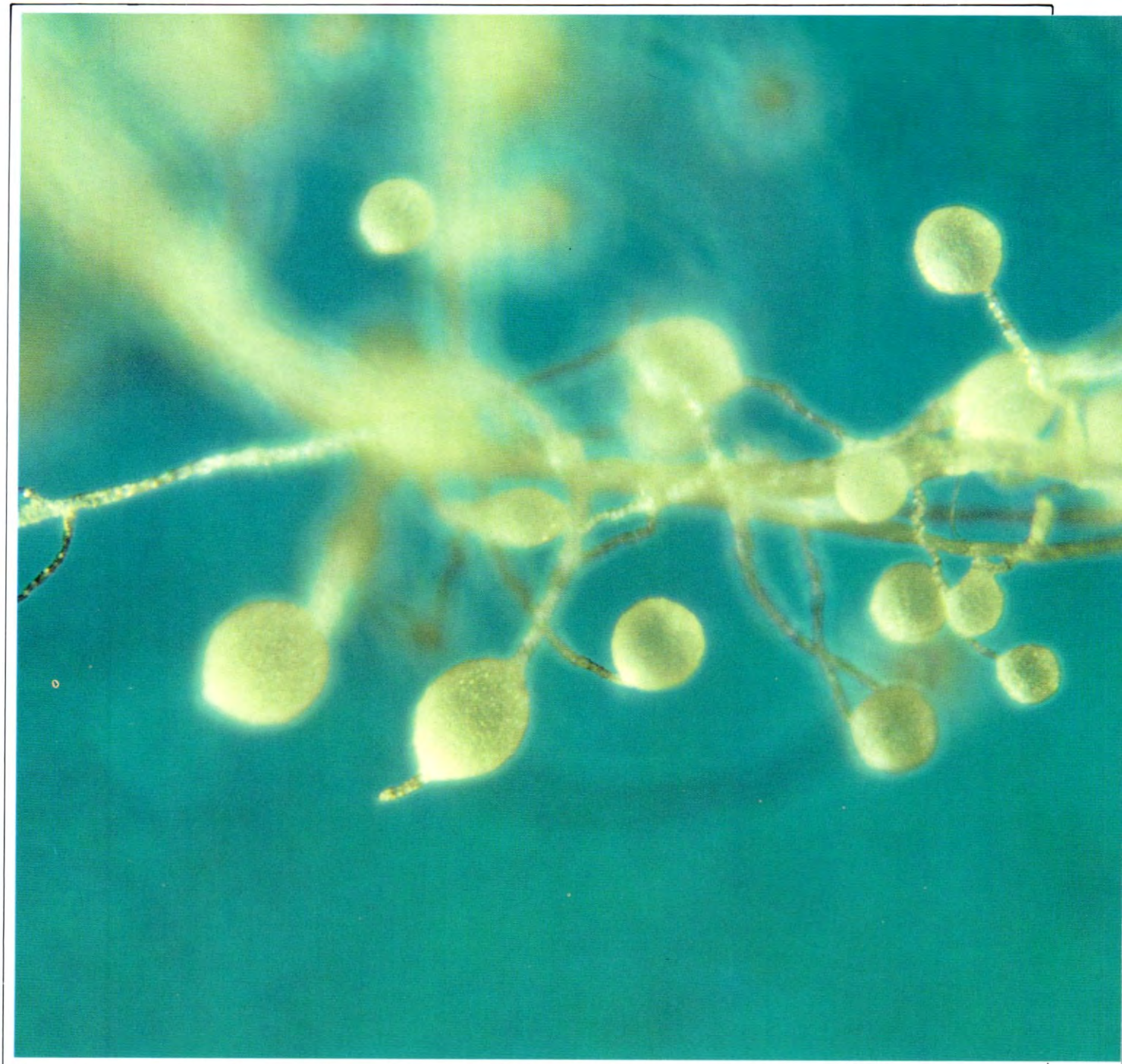
BY SUSANNAH ELIOTT & KEITH L. WILLIAMS
SCHOOL OF BIOLOGICAL SCIENCES, MACQUARIE UNIVERSITY

ROUGHLY A BILLION YEARS AGO, single cells, the basic units of life, began to interact and form multicellular communities. This cooperation had immense benefits—instead of having to deal with all the problems of life within the confines of a single cell, specialisation was possible. Some cells could concentrate on obtaining food for the collective, while others specialised in defence or looked after administrative affairs. As these cellular communities evolved, individual cells became increasingly specialised until they could no longer survive outside the conglomerate. One group of organisms that still exists today gives us clues as to how these initial evolutionary steps may have occurred. These are the cellular slime moulds, a group of soil inhabitants that spend much of their time as single-celled amoebae but, in adverse conditions, aggregate to form a cellular collective.

At first sight, slime moulds and people appear to have little in common but,



Blue poles in yellow—or slime poles? A forest of slime mould fruiting bodies. These simple organisms are used to study how complicated animals like ourselves are constructed.



RON OLDFIELD

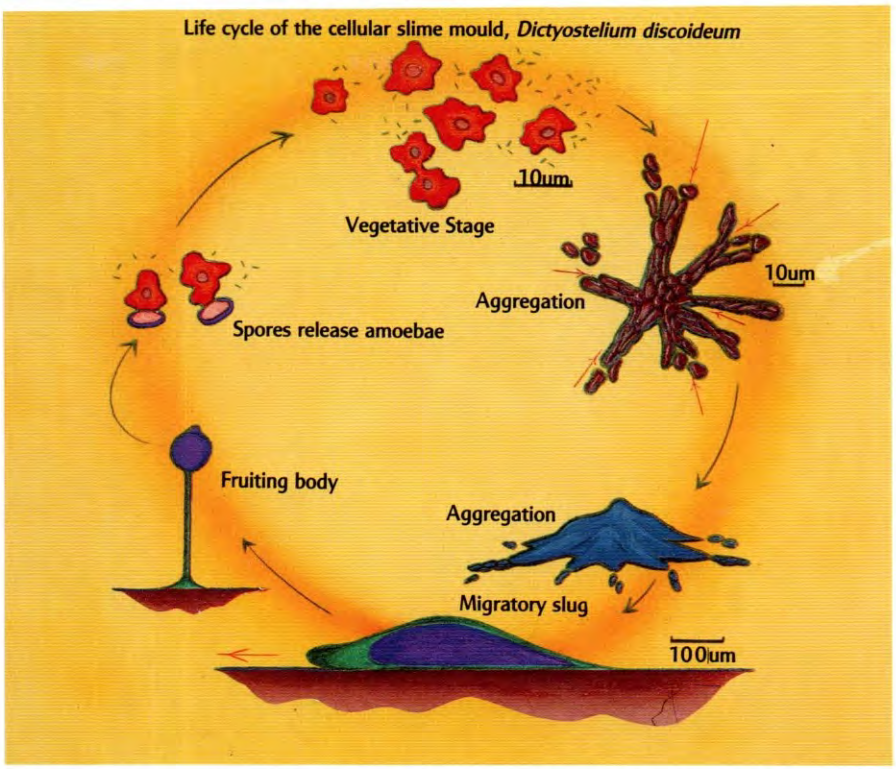
Slime moulds in the genus *Polysphondylium* form complicated fruiting bodies that have whorls of tiny fruiting bodies at intervals along the main stalk.

when it comes to the basic components, there are many similarities: single slime mould amoebae resemble our own white blood cells (the infection fighters) and the slime mould's multicellular stage displays features common to all multicellular organisms. To form a cellular collective, slime mould cells must adhere, communicate with each other and control their shape. The same applies to complicated organisms such as people.

Although slime moulds were first recognised in the 19th century, it was not until the discovery by Kenneth Raper in 1933 of *Dictyostelium discoideum* that this organism became popular as a model for studying how complex organisms are constructed. While there are some advantages to studying *D. discoideum*, any one of a number of species could have been chosen as the popular laboratory organism. More than 50 species of cellular slime mould have been described and this almost certainly represents but a fraction of the actual number of species.

SLIME MOULDS GROW AND DIVIDE AS single amoebae as long as there are plenty of bacteria to eat. If they run out of food, however, a remarkable series of events takes place, which results in the amoebae cooperating to ensure the survival of some of their number in adverse conditions. Starved cells release a pheromone-like chemical that signals other hungry slime mould amoebae to aggregate. Like a bizarre pilgrimage, the cells stream together forming a miniature mountain. This mound then falls on its side to form a small slug-like creature.

Although formed by the aggregation of individual amoebae, the *D. discoideum* 'slug' looks and behaves like a discrete organism. The slug moves through the soil for up to three or four days without eating. Slug cells secrete a slimy material that covers the slug as it migrates, thus leaving a trail of slime behind it as it goes. The slime probably protects the tiny organism from drying out, and provides a constant surface on which the cells move, rather like laying down their own road! The slug is attracted to the light, and so moves towards the surface of the soil where it transforms into a plant-like structure called a fruiting body. About 70 per cent of slug cells form the thick-



IAN FAULKNER

Life cycle of *Dictyostelium discoideum*. The slug consists of two cell types: cells that will make up the stalk of the fruiting body ('prestalk' cells) occupy the anterior portion of the slug and extend around the outside (green); cells that will become spores ('prespore' cells) remain at the rear of the slug (purple).

walled spores of the fruiting body, and the remaining 30 per cent make up the basal disc and stalk. These latter cells are especially interesting as they die in the process of increasing the chance of spore dispersal and thus display a kind of altruism. The spores are presumably dispersed by passing insects, wind, rain etc., those that end up in more favourable conditions (where there is food) germinating to release single amoebae back into the soil.

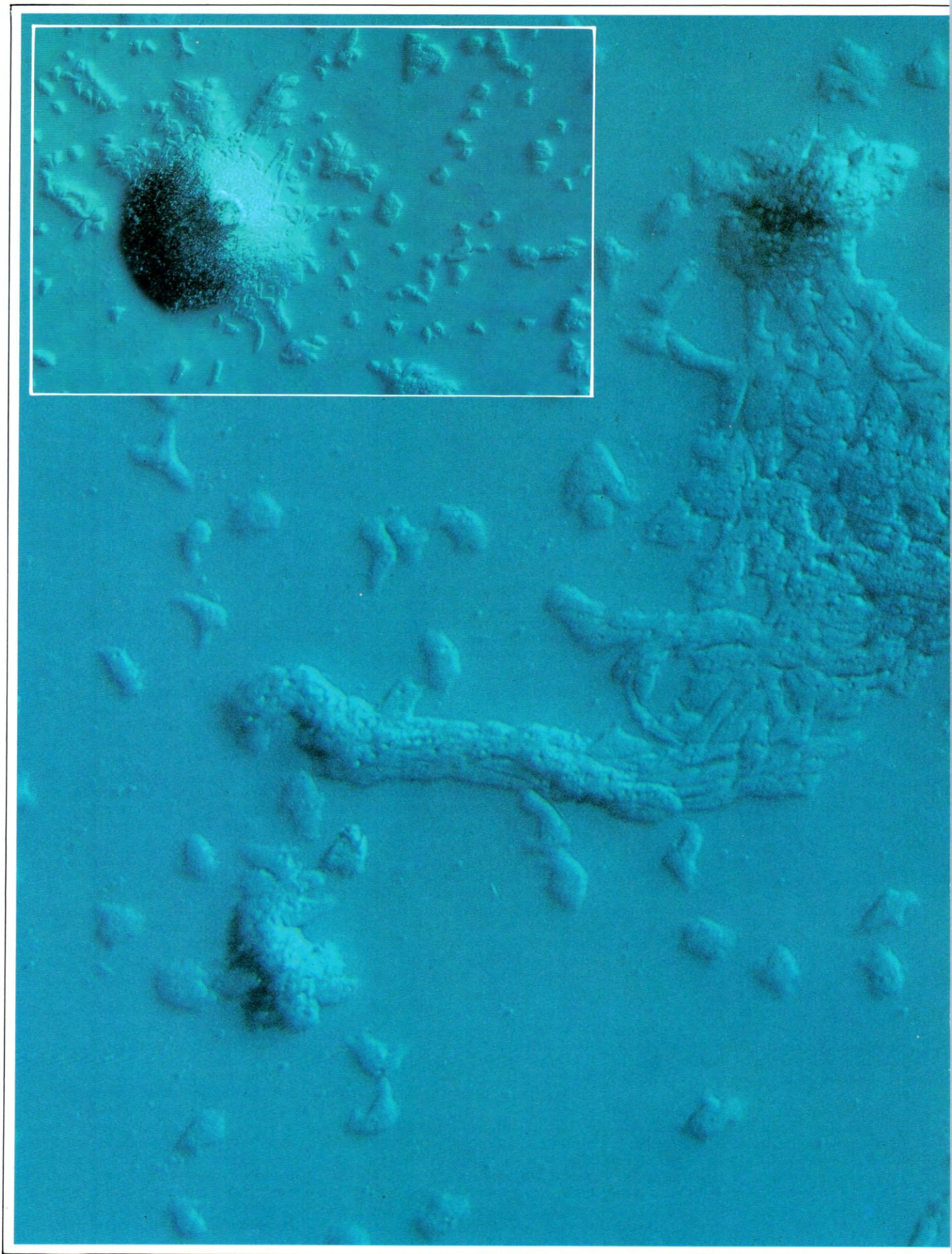
The size range of the multicellular stage of *D. discoideum* is breathtaking. Whereas the size of adult humans lies in the range of about one to three metres (or about a three-fold range in height), the *D. discoideum* fruiting body can be as short as one-twentieth of a millimetre or as tall as five millimetres (a 100-fold range in size). Fruiting bodies can contain as few as 13 or as many as a million cells. While most species of cellular slime mould form a fruiting body consisting of spores and stalk cells, some make a simpler fruiting body, which is comprised of spores with a non-cellular stalk. In these species the stalk material is secreted by all cells. Some species, such as *Nematostelium ovatum*, make a miniature fruiting body of only a single spore on a tiny acellular stalk less than one-hundredth of a millimetre tall. Others, such as those in the genus *Polysphondylium*, make a tall cellular stalk (up to almost a centimetre) with small clusters of fruiting bodies branching off at regular intervals. These are perhaps the most delicate and beautiful of all the slime mould fruiting bodies.

In Australia, slime moulds have been isolated in diverse habitats, ranging from snow country near Canberra to mangroves on Lizard Island. The species range is similar to that found in other countries, with members of the *Dictyostelium mucoroides* complex, *Dictyostelium purpureum* and *Polysphondylium pallidum* being common. *Dictyostelium discoideum* appears to be restricted to the Americas and Japan. Cellular slime moulds come in one of three basic colours: white, yellow or various shades of purple.

The cellular slime moulds are much more than a biological curiosity. Unlike more complex experimental animals, such as rats and monkeys, the entire life cycle of *D. discoideum* can be observed in a petri dish over less than a day. Large numbers of cells can be easily cultured in the laboratory. The study of slime moulds has led to important findings in animal cell and developmental biology, and is helping us understand just what makes multicellular organisms tick.

One process that has remained a mystery is the formation of the animal embryo. After fertilisation, the egg undergoes numerous divisions to form a spherical mass of similar cells. Then, in a remarkable process called morphogenesis, cells move about within this mass taking on particular shapes and functions. Some cells form the brain and nervous system, for example; others make up the kidney, liver and so on until a complete embryo is formed. How these cell movements are coordinated and how each cell 'knows' what kind of cell to become remains a puzzle.

The *D. discoideum* slug is an ideal 'model' system for studying this complex process. Whereas an average slug consists of two or three cell types and about 100,000 cells, an adult human contains about 200 different cell types and roughly 100 billion (10^{14}) cells. Unlike the animal embryo, the slug is formed by aggregation of cells so the complications of cell division and growth are avoided when studying slime mould development. Cells that eventually become the stalk of the mature fruiting body ('prestalk' cells) form the nose of the slug and a type of primitive skin that envelopes the creature. Cells that form spores (the 'prespore' cells) occupy the posterior inner portion of the slug. The same sorts of questions asked about the animal embryo can be asked about slime mould development: how do cells 'know'



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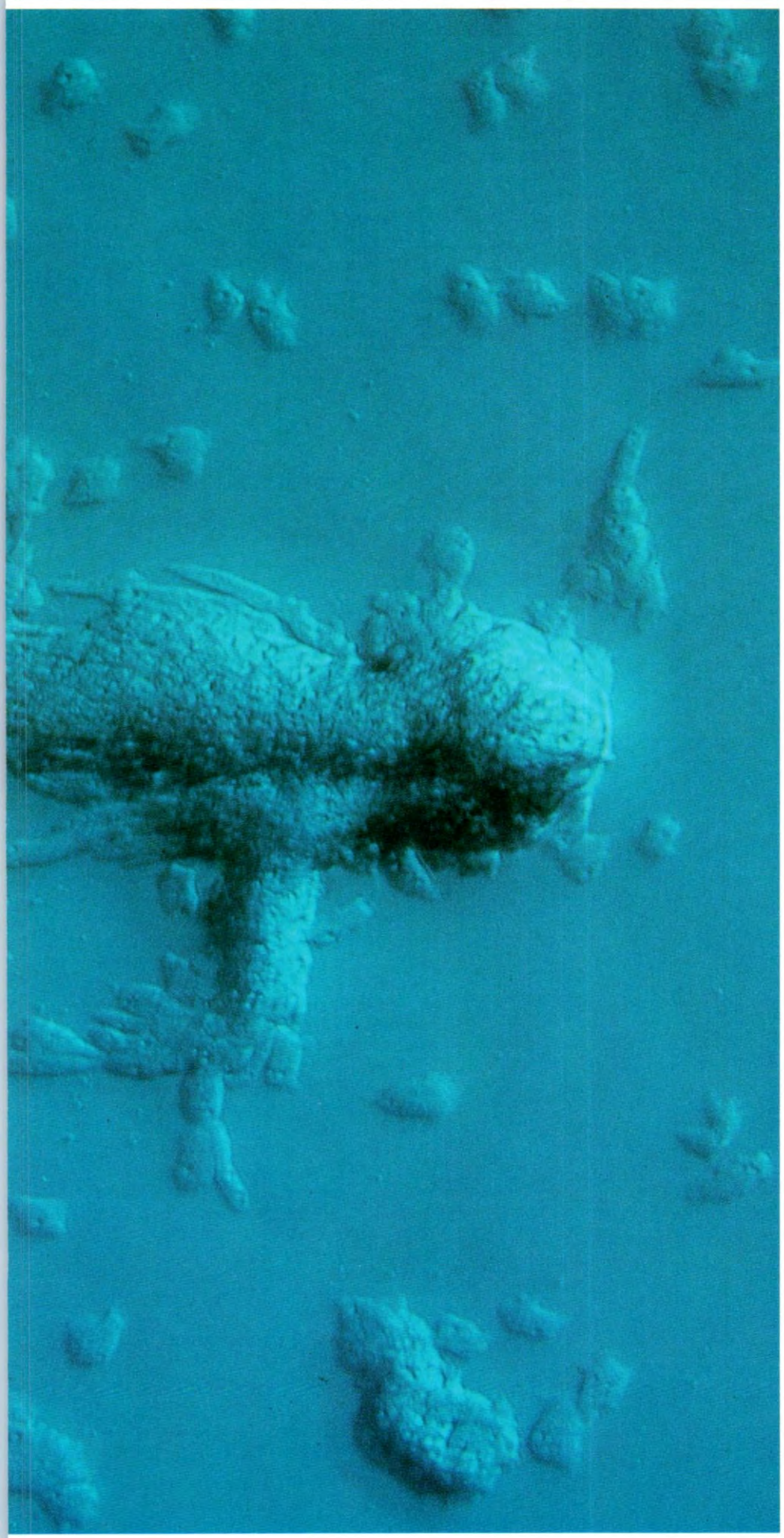


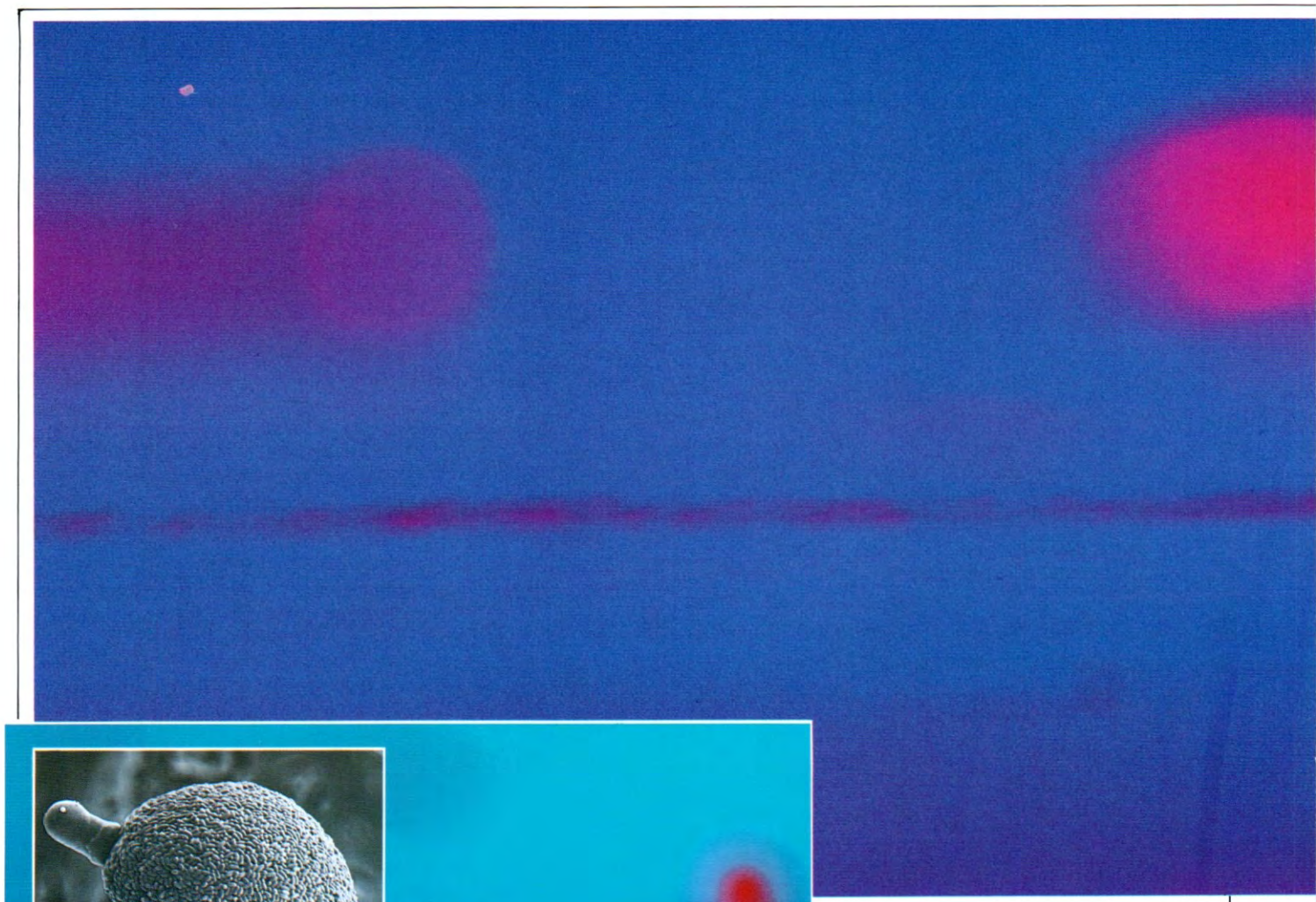
whether to be prestalk or prespore cells and, once decided, how do they avoid becoming mixed up? While such questions are far from fully answered, some clues are appearing.

TO BUILD A MULTICELLULAR ORGANISM the component cells must stick to each other. Cell adhesion in *D. discoideum* begins during aggregation; starvation leads to the manufacture of adhesive molecules (glycoproteins) that physically hold cells together, allowing them to form chains. The specificity of these sticky glycoproteins enables different species of slime moulds in the same soils to recognise and selectively adhere only to cells of their own species. Many of the techniques used to study adhesion in mammalian development were pioneered in aggregating *D. discoideum* amoebae.

If you mash up a liver and a kidney, and mix the two cell types together, they will sort out from each other, liver cells sticking to other liver cells and kidney cells to other kidney cells. The same thing happens with a disaggregated *D. discoideum* slug: prestalk cells bind to other prestalk cells and prespores to other prespore cells. This differential adhesion is one of the reasons why the different cell types within all multicellular organisms form separate tissues. (If this were not the case we would all be shapeless masses without distinct structure!) Differential adhesion is probably just one of a variety of mechanisms that enable cells to recognise each other. Understanding how these mechanisms work to maintain a normal human being will undoubtedly help us determine what happens when things go wrong (leading to birth defects and cancer, for example).

It is not enough for cells within an organism to stick together, they must also be able to communicate with each other in order to coordinate their activities. One of the earliest discoveries by researchers on *D. discoideum* was that single amoebae send each other chemical messages when they aggregate. The chemical used, cyclic AMP, is also a common messenger molecule inside cells of our own bodies. When cyclic AMP binds to the surface of aggregating *D. discoideum* amoebae, three things happen: within a few seconds the amoebae move towards the source of the cyclic AMP signal; then after about a minute, the amoebae release cyclic AMP themselves, amplifying the message. Finally, a range of genes specific for life as a

Single slime mould amoebae live in moist soils where they move about by extending projections called pseudopodia (meaning 'false feet'). They live as single cells indefinitely (main photo) unless they run out of bacteria to eat. Each amoeba is about one-hundredth of a millimetre in size. Starving amoebae send messages to each other that enable them to aggregate, forming a small mound of about 100,000 cells (inset).



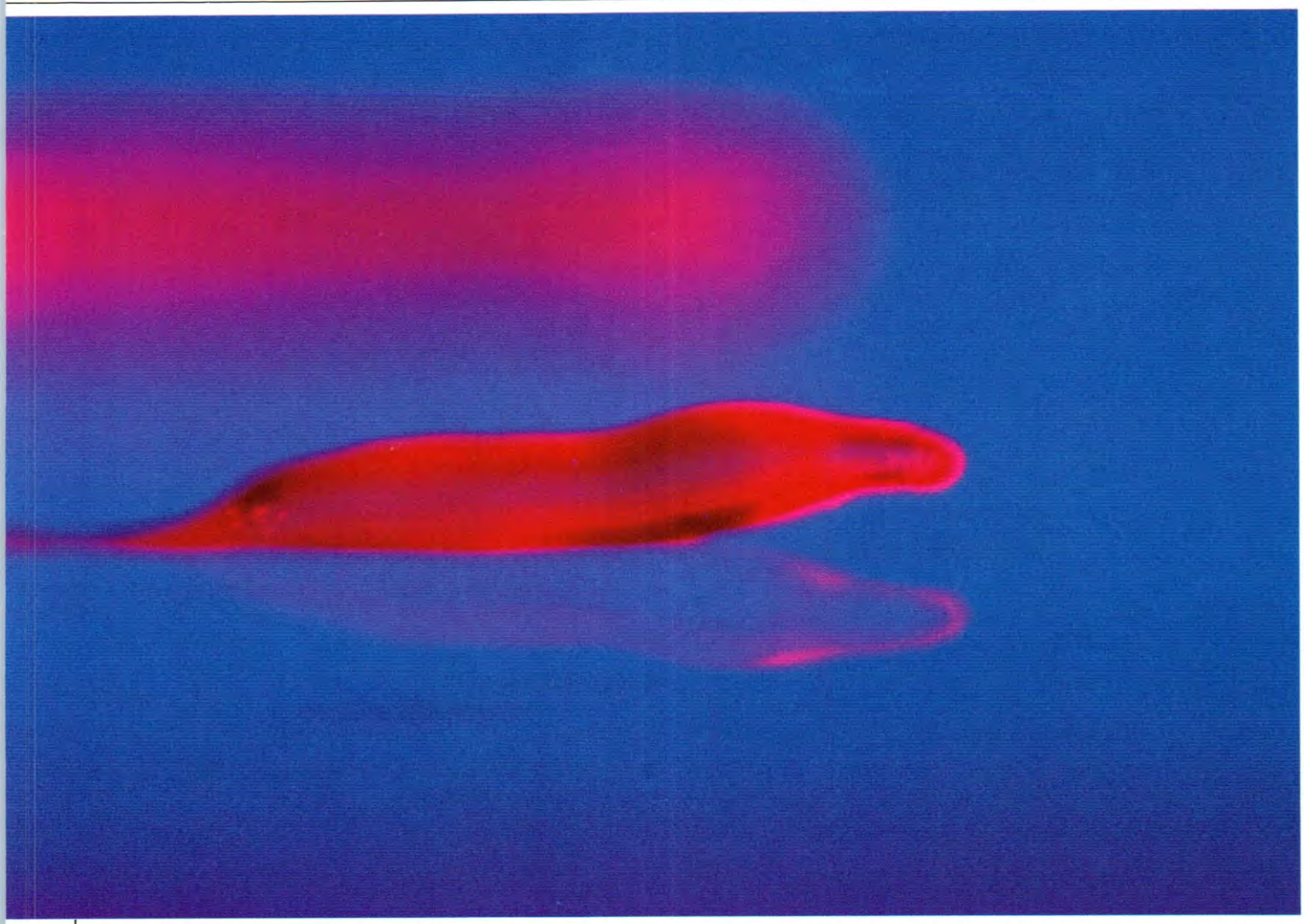
SUE DOYLE

RON OLDFIELD

slug or fruiting body are activated (this takes several hours). Recent research is beginning to unravel the molecular wiring behind this signalling process.

If a signal is to be effective there must be a means to control it. Sending messages between cells is a bit like using morse code: it's no use having one long continuous signal because it will not make sense. The signal must be broken up into a series of beeps that are intelligible to the receiver. This is done in *D. discoideum* by releasing pulses of the signal (cyclic AMP) and destroying it using an enzyme called phosphodiesterase. Although the chemical signal is different and the process less well understood, similar things probably occur within our bodies when white blood cells are attracted to wounds. Only in recent years has it become clear that cell signalling is used in almost all aspects of cell behaviour and development, including hormone action, immune responses and even memory. At the biochemical level, the triggering of these processes is analogous to the events occurring when a starving *D. discoideum* cell receives a cyclic AMP signal.

The slugs eventually form a specialised plant-like structure called a 'fruiting body', which consists of a ball of tough resistant spores about five microns long (inset) atop a slender stalk about two to three millimetres long.



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The miniature mountain of slime mould amoebae falls on its side forming a small sausage-shaped organism, the slug, that migrates through the soil. This photograph shows a slug moving across an agar plate.

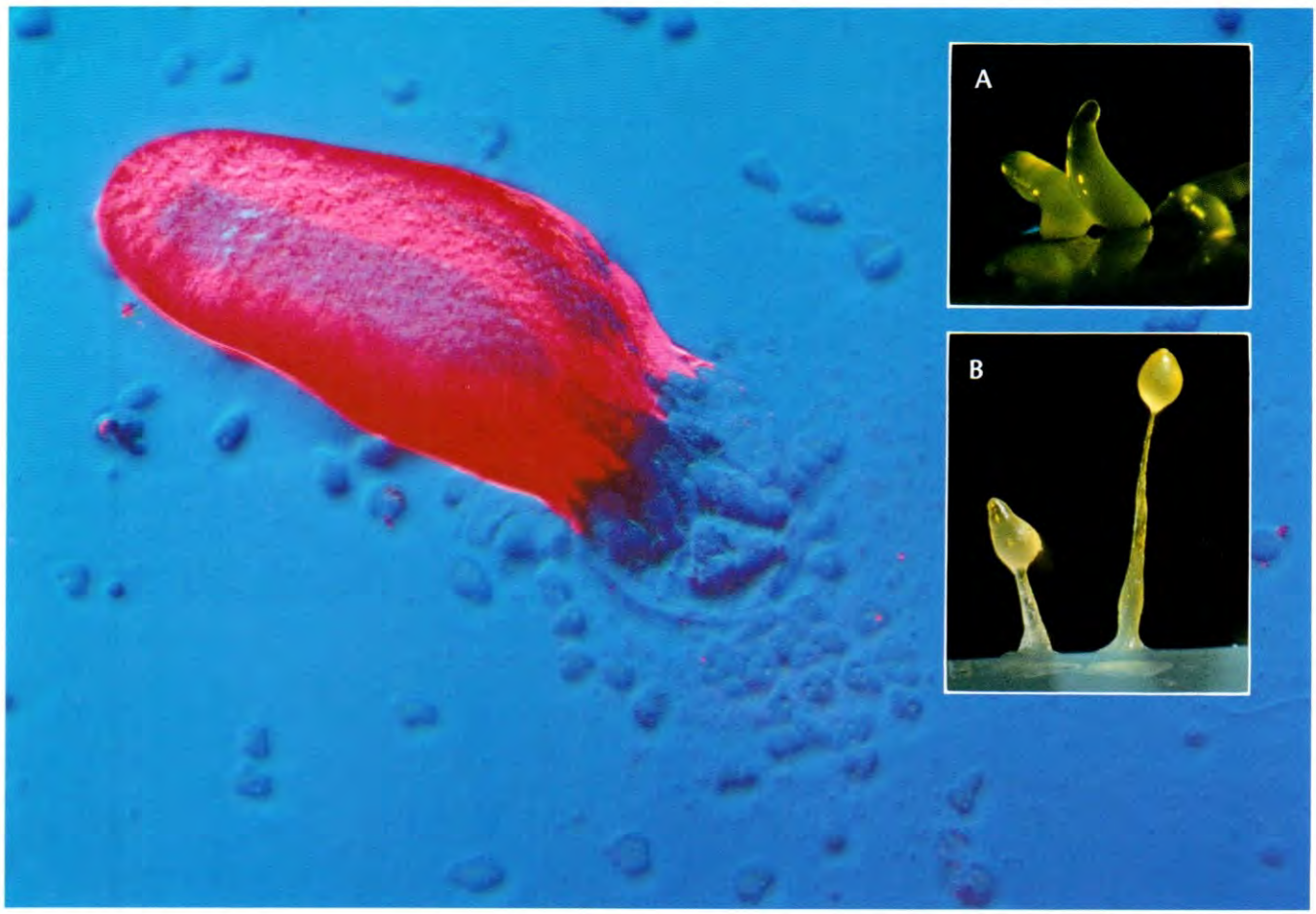
Cell shape becomes crucial in a cellular collective and individual cells must coordinate their shape to maintain the integrity of the whole tissue. Until recently, the eukaryotic (or nucleated) cell was thought to be a bag containing organelles surrounded by an unstructured fluid, the cytoplasm. We now know that the cytoplasm contains an intricate network of protein fibres of various sizes and shapes (the so-called 'cytoskeleton'; 'cyto' meaning 'cell'). It is the cytoskeleton that gives cells their shape and enables them to move. In a multicellular organism the shapes of individual cells ultimately determine the shape of the whole organism. If cells were just jelly, so would we be!

Dictyostelium discoideum has become popular for studying cell shape because cytoskeletal fibres can be observed directly in living cells or isolated in large quantities for studies in the test tube. The two structural proteins found in muscle (actin and myosin) have received special attention, since they are also found in non-muscle animal cells (and slime moulds!) where they are involved in cell division, movement and determining cell shape. Actin and myosin filaments have been known for many years, but the puzzle has been how they operate at the molecular level. Recently, a whole range of other proteins have been discovered that act as the nuts and bolts of the cytoskeleton, attaching actin and myosin fibres to the cell membrane, and controlling their length and position within the cell. This represents a new lead in understanding how cells control their shape, divide and move.

In a few simple organisms, including *D. discoideum*, genetic engineering techniques are available for specifically disrupting genes. The importance of any protein can be examined by disturbing its gene, so that the protein is no longer made. *Dictyostelium discoideum* has been engineered so that it is unable to make myosin. Cells still survive as single amoebae, although they divide erratically. While these myosin-less cells aggregate and form spores and stalk cells, they are unable to construct a slug or fruiting body because the cells don't have enough control over their shape to make a proper tissue. This shows that there is more to making an organism than making the right types of cells!

OFTEN INDIVIDUAL PROJECTS IN SCIence are, of necessity, extremely specialised and concentrate on a small part of a much larger problem. To understand how a whole organism is constructed, however, the various pieces of the jigsaw must be fitted together. The next challenge in slime mould research is to integrate the pieces in order to describe the development of the whole slug and fruiting body, thus combining studies on cell signalling, adhesion and cell shape (the cytoskeleton). Time must also be included in any such study. Mutant *D. discoideum* strains that have rapid development are known. Spore and stalk cells are made in the correct proportions, but the developmental process is speeded up so that cell movements are uncoordinated and the multicellular phase is a mess. Thus it is not enough for cells to 'know' *what* to become, they must also 'know' *when* to become it.

Not only are slime moulds useful models, they also have potential on the commercial front, in the realm of biotechnology. Many human proteins are needed in medicine (such as insulin and growth hormone), but are difficult to obtain. This is because they often occur in small quantities and, until recently, could only be isolated from human blood, dead people or other mammals. Modern technology has overcome this problem by genetically tricking simple organisms like bacteria into manufacturing human proteins. These cells can then be grown very cheaply in large quantities. Bacteria, how-



RON OLDFIELD

ROB KAY

ROB KAY

IS IT A PLANT, IS IT AN ANIMAL, IS IT A FUNGUS?

In biology we are used to dealing with organisms that can be classified as plants, animals, fungi, protozoans (single-celled organisms), or bacteria. But, as befits a group of organisms as curious as the cellular slime moulds, it is apparent that they do not exist to fit into neat categories! It is hard to pin down exactly what a slime mould is. Sometimes they are single cells like the protozoans, but they can also be multicellular and have features similar to plants, animals and fungi. The slime mould fruiting bodies look very mould-like (hence their name) and they are often classified with the fungi, although this remains controversial. Working out the evolutionary relationships between the cellular slime moulds and other organisms is further hindered by their almost complete absence from the fossil record.

Although this article emphasises the animal-like nature of slime moulds, their plant-like features are equally interesting. Cellulose is a major structural component of plant cells, and it is one of the features that distinguishes plants from animals. *Dictyostelium discoideum* makes cellulose as a major structural component of the slime and in the walls of the (plant-like) mature stalk and basal disc cells. Surprisingly little is known about how cellulose is synthesised in any organism. Recently, enzymes from slime mould cells have been reported to synthesise cellulose in a test tube. This is an exciting breakthrough in research on one of the world's most common molecules.

Close-up of a slime mould 'slug'. Individual cells seen in the background have failed to join the aggregate. The red colour has been produced using filters to visualise the slug's texture. Slugs vary in size from about one-tenth of a millimetre to one millimetre. Inset: stages in fruiting body formation of *Dictyostelium discoideum*. A. Transformation of slugs into the 'standing finger' stage. B. Formation of mature fruiting body.

ever, are unable to modify proteins in the same way as animal cells. Therefore other more sophisticated biological factories have been sought. The problem is that the more complex the organism, the more complicated and expensive is culture of its cells.

Dictyostelium is an attractive compromise, since it is almost as easy and cheap to grow as bacteria, yet, as we have seen in this article, it has many features common to sophisticated animal cells. A major advantage of *D. discoideum* is that it contains plasmids (circles of DNA), which have made genetic engineering in bacteria so easy; this is quite unusual for complicated cells. Research on the use of *D. discoideum* in biotechnology is only just beginning. It is possible, however, that in ten years time *D. discoideum* will be a popular organism in biotechnology. Perhaps the newspaper headline "Cancer cure from slime factory" is not as far fetched as one might think!

So much for slime moulds in the laboratory, where considering them as 'simple people' is helping us to understand ourselves. What about slime moulds in their natural environment? To this day very little is known about the ecological importance of these bacterial predators, which undoubtedly provide a significant link in the food chain in the soil. With increasing interest in the environment, perhaps more attention should be paid to the slime moulds in soils and to the effect of agricultural cropping practices on their abundance. There is some indication that their numbers drop in soils used heavily for agriculture. Maybe they could be used as an early warning system for monitoring the 'health' of soils? ■

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Susannah Eliott is a Ph.D. student in the School of Biological Sciences at Macquarie University. Her thesis project involves the study of molecules involved with the coordination of cell shape in the Dictyostelium *slug. Professor Keith Williams runs a research group in the School of Biological Sciences at Macquarie University that concentrates on the use of* Dictyostelium *as a model for tissue formation. A second major interest is the use of* Dictyostelium *in biotechnology.*

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WHERE HAVE ALL THE FROGS GONE?

"When the declines of frog populations are examined, there remains a large number of instances that defy explanation. Why have they disappeared, and why have the disappearances of frogs on several continents happened simultaneously?"

BY MICHAEL J. TYLER
DEPARTMENT OF ZOOLOGY, UNIVERSITY OF ADELAIDE

THE SOUND OF A HUGE CHORUS OF male frogs in a marsh inviting females to join them is either music or a din, depending upon your point of view. Aristotle complained bitterly at the disruption of his sleep, whilst French landowners once required peasants to silence the local choirs by beating the reeds with sticks. But today the ponds are silent and in many countries people are asking "Where have all the frogs gone?"

I'm concerned because I'm a frogophile and I accept that others may need to be convinced of the significance of declines in frog populations. Is this just an acceptable price that we must pay for a developing world or are frogs a subtle early-warning system of an environmental degradation that we have not noticed?

IN 1980 TWO FROG SPECIES ABUNDANT BUT localised in south-eastern Queensland disappeared without trace. One was the Gastric Brooding Frog (*Rheobatrachus silus*), which was the focus of worldwide

M. DAVIES

The Eastern Dwarf Tree Frog, *Litoria fallax*, once widespread in eastern Australia, is reported to be in decline throughout its range. No logical reason for its demise has been found. Right: the author, Mike Tyler, spends much of his time in the field surveying frog populations. It is a never-ending source of surprise to him that he hasn't developed webbed feet!

M.J. TYLER

One of the only series of photos of the northern Gastric Brooding Frog giving birth. This remarkable frog converts her stomach into a 'womb' and gives birth to live young through her mouth. Behind this baby frog are another 23 waiting to be born. Once plentiful, this unique species has not been sighted for ten years.

interest. The extraordinary habit of the female of swallowing her young, converting her stomach to a womb and, finally, giving birth to fully formed juvenile frogs through her mouth, had attracted the attention of the media.

The Gastric Brooding Frog was so plentiful that anyone in the right place would be guaranteed the chance to see them in the rock-strewn creeks. Then, without warning, there was none. Ten years later we still have not the slightest clue about the cause of their demise. This extinction, and it really does appear to be an extinction, was of national and international significance. The Diurnal Frog (*Taudactylus diurnus*) lived in the same geographic area as the Gastric Brooding Frog and it too disappeared at the same time.

In September 1989 frog and reptile specialists (herpetologists) gathered at Canterbury, Kent for the First World Congress of Herpetology. During the week of conferences, symposia and workshops, Australian participants discovered that in many countries frogs were on the decline.

Responding to a need to obtain hard facts about the declines, the National Academy of Science in the United States organised a meeting at the University of California's Irvine campus in February 1990. Entitled "Declining amphibian populations—a global phenomenon", it brought together specialists from several continents.

But why bother? Does it really matter if a few frog species become extinct? These are the kinds of questions that had to be addressed by anyone learning of the concerns being expressed for frogs. If you care about frogs as animals, then of course it matters; but the support of the uncommitted can be gained readily from case histories of the implications of a frogless world. What happens when frog numbers drop is well demonstrated in Asia as a result of the gastronomic preferences of Europeans and Americans.

AS A NATION, THE FRENCH HAVE ALWAYS been associated with eating the legs of frogs. Whenever conflict arises between England and France the English resort to calling the French "Frogs". It's a derogatory use—something vile.

I was introduced to frog meat at the village of Senonches in the province of Eure-et-Loire west of Paris. As an 11 year old I accompanied the collectors to the beautiful lake (L'Etang de Badouleau) where there lived a colony of the Edible Frog (*Rana esculenta*). The frogs were caught with rod and line. There was no hook—just a 2 × 2 centimetre square of red cloth that the fisherman would gently bounce on the surface of the water. Within moments frogs' heads would break the surface and they would leap and grab the lure. With a flick of the wrist the line would be jerked up with the frog still firmly holding the lure. With his free hand the fisherman would catch the frog in mid-air and pop it into a wicker basket. Back at home the frogs would be killed, the back legs severed and the skin pulled off them like a pair of trousers, dusted with flour, fried in butter and herbs, and served with a tossed salad.

No doubt the local lake had provided the villagers with a supply of frogs for centuries but in the 1950s the demand for frogs' legs in France exceeded local supplies and so they were imported, principally from eastern Europe. Imports now run at thousands of tonnes of legs each year. And it is not just the French that import them: the United States imported 7,066 tonnes in 1982 and 5,377 tonnes in 1983; Belgium 4,131 tonnes in 1983 and Italy 1,145 tonnes in the same year.

The average weight of the legs of the *Rana* species that form most of the trade is 40–50 grams. That means a minimum of 20,000 frogs per tonne. The extent of the trade is mind-boggling: we are looking at a situation of billions of frogs being killed each year. And, unbeknown to the exporters, the frogs had been performing a free insect control program. In agricul-

About 12 tonnes of frogs' legs are imported annually into Australia for human consumption. These are *Rana cateşbeina*, which are farmed in Indonesia. The French have consumed a staggering 40,000 tonnes of frogs' legs over the last six years, most of which are imported and often taken from wild populations.

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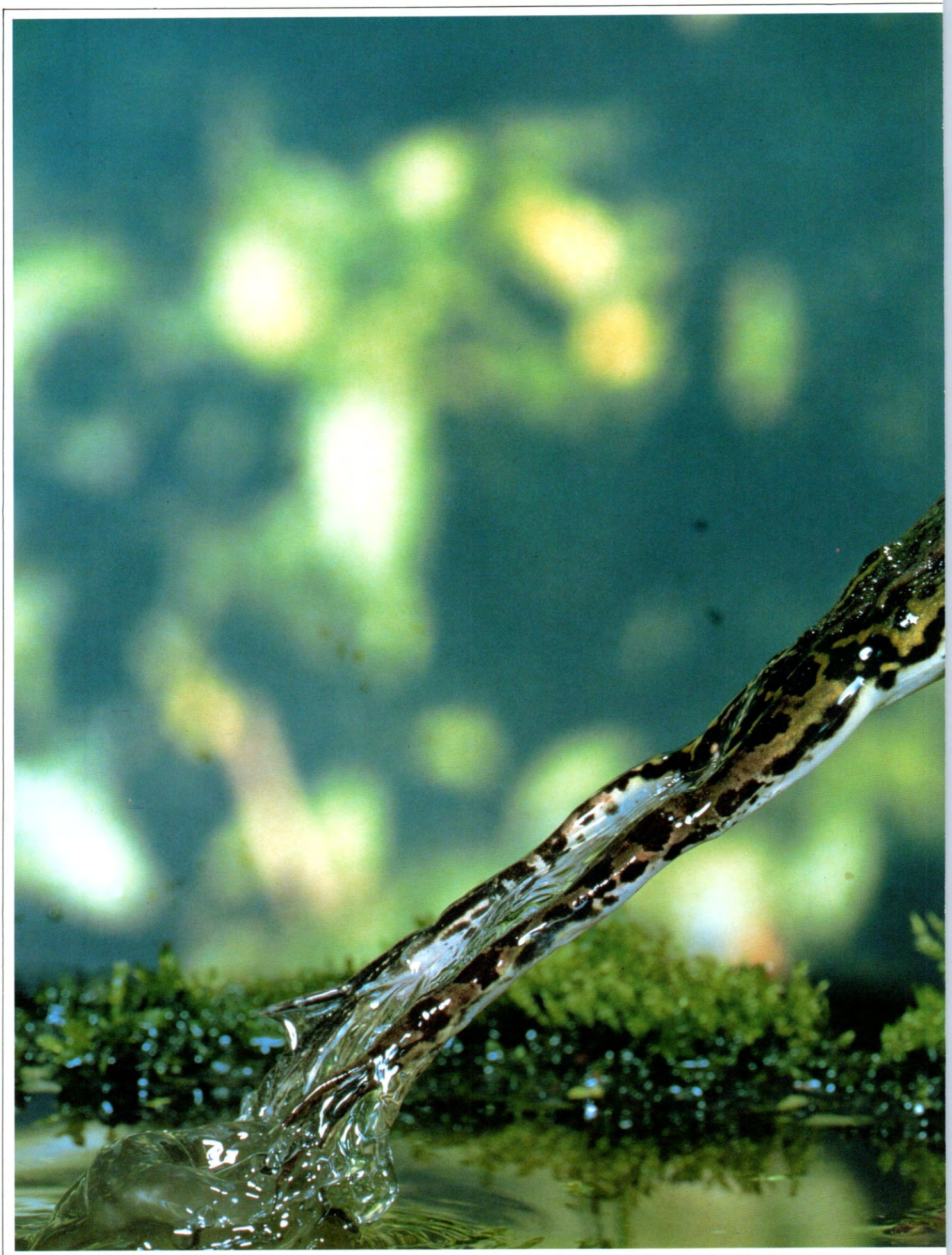

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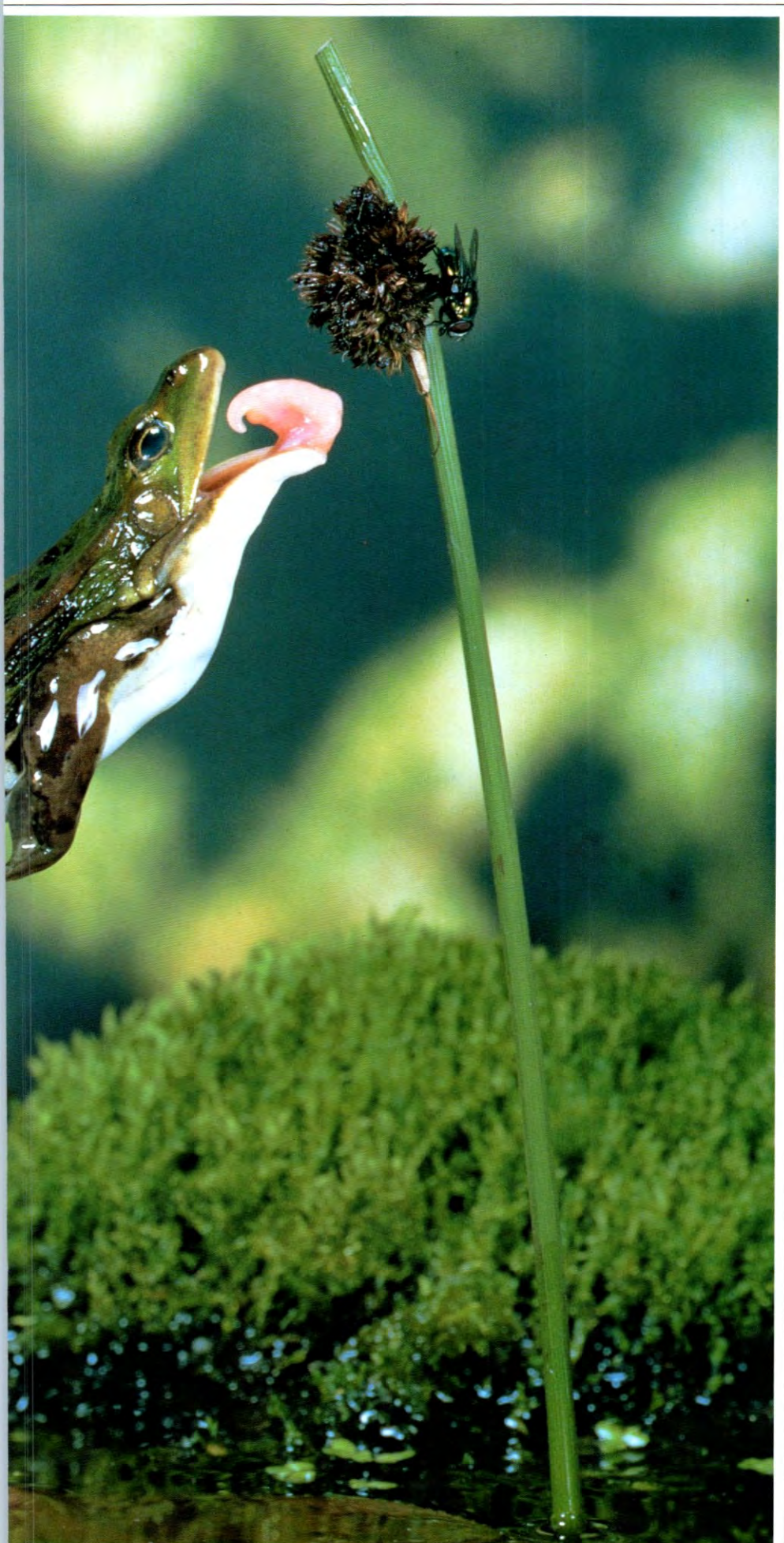

tural areas they had been eating insects that were significant crop pests. In 1988 the governments of India and Bangladesh, which were major exporters, responded by banning frog exports from their countries, but the damage had been done, and it has been reported that the levels of use of chemical insecticides to replace the frogs has increased dramatically.

If the decline of frogs could be attributed solely to consumption it would be possible to reverse the trend by promoting the idea that captive breeding colonies should replace the taking of frogs from the wild. Unhappily there is no such simple solution. Frogs are becoming noticeably less plentiful in countries lacking the tradition of eating them and not involved in exporting them.

To return to the example of the Gastric Brooding Frog, in Australia the species disappeared from an environment in south-eastern Queensland that most would regard as highly secure and included a small national park. If reserves are little bits of land that we try to maintain in a pristine state in perpetuity, evidence of population declines within them are extremely disturbing.

PARTICIPANTS AT THE NATIONAL ACADemy of Science workshop included statisticians and climatologists. With their help, could we attribute the declines to the greenhouse effect or blame them on damage to the ozone layer? The workshop concluded that it couldn't identify a single cause at a global level. It heard evidence that in parts of Europe and the United States acid rain made breeding ponds acidic, preventing spawn and tadpoles from completing development. It recognised that land clearance and other human activities have eliminated frog breeding sites and so brought about their demise. For example, Dr Hans Nettman of the University of Bremen pointed out that a major cause of demise in Germany is the shift in land use from cattle country to crop growing—a change that resulted in the elimination of ponds. But there remained an extra factor.

Dr David Bradford of the University of California, Los Angeles, reported that in 1977–1980 he had studied the habits of the Mountain Yellow-legged Frog (*Rana muscosa*), which lived in a series of lakes 3,000–4,000 metres high in the mountains of the Sierra Nevada in California. He came to Adelaide University and worked in the Department of Zoology. Returning to California in 1989, he found that frogs had disappeared totally from 37 of the 38 lakes that he had studied. He was unable to detect any change in the physical environment or to suggest any cause for the disappearance.

Frogs perform a vital role in controlling insect pests. The long adhesive tongue makes catching a meal a breeze. The decline in frogs around the world is cause for concern—certainly insect pests could increase without this natural biological control.

MARIE LOCHMAN/LOCHMAN TRANSPARENCIES

There is good evidence that salinity in freshwater swamps in the Western Australian wheat belt has caused a serious decline in frog populations, even to the point of local extinctions in some areas. Note the salt crystals at the water's edge. Right: *Rheobatrachus vitellinus* has not been seen in the field for two years. Its habitat in Eungella National Park, northern New South Wales, has not been disturbed in any way, making its disappearance a mystery. Bottom Right: the Eungella Torrent Frog (*Taudactylus eungellensis*) has also disappeared from Eungella National Park. This unique frog was the only species known to communicate using its hands—the male 'waves' to the female. When he gets closer, he strokes her with his hands.

In Costa Rica Professor David Wake of the University of California found that salamanders (tailed amphibians) were also in decline. He described one species once so abundant that he had counted up to 80 sheltering under a single log. In March 1989 he and two other zoologists could find only three individuals in an entire day's search.

In Australia the declines of frogs are poorly documented but definitely real and dramatic. At least 20 species are affected. The evidence is that most population declines occur in the south-east and east of the continent, including the well-known Golden Bell Frog (*Litoria raniformis*). Following media interest in the phenomenon I received comments from various people who agreed that frogs are not as plentiful as they used to be. Here are just three of the comments: Mr Crowe of Port Fairy, Victoria, wrote "I have not heard the frogs' chorus for maybe two years". Mr Byatt of Tweed Heads, New South Wales, stated "There would be literally thousands of frogs jumping all over the roads. . .now you hardly see any". Mr Matheson of Nambour, Queensland, told me "It is years since I have found a single specimen of the tiny emerald green frogs [probably *Litoria fallax*] that were once reasonably common at my place".

We know that frog populations often fluctuate wildly. And certainly there is evidence that in northern Australia frog numbers actually may have increased as a result of human interference (quarrying for road materials has provided temporary breeding ponds safe from fish). But the list of human activities that reduce frog numbers is long. It includes swamp reclamation, insecticide and herbicide use, salination following deforestation, and pollution of a variety of kinds.

But when the declines of frog populations are examined against that list, there remain a large number of instances that defy explanation. Examples include the apparent disappearance of *Rheobatrachus vitellinus* and *Taudactylus eungellensis* from the Eungella National Park near Mackay. Their habitat appears totally unaffected by any form of human action. Why then have they disappeared and why have the disappearances of frogs on several continents happened simultaneously?

R.W.G. JENKINS/NPIAW

M. DAVIES

As David Wake summarises, "Frogs were here when the dinosaurs were here and survived the age of mammals. They are tough survivors. If they are checking out now, I think it is significant". ■

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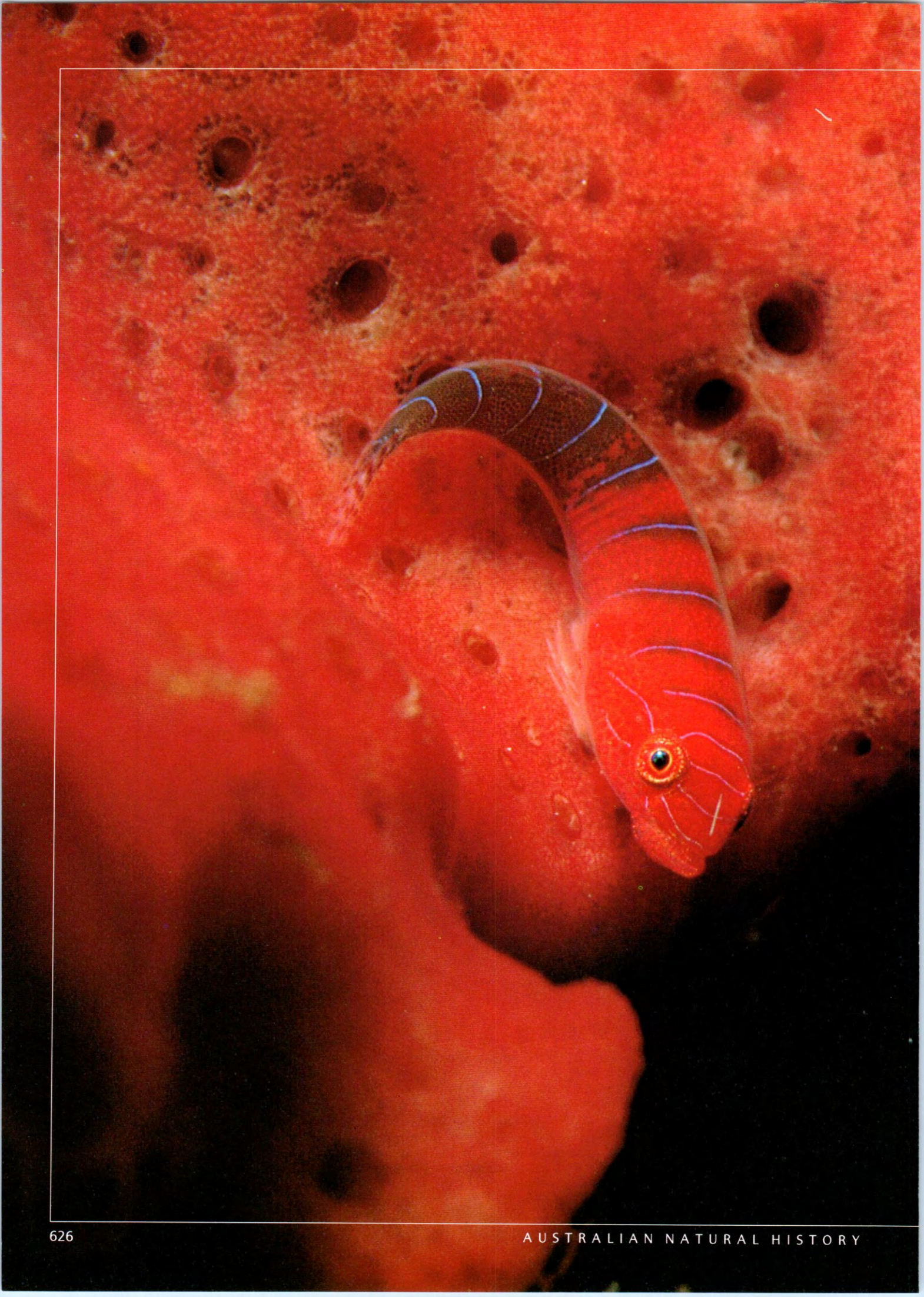
Michael J. Tyler is Associate Professor in the Department of Zoology at the University of Adelaide and Chairman of the South Australian Museum Board. His research interests are confined to the study of frogs.



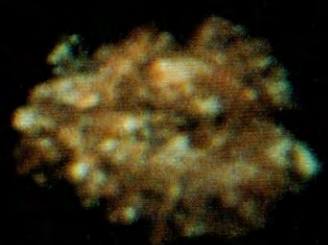
"These different patterns of colour are usually related to the varying colours of the substrates inhabited by clingfishes."

SOUTHERN AUSTRALIA'S ENIGMATIC CLINGFISHES

TEXT & PHOTOGRAPHY BY BARRY HUTCHINS
WESTERN AUSTRALIAN MUSEUM

ENTERING THE WATER FROM OUR DIVE boat, I descended through the deep blue of the southern ocean towards the bottom, 20 metres below. I was looking for the bright yellow stalk and bulbous head of the ascidian (seasquirt) *Pyura spinifera*, which together form clumps attached to the bottom. During the previous dive, there was a small pale yellow fish clinging to the side of this invertebrate. The three-centimetre individual skipped around the head of the ascidian, unperturbed either by my presence or the current-induced swaying motion of its host. Now armed with camera and flash, I was determined to find it again and photograph this unknown fish.

Approaching the ascidians cautiously, I was surprised to see a member of the morwong family, the Queen Snapper (*Nemadactylus valenciennesi*), also making a beeline for the same area. The morwong moved up to one clump of ascidians and, hanging almost motionlessly, slowly tilted upwards until it was standing on its tail. Such behaviour resembled that of fish in more northern waters being cleaned by the tropical



Western Cleaner Clingfish (*Cochleoceps* sp.) at a sponge, its cleaning station headquarters. Inset: on another sponge, this species assumes a paler colouration.

cleaner fish *Labroides dimidiatus* but it was far too cold for cleaner fish to survive here. Moving in for a closer look revealed that the morwong had a small fish with red-and-blue bands sitting on its eye. Another skipped across its cheek. I raised my camera, focused and fired. The flash caused the instant departure of the morwong but surprisingly the two small red-and-blue fish remained. Both slowly swam back to the ascidians and disappeared. On examining the head of the invertebrate, I once again found the small yellow fish. Closer inspection revealed very faint red-and-blue bands: the yellow fish and the red-and-blue one from the morwong were one and the same. It had simply resumed a paler colouration to match the background colour of the yellow ascidian. On other nearby ascidians were more of these fish—but what were they and what was their association with the morwong?

This was in 1977, the first of many trips to Western Australia's Recherche Archipelago, that marvellous underwater wilderness at the western end of the Great Australian Bight. The initial experience with the fish on the ascidian left an indelible impression—I would continue to observe this species for the next decade and, through this observation, come to work on all the Australian members of its family, commonly known as clingfishes.

THE CLINGFISH FAMILY, GOBIESOCIDAE, IS found in temperate and tropical seas worldwide. The majority of species are small—under ten centimetres long—although one African species grows to 30 centimetres. Clingfishes adhere to the substrate using a modified ventral fin in the form of a suction disc on the breast. I have found them clinging to seaweed, sponges, corals, seawhips and bryzoans, as well as sitting on the heads and bodies of other species of fish. A total of 118 species have so far been described but, based on my investigations, probably many more remain to be discovered.

In 1977, books on southern Australian fishes listed only four species of clingfish. My collecting in the seas and estuaries along our southern coastline has increased this number to 27. In addition, the shore-eels of the genus *Alabes*, originally placed in their own family Alabetidae, have now been included with the gobiesocids, raising the total number of species inhabiting southern Australia to 33. However, most of my clingfish collecting has been done in south-western Australia, so further work along the south-eastern portion of the coastline will probably see a further increase in this figure.

Many of southern Australia's clingfishes still remain undescribed, mainly because of the great difficulty in discovering their relationships to one another. A considerable number of the newly discovered forms appear like no other clingfish; this suggests they should probably be placed in new genera. However, until a full examination of all members of the family is completed, it would be foolish to start describing a new genus for every unusual species of clingfish.

Why has the family remained so poorly known in southern Australian waters? The answer is simple and two-pronged. First, being so small, clingfishes have proved difficult to detect and even more difficult to collect. My main collection tool is a small, fine-meshed beam trawl, which is towed behind a dinghy. I can work in seagrass beds as shallow as half a metre, at which depth many of the new species have been found. Second, members of the same species often come in many different colour patterns. The cross bands on the Tasmanian Clingfish (*Aspasmogaster tasmanianus*), for example, can be either pink, blue, green, orange, brown, yellow or red, with the number of bands ranging from 17 to 25. Some individuals of this species have regular banding, whereas others possess an almost tiger-like pattern of irregular bands. A rare pattern includes indistinct bands with pale blotches along the side of the body. This confusing array of colours and patterns has often made it difficult for collectors to detect new forms in their collections. As mentioned above, these different patterns of colour are usually related to the varying colours of the substrates inhabited by clingfishes.

Clingfishes also come in a variety of shapes, from the squat members of *Aspasmogaster* to the undescribed, elongate Hair Clingfish. Although some have distinctively shaped heads, especially the long flat one of the Spade-nosed Clingfish (*Cochleoceps spatula*) and the triangular head of the undescribed Spiny Clingfish, most species share a rather unremarkable sameness in their overall shape. Fortunately clingfishes possess some rather distinctive morphological features that, although too small to see without magnification, help with their identification. These include the patterns of papillae on their ventral sucking discs, the shape of their teeth, and the numbers and positioning of open sensory pores on the head. All clingfishes have prominent teeth, but some have exceptionally large ones, which suggests these may be carnivorous. This finding is supported by the cannibalistic habits of some aquarium-maintained individuals of the Spade-nosed Clingfish. Not only do they feed on smaller members of their own species, they will also attack any other inhabitant they can swallow. This assault usually involves a slow stealthy approach, the clingfish trying to blend in with the surroundings. When close enough, it pounces on the unsuspecting prey, swallowing it whole.

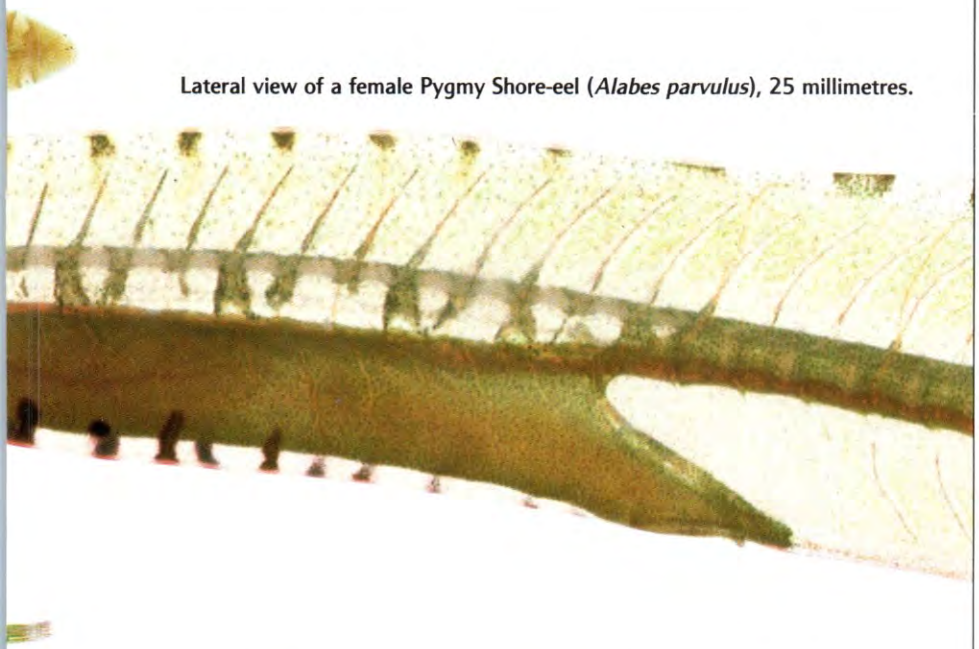
The family can be divided into two categories on the basis of habitat prefer-

Western Clingfish (*Aspasmogaster occidentalis*) resting on *Turbinaria* coral.

Common Shore-eel (*Alabes dorsalis*), lateral view, 70 millimetres.

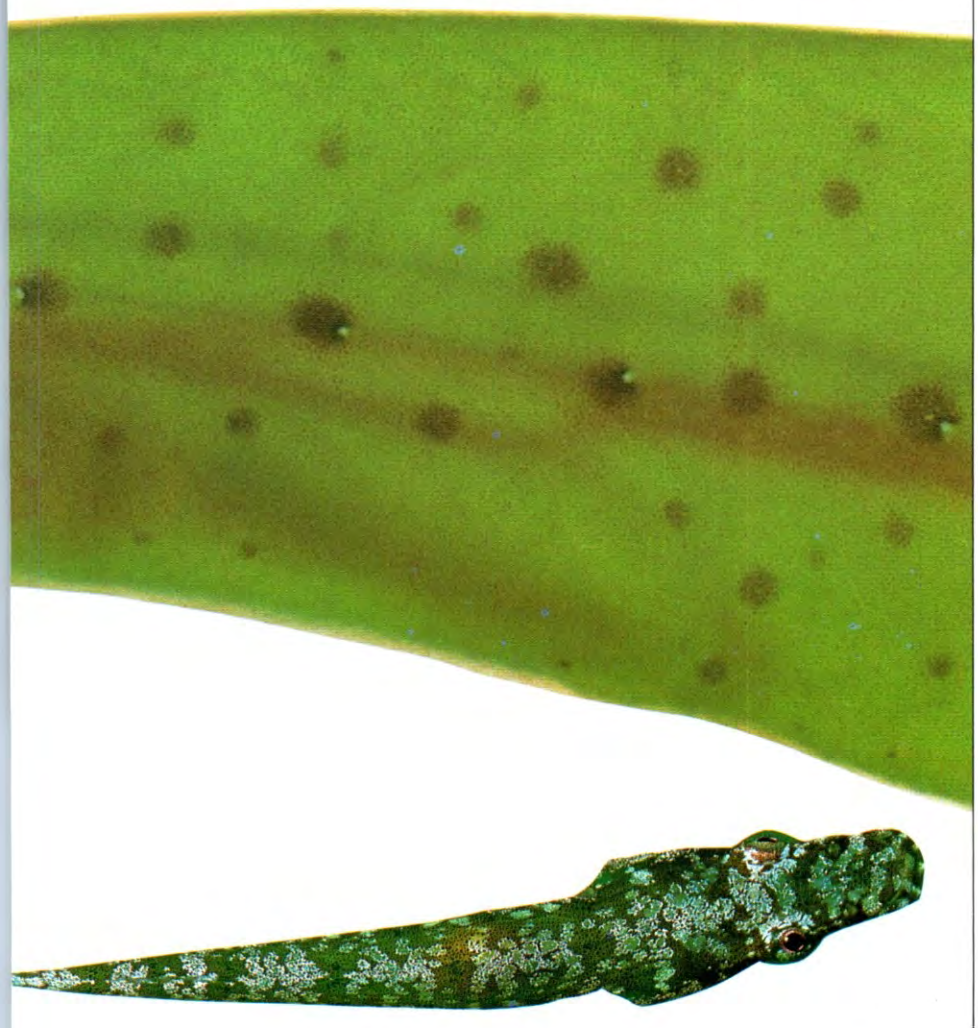
The undescribed Spiny Clingfish, dorsal view, 20 millimetres.

Small-finned Clingfish (*Parvicrepis parvipinnis*), dorsal view, 20 millimetres.



Lateral view of a female Pygmy Shore-eel (*Alabes parvulus*), 25 millimetres.

Deep-bodied Shore-eel (*Alabes brevis*), lateral view, 70 millimetres.



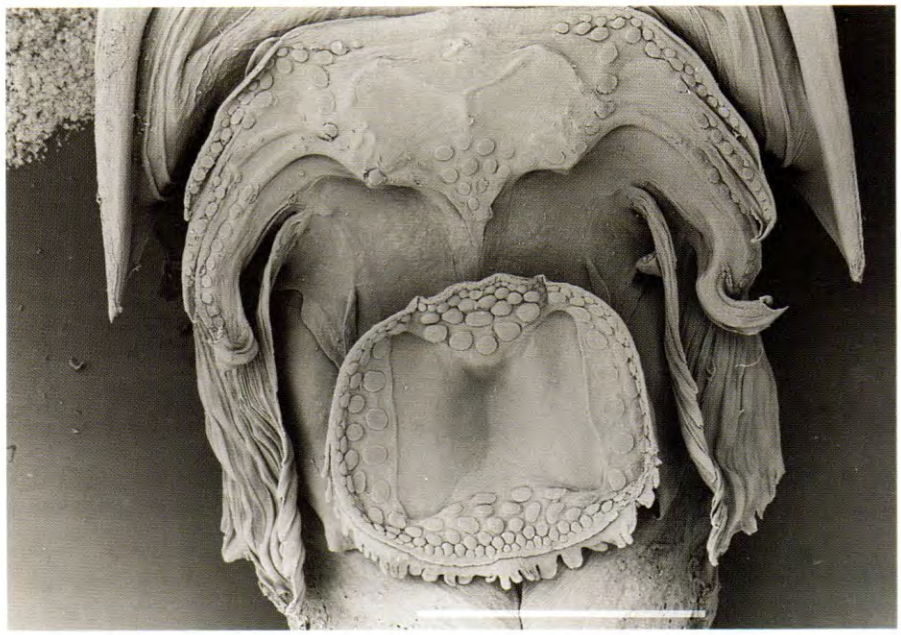
Spade-nosed Clingfish.

ences, namely reef dwellers and seaweed inhabitants. Reef dwellers either inhabit caves, clinging to the dark walls or squeezing themselves into cracks, or hide under rocks. Those that often occur in the open include the red-and-blue-banded clingfish mentioned earlier. The majority of the species, however, inhabits areas of seaweed. Some are found only in seagrass meadows, such as the Spade-nosed Clingfish, while others, like members of the genus *Parvicrepis*, inhabit weeds that grow on rocky reefs. Most seaweed inhabitants are well camouflaged within their surroundings to avoid detection by predators, whereas the reef species tend to be more gaudy in colouration. However, the latter also have the capability to blend with the surroundings when needed. They achieve this by reducing or increasing the size of their chromatophores (cells containing colour) in the skin to match the background.

Anyone familiar with shore-eels must be wondering why they have been included with the clingfishes. Shore-eels have more elongated, compressed bodies than the generally more robust and depressed clingfishes. Two species are almost completely transparent and look more like the larval forms of eels. The characteristic suction disc of the clingfishes is missing from all shore-eels, as are the pectoral fins. In addition, the wide gill opening on both sides of the head in clingfishes is reduced to a narrow slit on the ventral surface of the head in shore-eels. Nevertheless, research conducted in North America has shown that several unique features of the skeletal structure are common to both groups. The investigation suggested that the shore-eel is a more advanced form of clingfish, a finding supported by the presence of a vestigial sucking disc in one species of shore-eel, *Alabes dorsalis*. Unlike other shore-eels, this species has a rudimentary ventral fin just behind the gill opening. About one individual in 15 also possesses rudimentary papillae on the ventral surface of this fin. However, this finding has not received universal support and the two groups are best treated as separate subfamilies.

HARKING BACK TO THE FIRST MEETING with the clingfishes on the ascidian, I posed two questions: the first concerned the identity of the fish, which has now been answered. The second related to its strange association with the morwong. I also mentioned the similarity between the morwong's behaviour and that of fish being cleaned by the tropical cleaner fish *Labroides dimidiatus*. Could the clingfish in fact be another species that functions as a symbiotic cleaner?

The cleaning behaviour of *Labroides* spp. is well documented. These fish set up stations in prominent locations on the reef where other species of fish come to be 'cleaned'. This involves a cleaner fish inspecting the skin of the host fish for



Scanning electron micrograph showing the ventral sucking disc and papillae of the Spiny Clingfish. (Scale bar = 1 millimetre.)

Scanning electron micrograph of the head (ventral view) of the Western Rat Clingfish (undescribed) showing its dentition. Note the enlarged forward-projecting teeth of the lower jaw. (Scale bar = 0.1 millimetre.)

ectoparasites, even entering the mouth and gill cavities. Not only are parasites consumed, but mucus, pieces of damaged scales and other dead tissue may also be removed. In return, the host fish probably receives some tactile stimulation from the small cleaner fish as it brushes its ventral fins across the skin, not unlike the stroking of a cat. This may explain the unusual display performed by the host, the fish at times appearing to be almost totally oblivious to its surroundings.

The behaviour described earlier for the small red-and-blue-banded clingfish obviously fits this pattern. The clingfish usually selects a prominent feature, such as a large sponge, for its cleaning headquarters. Fish wanting to be cleaned approach the sponge in a submissive manner, thereby attracting the cleaner clingfish, which swims across to it. During the subsequent cleaning, the host fish often adopts a near vertical position best described as 'standing on its tail'. Meanwhile, the clingfish is busy at its work, flitting across the surface of the skin searching for ectoparasites, and probably also consuming mucus and any dead tissue. It always remains in contact with the host fish via its sucking disc. Unlike the more agile cleaner fish, cleaner clingfishes apparently never enter the mouth and gill cavities. Ectoparasites that may be targeted by the clingfishes include copepods of the genus *Caligus*. These small mobile parasites are common on the heads and bodies of many of the larger fish species in southern Australia. Some host fish have been observed swimming away from the station with the clingfish still attached, obviously the result of a disturbance while being cleaned. Others, particularly the Harle-

Harlequin Fish being cleaned by two cleaner clingfishes.

quin Fish (*Othos dentex*), may rest on the bottom during this activity. Cleaner clingfishes are sometimes attracted to divers who move in close to observe their activities.

The red-and-blue-banded clingfish is now known as the Western Cleaner Clingfish. It inhabits the southern Australian coastline from Melbourne to Perth. A close relative, the Eastern Cleaner Clingfish, is found in New South Wales. Both are undescribed and at present are included in the genus *Cochleoceps*. The eastern species is very similar to the western form, both in general body shape and behaviour, but differs in colouration (the cross bands on the body are more irregularly shaped and it lacks the more greyish posterior portion of the body).

The more I learn about the clingfishes of southern Australia, the more I am fascinated by them. It seems a pity that so many of the species are difficult to observe in their natural environment. Even though removing them to an aquarium helps me to better understand these enigmatic fish, it is far more rewarding to discover them doing their own thing in the wild. At least the cleaner clingfishes are easy to observe, and more and more divers are now experiencing the fascination of watching them and their hosts enjoying a mutually beneficial relationship. ■

Suggested Reading

Losey, G.S., 1972. Behavioural ecology of the "Cleaning Fish". *Aust. Nat. Hist.* 17(7): 232–238.

Whitley, G.P., 1950. Clingfishes. *Aust. Mus. Mag.* 10(4): 124–128.

Dr Barry Hutchins is a curator at the Western Australian Museum. His main interests are in the classification, evolution and ecology of leatherjackets and clingfishes.

"To my surprise a very aged and silvery rat fell out of the canopy ahead of us. It was such an old male that its teeth were worn down to the gums."

EMPEROR, KING AND LITTLE PIG:

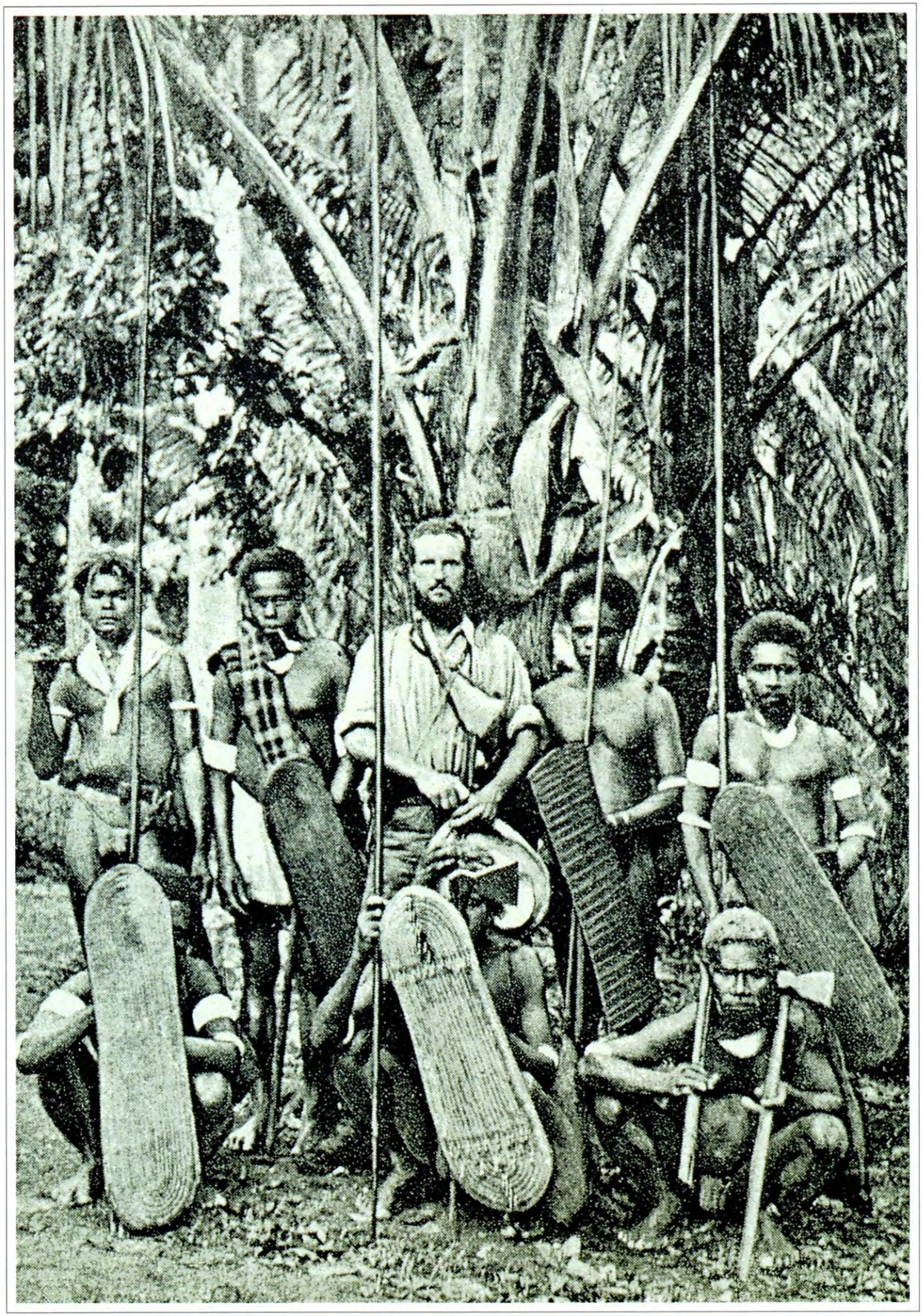
THE THREE RATS OF GUADAL-CANAL

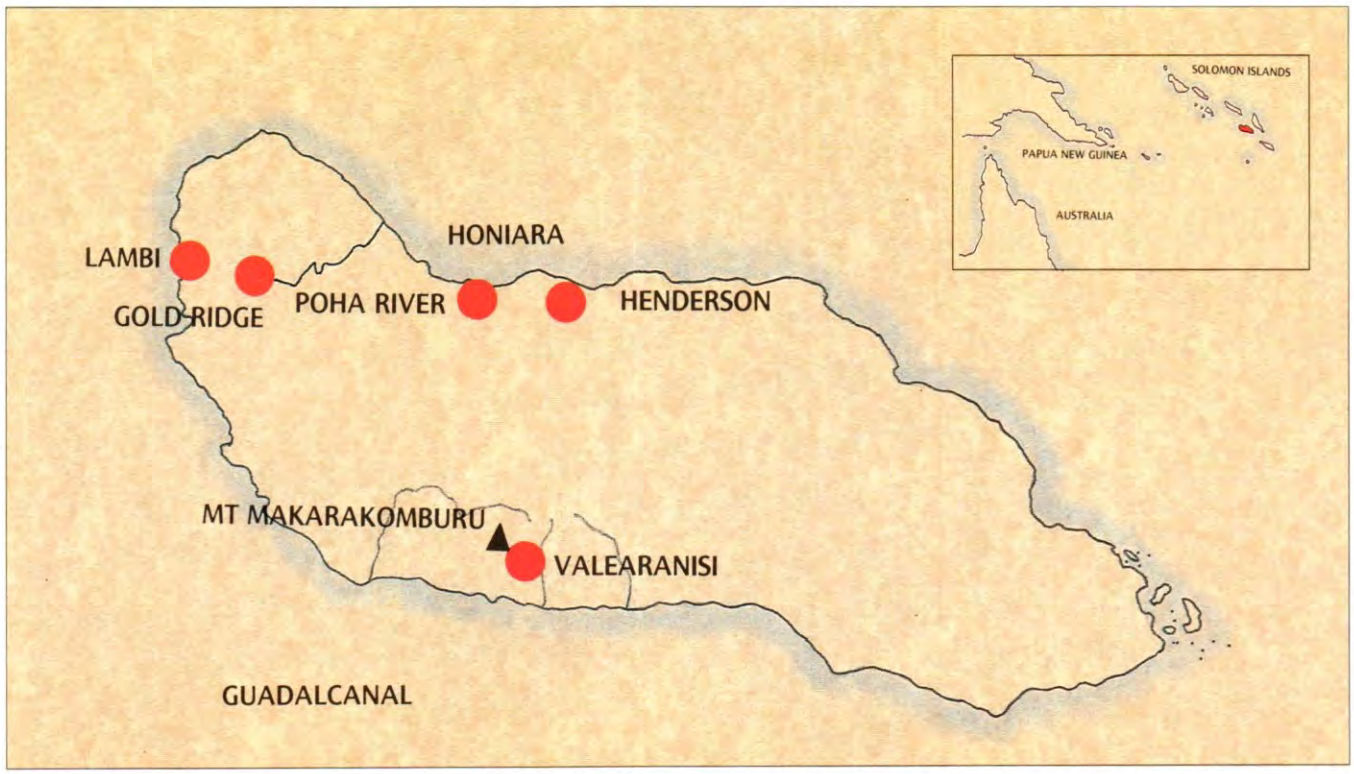
BY TIM FLANNERY

MAMMAL SECTION, AUSTRALIAN MUSEUM

THIS IS THE STORY OF THREE RATS, two apes and an island. The three rats and the island are named in the title; the two apes are myself and an English naturalist, Charles Morris Woodford. After chasing rats through the undergrowth for three years Woodford was made colonial administrator of the Solomon Islands. But that was in 1888 and in those days few Britons but eccentric biologists had ventured to the Solomons. The rat-catcher-turned-administrator left us an account of his

The author, Tim Flannery, in Mossy Forest above Valearanisi Village (1,230 metres altitude), taking a break from rat collecting.





CATHY MCGAHEY

days as a biologist entitled *A naturalist among the head hunters, being an account of 3 visits to the Solomon Islands in the years 1886, 1887 and 1888.* Like myself, he wished to climb the high mountains of Guadalcanal. His first attempt to contact the mountain people failed when his messenger went missing, presumed eaten. His second eventuated only after some intimidation and bribery, but failed to reach the summit when the village that was his objective at the foot of the mountain ceased to exist, 20 of its 29 inhabitants being killed by neighbouring tribes within a week of his arrival. Although not quite as hair-raising, my trip to the mountains did have its difficult moments.

Although Woodford was restricted to the lowlands, he made marvellous collections. Like most 19th-century naturalists he was more interested in the gaudy butterflies and birds of the tropics than rats. Nonetheless he did send a few examples of the more humble murids back to the British Museum for study. These had presumably been caught by the natives of the coastal village of Aola, where he stayed. Fortunately Mr Michael Thomas, then Curator of Mammals, had more than a passing interest in rats, and—unusual in a 19th-century scientist—a sense of humour. In 1888 he named the largest of the rats *Mus imperator*, the second in size *Mus rex* and, in 1904, the smallest and fattest *Uromys porculus*. These scientific names translate from Latin as Emperor Rat, King Rat and Little Pig Rat.

Naturalist Charles Morris Woodford, colonial administrator of the Solomon Islands, had an interest in the native rats and collected a few specimens, which he sent to the British Museum.

Subsequently Thomas transferred them all to the genus *Uromys*, which includes the large mosaic-tailed rats of the rainforest of Australia and New Guinea. He noted that "It is. . .in their relation to each other that their chief interest lies, for they seem to be. . .the slightly modified descendants of one single species that. . .has been isolated. . .for some considerable time". Time has proved Thomas to be correct in this but the situation is even more curious than he suspected: not only are the three species close relatives but they are not related to any other Solomon Islands rodents, being closest to species from New Guinea and Australia. A quick look at a map will show that Guadalcanal is remote from New Guinea–Australia. Many islands in between hold no such rats and just how three species came to coexist on this one island is still a mystery.

Very little is known about the biology of the three rat species. The Emperor Rat is large and grey, and is known from three individuals. It is over 60 centimetres long, a third of which is tail. The King, known from perhaps half a dozen specimens, is also grey and about the same total length, but with the tail comprising more than one half of this. The Little Pig, known from a single animal, is not much larger than a Brown Rat (*Rattus norvegicus*), but is a beautiful brownish red colour, is rather rotund and has a ridiculously short tail. Woodford reported that the Emperor Rat was entirely terrestrial, as its relatively short tail and great bulk might suggest; the King Rat he thought was tree-dwelling; but he recorded nothing of the habits of the Little Pig, although its shape suggests that it too might be ground-dwelling.

Shortly after Emperor, King and Little Pig were announced to the world they were forgotten. One hundred years later I picked up a copy of Thomas' work and became enchanted by these strange animals. They interested me from a biological perspective for a number of reasons. First, they represent the furthest extension of non-flying native mammals into the Pacific Ocean; all land mammals (except bats) found on islands further east have been introduced by people. Second, they are the only land mammals endemic to Guadalcanal. Therefore, the role they have to play in the forests and their interactions with each other may be easier to understand and may teach us much about more complex environments. Third, the three species seem to have arisen from a single ancestor. By studying them I might be able to learn about patterns of speciation in rats. And fourth, they were so mysterious—and I love large murids! To my surprise I found that not one scrap of information had come forth on any of the rats since Thomas' description. In Australia, if 50 years elapse without a sighting, a species is considered extinct. However, this seemed to be an unfair test to apply to the Guadalcanal rats, as I was fairly certain that no-one had looked for them over the intervening century. The National Geographic Society awarded me a small grant to investigate the problem and I was soon on my way to Guadalcanal, where I was to spend the early part of the festive season of 1987 in nocturnal wanderings along steep and slippery jungle slopes looking for the lost Emperor, King and Little Pig.

The place I had chosen for the search was the Poha River valley just west of the Solomon Islands' capital Honiara. Archaeological research by David Roe of the Australian National University had re-

Fossil jaw of an Emperor Rat found in a cave on the Poha River, Guadalcanal. The jaw is probably several thousand years old, evidence that these rats once lived in this dry and now largely deforested area in northern Guadalcanal.

DAVID ROE

vealed that in the last few thousand years at least two of the three rat species had inhabited the valley. I knew that some kind of rat still inhabited the area as I found in parts of the rainforest piles of nutshells from the Ngali tree (*Canarium indicum*) that had clearly been opened by a largish rodent. But what kind? Local people only rarely encounter forest rats and so were of limited help in this regard. Intensive trapping also yielded no result, and the chance to gain detailed information seemed to be slipping away. Only one technique remained: spotlighting night after night in the hope that I might see one.

As luck would have it, I had success of sorts on my very first night. I set out from my base camp after dark with two local assistants and had barely gone 50 metres when I saw, by the side of the path, a reed moving in a peculiar manner. Soon a kitten-sized red creature emerged and sniffed curiously in our direction. I was entirely taken by surprise and was loath to shoot the animal if there was a possibility of capturing it alive. I cautiously signalled to one of my assistants to move in behind it while I kept the spotlight trained on its eyes. Instead, he casually reached forward and instantly the creature vanished into the dense canes. Looking confused, he later explained that he had never before seen anything like the animal and had thought on first sight that it must have been a baby possum (*Phalanger orientalis*), which also has red fur but moves quite slowly and is easy to catch by hand.

During a further month of searching I didn't see anything like the animal again. To this day I don't know what it was. It was definitely a native rat somewhat resembling the Little Pig but it was climbing a reed and seemed to use its tail to grip with. The only Little Pig known has a very short tail and doesn't look like it could climb well. I tend to think that it was a fourth species of rat, one as yet unknown to science. The episode at least taught me how exasperatingly difficult it can be to gather information on rainforest animals.

After further work in the Poha River valley I discovered that the King Rat still inhabited the area: I found a single specimen in the same patch of forest where I made the sighting of the unknown rat. Late one night, high overhead in a huge forest tree, I saw a slight movement. I shot into the canopy with only the faintest hope that it might be anything but a possum (which have been introduced to the Solomons and are greatly relished as food). To my surprise a very aged and silvery rat fell out of the canopy ahead of us. It was such an old male that its teeth were worn down to the gums and it was clearly having trouble finding enough nourishment. Although it might seem counterproductive to shoot in such circumstances, the extreme difficulty of gathering information in any other way left me with no option. At least I had the first firm evidence in a century that the King Rat lived and we could gain some idea of genetic relationships and diet from detailed studies of the body. When I took the rat back to the village the older men looked surprised and identified it as the animal they knew as *siru* in their Nginia language. Many of the local people had never encountered it and our conversation, which continued late into the night, acted as a sort of cultural revival, the old men telling me and a circle of younger people all about the rat that was fast becoming myth and about the days of old.

FOLLOWING MY RETURN TO AUSTRALIA the interest that my work kindled in the Guadalcanal rats continued. After much trouble a veterinarian working in Honiara obtained two live King Rats caught by local people in a high mountain area called Gold Ridge. The female soon died but the young male still survives and is being kept as a pet by a wildlife photographer in Honiara. During my work in the Poha River area the old men had told me that the last time they had seen the huge, ground-dwelling species (the Emperor Rat?) was about 30 years ago high in the mountains at the head of the Poha

Helpers from the village of Valearanisi captured a Common Cuscus (*Phalanger orientalis*) for our dinner.

River. This, coupled with the find at Gold Ridge, made me determined to return to Guadalcanal and explore the mountain forests.

I finally got the opportunity to do just that in May 1990. The initial negotiations with landowners for permission to enter the Gold Ridge area was done by staff of the Solomon Islands Ministry of Natural Resources. Permission was granted but we had to abide by some taboos, the worst of which was a total prohibition upon cutting any uncooked animal on the mountain! This meant that we could not take tissue samples for biochemical analysis and could not even skin any rats, possums, birds or flying-foxes before they went into the cooking fire! I could see myself doing a half day's run down the mountain, scalpel in hand, if any vitally important specimen was found. Even if my fitness failed, I might at least gain some ecological information on the rats through observations.

On the afternoon of my arrival at Gold

A Ngali nut chewed by a rat. Such nuts with their distinctive chewing marks reveal the presence of rats in an area. Unfortunately it is difficult to tell which species has performed the task.

DAVID ROE

TIM FLANNERY

M. MACCOY

A King Rat captured by villagers at Gold Ridge, Guadalcanal in 1988.

TIM FLANNERY

A helicopter proved to be the only means of crossing the rugged terrain of Guadalcanal.

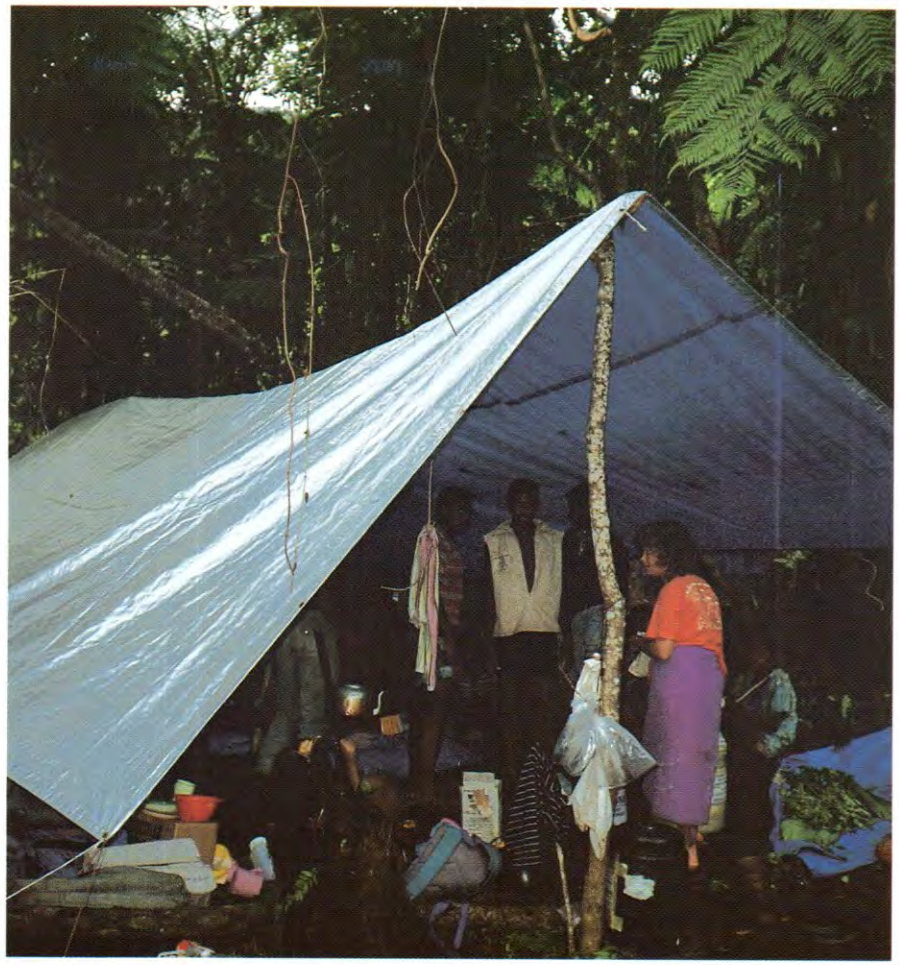
Ridge there was an air of tension at the mining camp. Many people had moved from the bush to be near the camp and road, and a quickly growing 'shanty town' was evident. Relations between the local residents and the mining company seemed strained, and some ill will was clearly spilling over onto us. On the following morning, just before we were to leave, an additional demand was put to us. We were to pay a $2,000 fee to a local landowner in order to cross the land between the mountain and the mining camp. The owners of the mountain were still willing for us to complete our expedition but disputes originating elsewhere had clearly led to an unfavourable reaction in some quarters and we reluctantly decided to try to reach the summit by another route. The only other way to do this was by ascending the south face via the 'Weather Coast' of southern Guadalcanal, so called because of the often appalling weather conditions that prevail there, many areas receiving in excess of 8,000 millimetres of rain per annum.

Fortunately we met a young man at Gold Ridge whose village was on the opposite side of the mountain. He convinced us that if we could just get to his village of Valearanisi our problems would be over. Thus we set out that day to get as far around the island as we could by car and from there to hire a canoe to complete our journey to the Weather Coast. On the way Peter (our man from Valearanisi) entertained us with tales of friendly people and an abundance of giant rats. He even told us of one man known as Hue Hue (the local language name of the largest rat species) who had gained this appellation on account of the prodigious numbers of the species he had caught. Problems began again at Lambi where the road terminates, when it became clear that no-one was willing to risk a journey to the Weather Coast in that season. I travelled by tiny canoe through high seas and rain from coastal village to coastal village searching for someone willing to take us, but without success. I arrived back at the safe harbour of Lambi after dark, depressed and sodden. That night I determined that we had wasted enough time and that we might as well use a 20th-century luxury unavailable to Woodford: the helicopter based at Henderson Field. We set off for Henderson before dawn on a market truck. The helicopter pilot estimated that it would cost us around $US1,100 for the trip and this seemed a reasonable price to pay for reaching our Shangri-la. In fact

the chopper was to cost over $US2,000 (that information on rats was looking terribly expensive), and Valearanisi to be less than paradise on Earth for Emperor, King and Little Pig.

Our arrival at Valearanisi was not unexpected, for we had got a message through on public radio that we were coming and a welcoming committee had gathered. The local people were indeed hospitable and friendly but, once again, previous dealings with mining companies was to prove a bane. The village head man explained that a $500 entry fee was expected from any strangers entering their land, as the mining companies happily paid that much and more. I was further surprised to encounter a comprehensive employment agreement being proposed, covering night rates, time-and-a-half on Saturday, Sunday off, and living-away-from-home allowance, benefits to which I myself was not entitled when in the field! Where a century before Woodford had encountered head hunters, I found sophisticated industrial relations advocates who would do the Australian Council of Trade Unions proud! I must stress that such concern for detail in finance is unusual in the Solomon Islands and even here people were enthusiastic to learn with us about their natural environment. I suppose that, if I had to deal with mining companies on a regular basis, I would learn to be equally careful about contracts and matters financial.

We started our ascent of the mountain that afternoon. After two days of agonised walking, often through rain on slippery mud trails, we reached the mossy forest above 900 metres that we hoped would be a rat refuge and everything seemed worthwhile again. We made camp in the only level spot we could find; a small gully that was so muddy it soon resembled the trenches at Verdun. I set out the box traps and was surprised to find the following morning that several had gone off. Upon peeking into the first my heart began to soar, for there crouching in the corner was a dark ratty shape. No less than three traps held rats and it seemed that victory was at hand! But imagine my disappointment when I had a good look and found I had trapped three Pacific Rats (*Rattus exulans*), a prehistorically introduced species that elsewhere in the Pacific has caused local extinctions. These particular rats were very dark and large compared to others I have seen, and have clearly undergone some local adaptation to the extreme conditions over the few thousand years they have inhabited the area. The mossy forests were full of these peculiar rats. And feeding upon the rats were the largest feral cats that I have seen. Combined with the abundant feral pigs, these introduced animals had totally devastated the mossy forest. Far from being a refuge, the forest was all but devoid of native life on the ground. I persisted in spotlighting for several nights, often in chilling rain over near-vertical slippery slopes but only succeeded in nearly shooting myself after a seven-metre tumble. No native rats were to be seen and detailed questioning of the local people revealed that the large rats were very rare, if not already extinct, in the region. Needless to say, Hue Hue was conspicuous by his absence, his namesake not having been seen in over 30 years.



TIM FLANNERY

The sodden camp site on the Weather Coast of southern Guadalcanal.

One lives and learns I suppose, and the result of field work is not always as anticipated. I am sure that Woodford counted his rats as among the least interesting of his biological discoveries, yet I consider them among the most fascinating. And what had we achieved at the end of one of the most difficult expeditions I have undertaken? High on the mountain we had discovered a new and spectacular kind of monkey-faced bat (genus *Pteralopex*). We only located a single specimen but its bright red eyes and black-and-white wings make it among the most distinctive of the bats I have seen. We also had information that is invaluable for the environmental management of Guadalcanal. Many had assumed that the mountains would act as a wildlife refuge even if the entire lowlands were logged and altered (and this process is already well advanced). This is clearly not the case and it would be valuable if management plans could be put in place that reserve some lowland forest before it is all either logged or turned to gardens.

I doubt that I'll be rewarded with a political appointment like Woodford was. Still, I think the effort of undertaking such work is worth it. It would be a pity should the Emperor, King, Little Pig and perhaps their unknown cousin slip into oblivion without anyone raising a helping hand. It might even be too late for the Emperor and Little Pig. Generally ground-dwelling species in the Solomon Islands seem to have suffered worst, perhaps as the result of the introduction of cats and dogs. However, Guadalcanal is a big place and I'm not yet willing to give up. There's still some extensive mountain blocks that remain unexplored. Perhaps the kingdom of the rats survives there. ■

Suggested Reading

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Dr Tim Flannery is head of the mammal section at the Australian Museum. He is currently scratching his head, trying to come up with a better word than 'rat' to describe the 100 or so beautiful native murids of our region.

W. TOLHURST

"Females that produce only daughters should rapidly replace those producing both sons and daughters—males, it seems, are something of a luxury!"

COPING WITHOUT SEX IN THE OUTBACK

BY CRAIG MORITZ
DEPARTMENT OF ZOOLOGY, UNIVERSITY OF QUEENSLAND

SEX. IT'S HARD TO IMAGINE reproducing without it. Yet a few species of plants and animals have evolved ways of producing young without any participation by males. The study of these organisms and their sexual relatives may help us to resolve one of the major problems in evolutionary biology: why have sex?

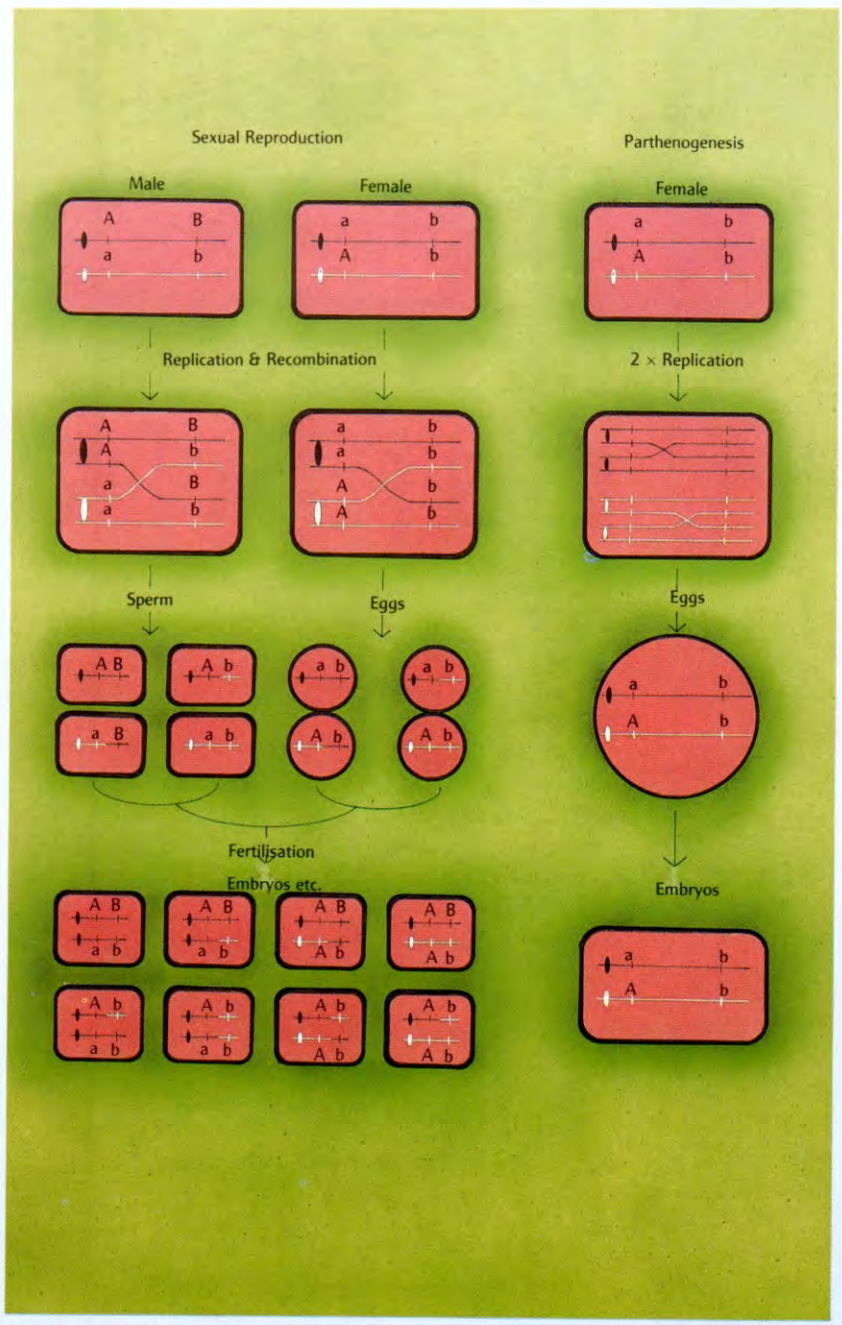
In sexual reproduction, eggs and sperm are produced by meiosis and then fused to form an embryo. Meiosis is the key: the chromosome number is halved (haploid) and segments are exchanged between chromosomes derived from the mother and father. This exchange, called recombination, is an important source of

Bynoe's Gecko is one of six gecko species that can reproduce without sex.

THE MECHANISMS AND CONSEQUENCE OF PARTHENOGENESIS

To reproduce by parthenogenesis, females must be able to produce eggs that can develop without fertilisation. This involves profound changes in meiosis so that eggs contain a full, rather than a half, set of chromosomes. Also the egg must be able to initiate development without the trigger usually provided by sperm penetration. These conditions have been met by a few species of reptile, but no birds or mammals. Several species of amphibian and fish have the appropriate changes to meiosis, but still require the interaction with sperm to begin embryogenesis.

There are many different ways of producing eggs with a full set of chromosomes. Meiosis can be eliminated altogether; there can be an additional chromosome doubling before meiosis (see diagram); the products of meiosis can be fused after the first or second division; or the chromosomes can be doubled early in development of the embryo. The genetic consequences range from total preservation (clonal inheritance) to the complete and immediate loss of variation. In most cases the variation among offspring of a single female is limited in comparison to the progeny of a sexual female.



Comparison of the mechanism and consequences of sexual *versus* parthenogenetic reproduction. The fate of variants (A *vs.* a, and B *vs.* b) at two genes (A and B) on a single pair of chromosomes is shown. The parthenogenetic mechanism in this case involves an additional doubling of chromosomes before meiosis (second row). Exchange of segments between the products of this doubling has no genetic effect.

IAN FAULKNER

variation in sexual populations. Others are the shuffling of chromosomes derived from the parents and the new combinations created by fertilisation. All these mean that the progeny of a single female is genetically diverse.

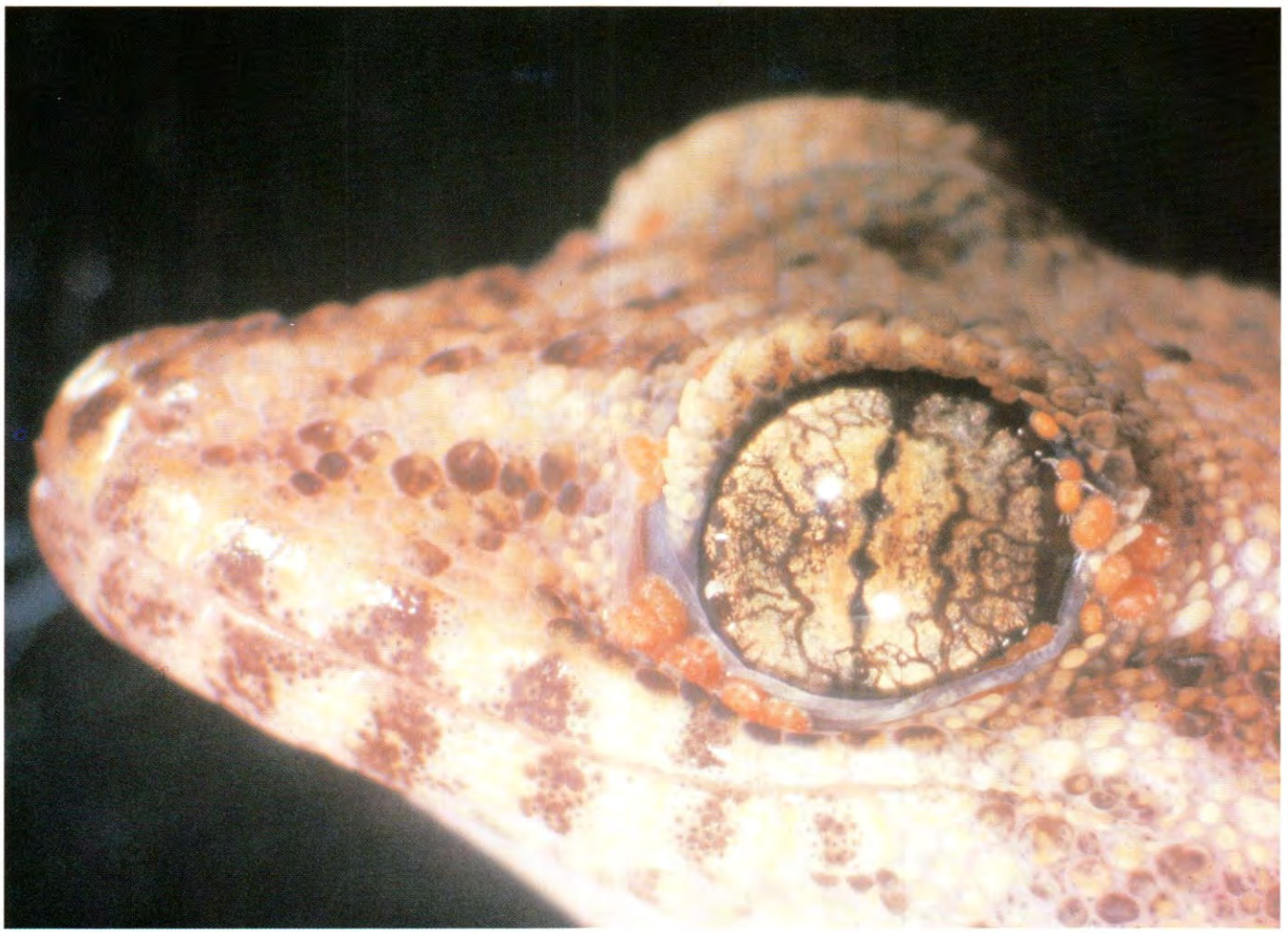
Parthenogenesis, literally 'virgin birth', refers to a variety of processes where a female can produce young without fertilisation of the egg. In the most common type, females produce only daughters that are genetically identical; they clone themselves. This is done by circumventing meiosis altogether, or by modifying it so that the eggs have the full complement of chromosomes and are genetic clones (see box).

Sex is by far the most common form of reproduction in plants and animals but it is not entirely clear why. There can be substantial costs. Think of the elaborate displays of a lyrebird, the aggression required for a dominant male elephant seal to maintain his harem, and the dependence of sparsely distributed rainforest trees on animals for pollination. Sex is also inefficient for population growth, which can be measured by the number of daughters produced per female. Females that produce only daughters should rapidly replace those producing both sons and daughters—males, it seems, are something of a luxury!

Most of the theories that seek to explain the predominance of sex focus on the genetic variation arising from meiosis and fertilisation. Fertilisation and genetic recombination can bring together combinations of genes that are particularly well suited to the environment. Genetic variation is supposed to be essential for a population to exploit a diverse habitat and to respond to changes in the environment. Most recently, attention has focused specifically on the effect of the biotic environment, particularly parasites and pathogens. The Red Queen hypothesis, for example, suggests that there is an evolutionary arms race between hosts and parasites. Like the Red Queen in Lewis Carol's *Alice in Wonderland*, hosts must run flat out to stay still, they must keep changing their genetic armoury as parasites and pathogens change theirs.

These are all very basic questions. How does genetic variation shape ecology? Why is sex so common? If our theories of evolution cannot explain something as common and obvious as sex, have we missed something important? Some answers to these questions can come from comparisons of the ecology, genetics and distribution of parthenogenetic organisms and their sexual relatives. In doing so, we must take account of their history—where, when and how did the all-female lineages evolve?

ONE GROUP WITH CONSIDERABLE PROMise for such studies is the parthenogenetic geckos. Geckos are an ancient and successful group of lizards distributed throughout the tropics. As usual, most



CRAIG MORITZ

The Red Queen hypothesis predicts that parthenogentic species should be more prone to infection by parasites than their sexual relatives. This appears to be the case for Bynoe's Gecko. This gecko is heavily infected by blood-sucking mites that attach themselves in large numbers around the eyes and hind limbs.

species are sexual. Only six of the 800 or so species are parthenogenetic. Some of these are very obvious: anybody who has spent time on Pacific islands will have seen small translucent geckos skittering around lights on walls. These include two parthenogenetic species, the Mourning Gecko (*Lepidodactylus lugubris*) and the Indo-Pacific Gecko (*Hemidactylus garnoti*).

Indeed, broad geographic distributions are one of the characteristics of parthenogenetic geckos. In many cases the parthenogenetic forms have a larger geographic range than their sexual relatives. The Mourning Gecko is a case in point. These are found on islands in the Indian Ocean, through the Pacific Ocean, to central America, whereas the sexual relatives are each restricted to one island, or to a few geographically clustered islands. Similarly, populations of the Pelagic Gecko (*Nactus arnouxii*) on the far-flung islands of the central and eastern Pacific are parthenogenetic, while the sexual populations are restricted to Melanesia (Papua New Guinea, Solomon Islands, Vanuatu) and Australia.

FRITHFOTO

The Pelagic Gecko illustrates the diverse distribution of parthenogenetic populations, which have colonised a broad area of the Pacific. Sexually reproducing members of this species are restricted to Melanesia.

CRAIG MORITZ

Craig Moritz makes a new home for Bynoe's Geckos at Ninghan Station, north-east of Perth. Both the parthenogenetic and sexual geckos are attracted to homestead rubbish dumps because of the abundant cover and associated insect food. New habitat can be made for gecko populations simply by piling up old sheets of roofing iron.

Another characteristic of the parthenogenetic species is that they are common in disturbed environments, often in association with human activity. I've already mentioned the penchant of Mourning and Indo-Pacific Geckos for house lights. The Pelagic Gecko is common in piles of coconut husks left to rot in copra plantations. But the prize goes to a species only found in Australia—Bynoe's Gecko (*Heteronotia binoei*). This species would be better described as the 'garbage gecko'. It is abundant throughout arid Australia and is most easily found in homestead rubbish tips. By stacking old roofing iron in their dumps, pastoralists are inadvertently creating ideal high-rise apartments for these small lizards. In fact, they are so common that herpetologists have long regarded the species as a relatively boring nuisance, usually encountered while searching for more exotic beasts. Well, it turns out

that Bynoe's Gecko is more exotic than most!

Surveys of variation in chromosomes and proteins have revealed that *Heteronotia binoei* is not one species, but several. There are at least four sexual species currently masquerading under this name, in addition to an undescribed species from central Australia that superficially resembles the Cave Gecko (*Heteronotia spelea*). The species are not readily discernible from their external appearance but have different chromosomes and, in some cases, overlap without hybridising. This situation is not all that unusual among Australian vertebrates—with the use of biochemical techniques many such 'cryptic species' are now being found. The remarkable thing about Bynoe's Gecko is that rubbish tips from central Australia to the western coast are crawling with parthenogenetic females. These are most easily recognised by having three (triploid) instead of two (diploid) sets of chromosomes.

Considerable effort in the past few years has been devoted to documenting the distribution of the different types of Bynoe's Gecko and to investigating their history. This involves looking at the genetic variation in proteins, chromosomes, and the DNA molecule found in the powerhouse of the cell, the mitochondrion (see box). This is like being a detective. I compare variants in sexual and parthenogenetic populations to infer what happened in the past. These studies are nearing completion for Bynoe's Gecko but are at an early stage for most other species of parthenogenetic gecko. However, some general features are already apparent.

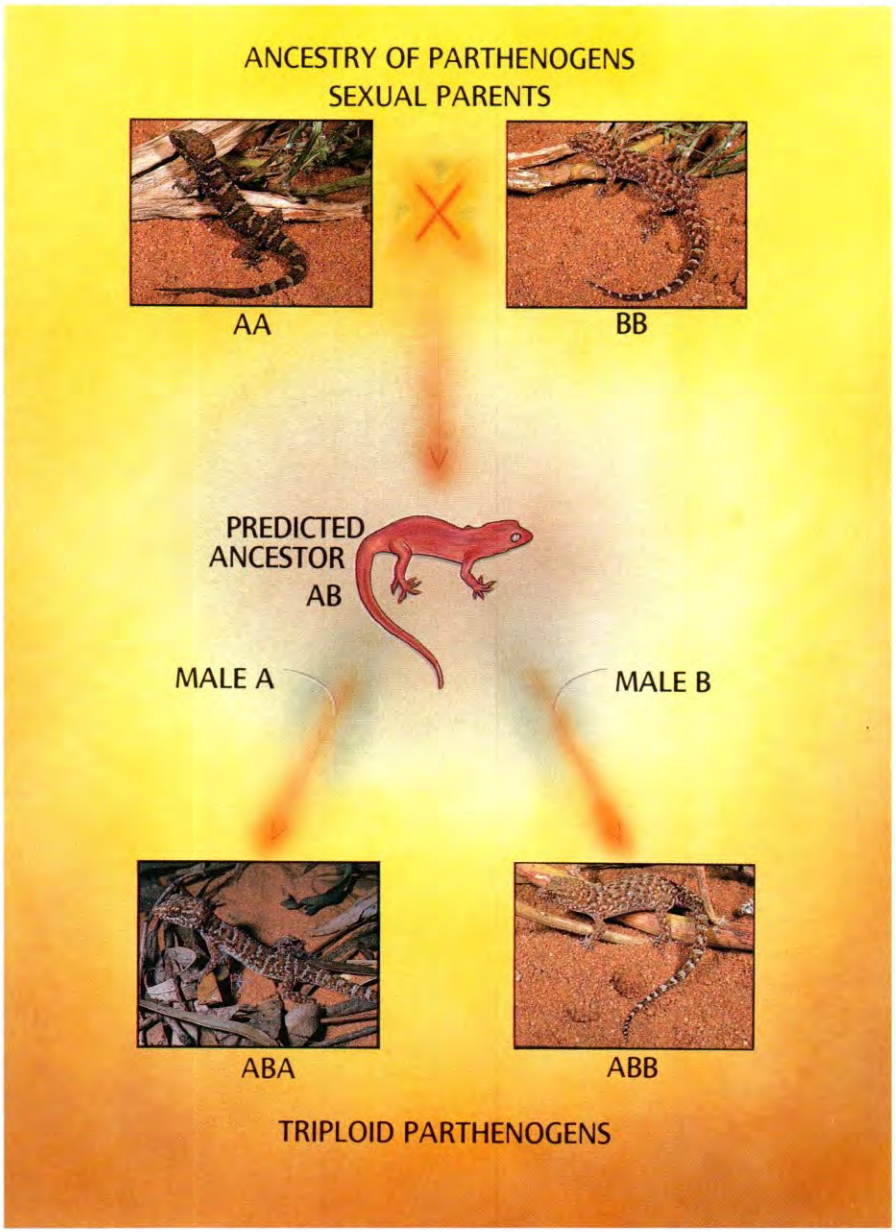
First, most (possibly all) of these parthenogenetic species arose by hybridisation, either between different species or between genetically different races within species. This is usually obvious because the parthenogens have a mixture of the protein or chromosome characteristics that distinguish the sexual parent species; in the absence of gene shuffling, the parthenogens are 'permanent hybrids'. Seen this way, parthenogenetic lineages are an aberration brought about by mismating between sexual species. For Bynoe's Gecko, the hybridisations were between two of the chromosomally different sexual forms, for now called the 'SM6' and 'CA6' races. There were probably two steps involved: the formation of diploid hybrids that could produce eggs with the full set of chromosomes, and fertilisation of these eggs by males resulting in the triploid all-female lineages found today.

Second, there can be abundant genetic variation within a parthenogenetic species—they are definitely not as uniform as some early theorists expected. This variation is epitomised by the parthenogenetic form of Bynoe's Gecko where a survey of 11 variable proteins found 54 types among 143 lizards. Contrary to the dogma, these parthenogenetic populations are usually more variable than the sexual populations. But even so, that variation is still clonal; the shuffling of genes that makes the progeny of any one female diverse is absent.

How did all this variation in Bynoe's Gecko come about? Detailed comparisons of certain proteins and chromosomes have shown that variations among the parthenogenetic lineages represent combinations of the variants present within populations of their sexual relatives. It seems that the parthenogens have frozen the diversity from both of the sexual parent species during repeated episodes of hybridisation.

Third, in contrast to the variation in proteins and chromosomes, the mitochondrial DNA (mtDNA) is usually quite uniform within a parthenogenetic species. In Bynoe's Gecko, parthenogenetic populations from Kalgoorlie to Alice Springs have no more variation than sexual geckos from a single rubbish dump and ten times less variation than is usually found between sexual populations. Similarly, only one or two types of mtDNA are found in parthenogenetic geckos from Fiji to French Polynesia and Hawaii. The same pattern has emerged from studies of parthenogenetic lizards in the Americas and Caucasia.

The reason for this uniformity lies in



IAN FAULKNER

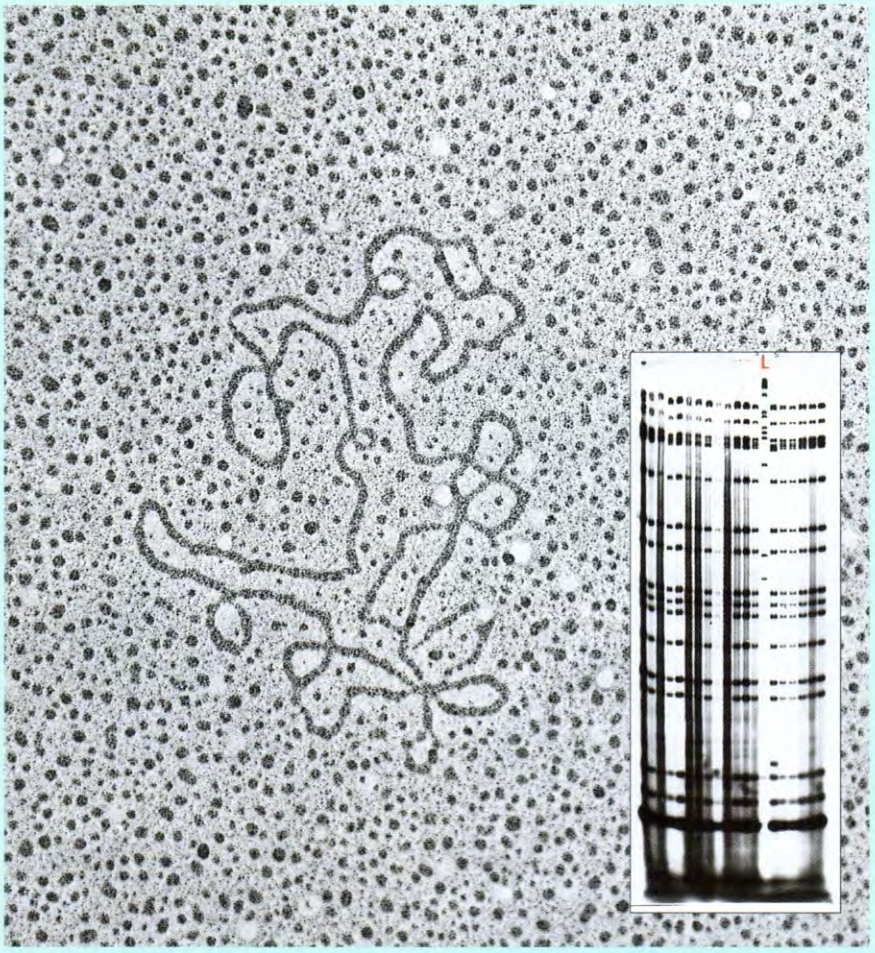
The all-female form of Bynoe's Gecko arose when two different sexual races ('CA6' = A, 'SM6' = B) crossed (top picture). This was apparently a two-step process. First, a hybrid with two sets of chromosomes (as usual) was formed (the predicted ancestor AB), at least some of the female hybrids producing eggs with two (rather then one) sets of chromosomes. Second, these hybrid females were mated with males of each sexual type to generate females with three sets of chromosomes (ABA and ABB), two from the hybrid female and one from the male. This complex ancestry can be seen in the morphology. Triploid parthenogens with two sets of chromosomes from the B parent (bottom right picture) show more of the red colour, have larger scales on the back, and less of the cross-banding than those with only one set (bottom left picture). A hybrid with two sets of chromosomes has never been found.

MITOCHONDRIAL DNA: A POWERFUL TOOL FOR EVOLUTIONARY BIOLOGISTS

Each mitochondrion contains a few copies of a small circular DNA molecule that codes for several of the enzymes needed for energy production and some of the components needed to produce these enzymes. Given its importance to the cell, it was surprising to find a decade ago that the sequence of mitochondrial DNA (mtDNA) changes faster than that of comparable nuclear genes. This, together with the ease of measuring variation (see below), has made mtDNA a valuable and popular addition to the toolbox of the evolutionary biologist.

However, mtDNA is more than just another tool; it has special properties. It is usually inherited only from the mother and doesn't recombine. Thus, changes in sequence—the record of evolution—are transmitted intact rather than being scrambled by segregation and recombination as are nuclear genes. All this means that we can estimate the history of the female lineage of a species. To find out what the males of a sexual species have been up to, we still need to look at nuclear genes or their products.

Compared with nuclear genes, mtDNA is easy to analyse. It can be separated from the more abundant nuclear DNA because of its structure: mtDNA is a supercoiled circle, whereas nuclear DNA is linear. Once isolated, the mtDNA is treated with enzymes that cut only at specific sequences of bases ('restriction enzymes') and the resulting fragments are separated according to size by gel electrophoresis. Minute amounts of DNA can be seen by tagging each fragment with radioactive bases.

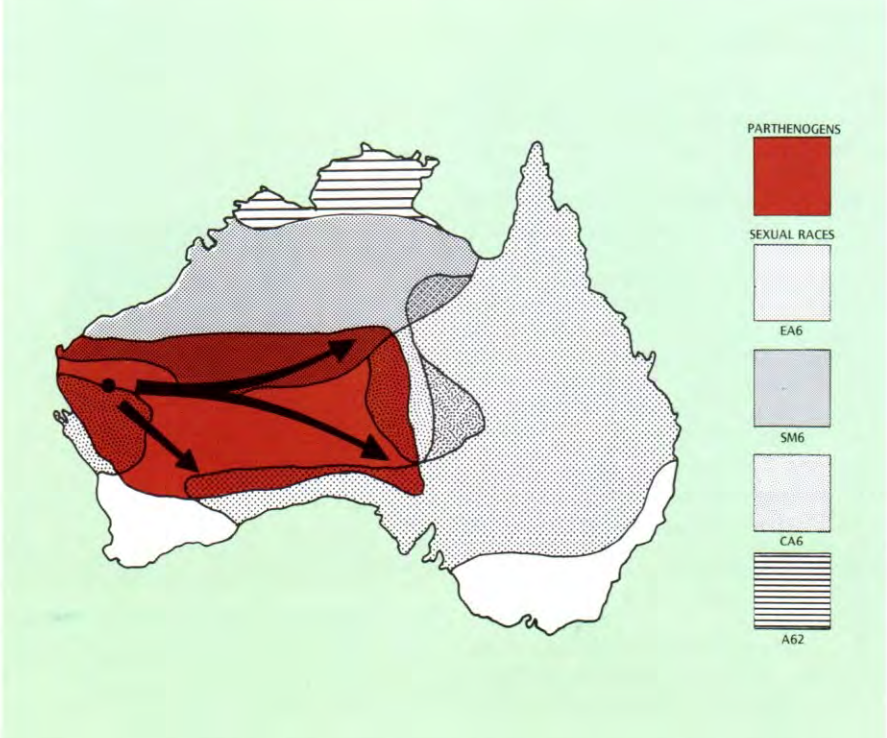


An electron micrograph of intact mtDNA. Inset: comparison of fragments of mtDNA from different lizards after treatment with a restriction enzyme. Each lane represents a sample from a different lizard except for L, which is a size marker (DNA fragments of known size). Note the similarity of fragment patterns across individuals.

the way that mtDNA is inherited: it is only passed through the mother (see box). One consequence of this maternal inheritance is that variation within sexual populations tends to be low compared to the differences between populations. Thus, if a parthenogenetic species originates through repeated hybridisations in a small geographic area, and if all mothers are of the same sexual species, then the mtDNAs inherited from the sexual species will be uniform even if the proteins and chromosomes (inherited from both parents) are not.

In the case of Bynoe's Gecko, we can even pin down where this probably happened. The parent species occur close together in both central and western Australia. However, the mtDNA in the parthenogens most closely resembles genomes in sexual lizards from northwestern Australia, specifically the western goldfields and the Hamersley Ranges. Therefore, it seems that the parthenogens arose in a small area somewhere in this region and subsequently spread eastwards to central Australia.

The uniformity of mtDNA in parthenogenetic Bynoe's Geckos also tells us that they evolved recently, at least in evolutionary terms. This molecule changes quite fast—the sequence evolves five to



The geographic distribution of the various sexual and parthenogenetic types of Bynoe's Gecko in Australia. Sexual forms are shaded in grey, parthenogenetic types in red. The 'CA6' and 'SM6' sexual forms are the parents of the parthenogens.

D.& V. BLAGDEN/NPIAW

Introduced into the Pacific by humans, the aggressive House Gecko appears to be displacing the parthenogenetic Indo-Pacific Gecko from houses.

ten times faster than genes in the nucleus. So, an ancient parthenogenetic species would have accumulated variation because of mutations in the mtDNA. To be as uniform as they are, these parthenogenetic lineages must have evolved only in the past few thousand years. In contrast, the sexual species probably separated millions of years ago. The same goes for the parthenogenetic geckos found throughout the Pacific and, in fact, all other species of parthenogenetic vertebrate so far studied.

SO WHAT DOES ALL THIS TELL US ABOUT the meaning of sex? Is there really any point to sex? It is quite clear that parthenogenesis works well in the short term. Even though these parthenogenetic lineages are quite young, they have spread across enormous distances and are incredibly abundant. This obvious success may be due to their enhanced ability to colonise—it only takes one parthenogenetic female to found a new population, whereas a sexual female must find a mate. This is a considerable advantage for the colonisation of distant oceanic islands. These islands have relatively few species of reptile present and most of the geckos are parthenogenetic. The spread of the Mourning Gecko has also been facilitated by hitching lifts on boats, in piles of bananas, just about anywhere.

The colonisation advantage may also explain the success of the parthenogenetic form of Bynoe's Gecko. These have flourished in an extremely harsh environment where local extinction may be quite common. In fact, the parthenogens appear to have displaced their sexual relatives from many areas. Perhaps parthenogenetic females are simply better at establishing new populations following local extinctions. We are currently studying this possibility by creating new 'habitat'—piles of roofing iron—and monitoring colonisation.

However, the future may not be so rosy. The very fact that so few species are parthenogenetic, and that those that are arose recently, suggests they are not long for this world. The reason may lie in interactions with other species rather than variation in the physical environment. Humans have inadvertently started a large natural experiment by introducing the House Gecko (*Hemidactylus frenatus*) to Pacific islands since World War 2. This very aggressive species (it makes the 'Tch tch tch' noise on houses in Darwin) appears to be displacing the parthenogenetic Indo-Pacific Gecko from houses. Perhaps the advantage of sex lies with parasites and pathogens. Studies of parthenogenetic fish and snails suggest that parthenogens suffer more from parasites, presumably because the parasites have adapted to the frozen genetic defences of the parthenogens. The distribution of parasites in parthenogenetic and sexual populations of geckos is currently under investigation.

These studies of the secret lives and past of parthenogenetic lizards are funded by the Australian Research Council, the National Geographic Society and the University of Queensland. They represent 'pure' curiosity-driven research. The questions asked are very basic and definitive answers hard to come by. If these and similar studies can provide a convincing explanation for sex, we will understand more about evolution. Already we have learned to focus more on biological interactions and less on the physical environment.

However, the implications are even broader. The common catchcry these days is that we need to conserve 'genetic diversity'. Sure, but why? How does genetic variation shape ecology and the response to natural selection? What is the best way to conserve genetic diversity? The urgent need for conservation is not in question. But to make adequate provision for the future of the biota we need to understand its past and the evolutionary process itself. Parthenogenetic lizards are a set of natural experiments that offer one approach to the problem. ■

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Dr Craig Moritz is a lecturer in the Centre for Conservation Biology and Department of Zoology at the University of Queensland. His interests are in evolutionary biology and the application of genetics to conservation. Much of the work described in this article has been collaborative, with significant contributions from M. Adams, P. Baverstock, D. Bolger, W. Brown, T. Case, S. Donnellan and collectors too numerous to mention individually.

FRANK HURLEY COLLECTION

"Now and then there appears out of the confusion of our complex and noisy civilization a being seemingly strayed from some more romantic day when galleons sailed the blue Caribbean and Marco Polo, moved by a great curiosity, set out on his adventurous journey to Cathay. In an age when human effort so largely tends toward making life a communal and unindividualistic affair, the figure of a man who desires solitude and the experience of penetrating an unexplored country, stands forth unique and somewhat incongruous. Such a one is Frank Hurley. . ."

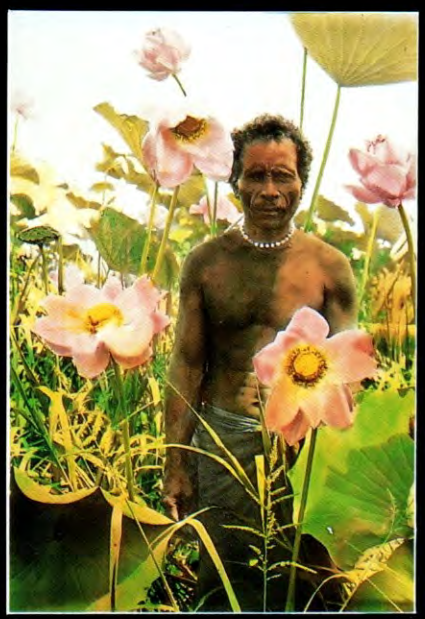
So wrote G.P. Putnam from the foreword to the book *Pearls and Savages* by Frank Hurley (G.P. Putnam's Sons, 1924). The desire to capture colour has been an aim of

COMPILED BY RIC BOLZAN
HEAD OF PHOTOGRAPHY, AUSTRALIAN MUSEUM

"The young woman who stands erect is not, as might be supposed, the widow. The two widows are the wretched creatures concealed beneath the canopies of *tapa* cloth." Wanigela, Collingwood Bay.

"We stood on the threshold of a great hall that extended like a vast cavern into a remote gloom. From roof and walls pended an amazing collection of fantastic masks in various stages of construction." Purari Delta, Gulf of Papua.

"Vaieki, the coxswain, in one of the giant fields of lotuses which bordered the shores of Lake Murray. These mammoth and flamboyantly lovely flowers are like all the vegetation of the district. . .extravagant and incredibly beautiful. The blossoms were of a delicate pink and measured up to fourteen inches across. The lotus is a new species." Lake Murray.



"The shore was bordered with rows of skulls stuck on poles and ornamented with ruffs of palm leaves which stirred with a weird motion in the breeze. . .The palm-fringed skulls are brought out. . .to display to visiting guests the prowess and power of the tribe." Kerewa village, Gulf of Papua.

FRANK HURLEY COLLECTION

photographers since it was first realised it was possible to make permanent images by the action of light. Frank Hurley was no exception. He experimented with Finlay colour in the 1920s, and a number of lantern slides produced from the negatives he made on his voyages to Papua in 1920–1923 were hand-coloured. These precursors to the 35-millimetre colour slides of today were produced by making a glass positive from the original negative, then dyes were used to painstakingly paint the emulsion. This selection of hand-coloured lantern slides is thought to have been produced by Hurley himself to illustrate lectures about his travels.

"Garments! What more beautiful than the exquisite brown skin with which Nature had endowed them, adorned with the plumage of birds and garlands of flowers. The debutantes of Eroro were wrapped in gowns of clinging Tapa bark draped like an apron in front and draped like an apron behind. From out this chic and racy attire blossomed the female form divine". Beiama, Oro Bay.

"The submarine glory of a coral reef, unexcelled for beauty among all the spectacles of the Universe." Torres Strait.

"Kaimari ladies. . .their dress, microscopically speaking, is customary rather then effective. The hair is shorn close, leaving a narrow ridge down the centre, and two rings above the ears resemble tufts of astrakan." Gulf of Papua.

"Day after day the file of brown men with Father Bach and myself at the head climbed the winding track to mountain crests or plunged into deep valleys, where we loitered beside cool mountain torrents that made the gorges noisy with their ceaseless song." Goilala country, inland from Kairuku.

"Certainly the message was clear, written on stone tablets in the wilderness; what was missing was a Marsupial Moses to read it."

LIFE'S SCROLL OF PROPHECY: CONSERVATION & THE FOSSIL RECORD

BY MICHAEL ARCHER
SCHOOL OF BIOLOGICAL SCIENCE, UNIVERSITY OF NEW SOUTH WALES

MOST OF US ARE CURIOUS ABOUT history because we presume it has something to teach us about the modern world. James A. Garfield, the 20th President of the United States, stood back to proclaim an even grander vision: "History is but the unrolled scroll of prophecy". For those of us buried up to our armpits in *pre*history, this vast yet simple statement encapsulates a major reason for devoting our lives to palaeontology.

After centuries of accumulating organic wonders from the past, we are now in a position to use this record to do much more than correlate rock units and terrorise little kids with skeletons of meat-sucking dinosaurs. If Garfield is right, museum and university fossil collections may provide one of the most powerful tools for predicting and hence potentially averting extinctions.

Extinction *per se* is not a demon in need of a wooden stake. On the contrary, considering that the 'blind purpose of life' (if it must be said to have any) is the compulsion to maintain itself, it can only do so if it can change its form to match the changes of an inconstant world. In most cases, that means replacement of one taxon by another better suited to produce the succeeding generation.

Unlike natural and necessary replacements in biological diversity, *inappropriate* extinctions are the consequence and hallmark of the spread of humanity. No gargantuan meteorite, no heaving, sundering Earth, no inexorable icesheet ever obliterated Earth's species at the rate we have managed, a rate so high that natural speciation processes are utterly incapable of filling the biological vacuum that rushes in behind. We will leave as a fossil record, for whatever creature next ascends the throne of global dominance, billions of beer cans, bitumen and an incredible decline in Earth's biodiversity.

In stark contrast to the anticipated fossil record of our own reign, the fossil rocks of Riversleigh in north-western Queensland contain, for those with eyes to see and understand, family albums of elegant, diverse creatures that came and went long before the first human picked up a stone in Africa. Yet they contain more than views of intriguing worlds lost. Herein lies the stuff of prophecy as well as revelation, the means for understanding the nature of the present as well as anticipating its future. For here are points along a lifeline with substance seen only by eyes not blind to the fourth dimension. By plotting the changes through time in diversity, relative abundance, morphology and distribution, we can 'connect the dots' of lines passing from the wraiths of life's past, through countless links to modern ever-changing descendants and, with properly restrained confidence (there being many factors to consider), on into the future of these lineages.

"It is impossible to determine from a decade or two of modern field studies the conservation status of a living species."

For example, from these rocks we have already discovered that platypuses, woolly ringtail possums, rat-kangaroos, orange horseshoe bats, mountain pygmy-possums and forest bandicoots have been on nose-dives of one kind or another on their way to their present condition. In contrast, colubrid snakes, cuscuses, many dasyures, peramelid bandicoots, macropodid kangaroos, gliding possums and Australian fruit-bats are on the rise and far better off now than they were in the Miocene. Yet other groups, such as pythons, brushtail possums, marsupial moles and ghost bats have pretty much held their own over the last 25 million years. These differences, albeit crudely summarised in this way, represent the beginnings of a historical database for reviewing current understanding about the conservation priorities of these animals.

Herein lies the main point of this essay: quite simply, it is impossible to determine from a decade or two of modern field studies the conservation status of a living species. It can't be done—not with confidence—because there is an important distinction between short- and long-term changes in populations. Short-term perturbations in populations may alert us to short-term problems (such as the modern reduction in habitat for the Koala), but we cannot rely on these to define the long-term health of a lineage. Rarity in a modern ecosystem cannot be interpreted as anything other than rarity. To tell if a lineage is in an overall state of decline, rise or stability, we simply must have a long-term perspective, one that spans thousands if not millions of years—not just a brief two centuries.

Let's consider the value of the fossil record to understanding the fate of another 'modern' species: the recently exterminated Thylacine or 'Tasmanian Tiger' (*Thylacinus cynocephalus*). Riversleigh's thylacinid record is now being studied by Jeanette Muirhead, a University of New South Wales palaeontologist with a rapidly enriching 'vision' of the history of this group. In the older (late Oligocene to middle Miocene) Riversleigh assemblages she has found five different kinds of marsupial 'tigers' representing at least three distinct genera. One of these, a 'primitive' form that demonstrates the close relationships of thylacines and dasyures, was recently described as *Nimbacinus dicksoni*. This diversity subsequently declined into the middle Miocene and, by late Miocene time, there was a single species, *Thylacinus potens* (known from the Alcoota Local Fauna). By the early Pliocene, this species had given rise and way to the modern one, *T. cynocephalus*. But this decline was not just in terms of biodiversity. During the Oligocene, Miocene and Pliocene, thylacinids were widespread over the continent. In the Pliocene and Pleistocene they were even in New Guinea. But by the middle Holocene, about 4,000 years ago, Thylacines had vanished from the Australian mainland, about the same time that the Dingo first appeared. By the time of arrival of Cook's ship with its hull-full of

Intrigue twines with horror as we stare at a photograph taken in 1912 of an arrogant hunter across whose knee is draped, in an obscene parody of life, a carcass of the now-extinct Thylacine.

AUSTRALIAN MUSEUM

grim reapers, the Thylacine was hanging on by its whiskers to the island of Tasmania, the only landmass Dingoes had failed to reach.

Clearly, *from the fossil record and this database alone,* it is possible to say that, before Cook's arrival, the house of 'Austral Tigers' was in severe decline. With invasion of Tasmania in 1803 and the introduction of hard-hoofed sheep to that fragile land, the heel of the English boot bit deep into the heart of native Australia. When the precious remnants of Earth's last population of Thylacines came face to face with one million introduced, brainless sheep, their fate was unfortunately sealed. Urged by State government bounties, we shot, snared and poisoned every one we could find until there simply were no more to destroy. On 7 September 1936, when the breath of life escaped the last captive Thylacine in Tasmania's Beaumaris Zoo, the last of this noble lineage, which had withstood more than 25 million years of natural change, crossed unnoticed over the threshold of extinction. Since that black day, dozens of futile expeditions to discover a still-surviving Thylacine, as well as attempts to deduce a non-human cause for the extinction, have failed to wash that blood from our hands.

That, in a nutshell, is how this act of biological vandalism unfolded. But what *might* have happened if Captain Cook had had aboard the *Endeavour* a conservation-minded palaeontologist who, in 1788, managed to discover and understand the warning of Riversleigh's fossil record? After weeks in the limestone hills, he would have come back to Cook with dire warnings about the dangerously brittle future of the Tasmanian Thylacine. Then, if his advice had been heeded from the outset, perhaps the tragic creature on Tasmania's Coat of Arms would still be alive. Certainly the message was clear, written on stone tablets in the wilderness; what was missing was a Marsupial Moses to read it. Unfortunately, Cook had no such colonial Cassandra, so the Thylacine is gone. With the memory fresh in our minds of the last 'Tiger's' blood dripping from the knife-edge of that 'resource development' program, Jeanette and the rest of us reading warnings about the future of life anticipated in the fossil record are determined to let nothing like this happen again.

The potential benefits of using the past to secure the future is not confined to the creatures of the land. Since 1962 there has been a great deal of controversy about the effects of the Crown-of-thorns Starfish on the Great Barrier Reef. On the assumption that human overcollection of the Triton (one of its natural predators) allowed its numbers to blossom, active control programs were instituted here and in Japan. Then Peter Walbran and his colleagues at James Cook University, supported by the Great Barrier Reef Marine Park Authority, sought an answer to the simple question that should have been asked in the first place: "Is it possible that blooms of this starfish are natural events and nothing to do with European activity on the reefs?" Like bushfires over much of Australia, it is even conceivable that these starfish-feeding frenzies are necessary for the healthy renewal of reef communities and perhaps, ultimately, maintenance of higher biodiversity. After coring and dating the reef, they found high numbers of Crown-of-thorns Starfish pieces extending back several thousands of years (see Quips, Quotes and Curios, this issue). Quite clearly, this predator was kicking up its tube feet long before Europeans picked a single shell off the reef. And, if true, the *control* programs, which involve injecting these creatures with formalin, quick lime and copper sulphate (all awful poisons to put into the reef's waters), may constitute the real problem, not the starfish's gluttony. What is urgently needed now is more research into the reef's fossil record to determine whether the high numbers of fossil starfish bits are the result of episodic blooms or constant medium density of this predator. In short, although we are in there like grim reapers swinging scythes of every type and dimension, we are still ignorant about whether or not this is appropriate intervention.

Documenting and understanding the history of biological change has always been the prime business of palaeontology. Preserving the *capacity* for that change must be the prime business of conservation. To be successful, knowledge of *both* the history and modern status of lineages is required to determine their current conservation 'health' as well as the range of factors that might affect their future. Conservationists must therefore consider the significance of long-term evolutionary and ecological trends determined by palaeontologists before making judgements about the status of vulnerable species and habitats. These *pre*-human trends must be determined before the conservation significance of historical change can be understood. Without this fourth-dimensional vision, many of the world's biological treasures will slip through our fingers—before we even knew they were sliding towards the abyss. ■

Suggested Reading

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Professor Michael Archer lectures in biology and geology at the University of New South Wales. Most of his non-teaching hours are devoted to the study of the fossil faunas of Riversleigh.

"In this you can see the paradox of the title of Darwin's great work, The origin of species. *He found the origin but lost the species."*

THE TEMPO OF SPECIATION

BY GLEN INGRAM & RALPH MOLNAR

VERTEBRATE ZOOLOGY, QUEENSLAND MUSEUM
VERTEBRATE FOSSILS, QUEENSLAND MUSEUM

ARE SPECIES INDIVIDUALS OR ABstractions? Are they real or classes? You are an individual; are species analogous? Or, are they classes, groups of things we define?

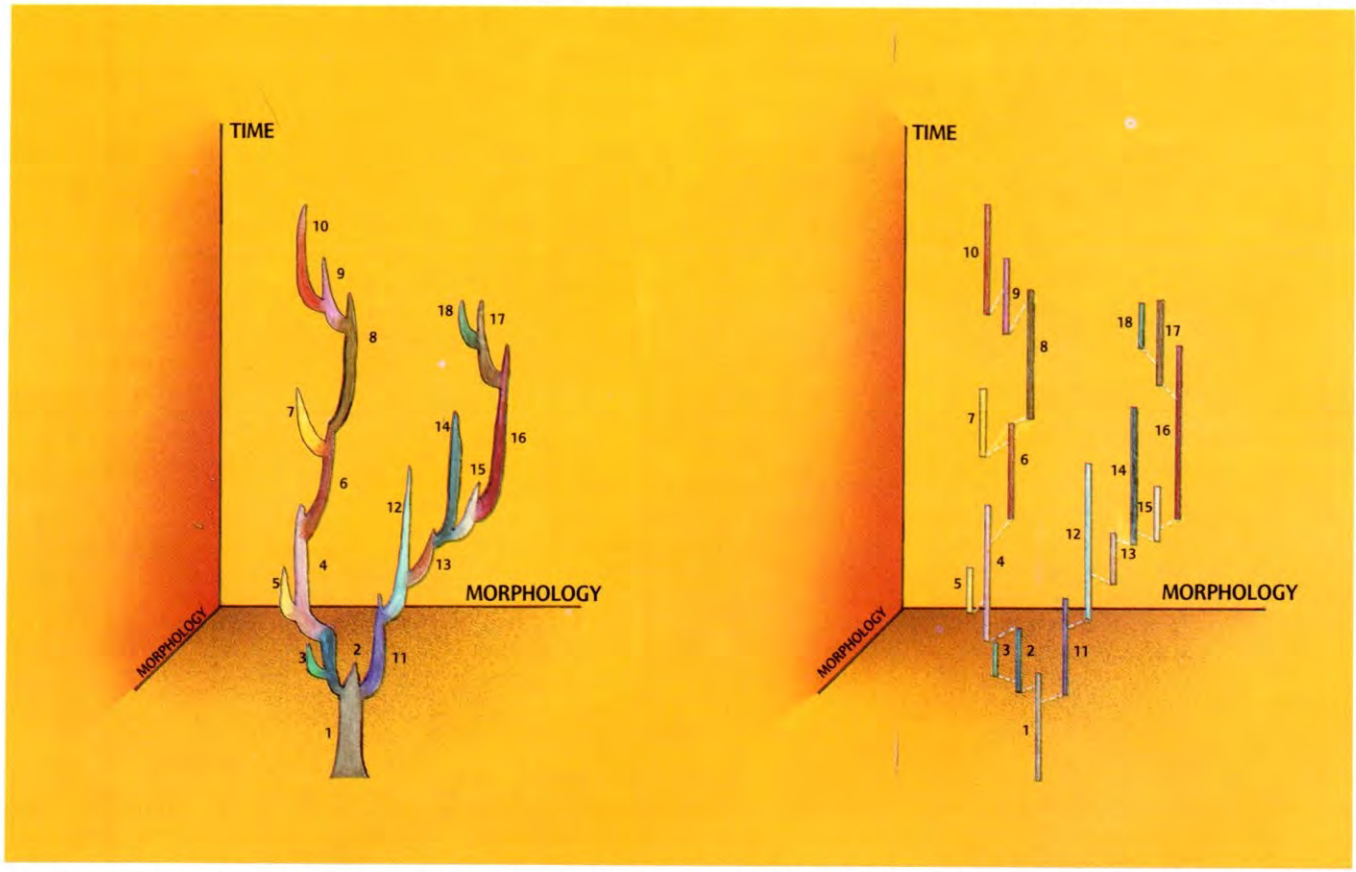
The distinction is very important. Individuals are real. They cannot be defined. They are discovered, described and named (baptised). Individuals are born, they change and they die. Despite change, they maintain their identity. They remain the same, even though there is modification in their appearances from birth to death. You, dear reader, do exactly the same. Despite change (ageing), you are still the same individual.

Classes are abstractions. They are defined. They are groups of similar things we designate. Take 'chairs' as an example. They are a class of manufactured items that have flat areas, where bottoms are placed, connected to nearly perpendicular pieces against which backs are rested. However, the class is contrived. What do we do with beanbags, for example? Are they chairs?

Similarly, is the species 'Red Kangaroo' analogous to chairs? Is it a class we have defined to include all large, fluffy marsupials with big ears that bounce along and send farmers broke? Or is it an individual we discovered? Individuals or abstractions—the answer is linked to two competing theories about tempo in speciation—phyletic gradualism and punctuated equilibria.

According to Darwin in *The origin of species* (1859), "The geological record is extremely imperfect and this fact will to a large extent explain why we do not find interminable varieties, connecting together all the extinct and existing forms of life by the finest graduated steps. He who rejects these views on the nature of the geological record, will rightly reject my whole theory."

The geological record worried Darwin. He thought species arose by gradual change—phyletic gradualism. Bit by bit, and slowly, an ancestral species transformed into a different, modified species. The transformation involved the whole population across its entire range. If his hypothesis were correct, the fossil record should contain graded fossil sequences. Nearly always, however, the record contained gaps. Species of one layer often were different to species of the following layer. New species suddenly appeared.



IAN FAULKNER

The 'Tree of Life' for 33 hypothetical species. A. From the perspective of phyletic gradualism, the branches gradually taper and diverge as species (solid colours) transform and merge with one another. A relatively slow and equal rate of transformation rules. B. The same tree viewed from the perspective of punctuated equilibria. The branches do not taper and are tenuously connected. Species have periods of stasis punctuated by speciation events (dashed lines). For most of the time there is little change then there is rapid transformation. (Based on Eldredge and Gould 1972: figs 5–9, 5–10.)

They weren't connected by intermediates.

Darwin said the gaps were imperfections in the fossil record. This is understandable. The conditions under which fossils form from dead plants and animals are very specialised, so fossils tend to be something of a geological curiosity. Further, the chance of having a sequence of specimens fossilised through anything from decades to millions of years is more remote. Then, even if both events do occur, for some fossils to survive erosion and metamorphic and tectonic changes, and then to be found, highlights the minuscule chance of finding a perfect record by which to test Darwinian tempo.

The important implication of gradualism concerned the nature of species. Counter to intuition, they could not be real. In time, one graded into the other. To us, now, they appear to be spatiotemporal entities but that is an artefact of our short temporal frame. We have only seen them through one time slice—that of recorded history. The small time slice makes species appear unchanging and discrete. But, in the perspective of the whole of geological time, 'species' have transformed.

In this you can see that paradox of the title of Darwin's great work, *The origin of species*. He found the origin but lost the species. At most, species were what a good naturalist recognised and defined. They were classes of similar individuals, artificial constructs for ease of human cognition.

Niles Eldredge and Stephen Jay Gould (1972) view speciation differently: "Many breaks in the fossil record are real; they express the way in which evolution occurs, not fragments of an imperfect record. The sharp break in a local column accurately records what happened in that area through time."

To this day, few graded fossil sequences have been found. Gaps are still the rule. This failure to locate sequences suggests another way of seeing 'tempo' within evolutionary theory. Gaps can be viewed in the opposite way: instead of being a sign that something is missing, they could indicate that nothing is missing. Eldredge and Gould decided that many of the gaps were real. If they were real, then the fossil record showed that, in most cases, "the history of evolution is not one of stately unfolding, but a story of homeostatic equilibria, disturbed only 'rarely'. . .by rapid and episodic events of speciation." Hence 'punctuated equilibria'. Species became extinct or continued in time, but they did not grade into other species.

That gaps are real, according to Eldredge and Gould, is a logical conclusion from the theory of allopatric speciation. This theory states that species only arise in small local populations isolated from the geographic range of the parent species. If new fossil species are not found where their ancestors lived, we can hardly expect to find graded fossil sequences in the local rock column. As well, most of the morphological change would occur early in the differentiation of a new species. This change would take place in the local population in a very short period relative to the total duration of the species. Again, in the fossil record, we should not expect to find graded fossil sequences.

The important implication of punctuated equilibria for the nature of species is that they are real. Species are spatiotemporal discrete entities. They suddenly appear in time (are born), persist over a long period with relatively little change, and become extinct (die). In fact, they are individuals. We discover them; we do not make them up. And species names are proper names like Georgina, Fiona and Ralph. They impart identity.

Despite phyletic gradualism's pedigree, there has been little hard evidence to support it. One recent study that does is Peter Sheldon's work on trilobites from Central Wales (UK). He examined approximately 15,000 trilobites from a period of about three million years. He found eight lineages where earlier 'species' merged gradually into more younger 'species'. He could not find any breaks.

So which is correct: phyletic gradualism or punctuated equilibria? It is difficult to say. The fossil record will never refute either of these hypotheses because of the ways in which they are framed. Gradualists can always argue that something is missing to explain gaps and the 'punks' can always pick gaps in gradients.

However, there may be a simple solution. Maybe we should just trust observation and be empirical. In the wild, individual species appear to be real: even across cultures there is a large amount of agreement among perceived natural entities. And why should we accept gradualism anyway? Darwin had no evidence for that kind of tempo. He simply imposed it. And, despite Darwin's conviction that his "whole theory" would be rejected if gradualism were false, nothing of the kind has happened. Punctuated equilibria appear to be here to stay. ■

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Dr Glen Ingram is interested in evolution and the philosophy of science. In 1987 he received a special commendation from the BBC Wildlife Nature Writing Awards. 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 the Miocene.

QUESTIONS & ANSWERS

COMPILED BY JENNIFER SAUNDERS
EDITORIAL ASSISTANT

Mammal Mystery

Q. In 1925 one of the finest and most comprehensive reference books on Australasian mammals entitled *The Wild Animals of Australasia* was published. I have long cherished my copy with its wealth of information and fascinating photographs of mammals, including species that are now extinct or highly endangered. Particularly interesting are two mysteries that the book presents.

On page 235 there is a photograph of a potoroo, entitled "Broad-Faced Rat Kangaroo (*Caloprymnus platyops*)", however, according to the *Australian Museum complete book of Australian Mammals* (1983), the last-known specimen of this extinct species was collected in 1875. Is this really a photograph of a long-extinct species and, if not, can the real identity of the individual in the photograph be determined?

The second mystery occurs on page 332 where the text gives distribution and descriptive details of what it refers to as a "Striped Marsupial Cat". This species was also listed in *Furred animals of Australia* (1947) up to and including the 8th edition, however, in more recent works, this "Striped Marsupial Cat" has been completely omitted.

What I find remarkable is that the authors were the most qualified zoologists of their time and yet this Striped Marsupial Cat has disappeared from scientific literature. What is the true identity of this striped marsupial? Did it exist and, if so, what has happened to it?

—Gary Opit
North Tamborine, Qld

A. In 1925 far less was known about Australian mammals than at present, and Burrell and Troughton's *The wild animals of Australasia* was a landmark publication at the time. However, inaccuracies did creep in. The animal figured on page 235 is almost certainly a Burrowing Bettong (*Bettongia lesueur*). The reference to the "Striped Marsupial Cat" is not a mistake, but a case where modern science has caught up with an old mystery. The records of large cat-like animals in the Atherton Tablelands region go back to the 1870s before the region's two tree-kangaroo species were identified. It now seems likely that the more reliable older accounts refer to tree-kangaroos, which are unusual-looking animals if you have not seen them before.

—Tim Flannery
Australian Museum

Lumholtz Tree Kangaroo—a probable contender for the name "Striped Marsupial Cat" before tree-kangaroos were identified.

JOHN BUTLER/LOCHMAN TRANSPARENCIES

N. CHAFFER/NPIAW

Deep Water Electricity

Q. I was most interested in your recent article on whalefishes. One of the most interesting of the whalefishes mentioned was Storer's Whalefish. This fish was said to have cavernous scales along or near to the lateral line and others along the skull. Could these scales be used by the fish to detect their prey by the use of electricity (like the Platypus)?

—Matthew West
St Ives

The Little Numbfish (*Hypnos monopterygium*) is strongly electric.

A. Your question regarding the possible use of electroreception to locate prey by whalefishes is interesting. Confirmation of such a possibility would require experiments on live whalefishes, as were done on the Platypus and Echidna (ANH vol. 23, no. 4, 1990). And with most whalefishes living deeper than one kilometre, our chances of obtaining a live one in the near future are not high. To date none of the microscopic sections of whalefish tissue examined has appeared similar to electroreceptor tissue.

There are a number of fishes that produce electricity and these can be divided into two groups. The first are strongly electric, for defense or to stun prey, and include the electric eel from the fresh waters of South America, the electric catfish from African fresh waters and the marine electric rays, including our own Little Numbfish. The second group are weakly electric, for electrolocation, and include the elephant-nosed fishes from the fresh waters of Africa and the knifefishes from the fresh waters of South America. These latter groups of fishes have electroreceptors that are modified portions of the lateral line system. Sharks also have weak electric field receptors on the snout and the function of these distinctive 'ampullae of Lorenzini', first described more than 300 years ago, has been discovered only in the last 30 years.

There is much to learn about the physiology of deep-sea fishes and many of our questions must go unanswered until we perfect a way to bring these fascinating animals to the surface alive.

—John R. Paxton
Australian Museum

Mangrove Growth

Q. In the last six months, there has been a phenomenal and sudden regrowth of mangroves—I think over half a hectare here at Port Welshpool. What strikes me as odd is a couple of hundred metres away, up a channel, all the mangrove swamps have died on one side. Can the fact that this side adjoins farmland, whereas the healthy side spreads into more mangrove swamps, have something to do with the dieback? Also, what is the likelihood that the young trees (now 15–20 centimetres high) will still be living after they finish dredging—about a kilometre from the regrowth area—for the new Tasmanian ferry, which will be starting soon?

—Helen J. Kennedy
Port Welshpool, Vic.

A. The mangroves found at Port Welshpool in Victoria consist of one species, *Avicennia marina* or the Grey Mangrove. At this location they are close to the southern-most mangroves in the world at Wilsons Promontory. The Grey Mangrove at

this latitude produces large crops of seeds every few years in early summer. These seeds actually germinate on the parent and, after dispersal, can colonise large areas very rapidly, however few of these seedlings survive to become adults.

The Grey Mangrove often grows in pure stands and, as with any monoculture, is susceptible to natural and human disturbance. Often large areas of mangroves die as a result of insect or fungal attack and even a severe frost can kill patches of mangroves. Human

PETER CLARKE

The Grey Mangrove is susceptible to natural and human disturbance.

disturbances as a result of clearing have destroyed large areas of mangroves in Australia, although oil pollution, sedimentation and disruption of tidal flow can also cause their demise.

The specific cause of the dieback at Port Welshpool and the impact of dredging on the mangrove stands are not easily answered without on-site knowledge and details of the dredging proposal.

—Peter Clarke
Plant Ecologist
CSIRO Div. of Fisheries

Exchange Rate

Q. Earthquakes are measured on the Richter scale, open-ended or otherwise, which I know to be logarithmic. However, I have never seen 'one Richter' defined. Could you please do so?

—Thomas Cobcroft
Ipswich, Qld

A. In theory, on the 'open-ended' Richter scale there is no upper or lower limit. In practice, however, the largest earthquakes recorded have been 8.9 magnitude (Japan 1933 and Colombia–Ecuador 1906). The smallest can be below Richter's original zero level and are assigned negative values. A magnitude 1 event would usually only be detected by a seismograph, while a magnitude 2 is about the smallest unit that can be felt by humans.

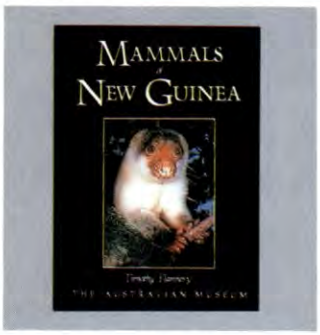
Earthquake signals cover a large size range, so the logarithm to base 10 of the maximum wave amplitude measured on a specific part of the seismograph is taken to compress the scale. This amplitude represents the maximum actual ground motion in a magnified form. It is corrected for magnification of the seismograph and for distance to the earthquake epicentre to give the Richter magnitude. Usually the results from several seismographs are used to assess this magnitude.

An increase of one magnitude step represents a ten-times increase in maximum earthquake wave amplitude but, as the scale is logarithmic, an increase of two steps is an increase of 10 × 10 (100) times. In terms of total energy released as seismic waves, an increase of one magnitude step is an energy increase of approximately 30 times and a step of two magnitudes is about 30 × 30 (900) times.

—Ross Pogson
Australian Museum

REVIEWS

COMPILED BY JENNIFER SAUNDERS
EDITORIAL ASSISTANT



Mammals of New Guinea
By Timothy Flannery. Robert Brown and Associates, Queensland, 1990, 440pp. $79.95.

The past decade has been exciting for zoologists interested in Australian mammals. It has been marked by the publication of at least a dozen major books in this field, yet every one of these has been flawed by an inability to compare Australian mammals with the related fauna of New Guinea. This difficulty has been obviated to a considerable extent by Timothy Flannery's *Mammals of New Guinea.*

Similar in layout to *The Australian Museum complete book of Australian mammals* (Strahan, 1983), it presents an account of what is known of the natural history of each mammal species with an accompanying column of data on measurements, survival status, subspecies, extralimital distribution, altitudinal range (very significant in New Guinea) and synonyms. The English, Indonesian and local (Niuginian) common names are listed, with the derivation of pronunciation of the scientific names. Most species are illustrated by colour photographs and, bearing in mind the rarity of these, this is in itself an eye-opener. In a few instances, old lithographs are used and the heads of many bats are represented by line drawings of preserved specimens.

A distribution map, often remarkably bare, indicates the localities of all specimens known to the author. These localities are combined in one introductory map, which eloquently demonstrates a lack of information from at least one-third of the island. Of enormous value to working mammalogists is an appendix of photographs of the skulls of 177 species, with dorsal, ventral and lateral views of crania, and dorsal and lateral views of the lower jaws. No comparable resource exists for the mammals of Australia.

On Flannery's account, which is by no means final, New Guinea has two species of monotremes, some 60 marsupials, 57 rodents and 70 bats. Australia has more than twice as many marsupials but the numbers of rodents and bats are comparable, even though New Guinea is only 12 per cent of the area of Australia. One expects a diversity of bats in tropical areas but the richness of the New Guinean rodents is less simply explained.

There can be no doubt that New Guinea and Australia are part of the same zoogeographical realm, but the New Guinean mammals are far from a simple subset of the Australian fauna. Only about five per cent of the combined marsupial and rodent species are common to both regions whereas, reflecting their greater mobility, about a quarter of the bats are. Clearly, a great deal of evolution has occurred independently in New Guinea and Flannery has combined his palaeontological and zoological expertise to produce an overview of the probable major trends in colonisation and radiation.

In geological terms, New Guinea is new. For most of the past 140 million years it was represented by no more than an east–west chain of islands that did not begin to coalesce into a continuous mountain spine until about 15 million years ago, under pressure from the northward moving Australian continental plate. There appear to have been only two periods during which there was a land connection with Australia: first, in the Eocene and Oligocene (55–25 million years ago); and again in the Pleistocene (two million years ago). It is not difficult to make a reasonable reconstruction of the two-way Pleistocene traffic across a Torresian bridge, but Flannery exposes some difficulties in estimating the time of arrival of the founders of the New Guinean mammal fauna.

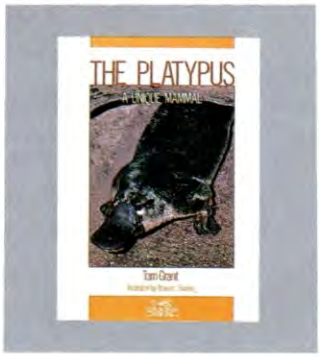
For example, if our understanding of the geological history of the region is correct, marsupials cannot have entered New Guinea from Australia later than the early Miocene (via the last of the Oligocene connection) but this does not gel with what is known of the Australian fauna at that time. Australian candidates for a pioneering role in New Guinea are being found in sediments provisionally dated at 14–10 million years ago (even 4.5 million years ago) but this seems far too late. It may be that the dating of Australian fossils is at fault.

The extreme endemicity of the New Guinean rodents is evidence of an early radiation (perhaps dating back to the late Miocene) of a founding stock distinct from that which gave rise to the 'old endemics' of Australia. Fruit-bats seem to have been among the first mammals to colonise New Guinea and Flannery points to the interesting fact that some of these are partly insectivorous, exploiting a niche that may have remained vacant until marsupials and rodents became established.

Much more research remains to be done and *Mammals of New Guinea* provides a scaffolding within which this can proceed. It is an extraordinary work, and even more so because it has been compiled over a relatively short period by one person incorporating the results of his own extensive field work. In terms of impact and originality it can aptly be compared with Gould's equally amazing, singly authored *Mammals of Australia*, published more than a century ago.

In recognition of this outstanding work, *Mammals of New Guinea* has been awarded a certificate of commendation at the 1990 Whitley Book Awards.

—Ronald Strahan
Australian Museum



The Platypus: A Unique Mammal
By Tom Grant. New South Wales University Press, Sydney, 1989, 73pp. $14.95.

This is the second edition of an excellent publication that has been available since 1984. It was the first book on mammals published in the Australian Natural History series (*The Koala* and *The Wombat* are the subsequent publications). The value of this series is that each book is written by an expert on the species. The author of *The Platypus*, Tom Grant, is an acknowledged expert on this amazing mammal and his book contains the wealth of knowledge he has gained over the years of observing and handling Platypuses.

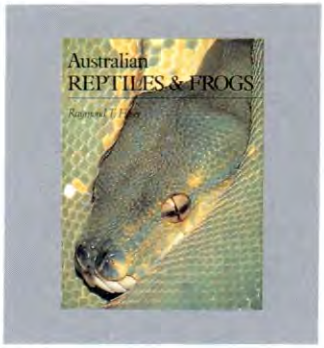
There have been few changes or additions appearing in this second edition but most notable, and a definite improvement, is the expanded "Contents" section and a species "Summary". The original approach of presenting the world of the Platypus through the seasons has been retained, but now also includes the important biological aspects of the animal (such as diet, reproduction, social organisation etc.) listed as subheadings within the "Seasons" chapter headings.

As one who is used to grab-

bing a book off the shelf to look up a particular aspect of the biology of an animal, I now find this book far easier to use. Those readers who were attracted by the readability of this book and its non-textbook layout will find these have not been compromised by the additions.

Some new information is also presented, such as the exciting discovery of the ability of the Platypus to detect, through its bill, tiny electrical fields emitted by its prey. Despite these breakthroughs in our knowledge of the Platypus, the book also points out that such basic information as gestation and egg incubation times are still not known. The section dealing with Platypus distribution and status paints a far brighter picture than the one we are used to reading about for Australian mammals. In these days of lists of extinct and endangered mammals the Platypus, it appears, is still to be found in reasonable numbers swimming and diving in the river systems of eastern Australia.

—Linda Gibson
Australian Museum



Australian Reptiles and Frogs
By Raymond T. Hoser. Pierson & Co., Mosman, 1989, 238pp. $49.95.

Most books on the Australian herpetofauna fall into one of three categories: field guides (with a scope that is national, State or local), books on groups of attractive species, or books that address the general natural history of reptiles or amphibians. Raymond Hoser's book fits none of these categories, but is a curious mixture.

The bulk of the book is made up of a series of colour plates, accompanying distribution maps and brief notes of about 50 frog and 150 reptile species. It is claimed on the jacket that this is the largest collection of such colour plates ever published. Possibly so, but 51 of the plates are in a couple of series of two snakes feeding and another 41 are views of habitats.

There is detailed advice on care of these animals in captivity and treatment of diseases as well as tips on photography. There is a major section on conservation in which sensible suggestions are unfortunately combined with a vitriolic attack on fauna legislation in general and the activities of officers of the New South Wales National Parks and Wildlife Service in particular.

The major impact of the book is the presence of so many photographs and it is these that will catch the attention of the browser. Most of the reptile shots are excellent, however the frog photos vary substantially in quality. It is perplexing that Hoser often does not heed his own advice to others: "the background should reflect the natural environment from where the specimens originated". Compare this philosophy with the photographs on pages 30 and 31—a Painted Burrowing Frog that burrows "in soft sand and mud" is perched uncomfortably on a handful of crisp eucalypt leaves upon a background of cracked wood, two toadlets from loamy soils are shown on dry bark, while a Holy Cross Toad that is associated with clayey soils is perched on a smooth rock! Hoser might have got away with such backgrounds if the subject species had met his own criterion of ideally filling most of the frame; unfortunately some occupy no more than five per cent of it.

The frog section of the volume has numerous factual errors in the species section, perpetuates taxonomic confusion, and has preposterous statements such as "Frogs have a soft permeable skin and may actually be burned by the warmth of human hands". What nonsense! He states that about 2,000 species of frogs and toads are known. It should be 4,000.

It concerns me that Hoser knows so little about frogs that he is unaware that Plate 92 "Frog, species unknown (Wentworth Falls, NSW)" is just one of the colour patterns of the Common Eastern Froglet that he illustrates (with a specimen from the same locality) in Plate 37.

Superficially the volume looks splendid with high-gloss paper and (mostly) sharp images but the text contains many serious errors and cannot be recommended reading for anyone who wants to learn about herpetology.

—Michael J. Tyler
Zoology Dept
University of Adelaide

Central Australia: Tracks in the Sand
Kakadu: Land of the Crocodile
Daintree: The vanishing Rainforest
The Australian Wilderness Series, distributed by Kestrel Film Productions, Victoria, 1989. Approx. 50 minutes each. $69.95 each.

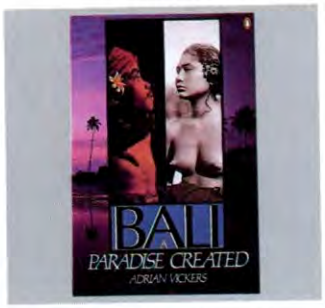
The star of the Australian Wilderness Series of videos is the uniquely beautiful Australian landscape, shown here in a variety of moods. *Central Australia: Tracks in the Sand* follows cartoonist Michael Leunig to Alice Springs as he seeks spiritual renewal and examines the special sense of guardianship that Aborigines feel for the land. In *Kakadu: Land of the Crocodile* this theme recurs as local Aborigines talk to Val Plumwood—a survivor of a crocodile attack—about their spiritual attachment to the land. The Aborigines tell Dreamtime stories about the crocodile to affirm its place in the environment and its right to survive. And *Daintree: The Vanishing Rainforest* shows the spectacular scenery and wildlife of this area through the eyes of a child who has returned from a future devoid of rainforests. Through her meetings with local identities we learn of the present-day threats to the rainforest and its fringing reefs and we are reminded of our responsibility to protect this environment.

These three videos raise many open-ended issues and, while the teachers' notes provided place heavy emphasis on

language skills such as debating, discussing and role playing, worksheets more appropriate to the scientific subject matter would have been helpful.

Some problems for class viewing include Leunig's black humour and off-beat cartoons in *Central Australia*, which some students may not be able to appreciate. Also the use of local characters rather than professional actors in *Daintree* sometimes make it hard to understand what they are saying, and their eccentricity (one elderly man wears a ponytail and a yellow mini dress) could distract classes from their message unless they had been prepared beforehand. While these may be minor points to the adult home viewer, they can make or break a classroom viewing. There is much to see and enjoy in these videos but you may strike problems if you show them to Year 8 on a rainy Friday afternoon.

—Merona Martin
Australian Museum



Bali. A Paradise Created
By Adrian Vickers. Penguin Books, Australia, 1989, 240pp. $24.99.

This book is the perfect antidote for anybody who has ever thought "if I see one more glossy poster, tour guide or television ad for Bali, I'm going to scream!" It should also be compulsory reading for every tourist, traveller, potential student or armchair intellectual who wishes to 'discover the real Bali'. As Vickers sets out to explain in the Acknowledgements section, he wishes to "bridge the gap...between general, often too-general popular or travel writing...and inaccessible, obscurantist academic work". As someone personally familiar with this gap, I would be more inclined to call it a *chasm* and any attempt to build a bridge a singular act of heroism.

The structure that the author uses to provide this bridge is technically known as 'historiography'—the analysis of how past events are selectively interpreted and reformulated by subsequent interest groups to create a picture that becomes more real than fact, and more traditional than tradition. This process is by no means unique to the history of Bali. However, what makes particularly fascinating reading, is the existence of two parallel sets of interpretations of Balinese cultural change—that provided by external observers from Dutch colonists to 20th-century tourists, and that provided by the indigenous protagonists.

The first chapter covers 17th to 19th-century external accounts of the Balinese by drawing largely on obscure Dutch reports. This is then compared with Balinese evidence in the form of literature, legal and religious texts etc. for the same period. The marked disparity in perceptions and values described set the scene for Chapter 3, ironically called "The Birth of Bali the Paradise". This documents the impact of colonial rule from the late 19th-century to the Japanese invasion and its aftermath, and covers the period during which Bali was 'discovered' by the first wave of European tourists, artists and researchers. The works of this generation—from Covarrubias' classic *The Island of Bali* first published in 1936, to Hollywood film images of "Bali Hai"—form the basis for popular images of 'traditional' Bali. Chapter 4 then documents tellingly the discrepancies between these static, idyllic images and the increasing social tensions, famines and political changes being internalised by the Balinese, culminating in the bloody end to the Sukarno regime in 1965. Finally, Chapter 5 gives an overview of what has happened since, that is, the process of recreating paradise for a new generation of tourists. This time, however, direct input from the Balinese people themselves, within the modern Indonesian nation, has included planning and control of the values and standards presented to the outside world.

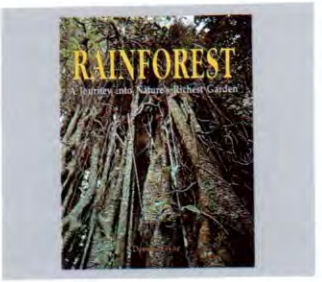
It is a fascinating and convoluted tale; at times depressing, at others amusing or exhilarating. Inevitably, given the breadth of time and the detailed nature of the subjects covered, there is some unevenness in the communication achieved. Perhaps because he is still quite young and fresh from the academic hothouse, Vickers' use of language is not always smooth and his persona fluctuates from dusty and discussive to almost glib cynicism. Many footnotes are provided that detail his sources but these are not listed in any convenient reference form. He is happy to provide thumbnail interpretations of subjects such as Margaret Mead's work on Bali, Clifford Geertz's reputation as an anthropologist and Sukarno's contribution to modern Indonesia. As these and other topics are issues hotly debated at length by experts, I am sure this book will provide much fuel for disagreement and nitpicking—good grist for the academic mill.

Chapter 5 in particular suffers from superficiality, perhaps because it is simply too soon to attempt a balanced analysis of the last 20 years. Vickers mentions the new wave of expatriate research into Balinese culture, but does not adequately assess its contribution either to Balinese ideas about themselves or to outside images.

Much of what has happened in Bali is no more than the dynamics of contacts between cultures. What makes the Balinese case so special, and worthy of endless study, is the rich fabric of culture, the vitality, self-awareness and resilience that the Balinese have contributed to this process. One should be careful, when rejecting the simplistic tourist propaganda images of Bali, not to throw out the baby with the bath water. Balinese culture is a dynamic synthesis between elements of Eastern cultures and island Austronesian people. The Balinese people, who emerge as the true heroes and heroines of this story, have had the pragmatic sense not to reject this image (which is, after all, one facet of their 'reality') but to manage it and to use it as a springboard for further cultural development and awareness. Perhaps it is this that makes Bali so different from Fiji, Hawaii, Jamaica or any other island culture that has become a tourist destination.

In summary: a worthy subject, a good cause, a brave attempt and a book well worth reading.

—Zoë Wakelin-King
Australian Museum



Rainforest Trees of Mainland South-eastern Australia
By A.G. Floyd. Inkata Press, Melbourne, 1989, 420pp. $45.00.

This book is a superb comprehensive guide to the rainforest trees of New South Wales and Victoria. It provides keys, highly detailed descriptions and line drawings of all 385 currently recognised species. The author brings to bear 30 years experience with the Forestry Commission of New South Wales, and it shows.

The text leaves no doubt that it has been written by a field expert. Floyd has arranged the description of each tree under 17 separate headings ranging from trunk characteristics, inner and outer bark, branchlets, leaves and venation, to timber and derivation of scientific name. He also gives the characteristics of each tree family as defined by its rainforest members. The depth of detail is extraordinary. In a 58-word description of the blaze of the Blackwood tree (*Acacia melanoxylon*), for example, the reader is told of the bright red and pink colour, growth rings, texture, beads of oozing sticky gum, astringent taste, and lack of smell and colour change. Key characteristics are italicised.

The descriptions are a mine of valuable ecological data as Floyd provides precise habitat parameters, lists of birds that eat the fruits, and details of seed germination. Remarkably, he also lists the precise localities where each species has been recorded.

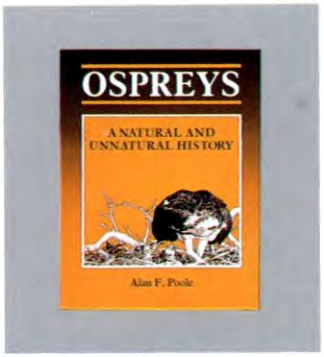
Floyd's main focus is wet rainforest and he does not include some vine scrub species like Brigalow (*Acacia harpophylla*), nor weeds like Camphor Laurel (*Cinnamomum camphora*). He is, however,

careful to include species that are essentially shrubs but which are known at one or two localities to take the form of small trees.

This book is so impressive that I am reluctant to make the following small criticisms: some of the drawings seem more decorative than diagnostic; the status of rare and endangered species is insufficiently emphasised; and the Queensland distribution data is sometimes inaccurate. Readers in south-eastern Queensland, however, should find the book invaluable if used in conjunction with the inexpensive *Trees & Shrubs in Rainforests of New South Wales & Southern Queensland* by J.B. Williams, G.J. Harden and W.J.F. McDonald (University of New England, 1984).

In summary, this book is highly recommended.

—**Tim Low**



Ospreys: A Natural and Unnatural History
By Alan F. Poole. Cambridge University Press, Cambridge, 1989. 246pp. $59.50.

The Osprey (*Pandion haliaetus*) is one of the most distinctive and unusual birds of prey. It is a fish-eating specialist, with reversible toes and spines (spicules) on the bottom of the feet to assist with grasping its slippery prey. To capture fish, an Osprey will plunge into the water feet-first, often disappearing completely below the surface—a fascinating sight and quite unhawk-like.

This species is one of a handful of birds that are found, with the exception of Antarctica, on all continents of the world. This distribution means that it is known to ornithologists around the globe and aspects of the Osprey's natural history have been studied in many countries—as have the particular and well-documented problems in its relationship with humans.

Two of this species' most publicised areas of interaction with humans are its nesting habits and its reaction to pesticides. Ospreys build large nests on open sites, such as the tops of dead trees. A pair will reuse its nest year after year, adding new material each breeding season, until eventually this may become so heavy that its perch can no longer support it. Because Ospreys nest near water, they are frequently in close vicinity to humans and in Australia (as well as other countries) some large precarious nests have been judged potential threats to nearby human habitation and activity. These nests have been successfully moved (with some publicity) to secure artificial platforms, where the breeding adults have continued to use them.

In the 1960s evidence was first found that Northern Hemisphere Ospreys were experiencing markedly adverse reactions to organochlorine pesticides, such as DDT. Because these birds were at the top of the food chain, they had accumulated the pesticides that were present in the bodies of their prey. These poisons caused a decrease in the Ospreys' reproductive success by thinning the shells of their eggs. After a certain level of thinning, the shells would crack and the eggs fail to hatch. There was a drastic collapse during the 1950s and 1960s in the world's Osprey numbers. International studies identified the cause and, once these pesticides were controlled or restricted, the Ospreys started to recover in the 1970s. Despite this, the security of their future is still not assured.

Few species of bird have been the subject of interest or the object of conservation efforts in so many countries. This book summarises the current state of knowledge of the Osprey, its natural history, continuing threats and management. There are many raptor enthusiasts who will enjoy this book. Its audience, however, should not be restricted to these. The book will deservedly appeal to many who have interests in animals or conservation.

—**Walter Boles**
Australian Museum

"Lacking respect for the perceived irrationality of environmentalists, and bristling at insults construed as racist, the Japanese have been backed into a cultural corner."

WHALING: THE CULTURAL GULF

BY KATHY GLASS & KIRSTEN ENGLUND
FREELANCE WRITER
MARINE BIOLOGIST

THE HOTTEST ITEM ON THE AGENDA OF the 1991 International Whaling Commission (IWC) proceedings, to be held mid-year in Reyjkavik, Iceland, will no doubt be evaluation of the whaling moratorium passed in 1982. The question is whether or not commercial whaling should resume.

Japan and the United States have traditionally been key players in this debate, with Japan the strongest opponent of the IWC moratorium and the US its main proponent, actively supported by other Western countries such as Australia, Britain and Germany. Scientists can produce research that supports each position, but unfortunately the cultural context—which helps create the entrenched perspectives on both sides—is routinely neglected in the international arena. We say "unfortunately" because, as two Western environmentalists who've lived in Japan, we've come to believe a comparison of public opinion, cultural differences and the histories of whaling in Japan and in the West reveals much about the source of this controversy and its potential solution.

The Japanese have historically depended on the sea, and whale meat has been eaten in Japan for at least 500 years. Traditional net whaling, as developed in Japan around 1606, was an innovative and courageous undertaking involving thousands of people and sustaining local whale populations with ecologically sound hunting practices. Taking females with calves was forbidden (in contrast to the Western practice of taking entire pods—a major cause of the worldwide decimation of whales), and the Japanese used all parts of the whale for food, fertilisers, oil and other products.

These historic roots of whaling are a large part of current Japanese attitudes. Harpooners were once revered as heroes, and to this day—despite the international pressure—Japanese whaling families consider themselves to be engaged in a proud occupation; the derogatory view of the opposition is incomprehensible. Indeed, most Westerners direct their criticism toward the atrocities of modern whaling with little or no concept of the impressive tradition of net whaling.

In our investigations we were surprised to learn of the respect that Japanese have always had for whales. Here it is not contradictory to regard animals as sacred and also to kill them for food. Whale monuments and 'gravestones' are still scattered throughout Japan, and the souls of whales are honoured in memorial rites. However, Japanese respect for whales doesn't translate into the American reverence. The Western perception of whales as intelligent, beautiful and spiritual is considered sentimental and irrational by many Japanese. They charge that US conservation groups too often project a single image of whales—for example, the majestic Blue Whale, hunted ruthlessly to a point from which it may never recover. Americans who respond to desperate appeals for protection may not be aware that not all whales are endangered, and that great strides toward protection of endangered species have already been made.

Lacking respect for the perceived irrationality of environmentalists, and bristling at insults construed as racist (including antiwhaling rhetoric such as 'cold-blooded' and 'barbaric'), the Japanese have been backed into a cultural corner. At stake are Japanese tradition and pride. While many Japanese are ambivalent about eating whale and prefer other more available and affordable meats, there does seem to be a consensus that, if whale hunting doesn't threaten extinction, there's no reason why the meat can't be consumed by those who want to.

The US position on whaling is made particularly untenable to the Japanese by the fact the Alaskan Inuit hunts of the endangered Bowhead Whale are condoned as subsistence (not commercial) by the US, the IWC and even Greenpeace. Japanese whalers claim whaling is just as vital to their communities as to the Inuit. In the Japanese view, the criteria for catch allowance should not be whether whaling is commercially operated, but whether the target species is endangered. Allowing Bowhead hunts makes the US posture toward Japan appear inconsistent with a genuine concern for conservation.

Japan's small-scale coastal whaling of non-endangered species such as the Shortfin Pilot and Baird's Beaked Whales (less than 400 per year) has both cultural validity and limited impact. But the wide-ranging pelagic whaling is a relatively modern development, an enterprise based more on profit than cultural continuity. The ban on this type of whaling is more appropriate, but it also creates a black market in illegally obtained whale meat, which impacts endangered species of whales and also affects dolphins, which are often sold as whale meat.

The Japanese insist, not unreasonably, that scientific and ethical aspects of the whaling issue be separated. But even the biological question is not simple. Much of the case against commercial whaling rests on the fear of still-unknown effects of hunting, even among populations thought to be increasing.

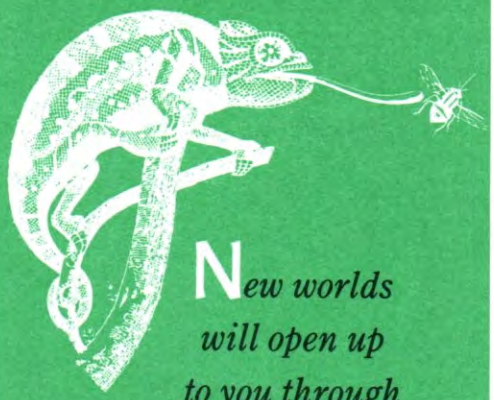
Statistics aside, the fact is most Japanese simply don't understand the environmental consciousness that fuels antiwhaling sentiment. This basic cultural gap is the root of the controversy. The widespread opposition to whaling we're so familiar with is part of a larger environmental movement that has no effective parallel in Japan. Encouraging environmental education and awareness is probably the most productive avenue now for antiwhaling forces.

A larger context is necessary for a more effective approach to 'saving the whales', and Western environmentalists have a responsibility to see the limits of their tactics when practised in relation to other cultures. Meaningful, enduring change must come from within a culture, not be imposed from outside.

Perhaps most illuminating for us has been the realisation of how culturally determined are our own views toward whales. Economic and cultural attachment to whale products has been negligible in most areas of the West, and environmental concerns play a significant role in the formation of our values. This situation is reversed in Japan. Although whales are a symbol in the West of everything wrong with the modern world, there's no reason to expect the Japanese to see whales in the same way.

Ultimately there is more at stake than whales, and forcing the Japanese to abandon a tradition for reasons they cannot understand would be a hollow victory. ■

Kathy Glass is a freelance writer; Kirsten Englund is a marine biologist. Both are environmental activists from the United States who lived and worked in Kyoto, Japan.



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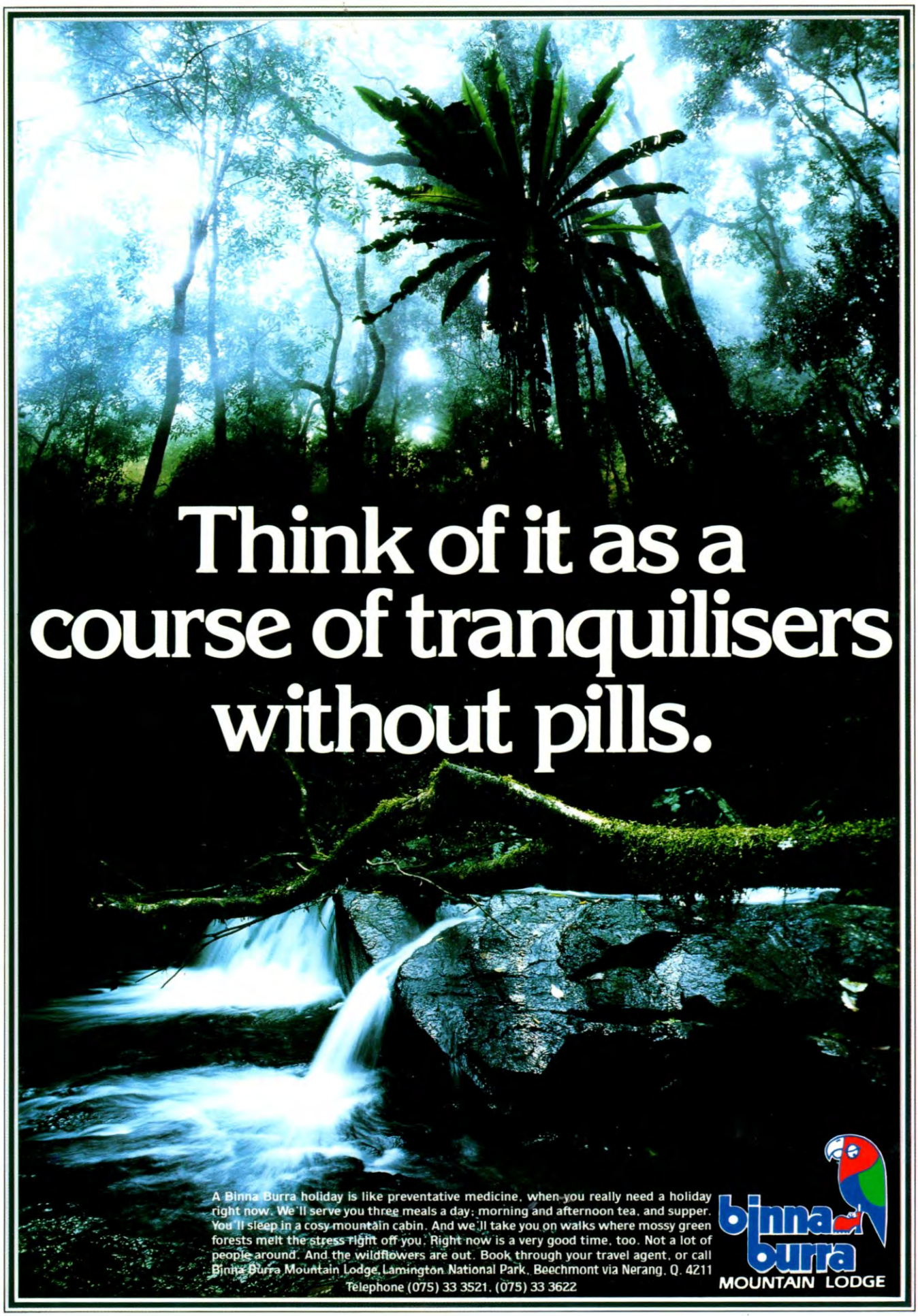
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