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ANH

Australian Natural History

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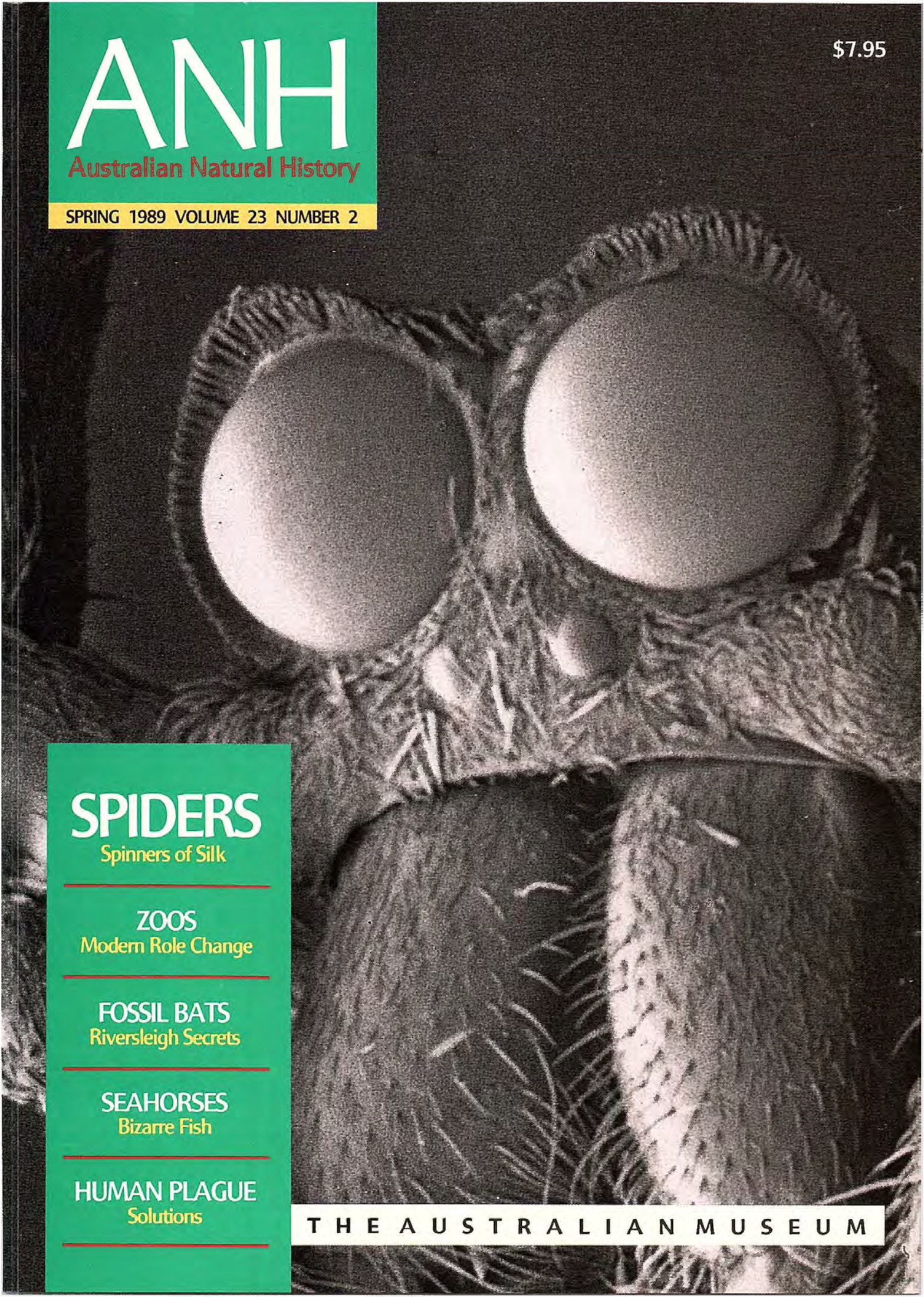


SPIDERS
Spinners of Silk

ZOOS
Modern Role Change

FOSSIL BATS
Riversleigh Secrets

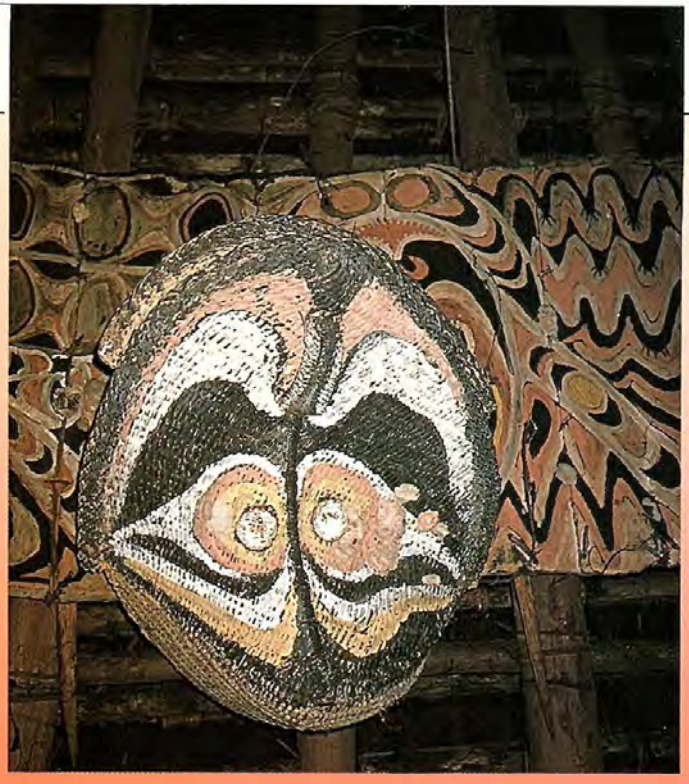
SEAHORSES
Bizarre Fish

HUMAN PLAGUE
Solutions

THE AUSTRALIAN MUSEUM

Papua New Guinea and Irian Jaya

A Unique Cultural Tour Into Tribal Melanesia



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Day 6:	Fly to Wamena.
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Front Cover
The net casting spider, (*Deinopis subrufa*), ensnares its prey in a silk net. SEM photo by Geoff Avern using the Australian Museum's Cambridge 120 Steroscan, 10KV, specimen uncoated.

ONUS ON US

BY FIONA DOIG
EDITOR

OUR PLANET IS IN CRISIS. RESOURCES are fast dwindling; at our present rate of growth, we will soon run out. The Earth simply cannot support our growing population.

Recently I returned from a trip to central Africa. What started as an interest in observing some of this continent's unique fauna ended up as a lesson on the destructive capabilities of one species in particular. That species is our very own *Homo sapiens*.

Of all the large mammals that I saw, none occupies such an enormous niche. You cannot turn around for the people—and this is in the rural areas. In countries like Rwanda, every available square centimetre of land is under cultivation. Yet people in Africa are dying from the effects of hunger.

I suffered not so much from culture shock as population shock. I already knew the planet was overpopulated. But coming from a relatively uncrowded place like Australia it was disturbing to see the reality of the situation for myself.

In talking to the Africans I got a sense of their culture. Possessions and ownership take far less precedence than the number of children they have. This is their greatest value. And that worries me. Because the more people there are the more stress that is placed on the Earth.

But is it just the numbers alone that create ecological crises? Tim Flannery, in the article on page 148, tells us that the average Australian consumes 60 times the resources of a person in the poorer countries. Perhaps simply advocating population control is not the solution. Perhaps that just raises the standard of living and consumption rate. Either way, we simply cannot keep taking. We cannot afford the ecological cost.

Were it any other species, we would be advocating culling programs and attempting to manage the population by some means. It would be very simple to set up an effective program to reduce our population. It would just be totally unacceptable to our moral principles. We are so tied up in our own survival that we forget to look at it in a global sense. Importance is placed on the individual. For what other species do we do this? What makes us so unique? Do we really think we are above the laws of natural selection?

Like it or not, we will be the cause of our downfall. If we don't act now to reduce our own population, it will occur automatically. Much sooner than we think. Evidence for it is appearing right now. Live. Here on planet Earth. Starring the ozone hole, greenhouse effect, pollution and a host of other environmental disturbances. I just wonder how much we will take with us when we go.

So what to do? Should we all go around wearing signs that say 'hazardous to the environment?'

If humans can only think in terms of the individual, then the onus is on each of us to take responsibility for our future. It is what must be done. If we want to survive. Let's put our so-called survival instinct into action. ■

Everywhere I went in central Africa, there were crowds of people.

FIONA DOIG

IN THIS ISSUE

BY GEORGINA HICKEY
SCIENTIFIC EDITOR

AUSTRALIAN MUSEUM'S VERY OWN spiderman, Mike Gray (pictured), discusses the various types and uses of spider silk against an evolutionary backdrop (page 112). This information comes to us after much crawling around in caves searching for primitive species. And in Quips, Quotes & Curios, Mike reports, for the first time ever, an extraordinary piece of jumping spider behaviour, witnessed from the comfort of his lounge room. No clues will be given here, though—find out for yourself on page 102.

Suzanne Hand is another contributor who has spent many hours crawling around in caves. But the caves she's particularly interested in are the multi-million-year-old remains of those once home to ancestral bats. At the Riversleigh Cattle Station in far north-western Queensland, Sue collects about 20 tonnes of fossil-rich limestone, which is then processed to reveal the perfectly preserved bat material within. Comparison with overseas and other Australian fossil and modern bats has enabled Sue to formulate the most likely origin of Australia's diverse bat fauna (see page 130).

Amanda Vincent, from Cambridge University, is one of the very few people in the world studying seahorses. Amanda is privy to many interesting facts about seahorses and their relatives, particularly their amazing reproductive behaviour (page 122).

In the last issue of ANH, Tim Flannery introduced us to what is now referred to as the 'Human Plague'. In this issue, with Telford Conlon, possible strategies that could help vaccinate against this plague—or, at the very least, buy us some time—are suggested. And to ensure that some of these points are driven home, Tim elaborates on his personal feelings towards the sensitive issue of wilderness in The Last Word (page 180). No doubt these articles will receive healthy comment from concerned readers.

Also in this issue we look at the changing role of modern zoos; exchange in cultural or symbolic property in the Lower Sepik River; the once-respected, later-despised pastime of egg-collecting; the issue of palaeontology as a 'real' science; the nature of mutations; and some amazing SEM photography.

Articles

PICKING UP THE THREADS
Spiders are generally considered to be consummate spinners of silk. Yet many hunting spiders use little or no silk to capture prey. The study of spider silk allows scientists to trace the evolutionary shift from web-building to hunting behaviour.
BY MIKE GRAY
112

PREGNANT MALES & HORSES' TALES
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BY AMANDA VINCENT
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ON THE WINDS OF FORTUNE
The rich Riversleigh fossil deposits in north-western Queensland have enabled scientists to formulate a moving picture of what Australia was like 20–25 and 3.5 million years ago and the likely routes of origin for many of Australia's faunal elements. The bat story is told here.
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ZOOS: FROM A MODERN PERSPECTIVE
What is the justification for holding animals in captivity? The answer depends on an understanding of the underlying roles and philosophies of modern zoos.
BY JOHN D. KELLY
140

A VACCINE FOR THE PLAGUE

Given the current human population growth pattern, by the year 2100 there will be over 50 billion people on Earth. This article looks at the limits of sustainable production and where we stand in relation to those limits.

BY TIM FLANNERY & TELFORD CONLON

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THE VALUE OF CULTURE

Exchange of dance rights and other forms of cultural or symbolic property for subsistence goods was reported for the Murik Lakes people (Papua New Guinea) some 50 years ago. That this sort of trade continues in today's Westernised society was, to these authors, quite surprising.

BY DAVID LIPSET & KATHLEEN BARLOW

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THE CURATE'S EGG

In the past, egg-collecting was a respected pastime; by the 1930s it was despised and made illegal. Although still illegal, we are only now realising the wealth of valuable information obtained in those 'ill-gotten' gains of yore.

BY WAYNE LONGMORE & WALTER BOLES

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ANYONE FOR 'SPINAGE'?

If the boom in wild foods continues, 'Botany Bay Greens' and other native 'spinaches' should regain their popularity as vegetables.

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STEPHEN HAWKING AND THE BIG BANG

There is no need to refer to a god to determine the way the universe began. As author of A Brief History of Time *has shown, all that is needed are the laws of science.*

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CLOSE ENCOUNTERS

Extraordinarily detailed images can be obtained with the use of a Scanning Electron Microscope.

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RARE & ENDANGERED

THE TASMANIAN GRANULATED SNAIL

A low fire frequency and respect for its rainforest habitat should ensure survival of this 'most peculiar' snail.

BY RON C. KERSHAW

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THE SCIENCE OF BEING WRONG

Palaeontology has sometimes been referred to as a 'soft' rather than 'real' science because it doesn't involve the testing of predictions. An unexpected find of the mole kind proves this wrong.

BY MICHAEL ARCHER

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CHANCE MUTATIONS

How do well-structured organisms arise at random? The answer (that they don't) depends on an understanding of what it means to be random.

BY RALPH MOLNAR & GLEN INGRAM

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THE LAST WORD

AUSTRALIAN WILDERNESS: AN IMPOSSIBLE DREAM?

Humans have been an integral part of the Australian landscape for 40,000 years. If we are to exclude the last of the megafauna from large areas, then we must replace them with a sensible fire policy.

BY TIM FLANNERY

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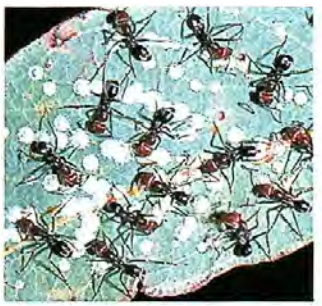

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LETTERS

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

Zieria Saved

As a direct result of the Rare & Endangered article published in the Summer 1988–89 issue of ANH (vol. 22, no. 11) concerning the rediscovery of what were thought to be extinct plant species, one of them has been hopefully saved from further urban development.

The plant concerned is the *Zieria* species growing near Nowra, New South Wales. Soon after the article was published I was contacted by a Nowra conservationist, May Letch, who was interested to learn more about the *Zieria*. When told of the general locality of the population she expressed some concern about the proposal for a new road through the area as well as associated urban developments. Her concerns were well founded as the proposed road was to pass right through the population.

Having contacted the Shoalhaven City Council and inspected the area with council staff, it is now most likely that the road development will be reconsidered with the plant population in mind. The possibility of protecting the population with a small flora reserve within any future urban development is also being considered.

Through the publishing of the article, the quick action of May Letch and the sympathetic attitude of the Shoalhaven City Council it is likely that the *Zieria* has avoided almost certain extinction.

—Mark Richardson
Australian National Botanic Gardens

***Zieria* sp. may have been saved from extinction as a result of the Rare & Endangered article published in ANH.**

MARK RICHARDSON

Passion for Passions

I have three *Passiflora edulis* vines in my garden and two of them have reached a point 17 metres from where the plant leaves the ground. The *Department of Agriculture Bulletin* on passions describes *P. edulis* as a native of Brazil but in my experience this is not completely correct.

When I was a schoolboy in the early '30s I lived in Belmont (New South Wales) on the shores of Lake Macquarie. Part of my haunt was a tiny scrap of rainforest (which I fervently hope is still there) about 200 metres north-west of Cardiff Point. Among the lichen- and liana-covered trees were two species of passionfruit vines that I am convinced were native to the area. The spot was a good half-hour's walk through the bush and boats were nowhere near as plentiful as they are today, so the chances of these vines having been planted by human hands I consider to be negligible.

Both species of the fruit were purple, but whereas one was normal as we know them today, the other was highly perfumed and so completely inedible. There was also a type of raspberry growing there, which I have not seen since. The fruit was woody, hollow and light red (not pink) but completely edible and made excellent jam.

Perhaps some boat-owning resident of Lake Macquarie could visit the scene and report on what they find?

—Thomas Lillicot
Sans Souci, NSW

A Lizard's Lunch?

In the interesting article on legless lizards by Michael Hutchins and Barbara Sleeper (ANH vol. 22, no. 11, 1988), a caption states that *Aprasia inaurita* "is believed to feed only on the eggs of small black ants, *Aphaenogaster* sp." I wonder if this is correct.

ANTHONY HEALY

The legless lizard *Aprasia inaurita*.

Aphaenogaster species are particularly small (for ants) and the Australian species are reddish brown to yellow, not black. Furthermore, the distribution of *Aphaenogaster* is decidedly patchy.

I wonder if, in fact, *Aprasia inaurita* preys on *Iridomyrmex* species? The ubiquitous small, black, fast-moving ants of the Australian landscape are in this genus, and are also eaten by the famous Thorny Devil (*Moloch horridus*).

Finally, would these lizards prey only on ant eggs? Ants have seasonal life cycles in most cases and I suspect that lizards have to eat larvae and pupae as well to avoid long lean periods.

—R.H. Crozier
University of NSW

Your point about the seasonability of ant eggs making this food an unlikely exclusive food item for Aprasia inaurita *is taken. Indeed, R. Jenkins and R. Bartell suggested in* A Field Guide to Reptiles of the Australian High Country *(Inkata Press, Melbourne, 1980) that ants in the genus* Iridomyrmex *are the most usual food. However, the information in the caption was based on John Coventry's (Museum of Victoria) more recent and as yet unpublished study of the natural history and distribution of herpetofauna in the Big Desert, Victoria. Presuming ant identifications were correct, examination of the stomach contents of captured* A. inaurita *revealed (if, indeed, anything) only* Aphaenogaster *eggs.*

—G.H.

Probe

The abuse of the natural resources of our planet has reached such proportions as to presage, without planned correction, a terminal point for life of all species. Your Rare & Endangered articles take on something of a euphemistic hue when related to the real depth of this problem. Publications such as yours should be saying more on subjects such as the current greenhouse effect, acid rain, ozone layer penetration, pollution in general, with probing articles concerning who is causing the problems and why, whether the problems are being corrected, and if so by whom, and if not who are the culprits?

The people must be educated, and quickly. Who is going to do it?

—Anon.

Expressed Disgust

I wish to congratulate you for the high quality of ANH, but I was disgusted to see the photograph of a male and female human apparently simulating 'the missionary position' of copulation (QQC, vol. 22, no.

12, p. 139). The discussion of the herpes simplex virus is relevant but the photograph adds no meaning to the article. I have four children, two of whom are young, and I do not wish to expose them to such a photograph at this stage. As a result, I removed the page before making the magazine available to them for reading.

I have a degree in science, diploma of education and am employed in the field of education. I do not regard myself as a 'prude'. My purpose in writing to you is to convey my disgust. Whilst some people may regard the photograph as having 'artistic merit' and the like, I wish to suggest that ANH will appeal to *all* without such photographs.

—A.J. Watson
North Turramurra, NSW

Solecism

We love your magazine. It is of high quality and a pleasure to read. However, may I draw your attention to a common misuse of the word 'myriad' on page 530 of the Autumn 1989 issue of ANH (vol. 22, no. 12) in the "Dinosaur Extinctions" article.

Please, please, please note that 'myriad' means 'ten thousand' and therefore does not require 'a' and 'of' before and after. It should simply read 'the myriad theories'.

—J.D. Swinnerton
Turramurra, NSW

Cactoblastis

I do want to congratulate you on this excellent production; it is superb. However, C. Creevy is a little off on page 620 (The Last Word, ANH vol. 22, no. 12). *Cactoblastis* was a pyralid moth.

—Dr John Mann, MBE
Sherwood, Qld

KATHIE ATKINSON

Cactoblastis cactorum.

Maps Please

I refer to the article "Voyage to Elizabeth and Middleton Reefs" (ANH vol. 22, no. 11, 1988–89). There is nothing worse than having an article about a remote location without including a reference map, particularly as I forward my copies of ANH overseas. In future please include detailed maps.

To the author (Patrick or Patricia—I concluded it was the former but one never knows these days): are not the Houtman Abrolhos Islands in Western Australia at the same latitude as Elizabeth and Middleton Reefs?

—Walter S. Mould
Glen Iris, Vic.

About the author: your conclusion on gender was wrong! About your question: the Houtman Abrolhos Islands are slightly north of Elizabeth and Middleton Reefs. As stated in the article, the reefs lie at 29° 56′ and 29° 17′ S respectively and the Houtman Abrolhos Islands lie around the 28° 39′ S mark. These islands constitute the southernmost coral reefs in the Indian Ocean (see Vincent Serventy's article, ANH vol. 22, no. 6, 1987); the reefs, however, are the southernmost coral atolls in the world.

—G.H.

Congratulations

We congratulate you on your attempt to improve an excellent journal but wonder, when you already appeal to such a diverse range of areas, how you possibly can. Without engaging in fulsome hyperbole your articles make us aware of how beautiful and complex Australia is.

—Gwenda Langford
Bulleen, Vic.

I just couldn't let my reading of the NEW big ANH pass without sending my congratulations for the terrific product you've all come up with. It's a great magazine which reflects great credit on the Australian Museum.

—Hal Cogger
Deputy Director
Australian Museum

Out of Line

We apologise for the missing line in the QQC item "Throwing up a Grubby Defence" in the last issue of ANH (page 6). The sentence should read: ". . .further tests revealed that it was only the benzaldehyde component of the regurgitant, and not the cyanide as would be expected, that repelled the ants."

—G.H.

QUIPS, QUOTES & CURIOS

COMPILED BY GEORGINA HICKEY
SCIENTIFIC EDITOR

A Meal with a Bite

Most falcons are renown for their gastronomic predilection for small birds. They make short work of avian prey taken on the wing (often after a dashing pursuit) or from the ground while feeding. Occasionally, however, that which promises well turns out to be a failure. Such was the case with one stuffed and resurrected specimen from the Australian Museum's bird collection, in which the biter had become the bitee.

In May 1903, an immature male Grey Falcon (*Falco hypoleucos*) was donated to the Museum by a Mr G.E. Driffield of Condobolin, New South Wales (A.J. North's *Nests and Eggs*, vol. 3, p. 267, 1912). It had been shot the previous day. Yet it was not the bird's distinction of being one of Australia's least common falcons that prompted its donation, but the extraordinary and literal dead weight attached to its foot. This was the dried bill and skull of a Ringneck Parrot (*Barnardius barnardi*), a common bird found in eastern mallee country. The parrot had evidently bitten its assailant and not let go during a struggle that would have seen many feathers fly. The nature of the skull suggests that the falcon had carried it with him for a long time—the skin is dehydrated and only remnants of feathers remain. The falcon presumably managed to devour the rest of the bird but the stubborn vice defied the carcass' total removal.

A similar encounter involving a Brown Goshawk (*Accipiter fasciatus*) and a tame Red-winged Parrot (*Aprosmictus erythropterus*) was reported in 1935 (*The Emu* 34: 316). The late A.C. Cameron, from Biddeston in Queensland, was alerted to a screeching, flapping mess on his lawn and, on closer inspection, realised that the parrot had bitten the hawk just above the foot, showing "no inclination to relinquish its advantage". Whether Cameron was brave enough to intervene, or whether he allowed nature to run its course, is not known.

—G.H.

Dried skull of a Ringneck Parrot with its bill firmly closed around the middle toe of a Grey Falcon's left foot.

ANTHONY FARR

Postnuptial Snack: A Mantid's Nightmare?

One of the more stubborn myths in the insect world, and one that would quench even the most jaded horror-story addict, concerns the copulatory behaviour of praying mantises. It all started back in the 1930s when Kenneth Roeder of Tufts University, Massachusetts, described in glorious detail the sexual cannibalistic habits of the female mantid (*Biol. Bull.* 69: 203–220, 1935): how she bites off the head of her hapless male partner; how this action severs the cephalic ganglion that, when intact, inhibits the male's sexually rhythmic movements; how, with renewed sexual vigour, the headless male completes copulation; and how, by adding insult to injury, she takes him as a postnuptial snack. Roeder did suggest this behaviour may be induced by the effects of captivity or by the nutritional state of the female. Yet despite his warnings (and whether one cares to admit it or not), the vision of a decapitated sex fiend is so appealing that it was snaffled up and embellished by popular science writers, many even implying that male mantids were incapable of mating without first having their heads bitten off. And so the myth has stuck . . . until only recently.

Eckehard Liske and Jackson Davis, from the University of California at Santa Cruz, showed that true sexual cannibalism, as described by Roeder, is not the norm (*Anim. Behav.* 35: 1524–1537, 1987). They analysed videotapes of encounters between freely fed male and female Chinese Praying Mantises (*Tenodera aridifolia sinensis*) and described what was, in fact, a lengthy and elaborate courtship procedure. In each case the male cautiously approaches the female. When the female visually fixates the male, he waves his antennae, stamps his feet and flexes his abdomen. The closer he gets, the more intense his display. Liske and Davis suggest that the function of the male display is to inhibit female aggression. The female also displays during courtship presumably to signal her readiness to mate. The male then takes a flying leap onto the female's back and copulates. No sexual cannibalism was observed.

Removal of the male's head resulted in rhythmic sexual

CYRIL WEBSTER/ANT PHOTO LIBRARY

A mating pair of praying mantises. The idea that males are incapable of mating without first having their heads bitten off is a myth that originated from over popular journalism.

movements, thus confirming Roeder's earlier report. But, because of the obvious visual component of this mantid's sexual behaviour, headless males were unable to mount.

In an attempt to induce sexual cannibalism, Liske and Davis starved the females for a certain number of days so that they ended up with two groups—one 'moderately hungry', the other 'starved'. Most of the moderately hungry females ate the male at some point during the observation period, but only one was seen to exhibit the true sexual cannibalism reported by Roeder: the male was eaten head-first after mounting but still managed to copulate. Of the starved females, most attacked their partners straight away; those that survived the initial onslaught mounted the females and copulated successfully.

The authors conclude that, in this species at least, decapitation is *not* an integral part of reproduction, cannibalism does *not* occur when the female is satiated, and that Roeder's largely ignored suggestion about sexual cannibalism being an artefact of captivity holds true.

Whether sexual cannibalism occurs to any significant extent in the wild is not known but Liske and Davis believe it would only occur if females were hungry, such as at the end of the breeding season when food supply is low. If, as suggested by Malcolm Edmunds (*TREE* 3: 77, 1988), cannibalism occurs when the female is sexually unreceptive, it would seem unlikely to occur in mantid species that use olfactory (rather than visual) courtship signals, for males would theoretically only make advances when they had received olfactory signals indicating the females' readiness to mate.

If sexual cannibalism in the wild occurred regularly, one would expect a bias in the female sex ratio. One study has shown this to be the case, but the bias may also have been due to greater longevity of the females (which is certainly the case in a variety of captive-reared species) or heavier predations on males than females.

In terms of natural selection, cannibalism by the female may result in an increased number of offspring, the food value of the male being put into the production of bigger and better eggs. Cannibalism would benefit the female, but would only benefit the male if he had fertilised the eggs. It is known that male mantids mate with more than one female during the breeding season, and that females, like other insects, store viable sperm in their spermathecae for long periods, thus making it likely that sperm competition occurs (see ANH vol. 22, no. 11, 1988, p. 506). So the benefits to the male of being eaten would depend on whether precedence is given to the sperm from the first or last mating. If precedence is given to the last mating (as seems to be the case for most insect species studied), natural selection would tend not to favour sexual cannibalism, unless it occurred only at the end of the breeding season. If precedence was given to the first mating, natural selection would tend to favour sexual cannibalism.

Observations of sexual behaviour in mantids that display lengthy courtship procedures would have us believe that the male's intention is *not* to be eaten (the flying leap, tucking in of the head while mating and the quick retreat). But then there are some species, such as the large Asian mantid *Hierodula membranacea* studied by Tim Birkhead and Susan Lawrence at the University of Sheffield (*New Sci.* 16 June 1988: 63–66), that do not perform courtship displays and sexual cannibalism (at least in the laboratory) is commonplace.

It's clear that much work needs to be carried out on wild mantid populations to find out whether or not sexual cannibalism does occur regularly in nature. Perhaps only some species indulge naturally in the practice. Certainly the frequency of sexual cannibalism in captivity is not consistent for all species studied; and it would seem unlikely that these inconsistencies could simply be put down to differences in the female diets. For those species, then, that are found to indulge in sexual cannibalism in the wild, further studies into sperm competition may shed some light onto the selective advantages involved.

—G.H.

Keeping the Starfish off the Reef

Protecting what is arguably Australia's greatest tourist attraction, the Great Barrier Reef, is a thorny problem. And it is exactly that when it comes to the ravages of the Crown of Thorns Starfish (*Acanthaster planci*).

While debate rages about the causes of the periodic population booms among the starfish, some tour operators face the problem of finding patches of undamaged reef for coral viewing. Researchers supported by the Great Barrier Reef Marine Park Authority (GBRMPA) have come up with a simple way to block off adult starfish from such key patches of reef. They have found that a fence with a 12-millimetre mesh does the trick (*New Sci.* 10 Dec. 1988: 28).

The fence is one metre high with an overturned top measuring 0.6 metres: starfish cannot squeeze through the mesh and, if they climb the fence, they drop off the overhang because they cannot grip the wire. The method is only good for keeping out mature starfish, since larvae can pass through the mesh and settle on the coral. But it does make the manual task of removing starfish from key reef areas an occasional, rather than full-time, one. Dr Leon Zann, Acting Coordinator of the Crown of Thorns Starfish Research program at GBRMPA, thinks that the underwater fences will be very useful in protecting relatively small areas such as coral viewing sites (a few hectares in extent) but doubts it would be possible to protect whole reefs. Unless research actually shows that human activity causes population increases in the starfish, broad-scale application of the fence would not be justified.

—B.B.

GREAT BARRIER REEF MARINE PARK AUTHORITY

Recording numbers of Crown of Thorns Starfish in enclosures specially designed to keep starfish off the reef.

Fairy-wrens Fancy Furgling

If reproduction and parenting are all about ensuring that your own genes are perpetuated, why do so many Australian birds form groups to raise just one batch of offspring? Cooperative breeding, as that behaviour is known, is a global phenomenon among birds but, for reasons that remain unclear, it is four times more common among Australian birds than those of any other country.

Ian Rowley and Michael Brooker, of the CSIRO's Division of Wildlife and Ecology in Perth, have uncovered an extreme case among the Splendid Fairy-wrens (*Malurus splendens*) in south-western Australia. Blood tests have shown that up to 60 per cent of the nestlings in any one nest are not fathered by any of the birds cooperatively rearing them: the males in the group, at least, are perpetuating genes unrelated to their own.

That phenomenon is the result of another odd piece of fairy-wren behaviour—also found in their eastern cousins, the Superb Fairy-wrens (*Malurus cyaneus*)—dubbed by the slang name of furgling. Furgling is a form of kleptogamy (literally, 'marriage theft') observed in the two species during their breeding season.

Males pluck a brightly coloured flower petal and, holding it in their beaks, go courting in a neighbouring group's territory, seizing any opportunity to mate with an unguarded female. The petal, Rowley believes, functions a bit like a white flag in wartime, signalling to other males that no aggression is involved in the territorial incursion. Several research groups are still trying to unravel, however, why the males then return to their own groups to raise offspring that are often the products of furgling raids by other males.

—B.B.

Why are over half the offspring of Splendid Blue Wrens not fathered by any of the males cooperatively rearing them?

GRAEME CHAPMAN/AUSCAPE INTERNATIONAL

The Number of the Beast

If you were asked to picture the Serengeti area of East Africa, one image that would spring to mind—whether you'd actually been there or not—would be the seemingly never-ending string of wildebeest, wending its way across the treeless plains. Images of smaller groups of non-migratory ungulates tend not to occupy precious space in the memory. Why? For all too obvious reasons—the herds of migratory ungulates are *so* huge. Migratory wildebeest, for example, number some 1.4 million, which is ten times that of Cape Buffalo—the most abundant resident ungulate in the Serengeti.

So why *are* migratory species so abundant, compared with sedentary species of similar-sized animals? This was the question posed by John Fryxell (University of Guelph, Ontario), John Greever (Harvey Mudd College, Claremont) and A.R.E. Sinclair (University of British Columbia, Vancouver) in a recent issue of *The American Naturalist* (131: 781–798, 1988). They suggested three possible hypotheses to explain the large disparity between migratory and resident ungulates. First, migrants cover a larger area and thus have access to a greater food resource. Alternatively, migrants may make better use of the available food, by grazing on a rotational basis, allowing the grasses to regrow before returning the next year. Or, perhaps their numbers are so large because they are not vulnerable to regulation by predation.

In order to test these hypotheses, Fryxell and colleagues developed a simulation model of the dynamics of wildebeest and grasslands interactions, based on the well-studied Serengeti ecosystem of East Africa. In their model they incorporated seasonal changes in grass quality (tropical grasses of Africa decline in quality as they mature). They also incorporated changes in habitat use. The Serengeti region is comprised of two basic habitats—open plains and wooded grasslands—and the movement of migratory wildebeest between these two

Bob Beale, Sydney Morning Herald's science writer, is a regular contributor to QQC.

habitats is determined primarily by the rains. They move onto the plains during the wet season to exploit the fresh green grass and temporary waterholes. During the dry season, when available water on the plains evaporates, they return to the wooded grasslands, with its higher annual rainfall, permanent water supply and taller grasses. Resident ungulates, however, never venture onto the plains, perhaps preferring the security of a permanent water supply in the wooded grasslands habitat.

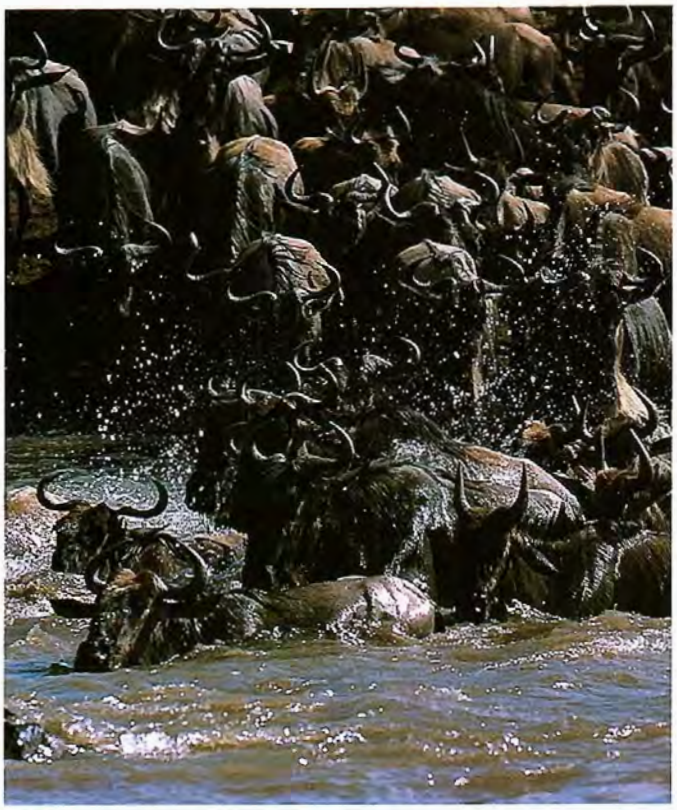
According to their model, the greater food resource available to migrants during the wet season cannot explain the disparity between migrant and resident populations. Herbivore abundance is determined during the period of relative food scarcity. On the assumption that grasses decline in quality as they mature, food would be most scarce in the dry season when old growth in the woodlands is unsuitable as forage. Both residents and migrants would be competing for the same limited food resource.

Grazing on a rotational basis could conceivably result in increased grassland productivity and thus larger populations of herbivores than would otherwise occur in a non-migratory system. However, for Africa at least, where migrants tend not to feed exclusively on old growth when they return to the dry-season woodlands, a ten-fold disparity for resident and migrant populations would not be predicted. At most, the authors suggest this feeding pattern may account for only a two-fold difference.

The third hypothesis—that migrant populations are less vulnerable to predation than resident populations—does seem to fit the facts. Lions and hyenas, the only predators in large enough numbers to have any significant effect on wildebeest numbers, are relatively sendentary animals that live in the woodland. Although a few predators wander onto the plains, they are unable to follow the migrating herds of wildebeest for any length of time because they have to feed their immobile young during the long period of dependence. Few prey exist the whole year round on plains, so most predators are restricted to the woodlands. Here they continually regulate the population densities of resident ungulates. According to Fryxell *et al.*'s their model, by spending a good part of the year away from predators, migrants can reach population levels ten times that of resident wildebeest.

—G.H.

Why are migratory wildebeest so abundant compared with their sendentary counterparts?



D. PARER & E. PARER-COOK/AUSCAPE INTERNATIONAL

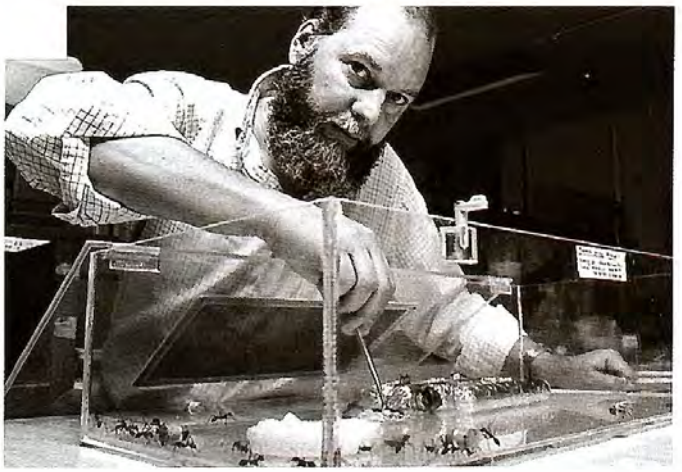
Putting the Ant into Antibiotics

Entomologists have puzzled for centuries about the function of the metapleural glands found in ant species. The glands, most often mounted like saddlebags midway along the insects' bodies, secrete complex chemical compounds. High on the list of speculation about the purpose of the secretions was the idea that they might play some part in the chemical communications that dominate life in ant colonies.

Now a team of Australian scientists has found strong evidence that, in Australian bullants at least, the secretions have a highly practical role to play in regulating infections in the colony. About five years ago Andrew Beattie, of Macquarie University, began studying bullants—which are conveniently large subjects—in an effort to learn how they coped with the infectious diseases caused by bacteria and fungi in their underground nests.

By immobilising individual ants, he and colleagues were able to painstakingly collect drops of fluid produced by the metapleural glands and, with help from researchers at other institutions, subjected it to chemical analysis.

Among the more than 20 novel compounds isolated from the fluid were several that have since proved to be highly effective agents against fungi and bacteria that commonly invade ant nests and bee hives. Most exciting of all, from a medical viewpoint, was the finding that some of the compounds also seem to be effective against human *Staphylococcus* infections, including the notorious 'Golden Staph' that plagues hospitals and hampers the healing of many surgical wounds.



MACQUARIE UNIVERSITY

The complex secretions of Australian bullants may have a role in regulating infection in the colony. Shown here is Andrew Beattie with some of his research subjects.

Drug companies are showing keen interest in the research, which shows promise of yielding a new class of antibiotics, and which may help tackle some of the resistance problems that increasingly limit the usefulness of the current generation of antibiotic drugs, such as penicillin.

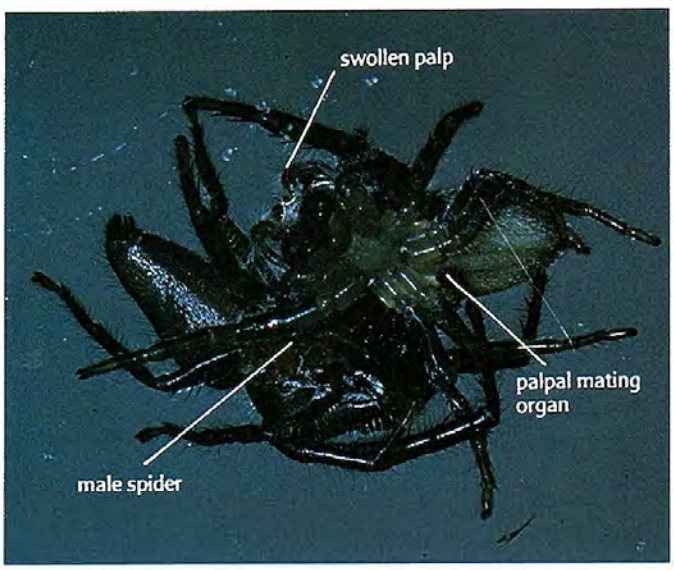
—**B.B.**

Jumping the Gun

Like most of humanity, biologists have a healthy interest in sex. Consequently, when I noticed two jumping spiders (*Opisthoncus* sp., family Salticidae) performing a courtship dance on my kitchen window, I became quite excited and rushed off to get my camera.

Upon returning, closer inspection revealed something rather odd. The female seemed quite torpid and made no response at all to the enthusiastic courting movements and touches of the larger male. This proved to be because she was securely tied down with silk threads, presumably by the male. Now, bondage is a lesser known aspect of the sex life of some spiders. Male flower spiders (family Thomisidae) often tie down their larger partners but this is mostly for their own protection. Some present the female with a silk-wrapped insect to chew on as well. As I could not recall any records of silk-tying behaviour for jumping spiders, I suspected that something unusual was going on.

Eventually the male decided that this one-sided courtship had gone on long enough. He moved to the mating position at the side of the female, clasped her with his legs, and applied his mating organ to her ventral abdominal genital opening. Male spiders, of course, store their sperm in little reservoirs inside the often complex palpal mating organs. These organs are placed at the ends of the palps—two short leg-like appendages, one on each side of the head.



MIKE GRAY

Ventral view of mating jumping spiders showing the male (lower left) applying his palpal mating organ to the abdominal genital opening of his partner.

It was at this point that, like Alice, I noticed the situation becoming curiouser and curiouser. The female had palps that were disconcertingly swollen at the ends. The penny then dropped. This was no female. The male spider was attempting to mate with another male, albeit an immature one. Immature male spiders can be recognised by the swollen end segments of the palps, which are enlarged to accommodate the mating organ structures forming within.

My discovery had no impact on this apparently gay male. He continued to scrape his mating organs vigorously across the area where, in the normal course of events, the female opening would be encountered. At intervals he changed sides to try his luck with the other palp. The male twice desisted, wandering off a short distance, but soon returned, each time starting a brief courtship routine before resuming his mating attempts.

Finally, after no less than three hours of this, the mature male gave up and departed, leaving its hapless victim still tied down. I left it there for two days, curious to see if it would free itself. Then, wanting to inspect the spider in more detail, I carefully collected it and placed it in an observation tube. The spider seemed undamaged and, although torpid, was still alive. After three days, however, its body colour started fading and a day later it was clearly dead.

Obviously the behaviour related above is both aberrant and rare. Jumping spiders are highly visual animals, able to recognise prey and mates at a distance. Males and females of the same species often look very different and reports abound of elaborate, visually based male–female courtship displays and antagonistic displays between males. Interactions between male and immature spiders also occur. These are often antagonistic, although mature males will initiate courtship with immature females, but this is soon broken off. Immature males and females, however, often do not differ greatly in appearance. In this encounter it is possible that the male spider simply mistook the sex of an immature male and started a courtship sequence with it. How this was then sustained through to attempted mating is less easy to explain, especially as physical contact should have given the male some chemical clues to his error. Perhaps in the spider as well as the human world some chaps just won't take no for an answer.

—**Mike Gray**
Australian Museum

Contraceptive Vaccines Move Closer

Research into contraception assumes greater and greater importance as world population figures skyrocket ever higher, and one of the most promising options—vaccines to prevent conception—seems to be within sight. A small proportion of men and women attending infertility clinics show signs that their immune systems have attacked sperm, as they would any foreign substance, by producing antibodies against it. Since those people show no other ill effects (aside from infertility), scientists have been trying to unravel the details of the process in the hope of finding a safe way to make it happen in fertile people.

Clinical trials are under way on a vaccine that acts against the early embryo, but the similarity of the technique to abortion may limit its acceptability. Paul Primakoff and colleagues from the University of Connecticut Health Center have now demonstrated that it may be possible as well to make vaccines against sperm (*Nature* 335: 543–546, 1988).

Working with guinea pigs, the team found that a surface protein known as PH-20, found on guinea pig sperm, can stimulate the formation of antibodies against the sperm when injected into females. The effect seems to be reversible, since immunised females regained their fertility within 15 months.

The protein is critical in the second of three phases of fertilisation, when the sperm, having made contact with the translucent shell (the zona pelucida) that surrounds the ovum, undergoes chemical changes that prepare it for the final phase of penetration and fusion with the egg. During the second phase, the surface protein PH-20 moves from the back of the sperm head to the front, where it has a required role in sperm adhesion to the zona pellucida. Antibodies to PH-20 block this adhesion.

The search is now on for a human equivalent of PH-20. Other researchers at the Medical Research Council's Reproductive Biology Unit in Edinburgh have developed similar vaccines against proteins on the surface of ova in primates.

—B.B.

Clinical trials are under way on a vacdine that acts against human sperm.

J. FRAZIER/ANT PHOTO LIBRARY

Feline AIDS Pre-dates Human AIDS

The epidemic of AIDS arrived with all its tragic consequences in Australia in the early 1980s. It was not until 1987, however, that cats were found also to suffer from a closely related disease, feline AIDS, now known as FAIDS.

Veterinary scientists at Sydney University have since shown that FAIDS pre-dates AIDS in Australia by at least a decade. The FAIDS story is still being unravelled, but the disease is known to be caused by a lentivirus (or 'slow virus') remarkably similar to the one that causes AIDS in people.

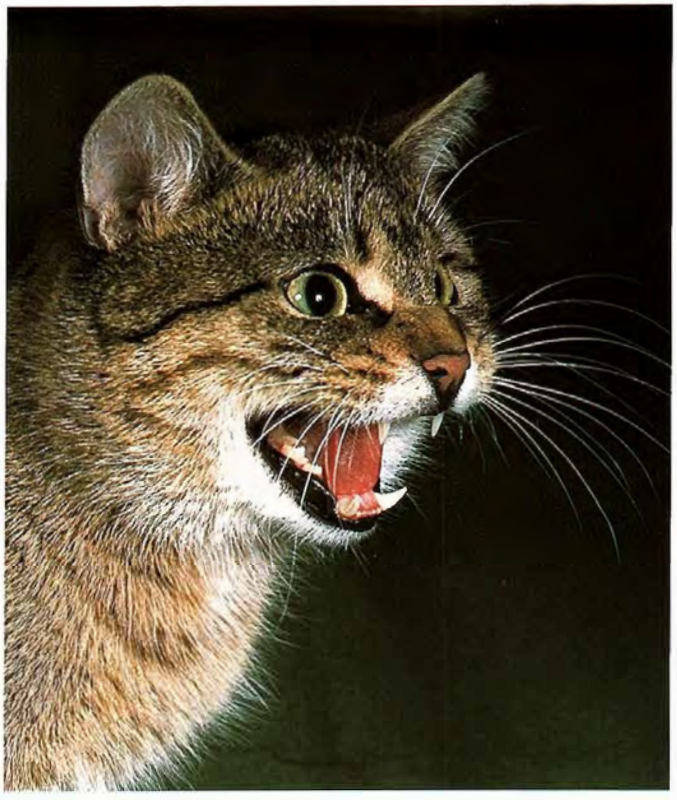
Like the human immuno-deficiency virus (HIV), the feline immuno-deficiency virus (FIV) suppresses the immune system, leaving cats susceptible to infection. In its active phase, the disease leaves cats with symptoms that can include ulcers, chronic lung infections, weight loss, diarrhoea, anemia, fever, miscarriages and even death. Margaret Sabine, a virologist at the University, notes that sheep, cattle and goats also suffer lentivirus infections, but the feline and simian (monkey) lentiviruses are clinically most like HIV.

Tests on blood samples collected from cats during another long (but unrelated) research project have shown that FIV was present in Australian cats as early as 1972. No evidence exists that AIDS spreads to cats, or that FAIDS spreads to humans, and both diseases are extremely difficult to spread. The main method of transmission of FAIDS seems to be through bites, not sexual contact.

Studies by Takuo Ishida, from the Nippon Veterinary and Zootechnical College in Tokyo, Japan, indicate that FAIDS is more common in cats that are allowed outside (presumably because of bites from other cats) and that it is more common in males (*New Sci.* 7 July 1988: 34). He also suggests that the recent spread of FAIDS in Tokyo is directly related to the overcrowded housing situation there. Outdoor cats have territories that are usually well defined and defended but in crowded situations territories often overlap, resulting in increased fighting and opportunity for the spread of FAIDS. Studies of FIV will hopefully shed light on the arrival and spread of the clinically similar HIV in Australia.

—B.B.

Feline immuno-deficiency virus has been present in Australia since 1972. Like AIDS it suppresses the immune system, but it is transmitted through bites, not sexual contact. Overcrowded human populations contribute to the spread of the disease.



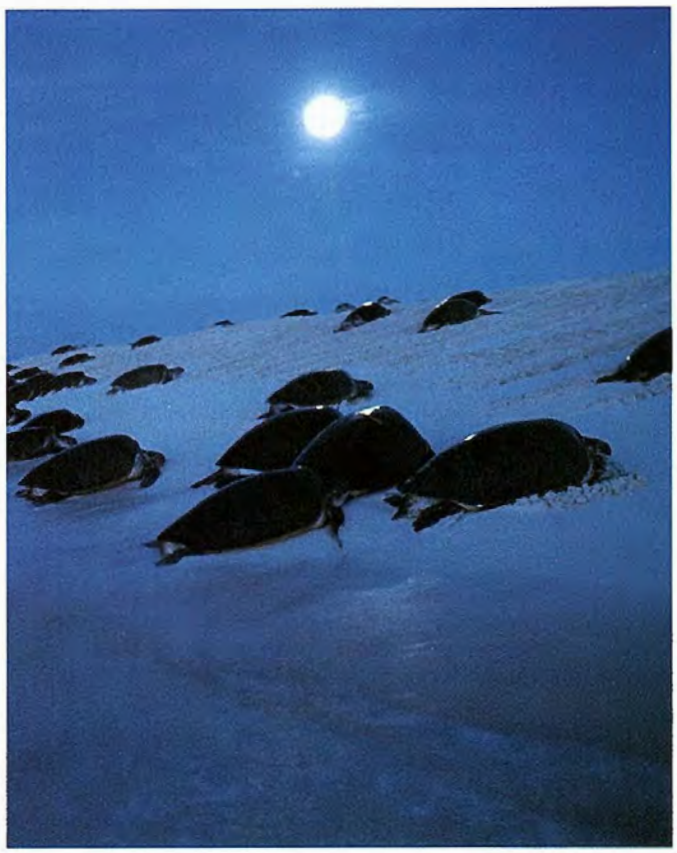
AUSTRALIAN PICTURE LIBRARY

Not Tonight Dear, I've Got an Oscillation

The Green Turtle (*Chelonia mydas*) is one of six turtle species that breed around northern Australia and Indonesia, but the number of Green Turtles seen nesting varies greatly from year to year. Those numerical fluctuations are in phase even at widely separated rookeries, and tagging surveys have shown that in any given year only a proportion of mature females from a particular feeding ground will breed.

Colin Limpus, of the Queensland National Parks and Wildlife Service in Townsville, and Neville Nicholls, of the Bureau of Meteorology Research Centre in Melbourne, have now found a way to predict two years in advance how many turtles will breed at the Great Barrier Reef rookeries (*Aust. J. Wildl. Res.* 15: 157–161, 1988).

They have found a strong correlation between turtle breeding and the Southern Oscillation Index (SOI), which measures the irregular seesawing of atmospheric pressures between the south-east Pacific and Indian Oceans. That phenomenon has a major effect on the Australian region's climate and the tropical oceans. Limpus and Nicholls believe the Southern Oscillation somehow determines the proportion of female Green Turtles able to acquire enough fat reserves—through feeding—needed for egg-laying. Since the physical preparation for breeding begins more than a year before egg-laying, the effect of a good or poor feeding season shows up two years later in the numbers of turtles at the rookeries. Their study is the first report of a biological impact of the Southern Oscillation that allows such a long-range prediction. Such predictions will be useful for management of Green Turtle populations, especially in areas where nesting turtles or their eggs are harvested.



PATRICK BAKER

Researchers have found a way to predict two years in advance the numbers of Green Turtles that will breed at Great Barrier Reef rookeries.

—B.B.

Rape in Other Animals

During a recent convivial lunch I was asked whether rape is known among species other than *Homo sapiens*. Being an intrinsically interesting question I decided to research the matter.

Of paramount importance in answering this question is defining rape as it occurs in *Homo sapiens*. A resort to modern dictionaries (such as the Oxford) gives the familiar (yet uninformative) definition: "to have sexual intercourse with a

woman without her consent". Slightly older dictionaries, however, offer a second meaning: "to snatch away", in other words to steal. Throughout all but a minute fraction of the evolutionary history of *Homo sapiens*, this second meaning seems to have been the most important one. Indeed, it is only in the context of theft that the human reaction to rape can be fully understood.

The great poet Geoffrey Chaucer was accused of rape; but the object of his *raptus*, Cecily Champain, may not have been a woman but a young boy. No-one seriously suggests that our greatest writer was a pederast or sexual molester; rather, his crime was most likely some form of abduction. Indeed, Chaucer's father, as a boy, had also been subject to *raptus* in the sense of abduction. Consider also the traditional view of rape in the law. In mediaeval times rape was punishable by death (and often a rather ghastly one at that); but then so was adultery. Courts were obsessed with showing that intercourse had actually occurred. The assault on the woman was largely ignored and, indeed, the trauma of the courtroom would often amount to a second assault.

What then, was the reason for this state of affairs? Why should rape and adultery be equally severely punished, and the physical assault of rape be given secondary importance to whether or not insemination had occurred? The answer I think lies in that old meaning of the word. Both rape and adultery were thought of as thefts—thefts of reproductive potential—and it is this that led to the extreme penalty under the law. The victim in this context can be seen as the male to whom the female belonged (or in the case of an unmarried woman, potentially belonged). It was his reproductive potential that was threatened. The incident could result in him devoting his entire life to raising someone else's genes.

In recent times courts have come to view rape differently. It is now the assault upon the woman that is considered paramount. With the advent of safe and socially acceptable abortions and birth control the reproductive significance of rape has slipped away. Indeed, this field may well be a fruitful area of research for those interested in the impact of science and technology on our morals and social values.

So, having defined rape in the human context, does it exist among other species? In its current context (sexual assault) it is impossible to say. Yet in its historic sense (theft of reproductive potential) it seems that rape does occur in other species.

In a fascinating letter to *Nature* (334: 696, 1988), Dr van den Bergh suggests that a reproductive strategy known as 'piracy' may be important for many species of fish. Pirate fish are the largest males that take over the nests of other males just long enough to inseminate some eggs; they then abandon them to the care of the original owners. The fish studied had no apparent way of dealing with pirates, yet future research may reveal strategies that reduce the theft of their reproductive potential. Perhaps masters of the art of reproductive theft are the cuckoos. However, among the bird species that they parasitise are found many mechanisms to ensure that the theft is minimised.

Theft of reproductive potential also occurs commonly among mammals other than humans where male ownership of females is prevalent. The most extreme forms of female ownership are found among some primates, the Hamadryas Baboon (*Papio hamadryas*) perhaps taking the prize. Male Hamadryas Baboons kidnap infant females and, through extremely brutal conditioning, train them to respond immediately to their every command. So effective is this system that Hamadryas Baboons can even capture the females of other baboon species, while their own females are safe from most other males. But even in this extreme case, that universal institution known as the 'sneaky rutter' (but more colloquially as 'sneaker.....'; see Dr Cuillin Bantock in Robyn Williams' *Best of the Science Show*, 1983) probably finds a way around the dominant male's guard.

The explicit term is used by zoologists (including the eminent Tim Clutton-Brock) to refer to the males of a species (such as Red Deer) that steal the reproductive potential of other males. Unlike pirates, which are the largest fish, the 'sneaky' male is usually a scrawny individual, either too young or too small to go three rounds with the dominant male. He often finds his opportunity when two dominant males are fighting it out. He then dashes in and inseminates the most available female, making a quick exit before the fight finishes.

Finally, it is of interest to examine again the case of the Hamadryas Baboon in this context. Is a female better off avoiding or cooperating in the sly liaison? To be 'raped' or not to be 'raped', that is ' *not* the question. To allow her dominant male to be 'raped' or not to be 'raped' (in the historical sense of course), *that* is the question. If the extreme form of male dominance really pays off (that is, if most of the offspring belong to the dominant male and the males survive to become dominant males themselves), then biologically a female is better off sticking with the brutal 'husband'. If, however, the sneaky males have a high reproductive success (that is, produce larger numbers of perhaps not-so-robust offspring but whose sons survive to reproduce using the sneaky strategy of their father), then a liaison might be just the thing!

—Tim Flannery
Australian Museum

The noted poet Chaucer was accused of rape but in its historical sense of abduction or theft.

AUSTRALIAN MUSEUM

"The stigma arising from their illegality and the fear of persecution prevented (and still prevents) the collectors from publishing their 'ill-gotten' information."

THE CURATE'S EGG

BY WAYNE LONGMORE & WALTER BOLES

ORNITHOLOGY DEPARTMENT, QUEENSLAND MUSEUM
ORNITHOLOGY SECTION, AUSTRALIAN MUSEUM

IN THE 1800S AND EARLY 1900S—ONE OF most important periods in the growing science of ornithology—oology (the study of eggs) was considered a worthwhile and important aspect of the study of birds. In Australia the situation was very much part of this trend. However in the 1930s, there was a worldwide backlash against egg collecting, culminating in Australia with the banning of illegal collecting and enforced by heavy-handed police raids on known collectors. Over-enthusiastic journalism was typified by the *Smith's Weekly*, dated 21 December 1935. In an article titled "Intrepid Anti-Birdnesting Squad Raids Scientists", the illustrations were captioned "Bloodthirsty bird's-nester caught red-handed in his den" and "Stirring scene when the intrepid Anti-birdnesting Squad raids gang of ornithologists at their ghastly work". The writers made merry with accounts of collectors gathering to gloat over their nefarious acts. Almost simultaneously in England, a journal dedicated to oology announced that, through unprecedented public pressures, it was to cease publication. Since then and until only very recently, oology has been nominally relegated to the archives of scientific knowledge.

Casting a modern and hopefully more objective eye on this episode of scientific history, it is possible to make a far more favourable evaluation of the early egg collecting activities. While it is true that many school boy collections consisted of little more than improperly prepared eggs lacking any documentation, the best collectors must rate among the finest and most observant ornithologists to have worked in Australia.

To these men, egg collecting was more than just the equivalent of the collection of stamps, coins or other gentlemanly pursuits of the day. Efforts of the early collectors in acquiring the clutches were more rigorous than merely wandering into the bush and returning with pockets laden with eggs. The oologist had to "know the birds—and know them darn well". It required extensive experience and dedication to recognise the behaviour of nesting birds, and hours of observation to identify the progress of nesting and the stage of development of the eggs. Nests themselves are not easily located; many are well camouflaged to avoid detection. Frequently it was only by noting subtle aspects of a bird's behaviour that a hidden nest could be discovered.

Contrary to what most people would at first think, a good collector would take the whole clutch early in the season. This ensured that the birds would re-nest without deleterious effects. If only single eggs were taken, particularly from nests containing just two, it could eventually cause significant decline in the local populations. And raiding nests when incubation was well advanced or when the season had progressed too far risked failure of the entire breeding attempt.

Eggs from the recently acquired Bettington-Hyem Collection in the Australian Museum.

The actual procurement of the eggs would often entail climbing or dangling precariously from high trees or cliffs and making the descent from these perilous positions while keeping the eggs from harm. Carrying pouches were usually used, but occasionally it was necessary to transport the eggs in trouser pockets or even the mouth—with, fortunately, only the occasional disaster.

When properly prepared, each egg had a single hole drilled in the side (end-blown eggs were definitely taboo among all self-respecting oologists) through which the yolk and albumen were carefully removed, before the egg shell was cleaned and dried. Each clutch was given a distinct set mark and cross-referenced to diary entries ensuring complete and authentic data. In the collector's cabinet room the clutch was given an individual card with full data before being finally placed in the proper drawer.

If anything justifies the actions of these collectors, it is the meticulous notes they took. These data were often more detailed than those recorded by birdwatchers and 'legitimate' professional ornithologists. In pursuing their avocation, the oologists accumulated information on a range of aspects of breeding behaviour, much of which is still missing from Australian ornithological texts. The stigma arising from their illegality and the fear of persecution prevented (and still prevents) the collectors from publishing their 'ill-gotten' information. Public reaction must have set our knowledge of bird breeding biology back quite some years.

It certainly must be pointed out that there was also a bad side to egg collecting. Some enthusiasts tended to gather only the largest clutches or became enthralled with eggs of one species, usually where eggs sported attractive colours or patterns, or belonged to species held in high regard, usually because of their rarity. As with most endeavours, there were always the 'rogues'. There were incidents of data manipulated to make clutches more valuable or exchanges of incorrectly indentified eggs. (One case of the latter was the passing of the eggs of the common Great Horned Owl, *Bubo virginianus*, of North America as those of the uncommon and prized Powerful Owl, *Ninox strenua*, of Australia.) Some local populations were occasionally almost decimated by overzealous raids. Fortunately these instances were infrequent.

IN NEW SOUTH WALES THE CONFISCATED collections were deposited in the Australian Museum, joining several earlier important donations. Together these form the largest and most comprehensive collection of eggs in any Australian museum; with recent acquisitions the holdings are approaching 20,000 clutches representing about 850 species. The majority are from this country but there is a good representation from other parts of the world. More than 20 notable collections form the major components of this accumulation.

The Dobroyde Collection was formed by the Ramsay brothers, one of whom, E.P. Ramsay, became Curator of the Australian

ANTHONY FARR

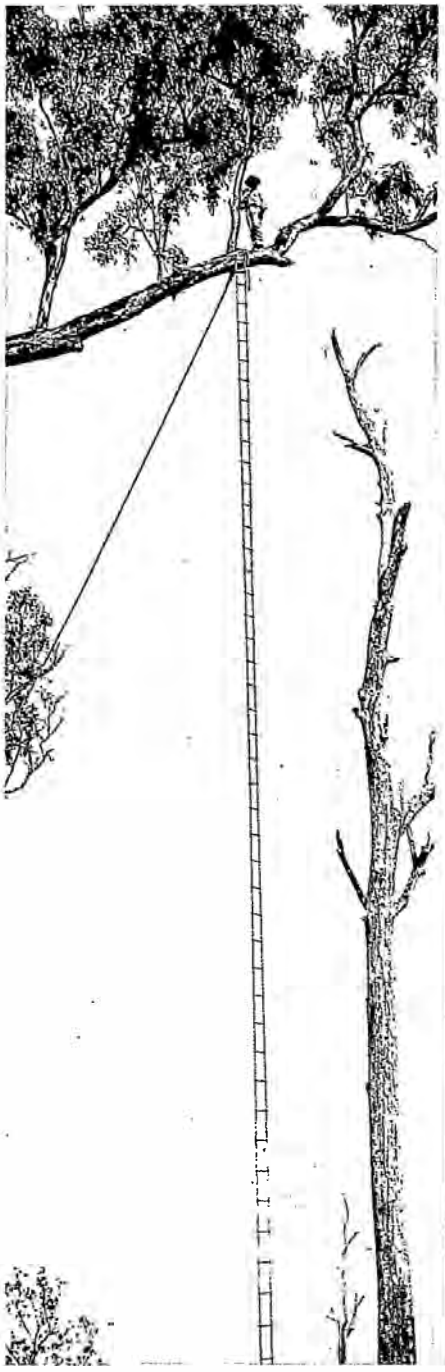
Museum in 1874. Ramsay was acknowledged as one of the country's foremost ornithologists, producing numerous publications during his career. Between 1882 and 1883 he wrote a series of articles resulting from his oological studies. These were illustrated with hand-coloured prints of the eggs. John Gould, however, wrote to Ramsay, convincing him to cease publication. Gould anticipated writing a similar tome on Australian eggs, but this never eventuated, and Australia had to wait before a proper reference finally became available.

In 1886 Ramsay employed a Victorian, A.J. North, to reorganise his Dobroyde Collection. North was later employed by the Museum to catalogue specimens received. He published many outstanding bird papers. Within three years the Museum produced North's *Descriptive Catalogue of the Nests and Eggs of Birds Found Breeding in Australia and Tasmania.* No doubt this catalogue included Ramsay's notes previously intended for the work successfully blocked by Gould. It included illustrations of eggs from the Museum collections reproduced by heliotype process. A limited number of copies had hand-coloured plates.

In 1900 North had competition from Melbourne with the appearance of a similar book by his rival A.J. Campbell. North countered with his monumental, four-volume *Nests and Eggs of Birds Found Breeding in Australia and Tasmania,* published by the Museum in 1901–1914. North utilised the large and growing collections within the Museum and his own extensive personal collection. This work included descriptions of the birds and of their nests and eggs, each account accompanied by a line drawing by Neville Cayley, Snr (father of the famous Neville Cayley, author of *What Bird is That?*). Additionally each species account contained diary extracts from many leading Australian ornithologists, both amateur and professional. North's efforts received wide acclamation. Again a limited number of copies were produced with Cayley's hand-coloured plates. Today these works are collectors' items. Both Ramsay's and North's collections were donated to the Museum.

Among the raided oologists were A.E. D'Ombrain and A.F.B. Hull. D'Ombrain was a Macquarie Street ophthalmic surgeon, while Hull had been the honorary ornithologist at the Australian Museum, appointed upon North's death in 1917. Their collections had been destined for the Australian Museum but, because of the premature confiscation, they arrived before anticipated. Foremost of the donated collections were those of W.D.K. Macgillivray and T.P. Austin, both well curated and notable for the extremely detailed data books that accompanied them. Little did these gentlemen realise how their lovingly curated eggs would find a new lease of life nearly half a century later.

It is now recognised that the long-neglected and spurned egg collections contain a wealth of valuable information, and today there is a worldwide revival in interest. In North America, the effects of pesticides on eggshell thinning in birds of prey and pelicans was confirmed from the study of eggs laid before and after the widescale introduction of these poisons. Australian ornithologists began to suspect that our birds of prey were suffering from the same problem. Penny and Jerry Olsen of Canberra examined clutches of eggs in Australian museums and confirmed the cause of eggshell thinning to be the use of pesticides such as DDT and DDE. Were it not for these collections, the data could not have been gathered and we could still be theorising on the cause of the decline in breeding success. When studies such as this use large numbers of egg clutches, it is much more sensible to employ museum collections than to invade the privacy of nesting birds.



In the past, some people would go to great lengths to collect eggs. (From A.J. North's photographic collection.)

Another contribution is to the mapping of species' distributions. Each clutch represents a known breeding attempt. By plotting the localities of these earlier specimens and comparing them with the known present breeding distribution, it can produce striking evidence of the shrinking range of some species. Information from the egg collections of the Australian Museum was used in the compilation of the historical sections of the *Atlas of Australian Birds,* and the collections are frequently consulted as part of environmental surveys.

Analysis of the records accompanying the clutches provides information on other topics such as the length of the breeding season, clutch size, nest site requirements, and changes in egg numbers and sizes throughout the year. Two particular areas aided by the collections are the study of nest parasitism by cuckoos and communal nesting.

Egg collecting did not cease after the 1930s. It continued as an illicit activity until recently. The *Sydney Sun* reported on 11 February 1983 the seizure of an illegal collection in New South Wales. "The [wildlife inspectors] were staggered to find an incredible collection of more than 2,000 eggs." It must be remembered that all official collection of Australian fauna is administered by the wildlife or conservation departments in each State or territory. Failure to obtain appropriate permits leads to hefty fines and confiscation of illegally taken material. Although illegal collecting cannot be condoned, there remains the need to recognise the potential value in these ill-gotten gains and to ensure that the accumulation of information becomes generally accessible.

Recently the Australian Museum received by donation the important Bettington-Hyem Collection. This well-documented collection contains several Australian species missing even from the Museum's sizeable holdings. Such donations to natural history museums ensure that the useable database continues to grow and permits us to address a range of environmental questions. Egg collections, correctly used in conjunction with other data, could hold clues to some of the answers. ■

Suggested Reading

Blakers, M., Davies, S.J.J.F. & Reilly, P.N., 1984. *Atlas of Australian Birds.* RAOU and Melbourne University Press: Melbourne.

Olsen, P.D. & Olsen, J., 1985. Preliminary report on changes in egg-shell thickness in Australian *Falco* species. *Tech. Publ. Int. Comm. Bird Preserv.* No. 5 1985: 389–392.

Mr Wayne Longmore, an Associate of the Australian Museum, was involved in the huge task of registering the egg collections of the Australian Museum (1977–78). He is currently employed as a technical assistant in the Ornithology Department of the Queensland Museum. Mr Walter Boles is the Collection Manager of Birds at the Australian Museum, and is in the process of completing his doctoral research on the Riversleigh fossil bird fauna.

"It provides an excellent green vegetable, especially when eaten raw in salads with feta cheese and olives."

ANYONE FOR 'SPINAGE'?

BY TIM LOW
FREELANCE NATURE WRITER

First Fleet convicts fed upon New Zealand Spinach (*Tetragonia tetragonoides*; also known as Warrigal Cabbage) the leaves of which may be eaten raw or cooked. This plant is growing at Burleigh Heads National Park on the Gold Coast.

IN 1779 JOSEPH BANKS WAS CALLED BEfore a House of Commons Committee to speak upon the suitability of Botany Bay as a convict colony. He testified that "The grass was long and luxuriant, and there were some eatable Vegetables, particularly a Sort of Wild Spinage; the Country was well supplied with Water," and so on. Botany Bay won the nod despite impressive competition from West Africa, and Banks' promise of free "Spinage" may have helped sway the vote. The plant in question is New Zealand Spinach (*Tetragonia tetragonoides*)—a seashore plant, not closely related to true spinach, that became the first Australian food plant to be cultivated overseas.

Cook and Banks first encountered New Zealand Spinach in New Zealand, and later at Botany Bay, and the captain made good use of the leaves as an anti-scorbutic or scurvy cure (see "Foods of the First Fleet", ANH vol. 22, no. 7, 1987–1988). In his journal, Banks considered the plant to "eat as well as spinage or very near it". He took seeds to England where they were grown in Kew Gardens, and later distributed to Europe and North America where New Zealand Spinach, also known as Botany Bay Greens, was sold through seed catalogues as a hardy summer-growing spinach. According to one early writer, the Reverend William Woolls, "during the whole summer of 1821, no other spinach was used at the Earl of Essex's family at Cashiobury". By the 20th century New Zealand Spinach had waned in popularity, although it still rates a mention in vegetable books and seed catalogues, both in Australia and overseas. It is likely to become more popular in Australia if the recent boom in wild foods continues, for it is very easy to cultivate, grows prolifically in the wild, holds great historical interest, and provides an excellent green vegetable, especially when eaten raw in salads with feta cheese and olives. Some Sydney restaurants serve the leaves as "Warrigal greens".

New Zealand Spinach is a shrubby seashore herb with bright green, rhomboid leaves that glisten as if covered in dew or fine sugar crystals, especially on the undersides. The flowers have four yellow petals and the green seedpods bear small horns.

Like many of Australia's seashore plants, New Zealand Spinach also grows inland, sprouting after rain on saline soils in west-

Bower Spinach (*Tetragonia implexicoma*) replaces New Zealand Spinach as the common *Tetragonia* species on southern Australian shores, where the beach sand is calcareous. Rarely do the two plants grow side by side. This specimen is growing at Beachport in South Australia.

PHOTOS: TIM LOW

On suburban Adelaide beaches Sea Spinach (*Tetragonia decumbens*), an attractive herb, forms low mats of edible foliage, a resource that goes largely unnoticed.

ern Queensland, New South Wales and northern South Australia, where it is eagerly grazed by cattle and sheep. In Europe and Africa, and along the coasts of California and Oregon, it has escaped from cultivation to become a feral plant.

Although one of Australia's more famous wild foods, there are surprisingly few records of Aborigines eating the leaves, and none at all from coastal districts. The anthropologists T. Harvey Johnston and J. Burton Cleland, working with Aborigines north-east of Lake Eyre in 1943, noted that its use as food there was "made known by the white man".

New Zealand Spinach has four close relatives among Australian plants, and these are probably all edible, although they are not well-known plants. One species is restricted to Shark Bay, another to the vicinity of Meekatharra, Western Australia, a third is widespread in the outback but widely confused with New Zealand Spinach, and the fourth, Bower Spinach, is a largely forgotten colonial bush vegetable.

Bower Spinach (*T. implexicoma*) of southern beaches is a creeper that trails over shrubs or forms thick mats on dunes. Early settlers cooked the leaves as spinach, and colonial botanist Baron Ferdinand von Mueller suggested the plant be cultivated as a vegetable.

Instead of producing hard pods that blow in the wind or float upon the waves, Bower Spinach carries dark red juicy fruits with a salty sweet pulp. Seagulls eagerly eat them, and probably help spread the seeds. Aborigines are not recorded eating either leaves or fruit, but must surely have nibbled the latter, at least as a snack food. The leaves are too salty to be worth steaming—the only leaf-cooking technique available to Aborigines, who had no pots for boiling.

Apart from these native 'spinaches', one *Tetragonia* species from South Africa has become well established in Australia. Sea Spinach (*T. decumbens*) forms thick mats two or three metres across on beaches in Adelaide, Perth and Geraldton. It has thick curly leaves, flowers crowded along the stems, and winged seedpods. Africans gather the leaves as a vegetable, which like those of other *Tetragonia* species have a delicate succulent taste.

Many species of *Tetragonia* occur in southern Africa, suggesting the genus probably evolved there. Australia's species may be descended from fruits that floated from Africa when the continents were closer, or from plants that spread prior to the break-up of the southern supercontinent Gondwana. ■

Tim Low B.Sc. is a full-time nature writer. He is the author of three wild food books, the latest being Bush Tucker, *which includes articles reprinted from his ANH column.*

"Hawking twisted in frustration as he touched his computerised communications machine: 'absolute nonsense!'"

STEPHEN HAWKING AND THE BIG BANG

BY ROBYN WILLIAMS
ABC RADIO SCIENCE SHOW

IT WAS A SLIM VOLUME ABOUT PHYSICS and cosmology. Despite containing only one equation ($E=mc^2$, of course!), the subject matter was deemed to be too technical by three publishers and they duly rejected the manuscript. The author, Stephen Hawking, Lucasian professor of mathematics at Cambridge, persisted. Bantam Books said *yes*. And the rest, dear reader, is publishing history.

By November of 1988, *before* the Christmas rush, *A Brief History of Time* had sold 600,000 copies in the United States alone! At least 150,000 had been printed in Britain and the book was in the top ten of the best seller list in Australia for months. I suspect the three publishers who said *no* must feel very much like the record company who turned down The Beatles.

But why the interest in quantum mechanics and black hole theory? There are many works on the universe and modern physics. Popular ones too, by John Gribbin, Robert Hanbury Brown and Paul Davies. Why should *this* one soar through the records?

One reason, obviously, is the eminence of the writer. Stephen Hawking has produced work of compelling originality and significance. Having shown to his satisfaction that black holes must exist, he went on to demonstrate that tiny ones are probably there too. Radiating to boot! But how can black holes, whose gigantic gravitational forces suck everything into their fearsome depths, yield up anything at all? Hawking's equations show they do.

Another reason for the success of Hawking's book is more uncomfortable, at least for the likes of me. He has a motor neurone disease and is wasted to skeletal thinness and dreadful incapacity. This is virtually all you hear and read about in the popular media. As if it's the ultimate miracle to have this mere brain and wheelchair tell us the fundamental news about the universe and its purpose. One television interviewer went so far as to ask Hawkings whether he's done so much and reached so far because he was on death's door and had to think differently, being disabled. Hawking twisted in frustration as he touched his computerised communications machine, which eventually spoke without emotion: "absolute nonsense!"

I prefer to think that the thousands who've read *A Brief History of Time* are moved by the incredible concepts Hawking tries to explain, as one who has actually tried to fathom some ultimate questions.

Stephen Hawking.

COURTESY TRANSWORLD PUBLICATIONS

Like, how did the universe begin? Could it have sprung from nothing? (The answer's yes, in a way—the difficulty is trying to define an instant *before* time began.) It is profoundly difficult to describe how quantum theory has modified Einstein's theory of relativity without using mathematics to illustrate what you're talking about. This is what Hawking manages to achieve, at least for me. In the beginning was the singularity. A Big Bang followed, time was never the same again. Until the next time.

Go along like this and you have lay people asking about ultimate purpose and even. . .about God. Hawking's been a little naughty here. I think he uses the word God rather like Mikhail Gorbachev does, more as an exclamation than an ultimate cause. Hawking's wife, said to believe in a Christian deity, is made uneasy by this offhand indulgence. Hawking does not have a personal god and says instead "If you like you can say that God is the embodiment of the laws of physics."

Meanwhile there are other scientists, usually physicists, who feel that there is such an order to the universe and the natural world, almost as if there is a blueprint, implying (if not actually stating openly) that this makes a *creator* almost inevitable.

But Hawking will have none of this, despite headlines about him trumpeting "in search of the mind of God". He has himself to blame for this. In the last lines of his book, after claiming that the ultimate quest—for GUT, the Grand Unified Theory, uniting the four basic forces (gravity, electromagnetism and the weak and strong nuclear forces)—may very soon be achieved, he hints that this may show us the "mind of God". Again, I think, he's being metaphorical. Like many scientists he appears to believe that questions like 'why does the universe exist?' are probably unanswerable.

He *does* say "what I have done is to show that it is possible for the way the universe began to be determined by the laws of science. In that case, it would not be necessary to appeal to God to decide how the universe began. This doesn't prove there is no God, only that God is not necessary."

Stephen Hawking was diagnosed as having a fatal motor neurone disease before he had even finished his PhD, 26 years ago. Since then he has married, had children, been awarded Newtown's chair of maths at Cambridge and won international fame. Professor John Wheeler, who invented the term black hole back in the 1950s, told me he's convinced Hawking has lived 24 years longer than his doctors believed possible because of the passion and commitment he brings to his science. This may be a romantic notion, Hawking undoubtedly would say so. But the compelling enthusiasm for his subject shines through his writing. That's why *A Brief History of Time* has been such an incredible publishing phenomenon. ■

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

The Carrai Cave Spider on its cribellar silk ladder web.

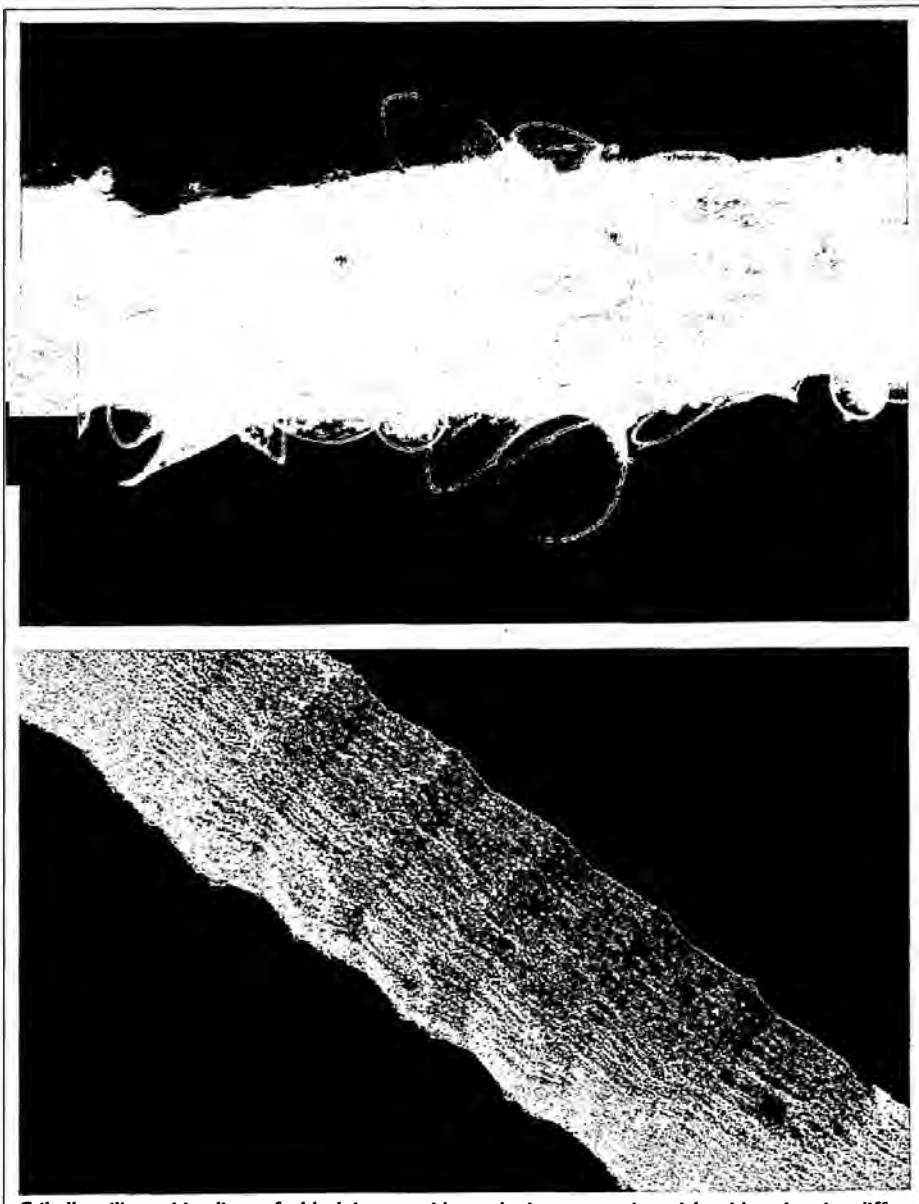
REG MORRISON/AUSCAPE INTERNATIONAL

"The long front legs lunged downwards, seizing the moth with their enlarged claws and scooping it up onto the lacy silk of the ladder."

PICKING UP THE THREADS

BY MIKE GRAY
ARACHNOLOGY SECTION, AUSTRALIAN MUSEUM

TURNING OFF THE RIDGE TRACK WE followed a spur downwards between tall eucalypts. The forest changed gradually until we were descending beneath a twilight canopy of subtropical rainforest. Occasional bands of limestone outcropped, pale against the dark brown soil. Above the rocky depression that marked the cave entrance we paused to put on helmets and head torches. The cave was easy to enter through a rock arch overgrown by ferns and roots. A steep mud and litter slide led down over rocks onto the bat-dung-strewn floor of the main chamber.



Cribellar silk catching lines of a black house spider and miagrammopine stick spider, showing differences in cribellar silk surface structure.

After a short search the torch light picked up what we were looking for. A small, bluish white ribbon of silk hung vertically just above the cave floor. A pale, long-legged spider sat motionless, head down on this lace-like silk 'ladder', its front legs extended so that their tips almost brushed the ground. This was the Carrai Cave Spider (*Progradungula carraiensis*), a primitive species known only from this small cave in the eastern highlands of New South Wales.

At the time, this spider was proving to be of considerable significance in spider classification. However, the aim of this trip was to gather more behavioural information, especially on prey capture. Spiders are well known as consummate spinners of silk, the most common examples of this being the webs they make to snare their prey. Despite this, many spiders are hunters that ambush, stalk or chase their prey, with minimal use of silk. But most hunting spiders are now believed to have evolved from web-building ancestors. At the time of its discovery, the Carrai Spider was remarkable as the only web-building member of a family of primitive forest-floor hunters (Gradungulidae). Consequently, I was anxious to learn how this spider used its peculiar 'minimalist' web in prey capture and, perhaps also to gain some insight into the evolutionary shift from web building to vagrant hunting behaviour.

The zig-zag ladder of lacy silk forming the snare was spun between two near-vertical support lines. These lines descended from a network of retreat threads above and were attached to the cave floor or wall below. Given the near-ground position of the ladder and its occupant, it seemed likely that small invertebrates wandering upon the cave floor might form part of the spider's menu. With this in mind, we collected several cave beetles and guano moths and released them near the ground attachments of the snare. When one of these (a moth) eventually obliged by walking towards the snare attachments, events moved rapidly. Apparently sensing ground or air vibrations, the spider twisted toward the approaching moth, its body supported on the ladder by the back legs while the outstretched front legs slowly probed the air. Suddenly, the long front legs lunged downwards, seizing the moth with their enlarged terminal claws and scooping it up onto the lacy silk of the ladder. This silk immediately detached from its support lines and wrapped itself tightly around the struggling moth, immobilising it in a neat silk package. As this occurred the spider bit its victim while clasping it tightly in a classic 'deadly embrace'.

This strange method of prey capture seems to combine aspects of both web snaring and active hunting behaviour. The spider ambushes and seizes its prey like a 'lie in wait' hunter but is aided in subduing it by the 'instant wrapping' function of the snare. Spiders related to the Carrai Spider, from Tasmania and South America, spin large semi-permanent horizontal sheet-like webs. It is quite reasonable to assume that the ancestors of the Carrai Spider did the same thing. Consequently, the Carrai Spider's small web can be regarded as a greatly simplified and reduced sheet web.

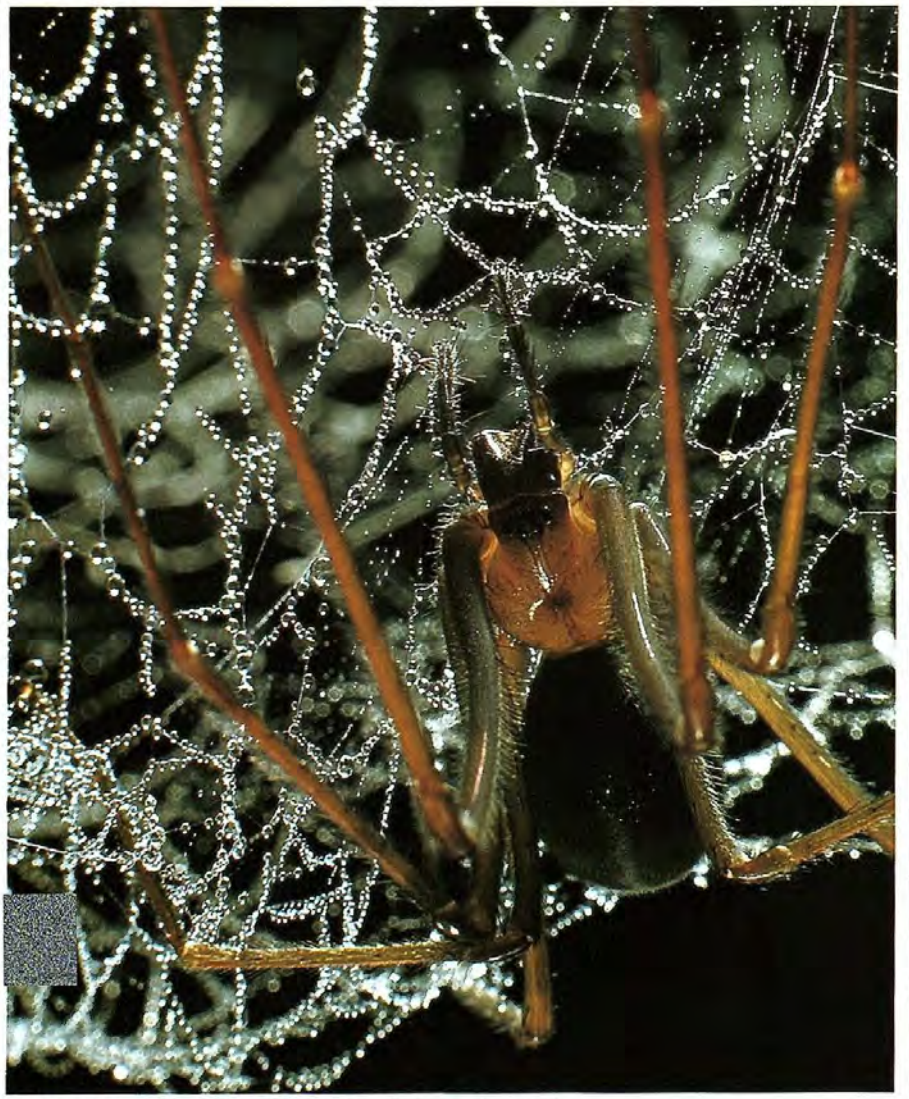
The ancestral sheet webs and the ladder snare of the Carrai Spider share a fundamental characteristic. Both are made with a special kind of silk that holds the prey and prevents or impedes its escape. This is cribellar silk, the oldest type of prey-catching silk known. This silk may have been present in the first true (or araneomorph) spiders, a characteristic (among others) that separated them definitively from their trapdoor (or mygalomorph) spider relatives many millions of years ago. Its presence today in the snare webs of all primitive and many 'modern' araneomorph spider families is testimony to both its evolutionary age and effectiveness.

CRIBELLAR SILK IS SURPRISINGLY complex. It is produced from the cribellar silk glands, which open via hundreds of delicately segmented spigots on the cribellum, the flattened spinning structure positioned just in front of the spinnerets. Together, these spigots spin a wool-like silk line consisting of very fine, closely packed silk fibrils. These fibrils are drawn out of the cribellum by the comb-like action of a row of toothed bristles (the calamistrum) on the metatarsi of the last pair of legs. Each combing movement of the legs pulls out a length of cribellar silk and in some species these form successive, discrete 'puffs' of fibrils. The fibrillar line itself, however, has no rigidity and so must be supported by longitudinal non-cribellar silk lines drawn from the posterior spinnerets at the same time as the fibril puffs are being combed out. These supporting lines may be straight (axial) or wavy and undulating. In addition, the small median spinnerets may supply fine silk lines that appear to bind the cribellar fibril mass to the support lines. Further support is often provided by spinning the cribellar lines along or between the foundation lines,

A large-eyed net casting spider (*Deinopis subrufa*) combing out its lacy net of cribellar silk. Inset: SEM of the comb or calamistrum.

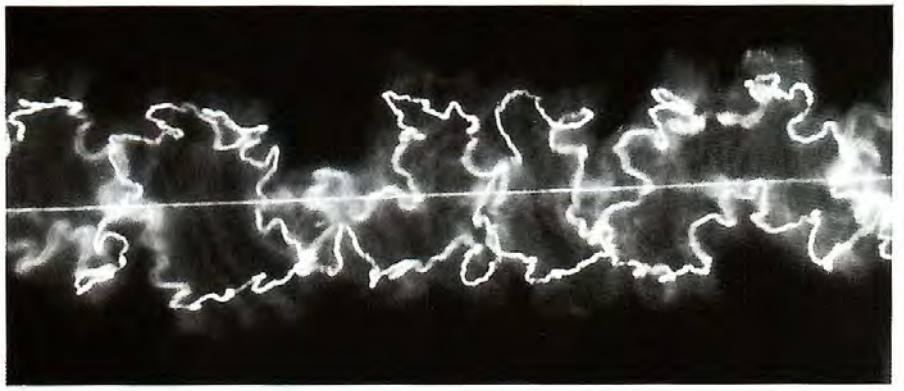
MIKE GRAY

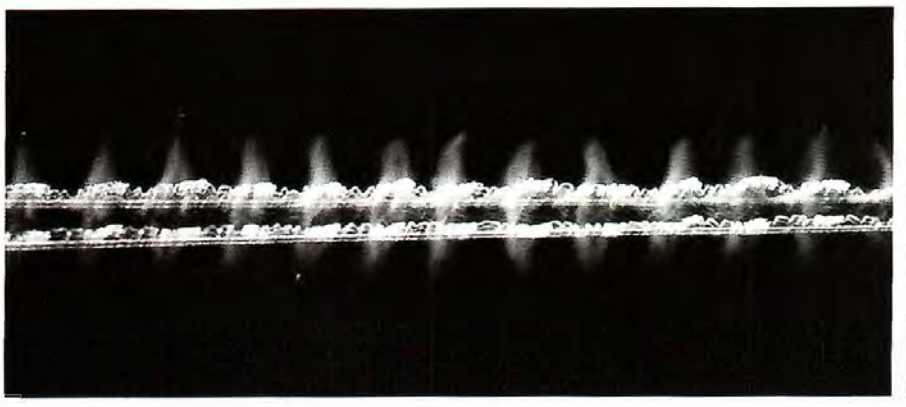
MIKE GRAY



REG MORRISON

The Tasmanian Cave Spider hanging from its large sheet web.





MIKE GRAY

Cribellar silk catching lines showing the straight and wavy silk lines that support the cloud-like mass of cribellar silk fibrils: Carrai Cave Spider and a net casting spider.

MIKE GRAY

A black house spider (*Badumna longinquus*) in its messy cribellar sheet web with entangled click beetle prey.

which form the basic framework of any web.

A cribellar catching line, then, is a compound structure made from at least three different sets of silk glands and spinning structures. As a consequence of this, cribellar lines are relatively thick and webs made of them often have quite a coarse appearance. Although they are not 'sticky' in the gluey sense, the fine cribellar fibrils do stick most effectively to prey animals. An electrostatic attraction process has been suspected but the real mechanism of their 'stickiness' remains unresolved.

The first cribellar webs were probably substrate sheets spun irregularly on foundation lines extending from retreat crevices. Present-day filistatid spiders, which spin small and rarely noticed webs under bark or radiating from crevices, still make such webs. These are effective traps for walking prey. The development of suspended sheet webs, in which the spider moves upsidedown on the lower side of the sheet, allows the capture of jumping and flying prey as well. Spectacular examples of large, suspended sheet webs can be seen in many Tasmanian caves. They are made by one of our largest spiders, *Hickmania troglodytes*, another primitive relict species related to the Carrai Spider. Smaller sheet webs are built by more familiar spiders such as the Black House or Window Spider (*Badumna insignis*). Such webs may contain hundreds of closely, often irregularly, spaced cribellar catching lines. Their prey-catching efficiency is related as much to the ability to simply entangle struggling prey in the maze of cribellar lines as to the apparent stickiness of cribellar silk.

The small spiders of the family Uloboridae are the only orb web weavers among the cribellate spiders. The wheel-

REG MORRISON

A net casting spider lines up an ant walking below it, before striking down with its outstretched net. The captured ant struggles helplessly in the 'sticky' net.

like orb web evolved as an efficient method of exploiting the enormous food potential of flying insects. Suspended as a two-dimensional structure with a central spiral line of catching silk, it is harder for flying insects to see and avoid while still providing a large planar catching surface. The small, slanted uloborid orb webs are usually found in sheltered situations among foliage and can be found around gardens or inside sheds. The spiral cribellar catching line has regular puffs of cribellar fibrils and these may increase the prey-holding area and catching efficiency of these orb webs. As we shall see, however, cribellar orb webs are the architectural equivalent of a great design idea just waiting for the right building materials to come along.

Two other groups of spiders whose unusual webs are derived from cribellar orb webs are also of particular interest. These are the net casting spiders (Deinopidae) and the miagrammopine stick spiders (Uloboridae). Most net casters have grotesquely enlarged posterior median eyes ('ogre-faced spiders') and long, stick-like

SILK: AU NATUREL AND BY PERSUASION

All spiders have silk-producing glands that supply silk via the many tube-like 'spigots' on the spinning organs or spinnerets. Most spiders have six or fewer spinnerets, only the rare segmented spiders (Mesothelae), survivors of ancient spider faunas, retain the primitive complement of eight. Modern spiders have lost the front or anterior median pair of spinnerets but a minority retain them in a much modified form as the cribellum. This is a wide, flattened, plate-like spinning structure covered with spigots and placed just in front of the other spinnerets. The cribellum produces the distinctive catching silk of the 'cribellate' spiders. The many spiders that have lost the cribellum often retain a mound-like vestige of it, the non-functional colulus.

Although silk is secreted in the glands as a liquid, in all but one case it polymerises to a strong, elastic fibre as a result of the shearing stresses applied when it is squirted or pulled from a spigot. Six distinct types of silk glands are known, each opening through different spigot sets and spinnerets, and each producing chemically and physically different silks with quite separate functions. These range from the strong elastic fibres used in web frame lines and draglines, to the bands of swathing silk used for wrapping prey, coloured silks for disguising egg sacs, and the special 'sticky' silks for catching prey.

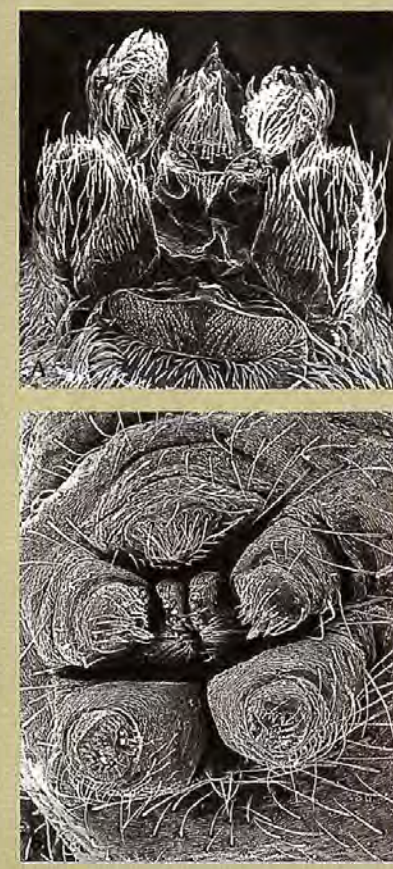
The flexibility and strength of spider silk has long fascinated humanity. In terms of speed per unit weight, a spider orb web withstands an impact equivalent to that of a jet aircraft each time a fast flying insect collides with it, and spider silk can be five times stronger than a steel filament of the same size. It is the sequential structure of the silk protein molecule that is responsible for the flexibility and strength of silk fibres. In dragline silk, for example, these properties are associated with repetitive regions of alternating groups of ordered and disordered amino acids (the building blocks of protein).

Yet such fibre properties have for a long time defied significant technological exploitation. It has been used to good effect in Aboriginal fish traps and as crosshairs in optical instruments, but not much else. The practical use of natural spider silk has foundered due to difficulties with mass spider maintenance, silk harvesting and low or variable production rates.

A spinneret showing the groups of silk-spinning spigots. The dragline spigot is the largest.

But then enter genetic engineering. Scientists have created a synthetic version of the gene (a DNA sequence) that codes for dragline silk protein synthesis. If this is inserted into the 'workhouse' bacterium *Escherischia coli*, it makes the bacterium produce granules of artificial spider silk, dubbed 'biosilk'. When these granules are chemically dissolved they can be spun into fibres.

Being light and tough, biosilk could have many important applications and, with appropriate alteration of the synthetic gene, might allow the production of 'designer' silk for specific purposes. For example, biosilk could be used as a component of composite materials in jet aircraft and spacecraft manufacture. More mundane uses might be in the production of bullet-proof vests and other specialised industrial clothing.



MIKE GRAY

Spinnerets of a cribellate (A) and non-cribellate (B) spider. Note the large unpaired flattened structure at the front of the cribellate spider. This is the cribellum, which in the non-cribellate spider is replaced by the non-functional colulus, seen protruding between the anterior spinnerets. Behind the spinnerets is the unpaired mound through which the anus opens.

bodies. Their small, rectangular silk nets represent part of a greatly modified orb web, the cribellar silk crosslines being equivalent to truncated spiral lines. The cribellar silk of the net has a coarse, coil-like structure and is very elastic and 'sticky' (a single strand will stick firmly to smooth plastic). Hanging from a sparse trapeze of threads slung among low foliage, the net caster holds this elaborately lacy little square of silk folded in its outstretched front legs. Often the spider will deposit a spot of faeces on the substrate below the net, perhaps as an aiming point. The enormous eyes, adapted for functioning in low light levels, register distance and movement of prey animals below. Upon detecting prey, the spider stretches the net to four or five times its resting size and, lunging down, envelopes its victim in silk. This technique allows net casters to catch prey as large as crickets and wandering trapdoor spiders while keeping them safely at 'arms length' in the net. Like many orb weavers they silk-wrap their prey, further securing it, before biting.

Some spiders have gone much further down the web reduction path. Miagrammopine stick spiders, close relatives of the orb web weaving uloborid spiders, make the simplest of all cribellar webs. These small, brown or green, stick-like spiders can be found in bushy gullies and gardens around Sydney but are more common further north. The snare is built among foliage and consists of a slanting foundation line (sometimes two or three) about 20–50 centimetres in length. Each foundation line is made up of two separate silk lines twisted around each other. A cribellar catching line is spun along the central segment of the foundation line(s). What a miagrammopine spider does with its simple catching line would do credit to any circus performer.

Once completed the spider sits at one end of the catching line and bites it in two. The spider's body bridges the resulting gap in the line, the cut ends of which are held by the front and back legs. The spider then tightens the catching line, hauling in slack and settles down to wait—something that spiders spend much of their time doing.

Small flying insects such as flies, wasps and ants are much more common than one might think. Eventually one of these collides with or even alights upon the cribellar catching line (some foolhardy flies often rest by hanging from non-sticky web frame lines). The spider, motionless until now, immediately jerks and tightens the line and then allows it to sag suddenly by releasing the loose silk held under its body. Done repeatedly, this rapid tightening and relaxing of the catching line causes waves and loops to develop in it and these securely entangle the prey. The spider then moves quickly out to its prospective meal, rolling up the catching line in front of it while paying out dragline silk behind to form a new foundation line. The spider's body, of course, continues to form a bridge between the lengthening new foundation line behind and the shortening catching line in front—all in all a performance of some dexterity. Once the prey is reached, the spider uses the balled catching line silk to help silk-wrap it and attaches the new foundation line to the wrapped prey, so finally eliminating the gap. Secure silk-wrapping of prey is important for all uloborid spiders because they lack venom glands.

The initial cutting of the catching line, which makes much of this spider's gymnastics necessary, may allow the spider to manoeuvre and 'whip' the catching line more effectively. The highly organised and dense cribellar fibril mass and the doubled foundation line probably reflect the need for such spartan snares to be especially sticky (more fibrils?) and capable of absorbing sudden impact and stretching stresses.

Despite its long pedigree and proven effectiveness as a prey-catching silk, cribellar silk does have limitations. It is expensive in terms of silk production and spinning it is a relatively slow process. In addition, the thickness of cribellar catching lines means that most cribellar webs are highly visible,

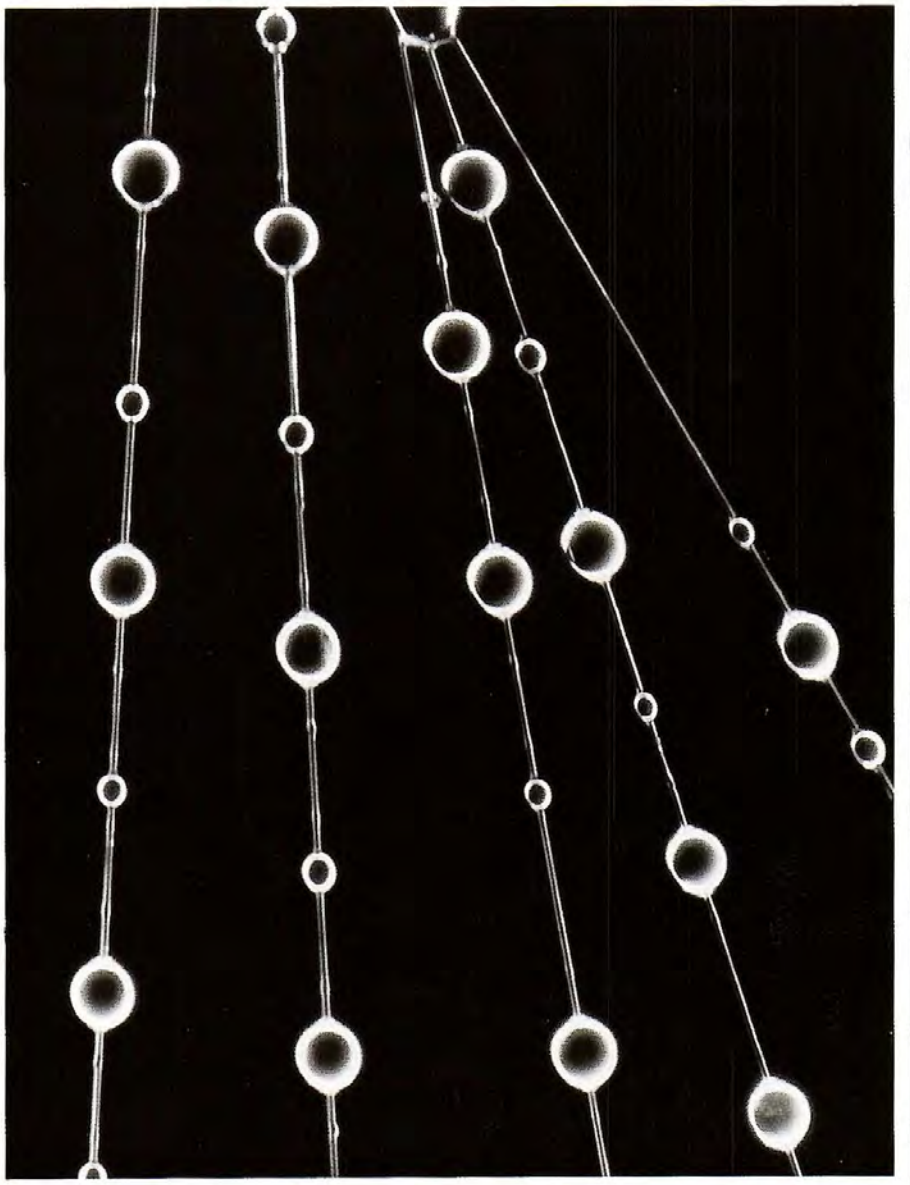
A colourful stick spider (*Miagrammopsidis* sp.) holds its single-line snare, awaiting a flying meal.

MIKE GRAY

allowing some potential prey animals to avoid them. In fact, cribellate web builders are a decided minority in today's spider fauna. The numerous non-cribellate spiders, thought to be descended from cribellate ancestors by loss of the cribellar silk organs and cribellum, include many common hunting groups (such as the wolf, huntsman, flower and jumping spiders) as well as some very successful snare web builders.

THE SUCCESS OF MANY NON-CRIBELLATE web builders is largely attributable to a single factor: the development of a new, more efficient type of catching silk. This is viscid silk—a liquid, glue-like silk that is truly sticky in the conventional sense of the word. Unlike other types of silk (including cribellar silk) that polymerise to form solid fibres upon extrusion from the spinnerets, viscid silk remains a liquid. A viscid catching silk line consists of a dry double support line along which viscid silk is placed in the form of regularly spaced droplets. These lines are produced from two sets of three spigots (called triads), one set positioned upon each of the two posterior spinnerets. The central spigot in each triad produces the two support lines onto which the remaining spigots deposit the viscid silk, each

Viscid silk catching lines of an araneid orb web weaving spider. Note the sticky silk droplets.



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Hunting spiders, like this huntsman spider (*Isopeda villosa*), do not use silk to capture their prey.

P. GERMAN/ANT PHOTO LIBRARY

ANTHONY HEALY

An araneid orb web weaving spider sitting in its web. Note the spinnerets at the end of the abdomen and the dragline (safety) thread attaching the spider to its web.

type of silk coming from different silk glands. How the viscid silk then breaks up into droplets is not understood. This is beneficial, however, as the droplets provide a large sticky surface area and sufficient 'glue' density to hold prey very effectively. Functionally, the viscid droplets are analogous to the regular cribellar silk puffs of the uloborid orb web spiral. Viscid silk lines are fine enough to make the snares almost invisible to prey animals and their production requires less silk. They are also simpler to produce and manipulate (with the spiders' specialised bristles and claws at the ends of the legs) so that web construction is faster.

Viscid catching silk is produced mainly by a group of spider families related to, and including, the orb web weaving spiders of the family Araneidae. This group also includes the comb footed spiders (Theridiidae, including the Redback Spider), the small 'money spiders' (Linyphiidae) and several minor families. Undoubtedly, however, the araneid orb web weavers are the most successful exploiters of viscid silk. Examples include the garden

Sticky swathing silk is rapidly thrown out over a fly by a Redback Spider (*Latrodectus hasseltii*), to prevent its escape.

DENSEY CLYNE/MANTIS WILDLIFE

ANGLED WEBS

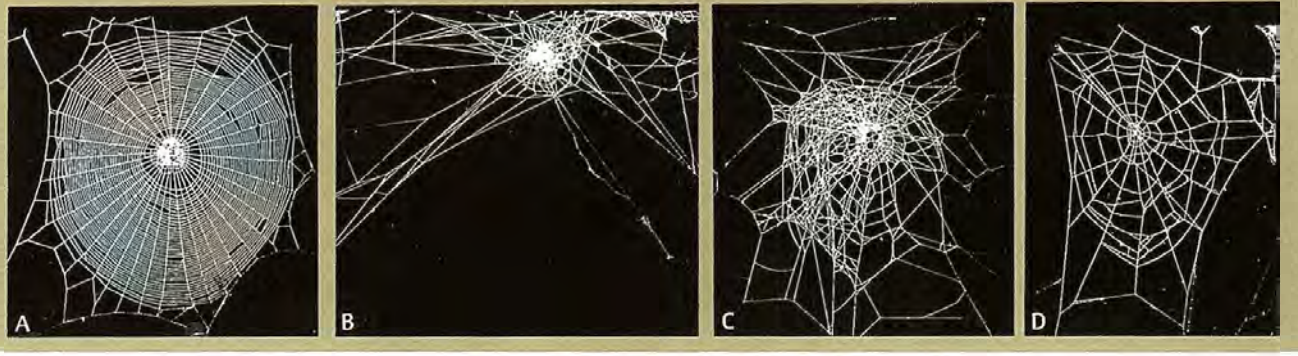
The effects of drugs on behaviour and physiology is a subject that has interested many research workers, among others. A personal example from my graduate years involved some memorable experiments that included assessing the physiological effects of LSD and other drugs on scorpion hearts.

At about the same time, medical researchers were observing the effects on web-building behaviour of dosing spiders with psychotropic ('mind altering') drugs that were commonly used in the treatment of psychiatric illness. This somewhat unusual line of research found that the normal geometry of several types of webs spun by stoned spiders (mostly orb webs, one of the most geometrically precise structures in nature) was altered in consistent and predictable ways depending on the drug administered. Eventually a wide range of drugs could be identified by their specific effects on spider web geometry.

One potential application of this research was as a bioassay technique to test for the presence of drug-like chemicals in the body fluids (such as blood or urine) of psychiatric patients. For example, the body of a patient suffering from hallucinations might itself be producing causative hallucinogenic chemicals similar in structure to the drugs known to cause such effects in normal people. Spiders could be fairly simply dosed by presenting the test animal with a droplet of concentrated urine or blood serum in sugar water at the tip of a hypodermic needle. Spiders normally ingest their food in a liquid state (prey tissues are liquified by external enzyme activity) and they will accept fluid presented to them, especially if they are starved beforehand.

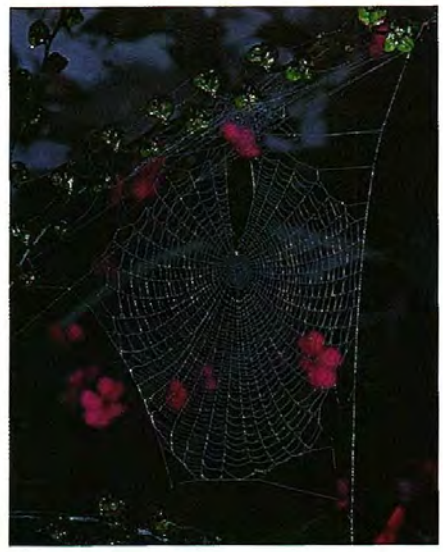
A graphic example of this methodology was performed in 1966 by G. Groh, M. Lemieux and A. Saint-Jen from Hospital des Laurentides in Quebec (*Image Roche* 1966: 3–8). It involved dosing an orb web spider (*Araneus diadematus*) with blood serum from a schizophrenic patient in a state of acute catatonia ('benign stupor'). The result was a web of quite chaotic structure, which was only gradually resolved into a semblance of its former self several days later. The idea was to follow this up by dosing spiders with purified fractions of serum to determine in which fraction the disturbing agent resided and attempt to identify it. Whether this was ever achieved I don't know but, in any case, modern technology has superseded the need for this interesting albeit rather inexact form of assay.

Changes in the normal orb web (A) in a spider affected by a drop of blood serum from a schizophrenic patient (B). Webs C and D show recovery toward normal web structure as the effects wear off.



DENSEY CLYNE/MANTIS WILDLIFE

An orb weaving spider (*Eriophora* sp.) wraps its insect prey in sheets of silk.



MIKE GRAY

The symmetrical web of an araneid orb web weaving spider.

orb weavers (*Eriophora transmarina* and *biapicata*), the golden orb weavers (*Nephila* spp.) and the St Andrews Cross Spider (*Argiope keyserlingi*). The substitution of viscid silk in place of cribellar silk in the catching spiral of the araneid orb web has allowed these spiders to exploit the orb design much more efficiently than the cribellate orb web spiders (Uloboridae).

The araneid orb web is often thought of as the culmination of spider web development. Certainly, because of its amazingly ordered structure and effective use of viscid silk, this is partly true. In reality, however, evolution presses on. Just as we have seen for the cribellar orb web, its viscid silk counterpart has undergone radical modifications associated with feeding specialisation. Perhaps the most striking examples of this are built by female araneid bolas spiders that prey exclusively on night-flying male moths. Australian bolas spiders (*Ordgarius* spp.) are often found in the Sydney region and occur across northern Australia. The large, ungainly looking females hide amongst foliage by day, one sign of their presence being a cluster of large urn-shaped egg sacs. Little is known about the tiny males except for their unique characteristic of emerging from the egg sac as fully mature adults. At night the female suspends itself sideways from a horizontal line and attaches to this a single vertical line some four to eight centimetres long. At the free end of this line, one to several balls of viscid silk are placed, so forming the 'bolas'. The upper end of the bolas line is held by the spider's second leg, rather like a fishing line, giving these spiders their other common name, the fishing or angling spiders.

The bolas spiders' single-line sticky snares are all that remain of the sticky spirals of their orb web weaving ancestors. To catch prey with this sort of web, however, something more is needed. Bolas spiders are able to emit a scent that mimics the odour put out by some female moths, to sexually attract their mates. This somewhat diabolical ploy causes male moths, intent on copulation to fly toward the spider. On sensing a moth's wingbeats (hair receptors on the spider's legs can pick up air vibrations), the spider begins whirling the bolas line in a circle beneath it. The moth flutters closer and closer until it is eventually hit by the viscid silk ball. The large volume of viscid silk in the bolas enables it to hold moths effectively. Ordinarily moths are renowned for their ability to escape from more conventional sticky webs by shedding numerous body scales and rolling out. But once caught by the sticky bolas the moth flutters furiously about in tethered flight until the spider hauls it in and dispatches it.

This trend in behavioural specialisation culminates in the bird dropping spiders (*Calaenia* spp.). They do not use silk at all in prey capture but, still using the scent lure, sit on a branch or leaf and simply grab their moth victim in mid-air with their powerful, clasping front legs.

Whether web builders or hunters, the spiders seem to have left few avenues of adaptive creativity unexploited. Such evolutionary opportunism, especially in the use of silk, has made spiders one of the most diverse and successful of all animal groups. ■

Bolas spiders (*Ordgarius* sp.). The sticky bolas hangs below the spider. When a moth approaches, it is whirled vigorously in a wide circle.

M.H. GREGG

JIM FRAZIER/MANTIS WILDLIFE

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Dr Michael Gray works on spider relationships and behaviour at the Australian Museum. His main interests are in the funnel web spiders, cribellate spiders and their relatives, and cave faunas.

RUDI KUITER

"After about two to six weeks, the male goes through a difficult 'labour' lasting up to two days, during which he bends and thrusts vigorously."

PREGNANT MALES & HORSES' TALES

BY AMANDA VINCENT
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EVEN IN OUR SOCIETY OF CHANGING SEX roles, we accept that, for the present at least, it is the women who bear the young. It can therefore come as a shock when I confess I study pregnancy in males. And, surprisingly perhaps, few countries in the world have as many pregnant males as Australia. Alarming, maybe? No (not even if you are a man), for the males I study are the seahorses and their relatives (family Syngnathidae). These fishes are among the most fascinating animals in the world. . .and not only because of their

A male *H. breviceps* undergoing a lengthy labour, during which 50–100 miniature seahorses will be born.

RUDI KUITER/ANT PHOTO LIBRARY

The Leafy Seadragon is one of two spectacular seadragon species unique to Australian temperate waters. It is a protected species.

ANTHONY HEALY

Sea horses are cryptic creatures. They can change colours, grow and shed long skin filaments and allow camouflaging microorganisms to settle on them. Shown here is the drab seahorse of Sydney Harbour, *H. whitei*.

unique reproductive system.

Seahorses have long been held to have magical properties. In ancient Greece, fishermen who found seahorses washed ashore believed these were the young of the giant stallions that pulled Neptune's chariots across the waves. The Roman natural historian Pliny stated that ashes of seahorse mixed with tallow and oil of marjoram, and applied to the pate with the bone of cuttlefish, would cure baldness. And in the Orient today, seahorses play a role in traditional medicine (to relieve back pain) and are used as aphrodisiacs.

That seahorses actually exist still surprises many people. Yet there are at least 35 species of seahorse in the world, all in the one genus *Hippocampus*. They are found in shallow coastal waters between about 45° north and 45° south, and range in size from the tiny 13-millimetre New Caledonian Seahorse (*H. bargibanti*) to the large 350-millimetre Eastern Pacific Seahorse (*H. ingens*). Their shape and basic behaviour vary little, however, unlike their close relatives the pipefishes. There are several hundred species of pipefish, divided into about 30 genera, and these are found in almost all the oceans of the world, including open waters, and even in fresh water. Also in the family Syngnathidae are the spectacular Weedy and Leafy Seadragons (*Phyllopteryx taeniolatus* and *Phycodurus equus* respectively), which are restricted to temperate Australian waters.

Many aspects of seahorse anatomy seem well suited to their usual habitat of seagrass beds: the head of a chess knight perches at right angles atop a body encased in bony plates; eyes swivel independently, contributing to excellent diurnal vision; sounds are produced, amplified and emitted for communication; only the dorsal fin provides propulsion as the seahorse glides along, while the two remaining 'ear-like' pectoral fins give the seahorse great manoeuvrability and stability; the prehensile tail is all important for grasping holdfasts to secure the seahorse; prey consists mainly of small crustaceans and fishes, which the seahorse ambushes and sucks with its long, tubular snout (surprisingly, seahorses have no teeth or stomach); and the unusual gills are shaped like bunches of grapes.

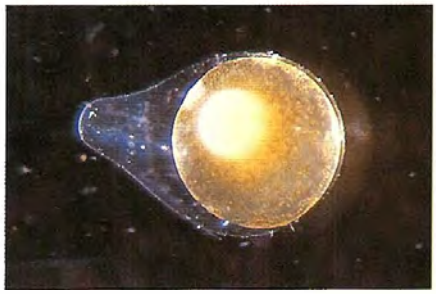
Both sexes of seahorses are very cryptic in the wild. They can change across a wide range of colours in seconds, grow and shed long skin filaments and allow microorganisms to settle on them to match their background. The result is that seahorses remain virtually invisible for long periods and are betrayed only by a slight rolling of an eye as they track food items. This

A male Big-bellied Seahorse resting: the colour is dark and the pouch is not inflated.

RUDI KUITER

camouflage may help in predator avoidance and may compensate for the seahorse's relatively slow swimming. Crabs are probably the most active predators but tuna, eldorado, skates, snappers and rays have also been known to take seahorses. However, being torn loose from the holdfast is most likely the major cause of seahorse mortality. Certainly many seahorses are washed ashore during storms in Australia, suggesting that the prehensile tail is all important for survival.

But all of these admittedly special features seem to me insignificant in the face of one great astonishing fact: males get pregnant! And I don't use the term pregnancy lightly. After a lengthy courtship, the female inserts her ovipositor into the pouch on the male's abdomen and transfers eggs.



Seahorse eggs are large (about 2.5 millimetres) and rich in oil droplets. The narrow end of the pear shape embeds the pouch wall.

She provides no further care. The male, on the other hand, fertilises the eggs—sperm are released from the urogenital pore above the pouch and travel down a tiny duct to the pouch opening. The fertilised eggs then embed the walls of the pouch. A large number of blood vessels in the epithelial tissue of the pouch supply the embryos with oxygen. Once the eggs have hatched in the male's pouch, the male nourishes the larval seahorses on a 'placental' fluid secreted with the aid of the hormone prolactin. Throughout incubation, the male alters the osmotic pressure of the pouch from being that of his body fluids to that of the salt water outside the pouch. After about two to six weeks, the male goes through a difficult 'labour' lasting up to two days, during which he bends and thrusts vigorously. The young are born looking like miniature adult seahorses and are at once free-swimming and independent, receiving no further care. In many ways, this male incubation is the exact counterpart of female pregnancy in mammals.

So why do I insist that the pregnant seahorse is male? In such cases, we revert to the most basic definition of the two sexes. Males produce many small, mobile gametes (sperm) and females produce few large, energy-rich gametes (eggs). And if the male gets pregnant, where does that leave our understanding of what constitutes male and female traits in general? It was this question that prompted me to start on my seahorse research three years ago. Since then, I have been studying their reproductive ecology as a means of addressing general questions about role reversal and the evolution of sex differences.

AMANDA VINCENT

The female seahorse places her ovipositor into the male's pouch and transfers eggs. The species is *H. breviceps*.

Egg transfer has just been completed. Note the caved-in abdominal walls of this female *H. breviceps* and the filled pouch of the 'pregnant' male.

RUDI KUITER

Newly emerged young are free-swimming and independent. They swim to the surface and attach themselves with their prehensile tails to floating weeds.

RUDI KUITER

ALTHOUGH I DID A FIELD STUDY IN Florida, my basic understanding of seahorse reproduction was largely established in a marine system at the University of Cambridge in England. This was partially because of the difficulty in seeing the animals in some environments, but mainly because it allowed me to carry out controlled observations and experiments. From this work, I developed ideas about the interactions between individuals. Some of these came as a surprise to me and it became obvious that it was time for field work, both to verify lab results and to answer new questions. In November 1988, I found myself in Australia, back in the water with the seahorses.

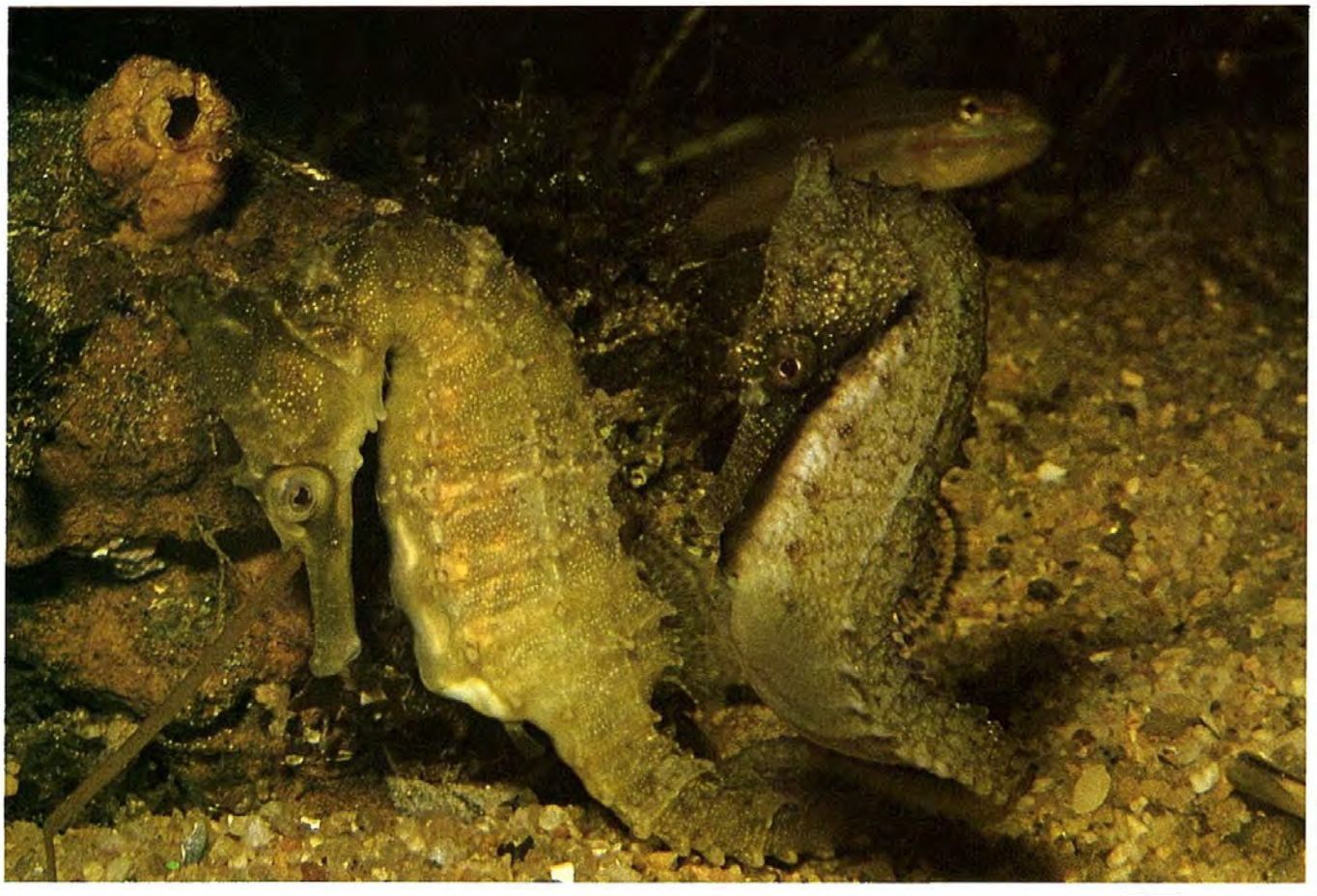
In my study of White's Seahorse (*H. whitei*) in Sydney Harbour, I found an example of what is perhaps the 'typical' seahorse mating system. These seahorses are medium-sized (125 millimetres) and live in seagrass beds in shallow waters (my study site was only under two metres of water), although they may also be found in deeper sponge gardens. They are less colourful than seahorses in tropical waters, thus blending in with their silty, drab habitat. In my lab studies, I had found evidence that suggested seahorses might be pair-bonded and hoped that the field work might resolve this question. It was encouraging to realise that the sex ratio of the area was approximately 1:1. There were about 20 *H. whitei* in a discrete patch of seagrass (3 x 14 metres), which I tagged with little numbered collars so each could be individually recognised.

It quickly became obvious that male seahorses are very site-faithful, usually found on the same clump of grass every morning. In my lab, I had seen pairs of seahorses 'greeting' each other every morning at first light. The male and female would change colour (as occurs during most interactions between seahorses), becoming brighter and more visible but retaining dark heads and ventral mid-lines. They would then carry out the first few movements of courtship: circling together with their tails clasping a fixed object like merry-go-round horses, and then moving in parallel across the bottom, often holding each other's tail. This would occur even if the two animals had mated recently or the male was very pregnant. I suspected that this behaviour pattern maintains the pair bond, so I was delighted to see the same ritual in *H. whitei* in the wild. Every morning, like clockwork, the female approached the male about half an hour to an hour after dawn and the pair greeted for several minutes. Even more interestingly, it was the same female and the same male that greeted every morning, and each animal refused to interact with any other seahorse, even if the stray individual was receptive to mating.

In this population, a pair of seahorses was usually found within the same five square metres, this 'range' overlapping slightly with those of neighbouring pairs, although the paired female sometimes moved in a radius of five metres or more around her partner. Unmated animals that had perhaps lost their partners passed near pairs without response (that is, without greeting or aggression). Laboratory studies indicate that, if competition for mates does occur, males are more aggressive than females, even though the result is pregnancy!

Seahorses give birth in the hours before dawn and in many species the births happen mostly on full moons and new moons when the tides are highest. Although it has been suggested that the timing maximises dispersal of the young or food availability for the young, we don't know what drives this lunar or tidal synchronism. However, the rhythm seems to be real, whether in the Caribbean Sea, the Indian Ocean or Sydney Harbour. *Hippocampus whitei* young are about ten millimetres long at birth, as are the young of almost all species, despite the huge range of adult sizes. Young of some seahorse species enter the plankton for several months but I saw some very young *H. whitei* (about 12–15 millimetres) already holding onto the debris on the bottom. Young seahorses suffer greatest predation and mortality and, although anywhere from 20 to 1,500 young are produced from a single brood, depending on the species, we must assume that only a very few survive to adulthood.

If there is a ripe female available, a male seahorse remates on the day he gives birth, despite the energetic costs of his 'labour'. It was interesting to see that in Sydney Har-



A courting pair of White's Seahorses (*H. whitei*). They initiate courtship by changing colour (although the face remains dark) and by moving about in tandem.

RUDI KUITER

bour, as expected, the male mated with the female he had been greeting daily. Laboratory work at Cambridge, however, had shown that if a male and female that have not been mating are put together, they will mate only on the third morning of courtship. Experiments indicate that this time period is imposed by the female, perhaps to allow her to prepare eggs. (If the female has been in daily contact with a pregnant male, she seems able to judge when to prepare eggs and will have them ready as soon as he has given birth.) Sure enough, the same is true in the wild. One *H. whitei* female from the Sydney Harbour study site had drifted rather a long way from her 'partner' and was beside another male, with whom she did not greet, for several days. She returned to her partner on the day he gave birth but it wasn't until the third morning that they actually mated! One of the roles of greeting is probably to cue the female as to the male's stage of pregnancy, so that time and mating opportunities are not wasted.

Pregnancy in seahorses lasts two, four or six weeks depending on the species and the water temperature. This may have something to do with adherence to the lunar and tidal cycles. Throughout the pregnancies of my *H. whitei* males, they continued to greet with the same female as before. It seems that in at least several species of seahorse there is very tight pair-bonding. So, throughout the summer months, pairs of seahorses around Australia are giving birth and remating.

A courting pair of seahorses (*H. abdominalis*). Note the pale and inflated pouch of the male.

WE DON'T KNOW MUCH ABOUT THE CONservation status of seahorses (or, indeed, most other fishes) but, in some parts of the world, dredging and bottom trawling by prawn fishermen are serious threats to seahorses. In certain populations their number and size are diminishing and the range of colours is narrowing. Unfortunately, a common sight is dried seahorses for sale in shell shops. Buying a dried seahorse seems a poor substitute for watching seahorses in their natural environment.

If you put on a mask and start swimming over nearby seagrass beds, looking very carefully, you have a good chance of finding these creatures. It isn't a good idea to keep seahorses in an aquarium, especially if you are a novice aquarist: they are demanding to keep, require very careful feeding and are difficult to breed. Still, many home aquarists persist and, sadly, most seahorses are sold as replacements for those that have died.. Other syngnathids, such as Leafy Seadragons, are protected species and as such it is illegal to catch them.

In Australian waters there are at least nine other species of seahorse (more are yet to be described) as well as many pipefish species and the two amazing seadragons—a total of 100 Australian species in the family Syngnathidae. I also studied the Big-bellied Seahorse (*H. abdominalis*) while based with the CSIRO in Hobart and the Short-headed Seahorse (*H. breviceps*) at Sorrento in Port Phillip Bay. These two species are in many ways unlike any of the other eight species of seahorse I have studied and, according to natural history photographer Rudie Kuiter, could perhaps be considered distinct from other seahorses. Certainly, they have very large pouches that, when full, threaten to engulf the male! The relatively greater size of the pouch may be a significant factor influencing their mating system. Unlike other seahorse species, *H. abdominalis* and *H. breviceps* males are known to take clutches of eggs from more than one female and there seems to be no evidence for pair bonding or greeting.

In contrast with most seahorses, *H. abdominalis* are frequently found on open bottoms, nestled in small depressions in the sediment. This is one of the largest species, in which males often have distinctive yellow flashes near the pouch opening. Oddly for seahorses, which are poor swimmers, individuals travel many hundreds of metres in a day and can put on a surprising turn of speed. Even more surprisingly, perhaps as a result of their greater size and speed and the exposed nature of their habitat, many *H. abdominalis* are not cryptic. All these differences in natural history influence the mating system and, although actual courtship and mating of *H. abdominalis* and *H. breviceps* are recognisably similar to that of other species, I found it much more difficult to understand the reproductive ecology of these southern species. That will be work for the future.

Very little indeed was previously known about the reproductive ecology of seahorses and I am finding that, as my research continues, the questions come more rapidly than the answers. Although seahorses are far removed from humans, studying their unusual reproduction may give us a fresh understanding of some of the differences between the sexes in ours as in other species. ■

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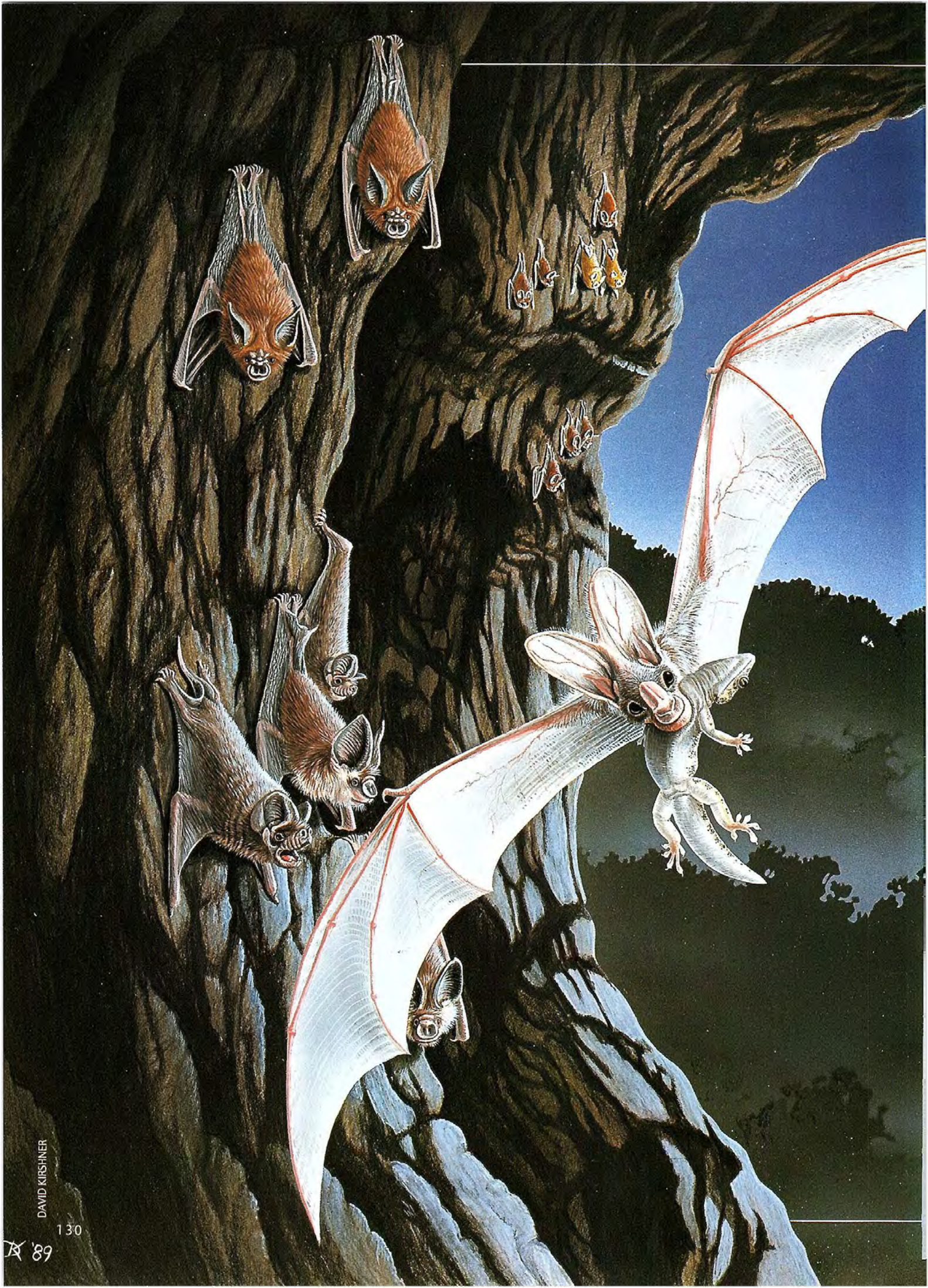
For the past four years, Ms Amanda Vincent has been researching the reproductive ecology of seahorses as part of her PhD (University of Cambridge). She studied seahorses in Australia in the summer of 1988–89.

RUDI KUITER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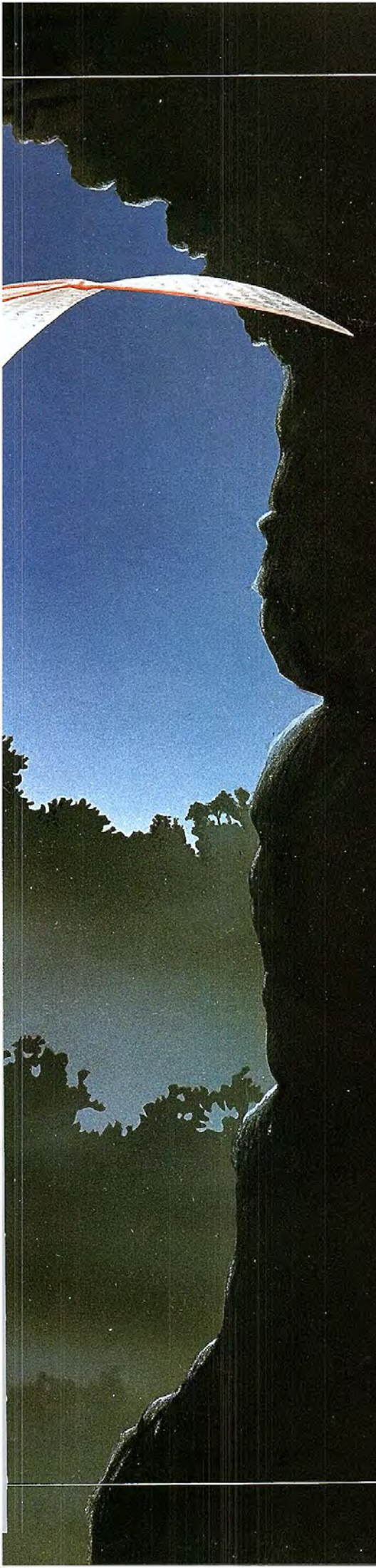


"Bats entered Australia well before the mid-Miocene collision of the Australian and Asian plates and many of these bats were poor fliers. Exactly how they made it to Australia is a puzzle."

ON THE WINDS OF FORTUNE

BY SUZANNE HAND
SCHOOL OF BIOLOGICAL SCIENCE
UNIVERSITY OF NEW SOUTH WALES

LIKE WALKING INTO A DRAGON'S MOUTH. the cave's hot, fetid breath rushes up to meet us as we squeeze through its narrow, letterbox entrance and, slithering, drop two metres to the floor. Inside, it's dark and uncomfortably warm, even hotter than the 30°C temperature outside under the burning April sun of the Gulf of Carpentaria's dry season. The acrid smell of fresh guano and 95 per cent humidity level tell us we're in the right place. The bats that our University of New South Wales team seek relish these steam bath conditions, produced in this particular cave by evaporation of spring water trickling through the black passages of the cave's hidden chambers.

Beyond the boulder-strewn entrance, our feet stir the fine, soft red earth floor and the tomb-like silence is broken by an-

Reconstruction of the Riversleigh rainforest 20–25 million years ago. At that time Australia already had a diverse bat fauna. Shown here are an ancestral ghost bat carrying a gecko, two types of leaf-nosed bats (above and below left) and two free-tailed bats (below left).

noyed twittering and the fluttering of wings. Torchlight lashes the ceiling, revealing tiny, apricot-coloured balls of fur: a group of 20 or so, four-gram Dusky Horseshoe Bats (*Hipposideros ater*) hang suspended by matchstick-thin legs. An equally small but dark-coloured bat, too quick for us to indentify, makes its escape through the cave entrance, artfully dodging spider webs and wasp nests. As if by agreement, a pair of brilliantly coloured Orange Horseshoe Bats (*Rhinonicterus aurantius*) spread their delicate wings and together disappear into the blackness while a dozen, much larger Common Sheath-tail Bats (*Taphozous georgianus*), flattened against the cave wall, legs laterally extended, calmly stand their ground. A bat-hungry children's python silently glides behind an overhang away from the torchlight.

Scattered over the cave floor are the fragile bones of generations of bats that have lived and died here. Alongside them are the skeletal remains of less frequent visitors to the cave, such as shelter-seeking possums and careless wallabies. Closer inspection of the cave floor shows piles of small fragmented bones in metre-thick mounds of dry guano. These are the remains of meals once enjoyed by large, carnivorous Ghost Bats (*Macroderma gigas*) whose bones also litter the floor. Frogs, lizards, small birds, carnivorous marsupials, juvenile bandicoots, small possums and rodents were brought in from outside as favoured foods of these magnificent bats.

The business of life, death and burial in the bat-filled limestone cave has continued since time immemorial. Twenty-five million years ago conditions inside such caves were probably very similar to today's. Outside, it was a very different story. Where today dry-adapted rock wallabies and rock-haunting ringtails hide from the sun among sparsely vegetated crags and crevices, a lush rainforest provided a green bower for an extremely diverse, tropical wetlands fauna.

IN THIS ANCIENT, STEAMY WORLD LIVED the rainforest ancestors of many of Australia's modern animals, as well as a suite of bizarre creatures that left no living descendants. Accumulating evidence indicates that forests covered most of northern Australia at that time. Much of our information about that leafy green world is being retrieved from fossil deposits on north-western Queensland's Riversleigh Station, located approximately 200 kilometres north-northwest of Mount Isa. Here the remains of thousands of mammals, birds, lizards, turtles, frogs, fish and even insects have been beautifully preserved in limestone that once accumulated as mud in the bottom of rainforest pools and lakes.

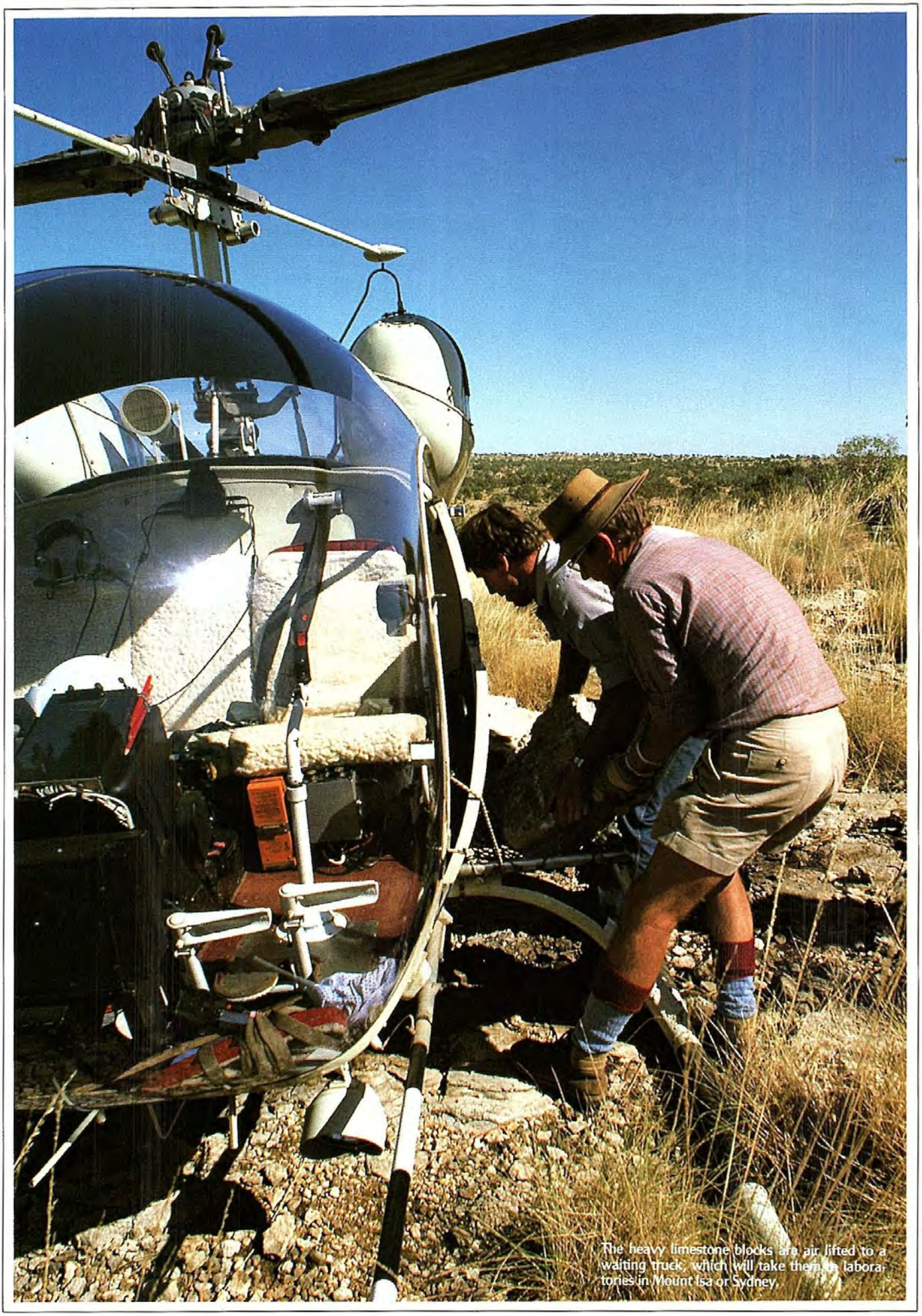
These spring-fed pools and lakes were evidently supersaturated with dissolved

KATHIE ATKINSON

Light explosives are used to crack the fossil-rich Riversleigh limestone.

KATHIE ATKINSON

Remnant vine forest lines sections of the Gregory River.



The heavy limestone blocks are air lifted to a waiting truck, which will take them to laboratories in Mount Isa or Sydney.

KATHIE ATKINSON

G.B. BAKER/ANT PHOTO LIBRARY

Northern Australia's Orange Horseshoe Bat appears to be a direct descendant of Riversleigh's fossil leaf-nosed bats.

limestone, just as Riversleigh's Gregory River is today. The lime-rich pools provided a perfect environment for fossilisation of the bones and teeth of rainforest creatures living in and around them. Mixed with these remains are those of bats and other cave-dwelling animals; it seems that the rainforested, limestone terrain of the Riversleigh area was once riddled with bat-filled caves. Bones accumulating in these caves appear to have been periodically flushed by streams into small pools and lakes near their entrances. In some cases, ancient cave floors have been preserved *in situ*, providing an opportunity to study parts of the Australian fauna not often represented in older fossil deposits.

Pockets of this bone-rich limestone are today exposed over an area of at least 40 square kilometres of Riversleigh Station. Some of these pockets are only metres apart, others kilometres apart. Some appear to preserve mostly aquatic creatures such as lungfish, crocodiles, turtles and even platypusses. In others, there is a mixture of aquatic and terrestrial animals, including lizards, snakes, parrots, cassowaries, songbirds, kangaroos, carnivorous marsupials, bandicoots, ringtail possums, cuscuses, koalas and of course bats. Most of the deposits are aged between 25 to 15 million years old, although one, called Rackham's Roost, is three to five million years old.

The older Riversleigh fossil deposits are situated on very dry, sparsely vegetated plateaus. Indeed, one of the few tangible links between the rich, rainforest faunas preserved in the deposits and the ancient Riversleigh forest of 15 to 25 million years ago are strips of remnant vine forest along the modern Gregory and O'Shanassy Rivers. Here, paperbarks, palms and cluster figs fringe the waterlily-lined river banks. Freshwater Crocodiles, turtles, frogs, pythons, lizards, wallabies and many birds and small mammals thrive along these watercourses. Away from the river, however, this remnant of paradise grades rapidly away into the hot, dusty spinifex-covered hills and flats more characteristic of arid central Australia.

At Riversleigh, traditional methods of fossil collecting (involving the time-consuming and often quite destructive use of hammers and chisels) have been abandoned in favour of more modern techniques. Light explosives are used to crack the extremely hard Riversleigh limestone that has for so long protected the fossils, and crowbars and sledgehammers are used to break it into portable pieces. These are transported to laboratories at the University of New South Wales in Sydney and Mount Isa Mines in Mount Isa where dilute

Dilute acetic acid is used to dissolve the Riversleigh limestone, revealing hundreds of perfectly preserved fossil teeth, skulls and bones.

ROSS ARNETT

Other fossil sites at Riversleigh were temporarily forgotten when the extremely bat-rich, 20–25-million-year-old Bitesantennary Site was discovered in June 1988.

acetic acid is used to dissolve away the limestone leaving the fossilised bones and teeth in pristine condition. Using this technique, fossils within one centimetre of cracks produced by the explosives are undamaged, including the most delicate of bat skulls.

Since intensive study of the fossil deposits began in 1983, Riversleigh has been providing our team of researchers with a great deal of information about the evolution of the Australian vertebrate fauna during the past 25 million years. It is also giving us our first good look at the history of bats on this continent, a group that makes up approximately 23 per cent of our modern, terrestrial, native mammal fauna. Bats are the most common animals in the Riversleigh fossil deposits, being present in large numbers at most sites. Even in the strictly 'aquatic' deposits the odd bat bone or two is usually found.

Before the Riversleigh bats turned up, two isolated, unidentifiable teeth—one from Lake Palankarinna in the Tirari Desert of South Australia and one from near Hamilton in Victoria—comprised the entire Australian pre-Pleistocene (that is, older than two million years) fossil record for bats. Now one of the world's best fossil bat records is providing quite unexpected information.

For example, the first fossil bat found in the Riversleigh deposits was identified in 1982 as a tiny, leaf-nosed bat belonging to a primitive group otherwise known only from similar-aged deposits in France. Subsequent study has indicated that many of the Riversleigh fossil bats have close ties with bats in Europe, Africa, Asia and even the Americas.

Until 1970, when the Hamilton tooth was found, it was generally assumed that bats winged their way south to Australia during the last million years when water gaps between Australia and South-East Asia were at a minimum because of the vast amounts of water tied up in the growing ice caps. The Hamilton tooth pushed this arrival date back to at least 4.5 million years ago and, in 1978, the Palankarinna tooth pushed it back a further ten or so million years. Recent reappraisal of the age of mammal-bearing fossil deposits in central Australia, however, indicates that the latter tooth is possibly closer to 25 million years old, as probably are the oldest mammal-bearing Riversleigh sediments.

From the Riversleigh deposits it is evident that by 25 million years ago Australia already had a diverse bat fauna. So far identified are over 30 new bat species, many of which are represented by literally thousands of specimens each. The fossil material includes perfectly preserved skulls, jaws, postcranials, periotic bones (those involved with reception of the high frequency sound used in echolocation) and even natural casts of brains.

Nine of these new bat species are from the three to five million-year-old Rackham's Roost deposit; the others are from the older Riversleigh sites. The latter are dominated by two groups: the leaf-nosed bats (hipposiderids) and ghost bats or false vampires (megadermatids). By Rackham's Roost time, the assemblage is closer to that found in the Riversleigh area today where plain-faced bats (vespertilionids) outnumber all others. The same pattern can be traced from European middle Tertiary to modern bat faunas. Other groups represented in the Riversleigh deposits are free-tail bats (molossids) and sheath-tail bats (emballonurids).

THE ONLY MODERN AUSTRALIAN GROUP not yet known from the pre-Pleistocene Australian fossil record are flying foxes and other fruit-bats (pteropodids). If fruit-bats *were* living in the Riversleigh forests we would expect them to be preserved in the fossil deposits. In tropical areas today, many fruit-bats inhabit caves, Cape York's Bare-backed Fruit-bat (*Dobsonia moluccense*) being a case in point. Cave-dwelling has not been a prerequisite for fossilisation at Riversleigh as the many non-cave-dwelling animals, such as possums, crocodiles, insects and birds, clearly demonstrate. The absence of pteropodids is a surprise. After all, many of these are large and conspicuous elements of modern tropical to subtropical rainforest faunas; they are present in fossil deposits of similar age in Eurasia and Africa; many living pteropodids readily fly long distances nightly to reach suitable food trees; they have radiated widely in the islands to the north of Australia; and, on at least some of these islands, they are the only bat colonists.

It is interesting to note, however, that the modern Australian fruit-bat fauna, which is comprised of only eight pteropodid species (only one of which is endemic), is markedly depauperate compared with those of many of the islands north of Australia. The New Guinea bat fauna, for example, includes 25 living pteropodids, ten of which are endemic. The success of fruit-bats in New Guinea (compared to Australia) may be due, at least partially, to historical events. As pteropodids reached the islands that formed New Guinea in the early to middle Tertiary, fruit-, blossom- and nectar-feeding possums were probably also colonising from the south. On the other hand, when pteropodids arrived in Australia, they would have encountered a long-established and very diverse herbivorous, arboreal marsupial fauna. Today, roughly equal numbers of pteropodids and possums cohabit New Guinea rainforests, while in Australia possums far outnumber fruit-bats.

Although there is at least one Riversleigh bat that is most closely related to a living American free-tail species, the affinities of the Riversleigh fossil bat fauna as a whole appear to lie primarily with Eurasia and Africa. Overall, there is no evidence of a Gondwanan origin for Australian bats as has been proposed for, among other groups, marsupials, ratite birds and some frog families.

Yet, the kind of bats dominating the oldest Riversleigh deposits are not noted for their ability to fly long distances, and certainly not across the water gap postulated to have existed between Laurasian Asia and Australia some 30 million years ago (a distance estimated to be at least 2,000 kilometres). Mostly they are leaf-nosed or horseshoe bats (hipposiderids), insect gleaners commonly tied to cave environments. In fact, the most common bats

MICHAEL ARCHER

in the Riversleigh deposits are ancestors of hipposiderids that today live only in extremely hot, humid caves and that quickly expire outside these conditions.

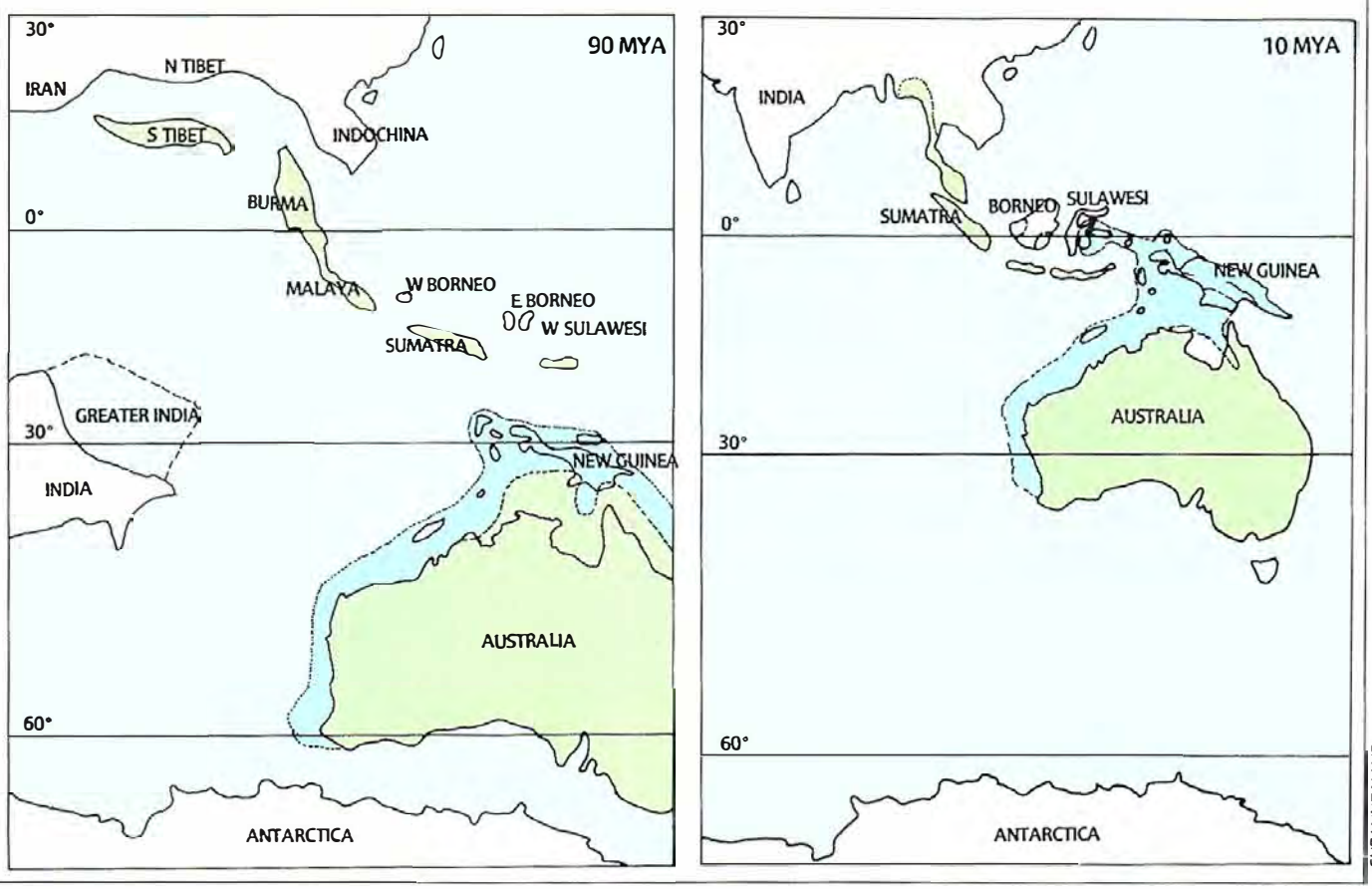
Of course, at this stage there is no way of knowing if the bat groups represented at Riversleigh were actually the first to successfully colonise Australia. For example, by Riversleigh time it is possible that fruitbats had already arrived in Australia and were living in other habitats. What we do know from the fossil record is that bats entered Australia well before the mid-Miocene collision (15 million years ago) of the Australian and Asian plates and that many of these bats (although not all) were poor fliers. Exactly how they made it to Australia is a puzzle.

Accidental or waif dispersal, such as on floating vegetation mats, has been postulated as the method of arrival for most of our terrestrial Asian emigrants, including songbirds, varanid lizards, tree frogs, elapid snakes, rodents and others, and it has been suggested that Australia's first bat colonists were actually storm-blown to our shores. There are modern records of Little Red Flying Foxes (*Pteropus scapulatus*), weighing around 400 grams, making 2,300-kilometre trans-Tasman crossings from Australia to New Zealand during cyclones. There is, however, little data to indicate whether or not hipposiderid bats (weighing 4–50 grams with, if we can judge by living taxa, very strict microhabitat requirements) would quickly be able to find suitable habitat, if indeed they survived the very wet and wild ordeal of transportation.

An alternate hypothesis to the waif dispersal hypothesis is that the water gap between Asia and Australia during the early and middle Tertiary was not nearly as wide as generally assumed, with island 'stepping-stones' for at least some biota having existed well before the mid-Miocene. In recent palaeographic reconstructions of this area, M. Audley-Charles from the University College in London postulates that a complex of Gondwanan continental fragments, which rifted from the northern edge of the Australian plate in the Mesozoic, existed between Australia and Asia during the Cretaceous and Tertiary. These fragments, he believes, would have enabled exchange of plants and animals for much of the time since the late Cretaceous (100 million years ago), with perhaps a decrease in potentially viable exchange routes in the Oligocene (approximately 30 million years ago), followed by an increase after mid-Miocene time when the Australian plate itself collided with the Asian island arcs. This hypothesis is supported by, among other evidence, data collected from the Australian pollen fossil record by Elizabeth Truswell (Bureau of Mineral Resources in Canberra) and colleagues. Their study refutes the idea that Australia was biologically remote from landmasses to the north prior to 15 million years ago.

Study of the Riversleigh bat deposits will almost certainly provide faunal evidence for one hypothesis or the other. In this respect, one of the most important sites at Riversleigh promises to be Bitesantennary Site. Among Riversleigh's most spectacular sites, it was discovered during the 1988 Bicentennial Riversleigh Expedition. The limestone at this site is brilliantly bat-rich; indeed, the best Riversleigh has yet produced. Bat bones, jaws, skulls, snail shells, the odd marsupial jaw, bird bones and frog skulls compete for space in the matrix. So far, at least five hipposiderid species appear to be represented and at least some of these seem also to be represented in other sites, thus providing the first opportunity to study complete skull material for a number of Riversleigh taxa. With such good material, it should be possible to accurately place these species within evolutionary lineages and so determine their times of separation and divergence from relatives on now very distant shores.

A SHORT HELICOPTER RIDE AND 20 MILlion years away from Bitesantennary Site, a deposit called Rackham's Roost is providing another important view of ancient northern Australia. Perched high above the Gregory River, Rackham's Roost is a three to five million-year-old cave deposit. The roof and most of the walls of this cave are missing but the floor—a solid pavement of pink-coloured limestone studded with bones and teeth—remains. Of all the Riversleigh deposits, Rackham's



Audley-Charles' reconstruction of the relative positions of landmasses in the Malay Archipelago 90 million years ago (late Cretaceous) and ten million years ago (late Miocene). By 90 million years ago, island stepping stones between Asia and Australia were available for good dispersers. Such stepping stones were evidently used by bats colonising Australia more than 30 million years ago. Note that ten million years ago the relative positions of continents and islands were similar to today. Outlines show present coastlines. Green represents Australasian land above water and blue below.

SUZANNE HAND

SUZANNE HAND

The pink-coloured bone-rich limestone floor of Rackham's Roost laps at the ancient, grey-coloured cave walls. At 3.5 million years old, this cave deposit is younger than most other Riversleigh deposits and provides important information about life in Australia's ancient woodlands.

Roost is probably most like modern cave deposits accumulating today in northern Australia. Among the fossilised remains are those of ancestral ghost bats and their vertebrate prey, including some of Australia's oldest rodents. The site is providing invaluable information about life in the Riversleigh area at a time when the ubiquitous rainforests of the early and middle Tertiary (15–65 million years ago) had already retreated to the edges of the continent, and woodlands (rather than today's grasslands) covered great tracts of northern Australia. In the case of Rackham's Roost, Riversleigh's prehistoric ghost bats have conveniently collected together for scientists a precious sample of life from the ancient woodlands of northern Australia.

Study of the Riversleigh bat-bearing deposits is in its infancy. The deposits are among the richest in the world, both in terms of numbers of taxa and individuals. The material is also extraordinarily well preserved, enabling detailed anatomical studies of not only new species but also taxa shared with (but often less well represented in) overseas deposits. The Riversleigh bats promise to shed further light on the arrival time of various bat groups, the course of evolution of bat communities and species over the past 25 million years, and the radiation and subsequent decline of particular species groups. And, because the bat remains are most often found alongside those of marsupials, they also provide a rare opportunity to compare rates of evolution in bats and marsupials, as well as a unique chance to correlate Australia's fossil mammal-bearing deposits with well-dated deposits in Europe and Africa.

As Australia's bicentennial year fades into history, it is interesting to consider the irony of those first intrepid Eurasian bats that hung, exhausted, from the trees of what to them might have been 'New Transylvania'. Although sentenced by the winds of fortune to this voyage more than 30 million years before similar fortunes transported the first Europeans, bats were long regarded to be relatively recent immigrants to Australia. The discovery at Riversleigh of a rich and ancient record of Australia's prehistoric bats is, for devotees of these winged creatures of the night, a far more exciting find than all the pyramids of Egypt or bones of Olduvai. ■

Suggested Reading

Audley-Charles, M.G., 1987. Dispersal of Gondwanaland: Relevance to Evolution of the Angiosperms. Pp. 5–25 in *Biogeographical Evolution of the Malay Archipelago*, ed. by T.C. Whitmore. Clarendon Press: Oxford.

Truswell, E.M., Kershaw, A.P. and Sluiter, I.R., 1987. The Australian–South East Asian Connection: Evidence from the Palaeobotanical Record. Pp. 32–49 in *Biogeographical Evolution of the Malay Archipelago*, ed. by T.C. Whitmore. Clarendon Press: Oxford.

Dr Suzanne Hand is a postdoctoral fellow of the University of New South Wales. For the past eight years she has been researching the origin and evolution of the Australian bat fauna.

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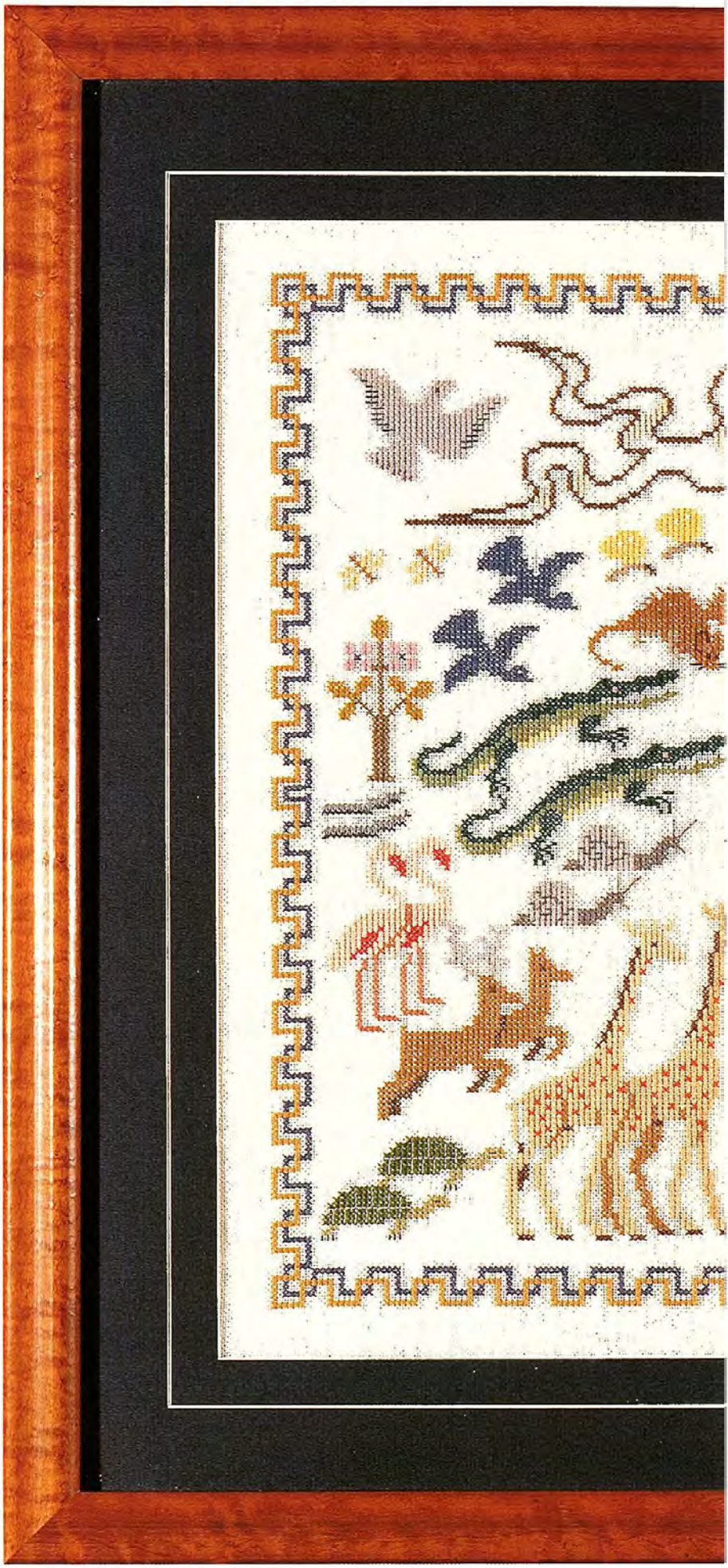
"Under present New South Wales legislation, Noah would have been fined up to $63,000 and/or imprisoned for up to seven years for holding animals in unacceptable conditions."

MANY PEOPLE, INFLUENCED PERhaps by Gerald Durell, regard zoos as a modern form of Noah's Ark, helping to preserve species that might otherwise become extinct. There is some truth in this perception, but the modern zoo is engaged in far more than the salvage of endangered animals. It is interesting, however, to remind ourselves of Noah's supposed achievement, which was to pack six members of his family and several hundreds or thousands of animals into a space of some 40,000 cubic metres, without loss of life, for about 150 days. Despite this favourable outcome, contemporary requirements for the humane and efficient treatment of animals in captivity would have resulted in widespread condemnation of his approach. Under present New South Wales legislation, Noah would have been fined up to $63,000 and/or imprisoned for up to seven years for holding animals in unacceptable conditions—and this for each specific offence.

Zoos have a long history. Traditionally they have been regarded as menageries, places where collections of animals were displayed. These collections were justified by their very existence and, inasmuch as zoos had any rationale, it appears to have been that 'bigger is better'. Their aim was to hold as many species as possible, without

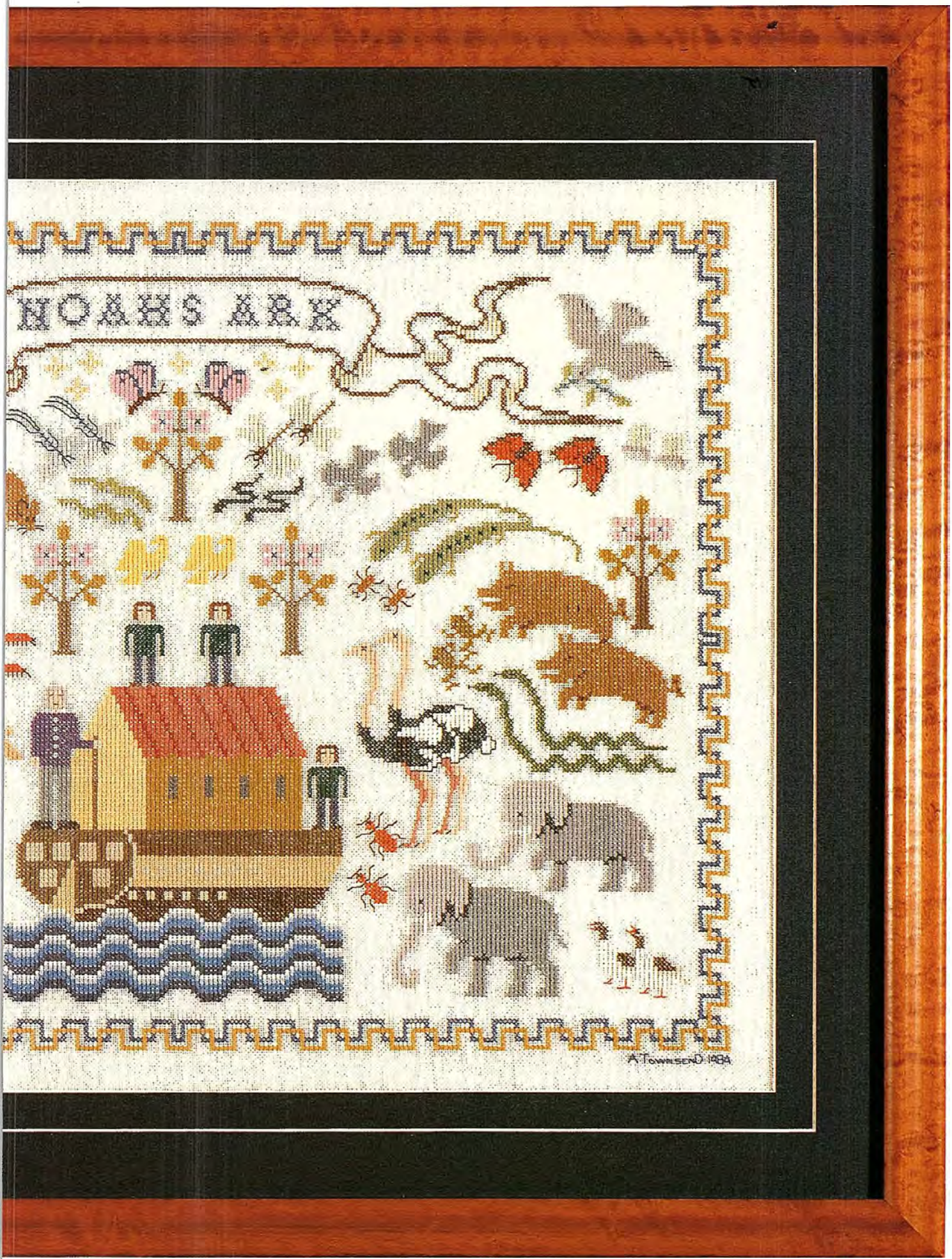


Many people regard zoos as 'genetic arks', preserving species that might otherwise become extinct. Yet modern zoos set out to do more than this. (Cross stitch courtesy A. Townsend and Stadia Handcrafts, Paddington.)

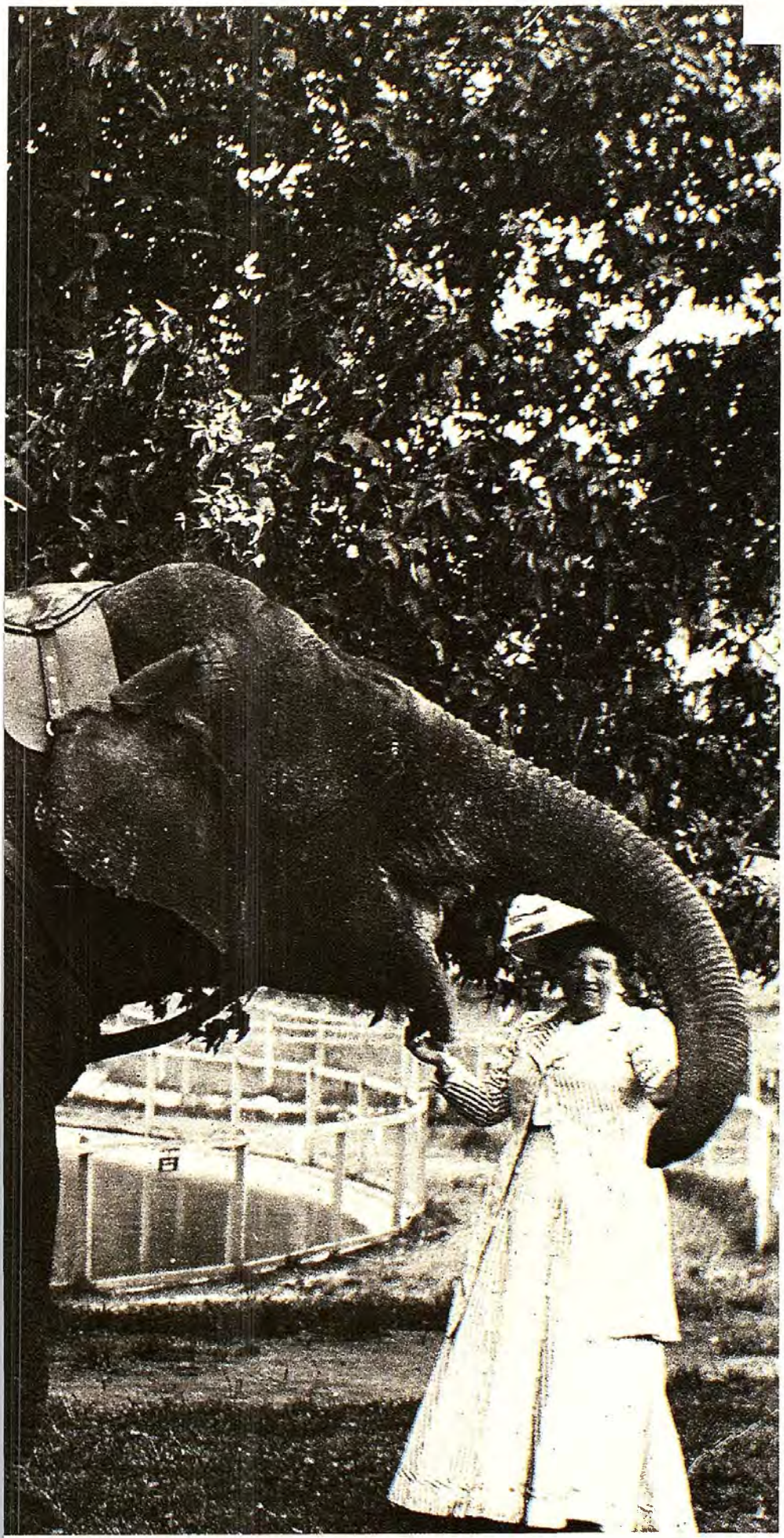
ZOOS: FROM A MODERN PERSPECTIVE

BY JOHN D. KELLY
ZOOLOGICAL PARKS BOARD OF NEW SOUTH WALES

ANTHONY FARR


NOAHS ARK
A. TOWNSEND 1984

COURTESY TARONGA ZOO



RAY JOYCE/WELDON TRANNIES

Although the external facade of Taronga Zoo has remained the same since its original construction in 1916, the philosophies and displays behind these walls have undergone major change.

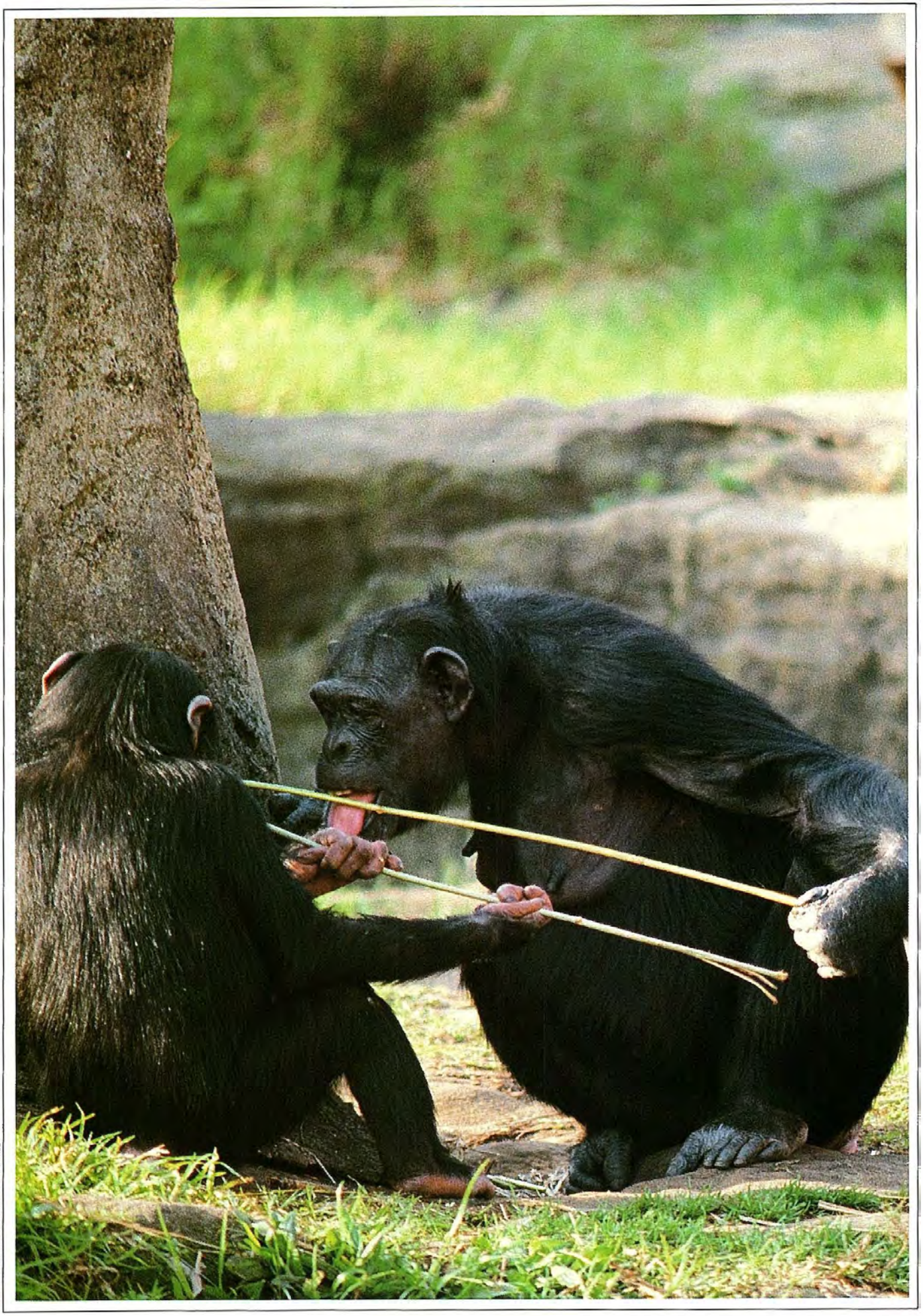
any regard to the preservation of a balanced educational experience to the visitors. In recent decades, the better zoos of the world have moved away from this 'stamp collecting' approach towards philosophies and methods of display that are designed to ensure that visitors leave with a greater understanding of the animals on our planet, their survival needs and, hopefully, with a greater concern for their future and ours.

Despite recent changes in zoos, remarkably few people have coherent, well-considered ideas of why zoos should exist. Forty or more years ago, one could justify their existence on the grounds that they provided an opportunity for an increasingly urbanised society to gain some idea of the diversity of the Animal Kingdom. Yet, as has been pointed out by Ronald Strahan, a previous Director of the Zoological Parks Board of New South Wales, the plethora of television documentaries and printed material over the past 25 years has brought most of us face-to-face with all sorts of creatures of which we were otherwise ignorant. This has led to a heightened public awareness of the need for faunal conservation and it has also spawned, or contributed to, a new interest in the rights of animals. Both of these ideas have led people, quite reasonably, to ask what justification there is for continuing to hold animals in captivity: answers to this question depend upon an understanding of the motivation and underlying philosophy of modern zoos.

THE WORD 'ZOO' IS A CONTRACTION OF 'zoological park or garden'. Zoology is not the passive display of animals but *the science of animal life*: a proper zoo is therefore an institution with the principal purpose of studying and teaching this science. It is directly comparable with a botanic garden, which is concerned with the science of plant life and is similarly based on the display of a wide range of living specimens.

In short, a zoo must display a balanced collection of representative species but these are held for a variety of purposes,

Zoos in the past were a combination of animal exhibits, circus and fairground. Famous old elephant 'Jessie' gave rides at Moore Park Zoo and its successor, Taronga Zoo, for more than 40 years.



JENNY MILLS/WELDON TRANNIES

COURTESY TARONGA ZOO

Conservation begins with education. A class at the Education Centre is a popular part of a school excursion at both Taronga and Western Plains Zoos. Orphaned animals that have been hand-raised and are unstressed by human contact are often used in these classes. Ding the Bat is an experienced teacher.

among the most important of which are: education, conservation and preservation of wildlife, and research. This is not to say that zoos should be heavy-handed centres of instruction: on the contrary, they need to get their messages across in a painless fashion to visitors who may have come to the institution for passive recreation. The task of a zoo is to make its exhibits so attractive and interesting that visitors can hardly avoid receiving its messages.

It is not often that governments are sufficiently enlightened to enshrine these ideals in legislation but the *Zoological Parks Board of New South Wales Act* of 1973 requires that the zoos operated by the Board provide services in education, conservation and research in a recreational environment. Legislation is one thing but we may ask how effectively these roles, required by the government and expected by the community, are being fulfilled by the two institutions currently operated by the Board, Taronga Zoo in Sydney and the Western Plains Zoo at Dubbo.

Over the past 20 years or so, from the time of Ronald Strahan's directorship of the two zoos, great steps have been taken in education. Both zoos operate educational services and, together, they provide face-to-face instruction in specially equipped education centres to about 150,000 school children per year. An even greater number are assisted by the provision of programs and project sheets for the use of classes who do not wish, or are unable to obtain, the services of a zoo education officer. Since the establishment of the first zoo education service by Taronga in 1968, every other publicly owned zoo in Australasia has followed suit, but the Zoological Parks Board of New South Wales continues to lead the way.

In February 1989, the Board appointed a Manager of Education Services to address the needs of the general public, of ethnic or migrant groups, and of disadvantaged and handicapped people in ways that had not hitherto been possible. Although working closely with the existing school-oriented units, the Manager will coordinate voluntary zoo educators and support groups to spread the zoo's education messages more widely.

It is self-evident that the conservation of wild animals is best conducted in their natural environments but, when the environment fails to provide sufficient support, zoos can sometimes come to their aid. In recent years, the Zoological Parks Board of New South Wales has taken very positive steps in this area. Indeed, one of the principal reasons for establishing the open-range Western Plains Zoo was to assist in the preservation of large, endangered hoofed animals. For example, the Western Plains Zoo has been so successful in the breeding of the Przewalski Horse (*Equus przewalskii*) that we are now contemplating the possibility of exporting some of these back to their original homeland in Mongolia.

A less familiar animal is Leadbeater's

Modern zoos attempt to display animals in enclosures that closely resemble their natural habitat, with plenty of space in which to display their normal behaviours. Word-famous Chimpanzee Park, roughly the area of a football field, provides Taronga's chimps with a grassy, moated habitat with shade trees, fallen logs and artificial termite mounds to keep them busy 'dipping' for malt inside the mound.

NATFOTO/ANT PHOTO LIBRARY

Western Plains Zoo, Australia's first open-range zoo, specialises in the display of animals that need plenty of space. The Zoo's herd of rare Mongolian Przewalski Horses has bred so successfully that some may one day be exported back to their homeland.

A.P. SMITH/ANT PHOTO LIBRARY

Conservation is a major objective of both Taronga and Western Plains Zoos. Along with other Australian and overseas zoos, Taronga is successfully breeding the rare Leadbeater's Possum which, until about 25 years ago, was considered to have completely disappeared.

T. & P GARDENER/NPIAW

The Malleefowl, once numerous in New South Wales, Victoria and South Australia, is fast disappearing due to predation and habitat loss. A cooperative effort between Taronga and Western Plains Zoos and New South Wales National Parks and Wildlife Service began last year to conserve this extraordinary, mound-building bird.

COURTESY TARONGA ZOO

Research is a growth area at Taronga Zoo. The sonar abilities and captive breeding requirements of the threatened Ghost Bat (*Macroderma gigas*) is one of the research team's major projects.

Possum (*Gymnobelideus leadbeateri*), from the Mountain Ash forests of Victoria. Once thought to be extinct, it is now recognised to be rare and endangered but, in recent years, Taronga Zoo has developed captive populations of such sufficient size that we can begin to consider the re-establishment of colonies in selected habitats.

A major program currently under way involves a study of the biology, including the reproductive physiology and captive propagation, of the Malleefowl (*Leipoa ocellata*). Working in conjunction with the Australian and New South Wales National Parks and Wildlife Services, the two zoos are engaged in a captive breeding program aimed at re-establishing viable communities of this mound-breeding bird in its original semi-arid, eucalypt woodland habitat.

In cooperation with the Conservation Commission of the Northern Territory, the Western Plains Zoo has embarked on a significant conservation program for the Bilby (*Macrotis lagotis*) and the Rufous Hare-wallaby (*Lagorchestes hirsutus*), both seriously endangered species from the arid inland.

Such conservation efforts are vital to the preservation of the species and also to the maintenance of the greatest possible genetic diversity. Successful breeding is not merely a matter of putting a male with a compatible female: it is essential that each mating be planned so as to reduce the effects of inbreeding. This is true also of all species kept in captivity (apes, ungulates, big cats etc.) and the Zoological Parks Board of New South Wales has led the way in development of cooperation between all of the major zoos of Australasia in joint

DEAN LEE/WELDON TRANNIES

The Giant Pandas on loan from China attracted enormous crowds to Taronga Zoo. Although recreation may have been a primary reason for visiting, people went home carrying a strong conservation message and a desire to learn more.

breeding programs in which the ownership of particular animals is regarded as a very secondary consideration. The Board will shortly establish a Foundation that has, as its major aims, the raising of public consciousness to the importance of the role of zoos in conservation and the generation of funds to support work in this area.

A professional, creditable program of research is essential if a zoo is to meet its responsibilities. To this end, the Board appointed its first Curator of Research in 1988. The Curator will coordinate all research in the two zoos, whether conducted by staff or by scientists from other institutions. Research programs already under way involve zoologists from the universities of Sydney, New South Wales, Macquarie and New England, and it is the view of the Board that such cooperation represents a very appropriate utilisation of the zoo's resources to the benefit of the community as a whole.

Matters of zoological education and research are readily understood by professionals but not so easily understood by the general public. Most people come to zoos primarily for recreation but recent visitor surveys demonstrate that their second strongest motivation is a desire to learn more about animals and their environments.

Perhaps the most striking illustration of this can be seen in the public response to a recent successful exhibit of the Giant Panda (*Ailuropoda melanoleuca*) on loan from China. The Board decided, very deliberately, that the animals would be used to focus attention on the role of animals in our environment and on the threats to animals and their ecosystems by environmentally insensitive developments. Surveys of visitors leaving Taronga Zoo after viewing the pandas revealed that 64 per cent of visitors regarded the conservation of endangered species as the principal message that they were taking home. This is very significant because the zoo had set out to convey its conservation message within an overall recreational theme. In other words, people can be simultaneously entertained and educated in a way that encourages the desire to learn more.

Despite all such achievements by the better zoos of the world, they are not far beyond the threshold of development. Much more effort must be directed to their activities in education, conservation and research, while continuing to explore more effective means of husbandry and display. In the past, zoos attempted to be self-sufficient entities but we now recognise that their justification lies in their integration into a total approach to wildlife, and human conservation. Justification for holding animals in captivity in zoos of this nature is easy to define: these animals are ambassadors for those that remain, however precariously, in the wild. ■

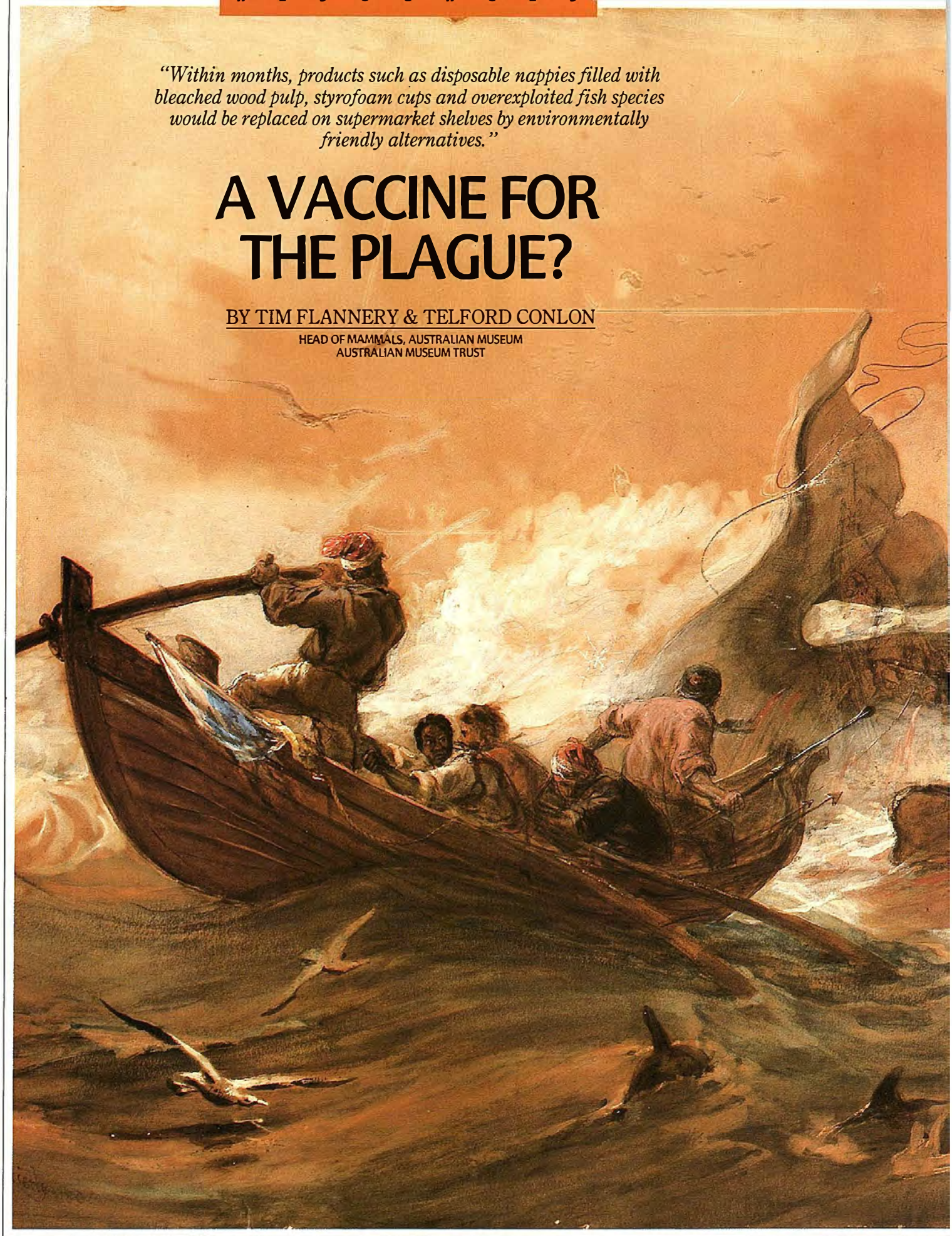
Dr John Kelly is the Director and Chief Executive of the Zoological Parks Board of New South Wales, which manages both Taronga Zoo in Sydney and the Western Plains Zoo in Dubbo.

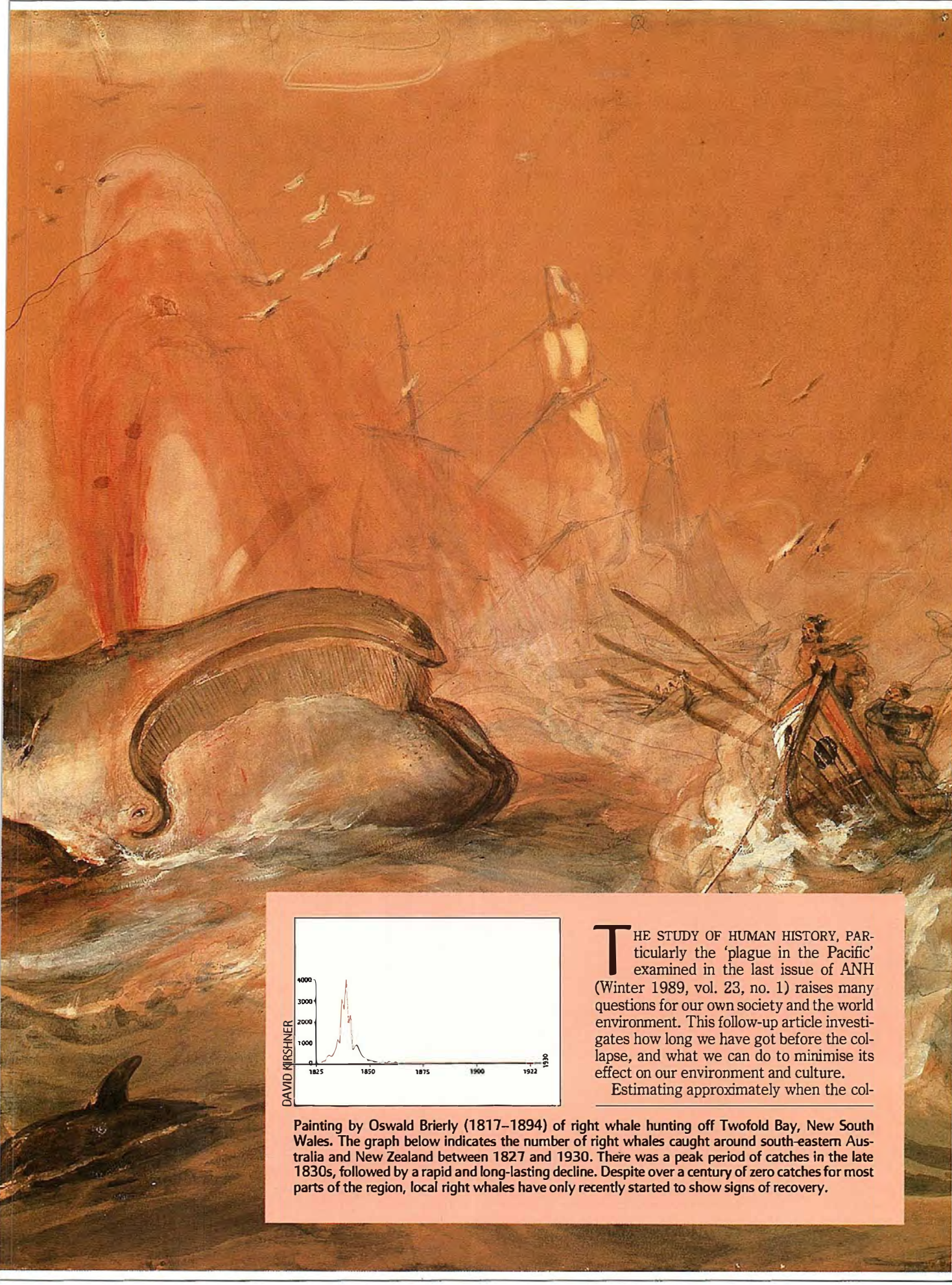
"Within months, products such as disposable nappies filled with bleached wood pulp, styrofoam cups and overexploited fish species would be replaced on supermarket shelves by environmentally friendly alternatives."

A VACCINE FOR THE PLAGUE?

BY TIM FLANNERY & TELFORD CONLON

HEAD OF MAMMALS, AUSTRALIAN MUSEUM
AUSTRALIAN MUSEUM TRUST





DAVID KIRSHNER

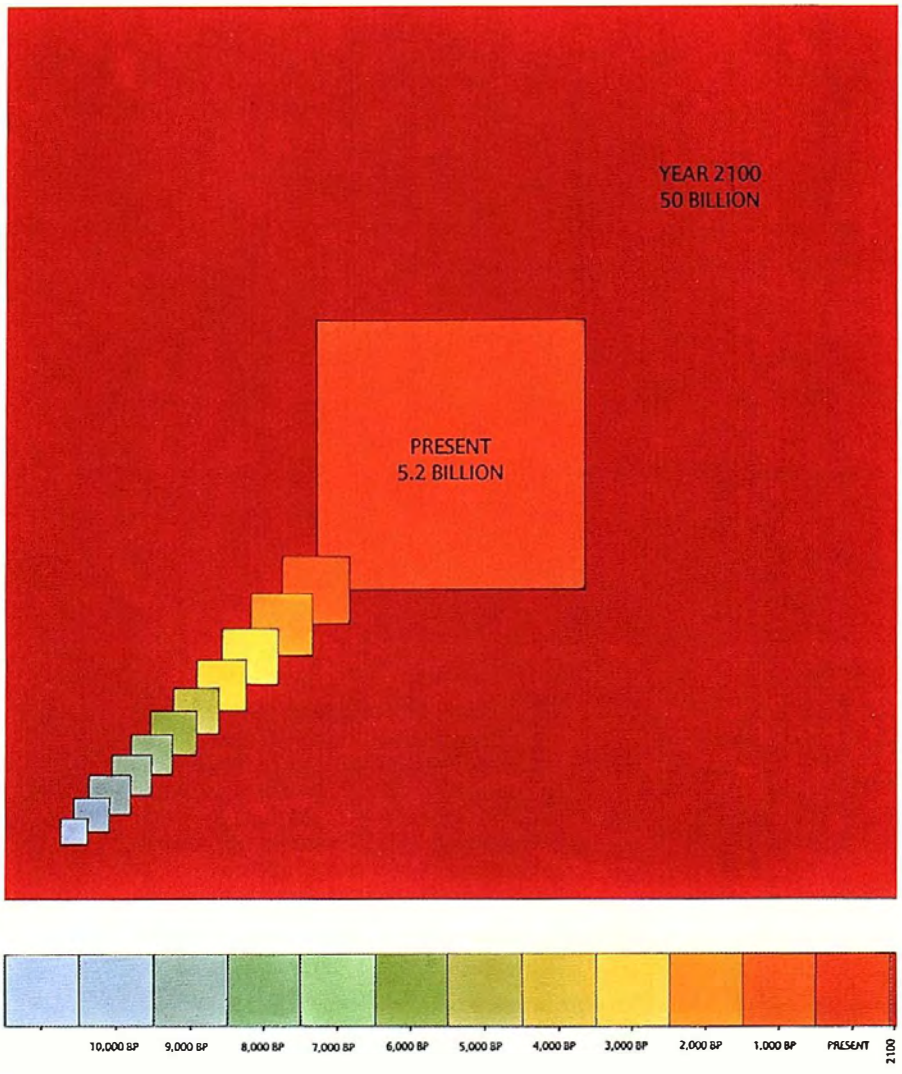
Painting by Oswald Brierly (1817–1894) of right whale hunting off Twofold Bay, New South Wales. The graph below indicates the number of right whales caught around south-eastern Australia and New Zealand between 1827 and 1930. There was a peak period of catches in the late 1830s, followed by a rapid and long-lasting decline. Despite over a century of zero catches for most parts of the region, local right whales have only recently started to show signs of recovery.

THE STUDY OF HUMAN HISTORY, PARticularly the 'plague in the Pacific' examined in the last issue of ANH (Winter 1989, vol. 23, no. 1) raises many questions for our own society and the world environment. This follow-up article investigates how long we have got before the collapse, and what we can do to minimise its effect on our environment and culture.

Estimating approximately when the col-

lapse will come, if present trends continue, is not difficult. Whether on a small island (such as Easter Island) or an entire planet, there are limits to the sustainable production of food, energy and shelter. When human population growth and resource use exceeds sustainability, overexploitation, which involves destruction of the resource base, begins. Because of the nature of exponential growth (as typified by the current human population growth pattern), plague species, once they begin to overexploit, are unable to avoid a drastic decline. As the history of the Pacific shows, when humans are involved this process inflicts irreversible damage on the environment. What then, given our current and forseeable technology, are the limits of sustainable production? And where, presently, do we stand in relation to those limits?

UNDERLYING THIS ENTIRE QUESTION IS human population growth. There are currently 5.2 billion people on planet Earth. This situation is of course unique in human history and, for a single species of our body size, such numbers have almost certainly never been attained in the entire history of the planet. Even more significantly, our population is growing more rapidly than ever before. If the current trend continues, the Earth will hold over 50 billion people by the year 2100. But then the planet could never sustain 50 billion people at our current level of resource use. Resource use differs between the Earth's richest and poorest nations by just under two orders of magnitude (Australians lie near the top, using about 60 times the resources of an average person from the poorest nations). Even if the Earth could sustain all of us at half the resource use of the wealthiest nations such as America (this would entail a massive rise in the standard of living for the majority of people on Earth), population growth alone would mean that by 2100 people would have to exist on just a tenth of their 1989 resource budget. Of course these figures are totally unrealistic. Wealth is not evenly distributed, and there is good evidence that the Earth simply could not sustain the present population at half the American standard of living. A crash is clearly inevitable sometime between now and 2100. Examination of resource use allows us to be somewhat more precise.



World human population growth. In this diagram, the area of the boxes represents the number of people at various times. The small blue box represents the number of people on Earth 2.5 million years ago, the next box at 8,000 years BC (10,000 BP), then at 1,000-year increments to the present (large orange box at centre). The red background represents the number of people expected in the year 2100 if the present exponential growth pattern continues. To presume our resources at our current rate of usage will sustain us in the year 2100 is unrealistic.

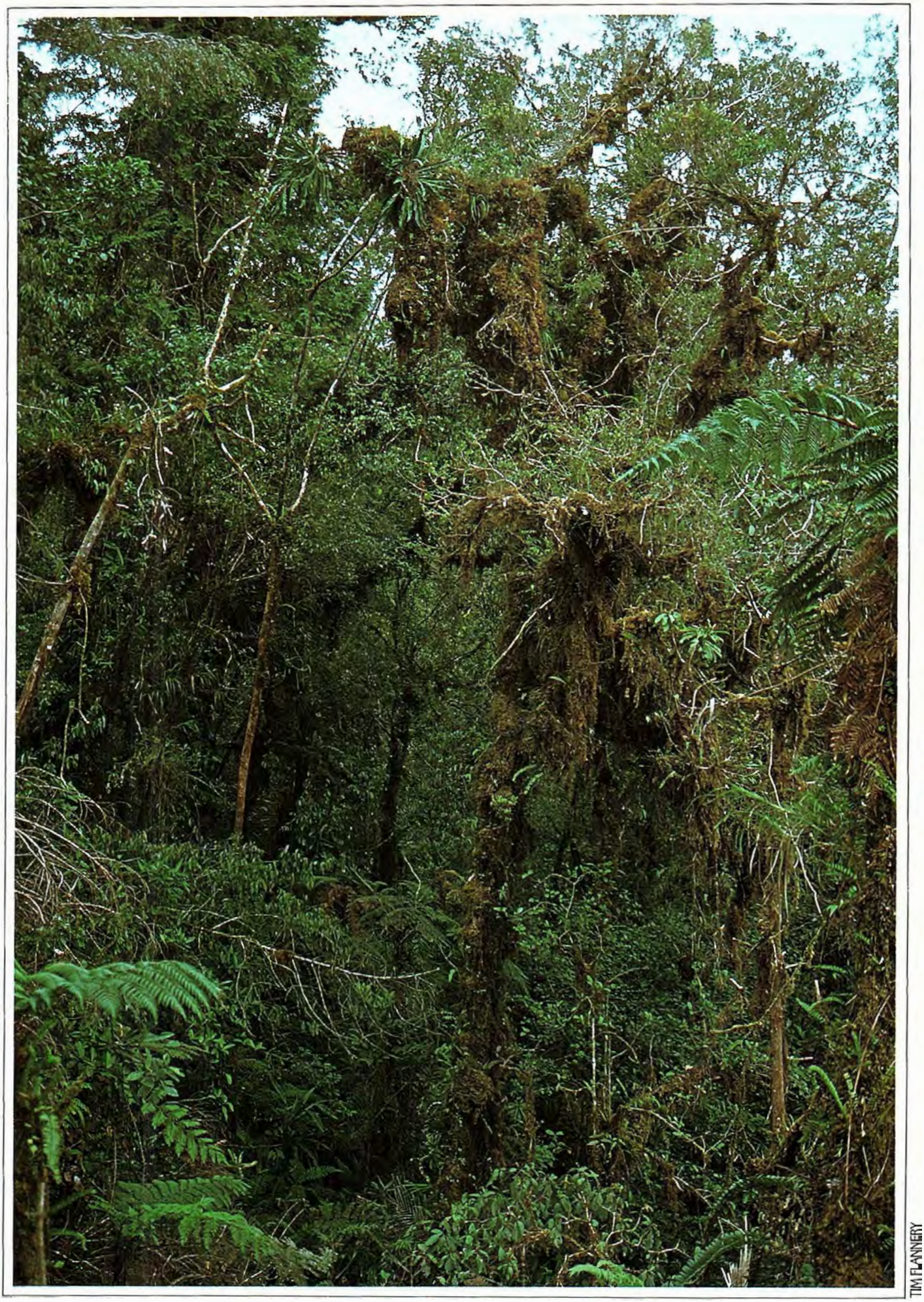
Rates of energy consumption and the sources of energy are very different in the developed nations and the third world. Third-world countries are largely dependent upon fuelwood for their energy needs. In Africa, for example, 63 per cent of total energy consumption comes from fuelwood. But unfortunately these reserves are grossly overexploited. Currently two billion people depend on fuelwood and other traditional energy sources for their daily needs. Of these, 100 million cannot obtain enough wood, while a further one billion only meet their minimum needs by overexploiting existing resources.

The developed nations rely upon the two major energy resources of fossil fuel and nuclear power and, despite years of earnest endeavour and massive research programs, viable replacements for these sources have not been developed. Although it has long been accepted that fossil fuels are non-renewable, and thus at best a 'stop gap' measure for our species, it is only recently that the implications of their use at current rates are becoming clear. Coal-fired power stations have been clearly shown to be a major cause of acid rain and the enhanced greenhouse effect. Indeed, if current predictions are accurate, the greenhouse effect alone will annihilate a large percentage of world biotic diversity. Species limited to 'islands' of habitat, whether they be nature reserves or naturally limited communities, will be hard hit as climate changes. Entire unique animal and plant communities on the world's mountain tops will simply vanish with the two to five degrees increase in temperature predicted over the next 50 years. Cold-adapted plants and animals of the mountains will simply be pushed out by warm-adapted species. For the islands of tropical Melanesia, as much as two to ten per cent of all mountain species may disappear. And the tropics is an area where the greenhouse effect is expected to have a relatively minor impact! This is doubly tragic, for New Guinea's cold mountains have acted as a refuge for many plants and animals of old Gondwana. The New Guinea lowlands support a more recently established flora and fauna, much of which is Asian in origin, which will replace the ancient, cold-adapted forms.

Although coal-fired power stations are only one of many factors responsible for the greenhouse effect, it is important that their use be scaled down. Could nuclear energy be an alternative? Given current practices it too is a non-renewable resource. Even at current rates of consumption there are only enough recoverable uranium reserves to last between 37 and 70 years; and this is providing we are willing to live with the oc-

New Guinea's high mountain forest. Will it disappear due to the greenhouse effect?

DAVID KIRSHNER



TIM FLANNERY

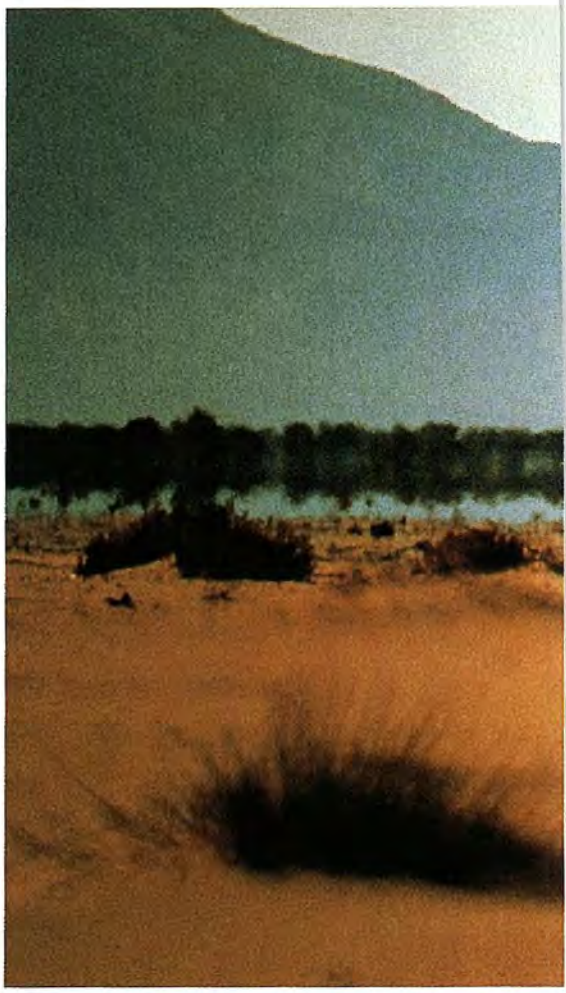
casional disaster, the accumulation of radioactive wastes, and the resultant environmental damage. If we decide to replace coal power with nuclear power to slow down the greenhouse effect, then uranium would be used up much more quickly, as one tonne of uranium in a light water reactor produces the equivalent energy of only 8,830 tonnes of oil (approximately 30,000 tonnes of coal). It is possible to get better results from fast breeder reactors. However, there is only a single fast breeder reactor (France's Super Phoenix) in commercial use at present. This is because they produce more plutonium than is actually consumed, and many fear this would lead to an unbridled proliferation of nuclear weapons, especially in our increasingly economically and politically unstable world. Thus it seems that energy use by the developed world is *already* unsustainable and, barring an extremely rapid development of an alternative like solar power or fusion, this situation is likely to remain unchanged in the next decade or two.

And what of food production? Although this is somewhat more difficult to assess, there are indications that we have already exceeded sustainability. In Australia for instance, fisheries over the past 200 years seem to have been little more than exercises in mining. Even those fisheries that were overexploited and destroyed in the early days of European colonisation have never recovered. Elephant Seals (*Mirounga leonina*) were exterminated on King Island very early in the 19th century and have never returned. Southern Right Whales (*Balaena glacialis*) are among the best understood of the species that were overexploited before 1850. The industry resulted in the killing of only about 26,000, mostly in a single decade. Yet these seemingly trivial activities irretrievably crippled the species and the industry. It is now about 150 years since Southern Right Whales have been exploited in any numbers in Australasia, yet they remain one of the world's rarest mammals. Only in this decade have they begun to show slight signs of recovery. In recent times many other fisheries have followed suit. Prawns in northern Australia, Southern Bluefin Tuna (*Thunnus maccoyii*), and flathead (*Platycephalus* spp.) are just a few species that today only sustain a fraction of the catch of previous years. If the right whales are any guide, it may be a long time before any sign of recovery is seen, if indeed they do recover at all. Presently it is the smaller species (such as Skipjack Tuna, *Katsuwonus pelamis*) and those previously unreachable because they live in deeper waters (such as Orange Roughie, *Hoplostethus atlanticus*), that are being mined.

Our agriculture is doing no better. Dryland farming to produce wheat and wool is leading to rapid loss of irreplaceable soils, while irrigation brings salination and further loss of productivity. That such practices lead to an irreversible loss in productivity can be seen by examining areas in other parts of the world that in earlier millennia supported agriculture. It is no accident that deserts now stand in areas such as north Africa where Rome once grew its wheat. Two thousand years ago this area was the bread basket of civilised Europe, but overexploitation destroyed the soil and 2,000 years later the area is still largely unuseable. Thus in a very real way we are all still paying for the building of the Roman

Spanner Crabs have only recently been exploited. How long will this resource last?

Dry-land farming to produce wheat leads to rapid loss of irreplaceable soils. All that remains of areas in northern Africa, which 2,000 years ago supplied bread to civilised Europe, is desert.



Empire, just as future generations will long be paying for the European colonisation of Australia.

We greatly fear that with only 5.2 billion people on Earth we have already passed the point of sustainability and are currently surviving only by destroying the world's resources. If this is true, the crash must be very close indeed. Our guess is that we are already experiencing the beginning of it. Chronic starvation in parts of the third world, massive flooding, loss of primary productivity and increasing desertification are the first signs. The present trickle will turn into a cascade sometime early next century. How the cascade will manifest itself, and what we can do to modify it, are questions that should be pre-occupying the minds of all the world's decision-makers.

How are we presently coping with the crisis? Of course, many development-oriented people are not even aware of it! But, of those who are aware, how do things lie? Unfortunately even major environmental groups espouse some policies of little long-term use, and others that are downright destructive. Perhaps the worst policy espoused by many 'conservation' groups is opposition to any kangaroo harvesting. Federal and State government authorities have over the years evolved a kangaroo management program that stands as a model achievement for the sustainable utilisation of resources, even though damage mitigation, and not resource utilisation, is its primary goal. It includes regulation of the harvest, a monitoring process, and assessment and feedback procedures that are the essence of any good management program. Because of its development, the kangaroo industry appears to be the only significant sustainable primary industry in the Australian arid zone. With some modification, the program could be applied to all of our uses of non-agricultural food resources. Indeed, it is vital that resources such as our fisheries are managed in such a manner. The point needs to be made that these harvests are the least environmentally destructive means of producing food in the greater part of Australia. We should be looking at ways to extend and improve these excellent management tools. There is no doubt that, if we have a future, then such programs will be a vital part of it.

Policies that are of no long-term benefit also abound. A good example of these is the proposed locking-up of the tropical rainforests of northern Queensland. There are two major flaws with such a strategy.

Australia is the only developed nation with substantial areas of rainforest. Properly managed, they would be capable of producing vast, sustainable resources for the world.

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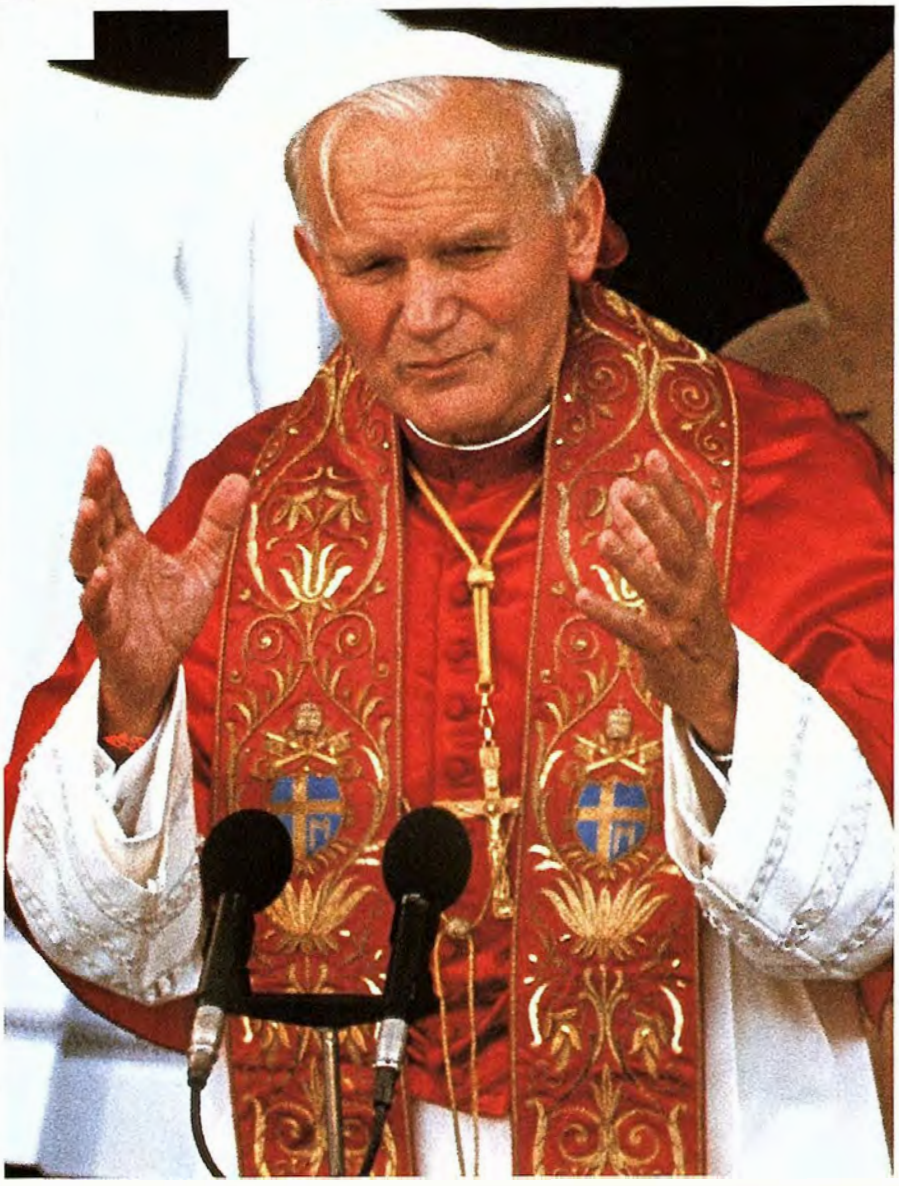

The future of our planet lies in the hands of Pope John Paul II. Were he to decree that birth control was acceptable and smaller families desirable, human population growth, especially in underdeveloped countries, would be drastically reduced.

IS OUR ECONOMY SUFFICIENT?

The words economy and ecology share the same Greek root, meaning household. Economy was first used in its modern sense—that of a system of production and distribution of wealth—in 1767. Ecology, meaning the relation between organisms and their environment, was coined over a century later in 1873. However, it is only now, a further century on, that we are realising the interdependence of these concepts. We can no longer take for granted the ecological basis of an economy.

A conventional notion of our time is that the price mechanism is the means of signalling the scarcity of resources. A rising price means use less and find a substitute. This assumes a stable ecosystem. We now know that the price mechanism is inadequate as a regulator. Other criteria have to be used to indicate that the environment is being damaged. The atmospheric ozone layer, for example, was not priced into the market for chlorofluorocarbons. The problem had to be dealt with by political action (the world agreement on scaling down on use of chlorofluorocarbons). What price signal does soil erosion give to the wheat market? None. What will be substituted for expensive bread? There will be no substitute, as the very soil will be destroyed.

A further assumption of the market economy is that society remains stable and well-enough organised for price signals to be transmitted. However, it is difficult to imagine an orderly distribution of timber (or anything else for that matter) on Easter Island when the last stands of forest were about to be exploited. When the ecosystem on Easter Island collapsed, so too did the island's economic and political system.

We are not saying that Australian society is about to collapse because of environmental stress. What we are saying is that a market economy is based on stable central authority and on an ecosystem taken for granted. When that ecosystem comes into command, as will inevitably happen if we don't slow our growth, the market and political system will come under intense pressure. And what will happen then? Will the central authority transform into a police State, or will there be fragmentation to warlordism? Who knows?

Firstly, the nature of exponential human population growth ensures that there will be a dying need to utilise such resources early next century. Are we simply locking away these resources so that they can be pillaged by our resource-starved children? This will certainly happen unless action is taken. Secondly, proper rainforest management has so much to offer the world. Rainforest is in many cases the only major renewable resource available to developing nations. Yet they are presently destroying this one hope for their future. We continue to import their rainforest timbers, yet offer nothing to help them manage their resource. Would it not be better if we were to develop a program for sustainable rainforest utilisation here in Australia, and export this technology to the developing world, where it is truly desperately needed? Australia is in a unique position to do this, for we are the only developed nation with substantial rainforest resources. A vast, well-funded forestry and environmental studies institute, situated in Australia's wet tropics and attended by foresters from throughout Oceania and Asia, would do far more to avert the looming biological crisis than any wilderness area. Although it is commonly believed that rainforests are delicate systems that cannot endure interference, nothing could be farther from the truth. Because of their complexity they are exceptionally robust. Properly managed, they are capable of producing, in a sustainable manner, vast resources for the world. (Certainly this is the case for the rainforests in Melanesia.) Indeed, their use may be preferable to that of eucalypt forest because of the great length of time needed for tree-hollow development, necessary for many birds and animals, in eucalypts.

IT'S ALL VERY WELL TO STATE THE PROBlems, but of little use if constructive solutions are not proposed. We therefore suggest two possible solutions that, at the least, will buy us time. These involve arresting human population growth and giving consumers the choice of buying environmentally sound products.

Human population growth must be slowed and ultimately reversed at all costs. In a very real sense the future of our planet lies in the hands of Pope John Paul II and a handful of others. Were the Pope to decree that two- or even one-child families were desirable and moral, and that 'artificial' birth control was allowable, an immediate impact would doubtless be felt, especially in South and Central America. It might even be enough to buy us a few years in which to deal with the crisis. The Catholic hierarchy has thus far resiled from such a proclamation, believing that the Earth can support 40 billion people. Even if this were true (and we have not yet seen their proof),

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If food and other items were labelled according to their environmental cost of production, people would be more inclined to buy 'friendly' alternatives, reducing the demand and therefore the production of less environmentally cost-efficient items.

at current rates that number will be achieved next century. What will the church advocate then? Surely Australian Catholics can voice their opinion on this matter.

Human population growth is not only a third-world problem. Because of our greater resource utilisation, each additional Australian, for example, puts approximately 60 times more stress on the world ecosystem (in terms of energy use) as does an individual from the poorest nations. Australia's population growth of one million over the past five years, if largely from births and third-world immigration, equates to adding 60 million people from the world's poorest nations to the planet. It is clear that we must stop growing. This is a relatively easy matter for us: by simply stopping immigration we would fall to a level of zero population growth. The decision to stop immigration is an inevitable one. We must take it now if we hope to mitigate the coming disaster. After all, if we cannot achieve a zero population growth, then what right have we to preach to the third world?

We must reveal the true (that is, environmental) cost of the products we use. Overexploitation of resources is literally killing our civilisation, yet it can be slowed. Again, such a move would at least buy us a little time. If the true cost of an item was reflected by its price, then the matter would be largely solved. For example, if bread or hamburger meat were to be taxed so that soil erosion or lost rainforest productivity could be compensated for, their price would be astronomical. Of course it would be an impossible job to get politicians to impose such taxes. But there is another way. All of the items that we use *could* be labelled according to their true (environmental) cost. For instance, products made at a real cost that far exceeds their monetary value could be labelled with a red sticker. These products would include, for example, all items made from wheat, and such extravagances as disposable nappies filled with bleached wood pulp, and any others that result in overexploitation. Products whose production involves no environmenal cost, such as the leather and meat from kangaroos and probably potatoes, could merit a green sticker. Such a scheme would serve two purposes. Firstly, it would cause an immediate decline in the use of non-sustainable production methods, for fewer people, we suspect, would buy items with red stickers when environmentally cost-efficient 'green' alternatives were available. Secondly, this would result in a great inducement for industry to produce more environmentally sound products. It is certain that, within months of the introduction of such a scheme, products such as bleached disposable nappies, styrofoam cups and overexploited fish species would be replaced on supermarket shelves by environmentally friendly alternatives. Governments might take soil erosion more seriously, and great improvements in our use of the semi-arid zone would follow. Some such scheme is imperative. We think that this one, if wisely administered, would go a long way towards securing a future for our children on this planet. ■

Dr Tim Flannery is a research scientist with the Australian Museum. He has spent the last eight years researching rainforests, their mammals, conservation and human use in Melanesia. Dr Telford Conlon trained as a biophysicist and is now a trustee of the Australian Museum.

This middle age-grade *tumbwan* was acquired in Murik from a trading partner as a departure gift, perhaps sometime in the 19th century.

DAVID LIPSET

"We wanted to know what had been traded and why, in particular, this sort of exchange continued to go on in this day of boom boxes, videos and newspapers."

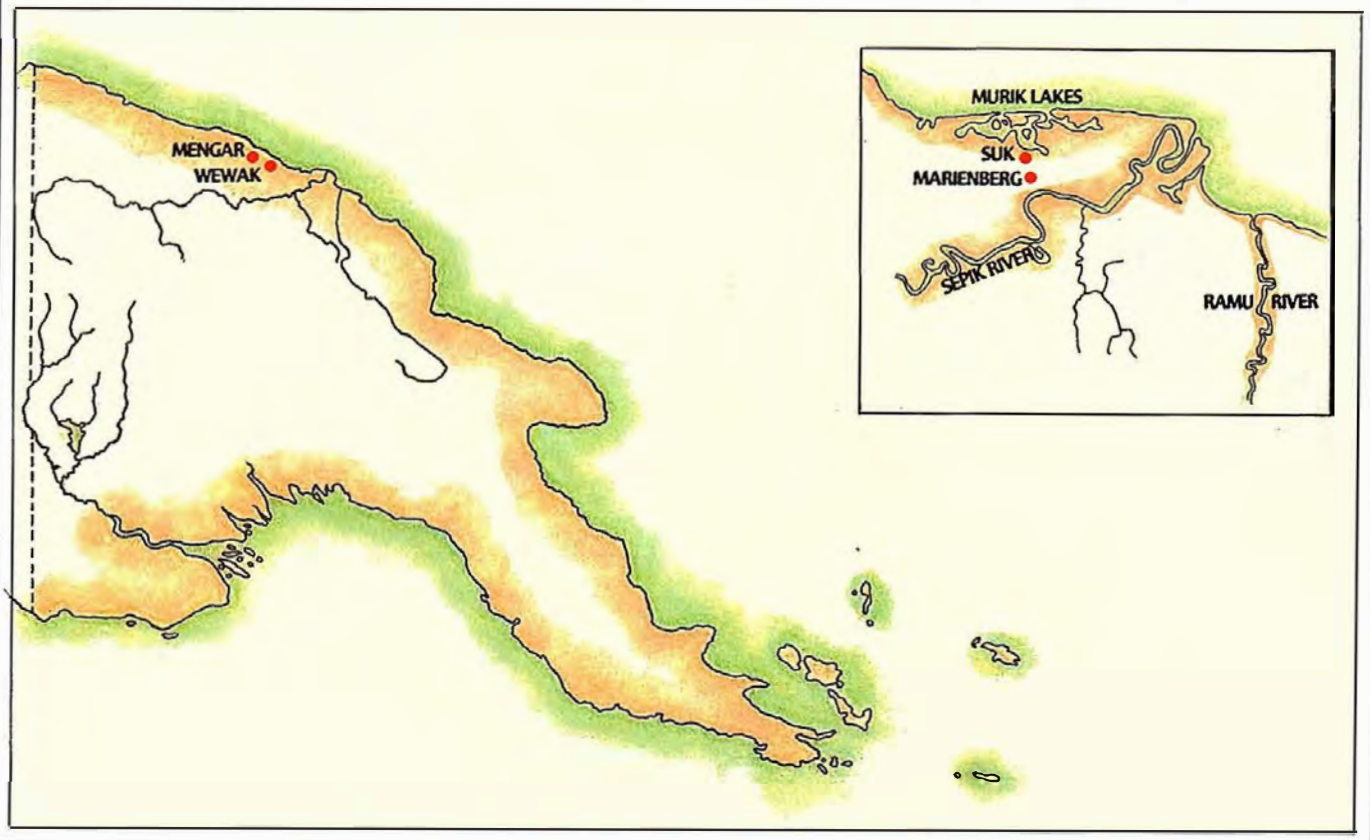
THE VALUE OF CULTURE

BY DAVID LIPSET & KATHLEEN BARLOW
UNIVERSITY OF MINNESOTA, MINNEAPOLIS, USA

BY THE LIGHT OF SEVERAL kerosene pump lamps, a pirouetting pair of tall leaf-covered figures pranced on the beach from dusk till dawn. The stage was demarcated by a throng of onlookers who served as the chorus for the dancers, singing and beating hand drums. In their midst were two senior men, seated in chairs as guests of honour. When the food arrived (two meals were prepared in the course of the night) it was they who were served first. We understood that these elders were from Mengar village, the traditional landowners of the little stretch of beachfront property, rights to which, it turned out, were at stake that night. The performers, their hosts, were Murik Lakes people who live in a landless environment along the mangrove lagoons at the mouth of the Sepik River in Papua New Guinea. They endeavour to resolve their subsistence deficits by relentless trade of their principle resources: fish, plaited baskets and other cultural property of the sort we saw displayed that night. This was the puzzle in the scene: the Murik were 'buying' landrights by 'selling' a dance to the Mengar. The dance, called a *singsing* in Melanesian Pidgin and a *teran* in Murik, was not merely a performance but a land purchase and a 'copyright' sale. In exchange for literally giving the performance, the dance paraphernalia and the feast to the Mengar elders, came rights to the

Kathleen Barlow, with her son Michael and Bujon of Darapap Village, in one of the temporary mangrove settlements where people go to collect fish, clams and firewood.

LISSANT BOLTON



CATHY McGAHEY

beachfront land on which urban Murik were squatting. Some of the Murik people were employed in Wewak town, looking after children enrolled in school, or receiving long-term hospital treatment. They wanted to formalise a relationship with their landlords, who were also hereditary trading partners, so that they would be allowed to exploit the small mangrove lagoon behind the beach.

The dance they were 'giving' that night—that is, handing over the costumes of the dance figures, teaching the step and the songs— was not being yielded once and for all. The Murik were retaining their 'copyright'. They would be free to perform it among themselves again or trade it elsewhere. They were simply granting dance rights to the trading partners, who would then be free to trade the dance elsewhere if they wished, providing they were able to assemble the costumes, called *tumbwans* in Pidgin and *Kumbun* in Murik. Dance rights, land and fishing rights were exchanged between the Mengar and the Murik on this evening in 1982.

We had known about this sort of exchange in the Sepik region through the ground-breaking work of Margaret Mead in 1938. She called it the "deliberate diffusion of nonmaterial traits" and we had understood that, in her time in the region, the Murik were the principle coastal impresarios, trading dance, sculpture and baskets, together with their smoked fish, at great distances, criss-crossing linguistic and political boundaries in their out-rigger canoes. In the 1930s, Mead had noted that "the price" of purchasing a dance from the Murik was "pigs, feathers, [shell] rings and tobacco" and that the Murik controlled what was a sort of seller's market. "If the price is insufficient", she wrote, "then a segment of the dance is withheld—an ornament or a piece of dance paraphernalia. The [buyers of the dance]. . .are apologetic to the Murik in this case. . .They say that the selling village is granting a tremendous favor to the buying village. . .The most extreme response to such a situation is one of bereavement and hurt" (1938: 333). Nonetheless, until we saw this exchange in 1982, we did not appreciate the full force of Mead's data. We had expected that 50 years of Western economic encapsulation would have curtailed, if not extinguished, such exchanges. We did not expect to find the valuation of Murik *singsings* in the contemporary context.

A second example of the on-going exchange of cultural property also took place during 1982. A man from a coastal village to the east of the Sepik River, who had been visiting his Murik trading partners for several months, suddenly became ill and died as he was preparing to return home. Now in Papua New Guinea, this sort of unexpected death is always understood to be the result of personal conflict. Some sorcerer is always held responsible. The news was brought back to the dead man's home village by a pair of men who were distantly related to him by the marriage of a mutual ancestor. The Murik feared the worst, dreading reputed vengeance by crocodile sorcery of the dead man's kin (see ANH vol. 22, no. 11, 1988, p. 490). Instead of a supernatural attack, a letter came back demanding compensation. The two Murik trading partners of the deceased had each to send a *suun kubiisan*—a large plaited basket filled with about 40 smaller baskets—as blood payment. The women with whom we talked thought that the demand was fair but they pitied the women in the two families who would have to do the work of plaiting the many baskets.

IN 1986 AND 1988, WE RETURNED TO THE Lower Sepik to do survey fieldwork on regional exchange from the perspectives of Murik trading partners. Visiting selected villages we focused on mythology, ethnohistory, production and exchange of subsistence goods and the changes in the system. But we kept our eyes open for more of this sort of exchange, the sort of exchange that involved what we call cultural or symbolic property. We wanted to know, in short, what had been traded and why—from both buyers' and sellers' points of view; and why, in particular, this sort of exchange continued to go on in this day of boom boxes, videos and newspapers.

In the course of visiting 20 villages in the Lower Sepik and North Coast region, we found many more instances of this sort of exchange. In general, they involved two different types of cultural property: the first comprises sacred objects, which are

Men at Darapap Village moving a motorised outrigger canoe in anticipation of a high tide. These canoes are the main means of transport for the Murik Lakes people.

An outrigger canoe from Karau Village, returning from Wewak, the capital of the East Sepik Province. People from the Murik Lakes must travel great distances to obtain goods for trade.

LISSANT BOLTON

imbued with power, authority and sometimes a spirit, and are owned by sublocal groups; while the second is personal knowledge owned by individuals.

In three instances, named insignia—configurations of shell and teeth ornaments, called *suman* in the Murik vernacular—were exchanged. In four cases, carved slit drums (*garamuts* in Pidgin) were exchanged. These usually are believed to have a spirit residing in them that 'cries' when the drum is beaten. Ten of the sacred objects exchanged were *tumbwans* of the sort we had seen perform that night in Wewak—costumes representing masked spirit figures that appear on special, usually ritual, occasions.

In two further instances, a gift or presen-

In Darapap, a pair of junior age-grade *tumbwans* (masked figures) chase and threaten each other in a piece of light-hearted village theatre.

ISSANT BOLTON

ISSANT BOLTON

A woman from Masan Village in the Marienberg Hills making a body decoration for use in a *singsing*.

LISSANT BOLTON

tation of food and/or shell valuables was made to a trading partner in order to obtain a name for a grandchild. Names in this part of Melanesia are thought to have power over the development of the bearer's personality and presence. The recipient is believed to resemble the namesake. In one of these two cases, the name was explicitly given by Murik in order to consolidate a relationship with a trading partner who owned excellent timber, which the Murik wished to use in the construction of new outrigger canoe hulls, the main vehicle of trade.

The most frequent transaction of sacred property is one in which rights to *singsings* are exchanged. These are indigenous 'operas', named complexes of songs, dance steps, masked *tumbwans*, dance costumes of shell and teeth ornaments, and percussion instruments. Subtexts of magical spells that empower the dancers and make them attractive to women are usually associated with them. The *tumbwans*, in addition, represent spirit beings, in the stories that are sung. We counted 21 instances of *singsings* being traded, most of them in the past few years. These included nine different *singsings*; one of them, called Aimaru, was traded five different times between groups. We recorded an instance in which a *singsing*, called Simoki, was performed by the Murik in exchange for 156 pigs, 200–300 sheaths of tobacco and a large feast. On another occasion, however, the same *singsing* was performed in exchange for only 14 pigs, six cartons of beer, one carton of tinned fish, Nassa shells, four boars' tusks and K226.40 (K1 = $A1.25).

The second type of cultural property is personal knowledge. Magic for making love and war is given, sometimes embodied in talismans of clay, or wood to be nibbled when one is ready to cast the spell. Trade partners also recount receiving skills as gifts, including techniques of cooking, fighting, methods for growing tobacco and artistic motifs. On some occasions when an object such as a drum, skirt or basket is traded, the right to make and give the design appearing on it goes with it. For example, a design for the front of a canoe was presented to a trade partner in appreciation of his attending a male initiation ceremony; a name and design of a men's cult house was presented by a host to his guests at their departure so that they could go live in a new location under his sponsorship; and grass skirt designs, which had been brought by a man who had married into a Murik village, were presented to his daughters on the occasion of their initiation. Once given, these designs may be inherited from

SEPIK DOCUMENTATION PROJECT

Museum collections of artefacts from Papua New Guinea present their curators with something of a challenge. The artefacts are often very important, both to the societies that made them and as sources of information about how those societies operated. However, the information they represent is often locked up inside them. The traders, planters, missionaries and government officials who collected them frequently failed to find out about them. Sometimes they failed because they didn't have the necessary language skills. Sometimes they didn't understand the sort of questions they could ask about the objects. And sometimes they simply weren't interested in knowing.

Objects play a critical role in our lives. They not only act as a buffer between us and the environment (as umbrellas do), enabling us to manipulate it to protect and feed ourselves. We also use them to make statements about ourselves (as the owners of Rolls Royces do), and to express feelings (as a gift of flowers does). In other words, we convey a whole range of meanings to each other through objects. People do this all over the world, although the objects they use and the meanings they convey change from culture to culture. The processes by which this happens are not well understood, and the study of museum collections in the context of cultures that produced them is one way to understand this more clearly.

The Sepik Documentation Project was designed to find out more about the individual objects in our collections of artefacts from the Lower Sepik. It was also designed to study the kinds of meanings people in the region comprehend in their objects, particularly as they transfer them about the region in trade.

The Lower Sepik is the region at the mouth of the Sepik River on the northwest coast of Papua New Guinea. It is a world of water, a network of lakes, canals and, of course, the river itself. Several groups of people, each speaking a separate language and inhabiting a number of villages, live in the region. People travel about from place to place by canoe (powered, by preference, with an outboard motor), and there is a longstanding and important trade between them in foodstuffs, in objects and in non-material things like songs and dances.

To undertake this project the Australian Museum employed Drs David Lipset and Kathleen Barlow to work in co-operation with myself. Lipset and Barlow were chosen for the job because they had already undertaken extensive anthropological fieldwork in the Lower Sepik and they spoke the language of the main group of traders, the Murik.

The field research was undertaken in two three-month seasons, in 1986 and in 1988. Funds for the second trip were given to Lipset by the McKnight Foundation and administered by the Graduate School of the University of Minnesota. We visited over 20 villages in the region, carrying with us folders of photographs of objects in the Australian Museum collections. Because there are so many distinct groups in the region, and because each group makes and decorates its objects in distinctive ways, it was possible to learn from people exactly where an object came from. We could then find out more about it. We asked not only how it was made, but also how it was used, what the designs and decorations meant, whether such objects would have been traded and, if so, to whom.

In some cases the particular object type was no longer made and people didn't remember much about it. Every now and then, however, a whole world of information opened up about an object for which we previously knew nothing. As well as learning specific things about the objects in our collections, we also learned more generally about the role of different objects in the societies we encountered—what things were important, what made them important, and how objects are woven into the fabric of people's lives.

This article discusses one part of the results of this research. Describing the regional trade in non-material things (like songs and dances), it illuminates a different approach to the ways in which objects and performances can be equated and valued.

KATHLEEN BARLOW

Lissant Bolton collecting information about objects in the Australian Museum collections in Mendam Village, Murik Lakes, July 1989.

—Lissant Bolton
Anthropology
Australian Museum

parent to child, given away or sold by their new owner.

WHEN DO ALL THESE EXCHANGES TAKE place? The most frequent contexts during which the exchange of cultural property occurs are associated with ritual. Attendance at initiation ceremonies was rewarded with such gifts as a canoe name, women's skirt designs or a *singsing* itself. But by far the most frequent context for this sort of exchange today is at end-of-mourning rites, of which we heard about 12 instances. In the Lower Sepik, mourning for close kin by spouses and siblings is observed by highly restricted participation in the social life of the community. The period of seclusion, which is variable in length from several months to several years, is concluded with a party, when mourners are ritually bathed, shaved, given haircuts and new clothes, and fed bounteously. It was most often in the context of the end-of-mourning party that we found the dances exchanged. Senior members of the mourning family, both male and female, sponsor such events. The larger the number of guests invited and the greater the spectacle staged, the more renown accrues to the sponsors.

In July 1988, we followed the preparations for an end-of-mourning party that was to be staged in Suk, a village near the Marienberg Catholic Mission Station. Teno, a senior man, was sponsoring the event to end mourning among his family for his deceased sister. He had requested that his Murik trading partner bring a dance troupe to perform during the party, in exchange for a lavish feast of pork, beef, local garden produce and plenty of beer. Rights to the dance, to its paraphernalia, the hand drums, the shell ornaments and its magic would be his to keep after the performance. The relationship between Teno and his Murik trading partners was a special, competitive one, associated with the reciprocal provision of services during ritual. Through the obligations of this feasting relationship, called *mwangaron*, Teno was making claim to acquiring the *singsing*.

When the Australian Museum team arrived in Marienberg, Teno's party was supposed to take place in a matter of days. But on the expected day, the dancers made no appearance, sending word upriver from Murik that they were as yet unready, that the ornaments were not finished and the *tumbwan* figure was not yet assembled. They did promise, however, to perform the dance at Christmas.

But we understood further that the *singsing* had not been performed because of a missing detail in the normal conventions of exchange between *mwangaron* feasting partners. In this relationship, the host (in this case Teno) is supposed to mount an enormous pig feast for his guests (the Murik): the cost of pigs and cows that he slaughters in their honour must be matched and repaid with a gratuity. The Murik, having received feasts consisting of two pigs and two cows, costing about K100 each, would have to meet this cost and pay it to their *mwangaron*. In other words, in addition to performing and giving the dance to their host, the protocol of the *mwangaron* relationship calls for the guests to pay for the cost of the pigs and cows in cash and up the ante a small amount. As one informant told us, "If we bought a pig for K100 to give them, then they ought to give us K120 or K150. . .If not, then we will taunt and insult them and beat them with lime powder." So the problem was not the decorations, nor the masked dance figure, the *tumbwan*. The problem holding up the exchange was that the Murik did not have the money to match the costs of the four animals that their host had given or would be giving them. Teno, the host, was looking forward to Christmas when we left Suk in September 1988. "The *singsing* they will give me will be to celebrate and make my guests happy", he told us. "It will increase my renown. I don't care which one they decide to put on. It is up to them."

The exchange of the dance was embedded in the context of ritual obligation, in this case to conclude mourning. Its performance was viewed by both sides as the duty of a hereditary feasting partner. Even though the exchange had, at least temporarily, fallen through, the motives and value of the dance, as a regional form of transactional cultural property, are at least partially visible. What Teno wanted to give

A small Murik men's cult house stands on the beach in Wewak town. The design for this cult house was traded to Murik from Sub Village on Mushu Island.

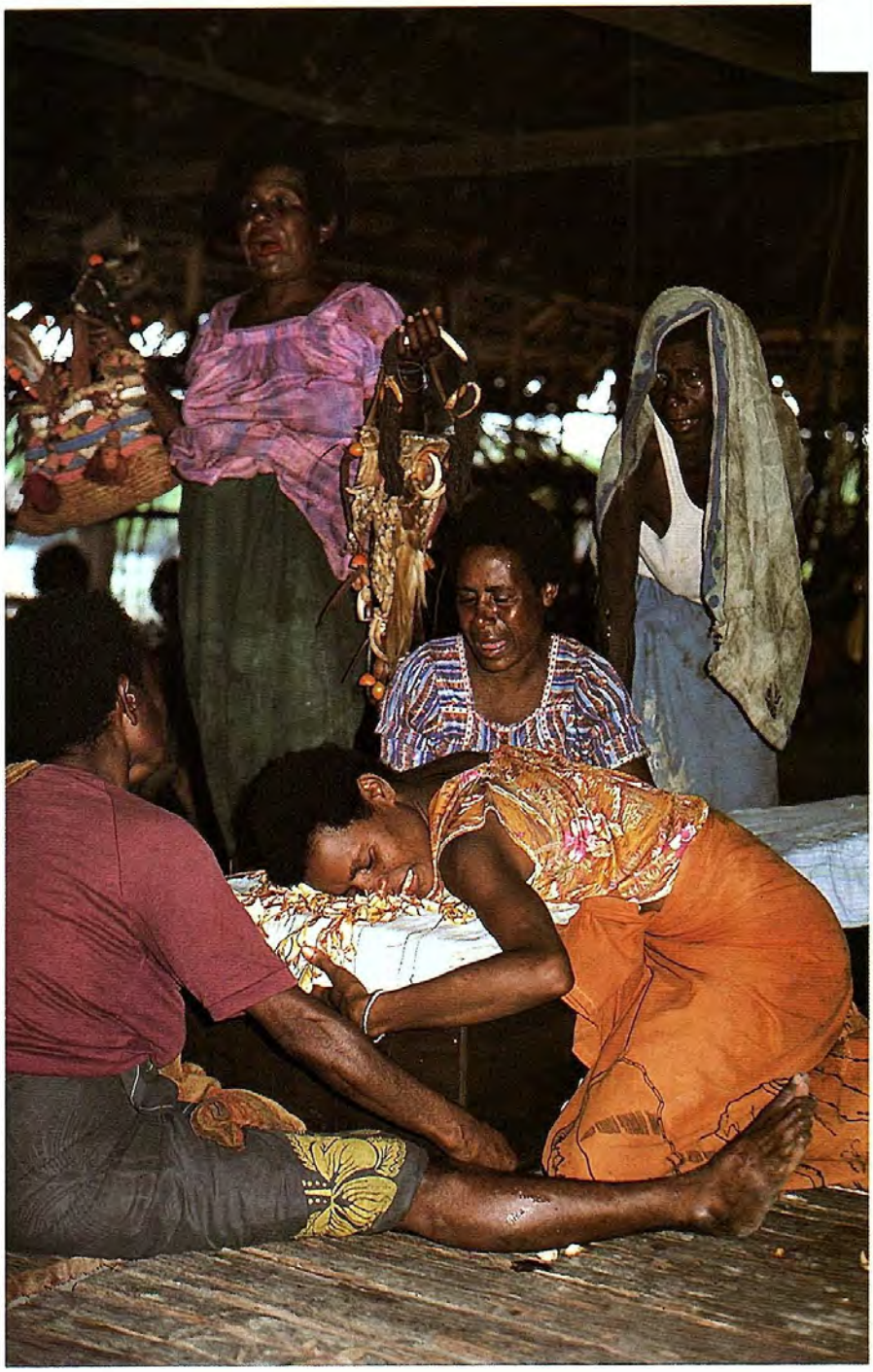
DAVID LIPSET

AUSTRALIAN PICTURE LIBRARY

People in Sydney, for example, simply go to performances to watch the show. In the Sepik, however, performances are rarely given to strangers—the very purpose of such performances lies in the moral transaction that takes place between the performer and the audience.

in exchange for the dance did not signify power, nor was it meant to placate his Murik trading partners, as it did in Mead's case. Instead, it stood for his adherance to the conventions of a hereditary feasting relationship, which called for the mutual provision of services during ritual. Teno wanted to host a grand party that would increase his reputation locally and in the region. He seeks the *singsing* for renown, for identity, rather than power. The Murik give it to settle a debt (Teno had already given them two cows) and avoid insult. Furthermore, the performance provides the Murik with an opportunity to convert cultural property into subsistence goods: their canoes will return home loaded down with parting gifts of pork and garden produce. Lastly, young men, who make up the dance troupe, get the excitement of going on tour in foreign territory. At stake in the exchange of this dance is not land, as in the earlier instance we observed in 1982, but what it means to be a person, a person free of mourning taboos, who pays off debts, who builds a reputation for generosity and who trades and performs. The goals of the exchange of cultural property are not identical in every situation. They vary especially in relation to the distance they span. What is constant, however, is the Sepik-wide valuation of cultural forms.

SINCE MEAD, THE SEPIK HAS BEEN KNOWN as a centre of artistic creation and exchange—a veritable studio, as François Lupu called it in 1973, in which "all is distinction, nuance, tenure and complexity." In this region, we still find intense trafficking of cultural property, in addition to exchanges of food and other material. Culture, meaning symbolic forms, circulates in this region as private property, creating prestige and defining local and regional identities in its wake. It is not so much *what* is exchanged but the *social context* in which it is exchanged that defines the meaning of the cultural forms that change hands. In the West, cultural property also circulates. Copyrights, training and objects are sold, audiences pay for rights to see performances. But the social context is neutral. We go to the Opera House in Sydney not to end mourning or initiate youth or to cede land and fishing rights. We sit in an audience of strangers to simply see the show. In the Sepik, the dance is rarely performed for strangers, for its very purpose and meaning lies expressly in the moral transaction taking place between performer and audience, as well as within the audience itself. Its meaning derives from the formulation of these relationships and from the on-going alternation of indebtedness that obliges the performance. ■



DAVID LIPSET

In the Murik Lakes, insignia representing the descent group affiliation of a deceased man are displayed, in this case, by a senior kinswoman in order to let the ghost know who he is.

Suggested Reading

Harrison, S., 1987. Cultural Efflorescence and Political Evolution on the Sepik River. *Amer. Ethnol.* 14: 491–507.

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Mead, M., 1938. The Mountain Arapesh 1. An Importing Culture. *Anthrop. Pap. Amer. Mus. Nat. Hist.* 36: 139–349.

Drs David Lipset and Kathleen Barlow are cultural anthropologists who are affiliated with the University of Minnesota. They have been doing fieldwork in the Murik Lakes and Lower Sepik region of Papua New Guinea since 1981.

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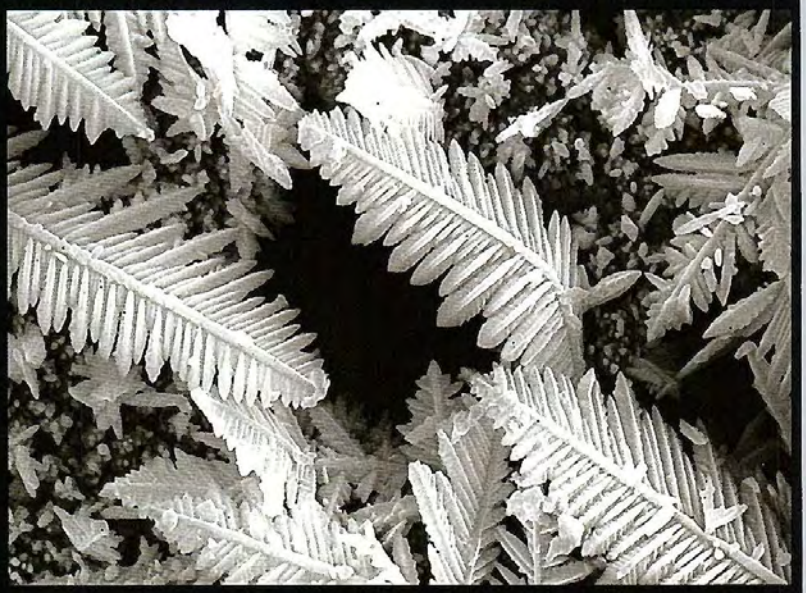


Silver crystals grown from a silver grid: a common test specimen for the SEM.

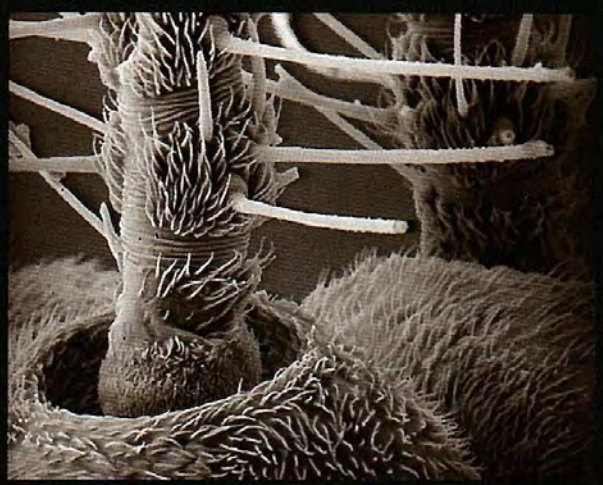
An extraordinarily sculptured shell (3mm wide).

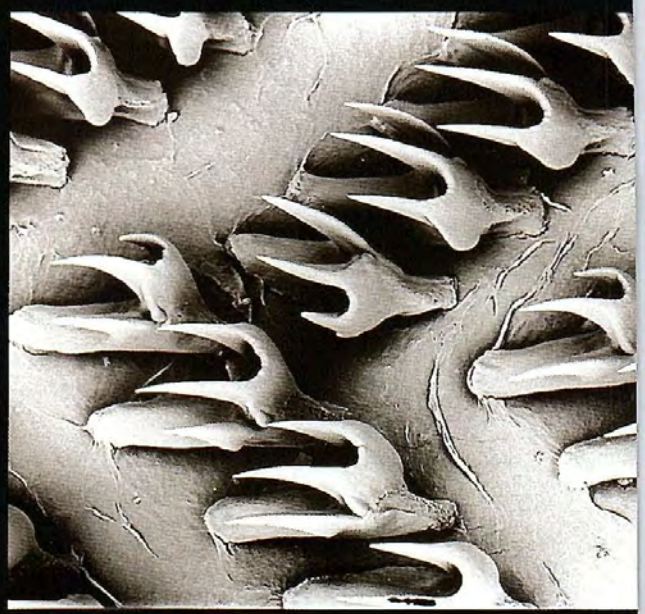
Teeth of an undescribed species of sea-slug from Tanzania: winner of the 1987 International Polaroid Competition for Photomicrography in the Electron Micrograph category.

An unusually shaped land snail (*Xenopoma hystrix*) from Cuba (1cm).

The antennae of a midge.

Base of an antenna of a midge.





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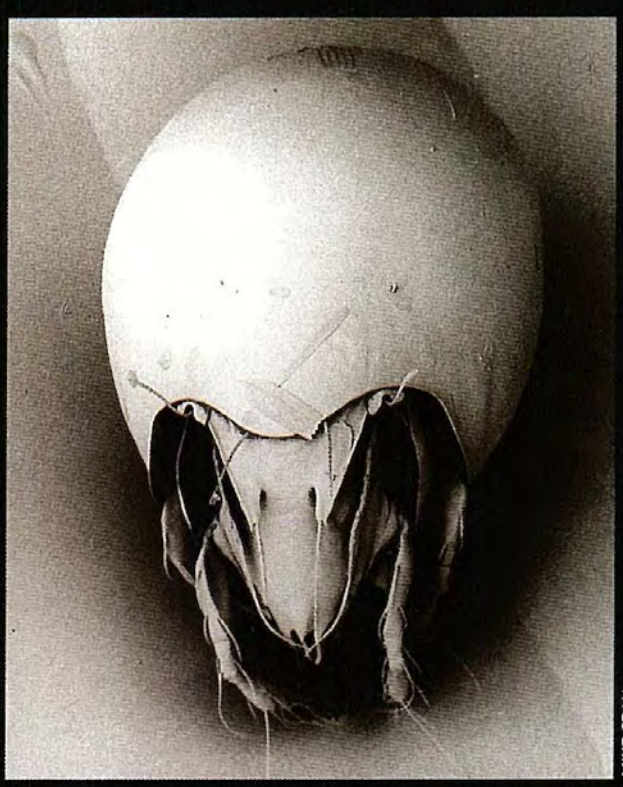

MIKE GRAY

The teeth of the sea-slug *Kalinga ornata*.

Detail of the head of a small moth fly showing eye ('bunch of grapes') and antenna ('seaweed').

The head of a black ant.

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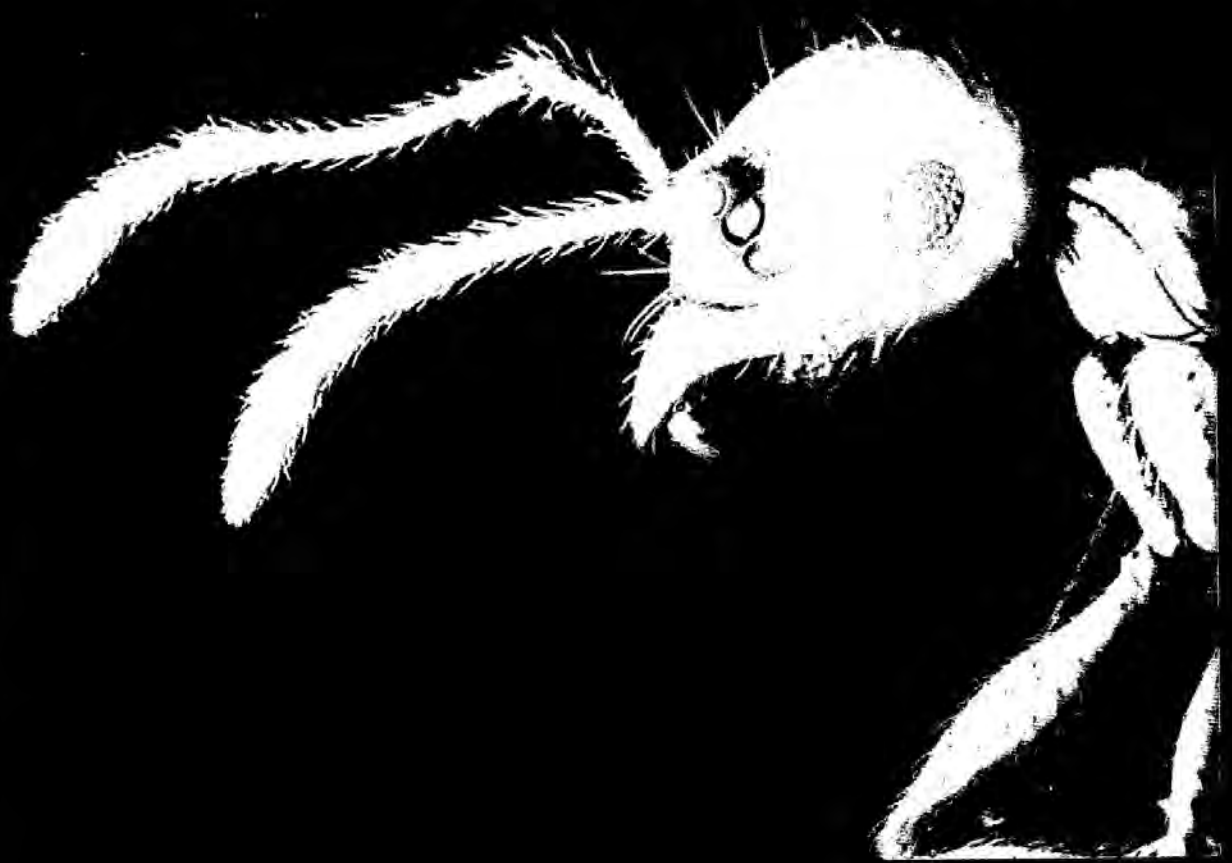


"For his perception of the shell he needed words such as 'most peculiar' and 'unique'."

THE TASMANIAN GRANULATED SNAIL

BY RON C. KERSHAW
QUEEN VICTORIA MUSEUM & ART GALLERY, LAUNCESTON

WHEN NATURALIST RONALD GUNN emerged from the north-eastern Tasmanian rainforest in October 1848, he carried with him several shells of a new snail species. His excitement can well be imagined, for this was certainly the most beautiful Tasmanian snail he had ever seen.

In a letter dated 17 March 1849 to Sir William Hooker, Gunn described this walk through the myrtle forest together with some detail of the plants he saw. His route probably started at a summer sheep run he leased at Diddleum Plains. This area, at the edge of the mostly unexplored forest, would have been a convenient starting and end point for north-eastern exploration.

The shells were sent to London where they were given the name *Helix launcestonensis* by the publisher–conchologist Lovell Reeve in 1853. But the genus *Helix* refers to the totally unrelated, introduced Garden Snail and in 1861 Von Martens replaced it with the generic name *Anoglypta*. For his perception of the shell he needed words such as "most peculiar" and "unique". Later Charles Hedley pointed out that the Tasmanian snail was in fact related to several large eastern Australian snails and its elaborate 'primitive' sculpture was probably ancestral for the group. The American expert Pilsbry reported in 1894 on both anatomy and shell of specimens sent, noting that, unlike many snails, the juvenile sculpture continued into the adult.

The Granulated Snail and its close Tasmanian relative *Caryodes dufresnii* belong to the family Caryodidae, which includes the large mainland snails found mainly on the Great Dividing Range. *Caryodes dufresnii,* which has many large elongate variations, was widely successful in Tasmania, although now harder to find. All species of the Caryodidae have a peculiar gland of unknown function within the anatomy but shells of mainland species have almost lost the characteristic sculpture of the probable ancestral snail. Most species, which include Australia's largest snails, are distinguished by a banded pattern. Their large eggs have been described as similar to those of small birds and excited early interest.

Caryodids were soon found to be related to species of Acavidae, a family of large snails living in Sri Lanka and Madagascar. Present opinion places the most probable ancient distribution pattern across Gondwana. When the Indian plate rafted north across the Indian Ocean and Australia broke away from Antarctica, unique characteristics evolved enabling recognition of these distinct families, although resemblances such as the nature of the teeth remind us of the relationship.

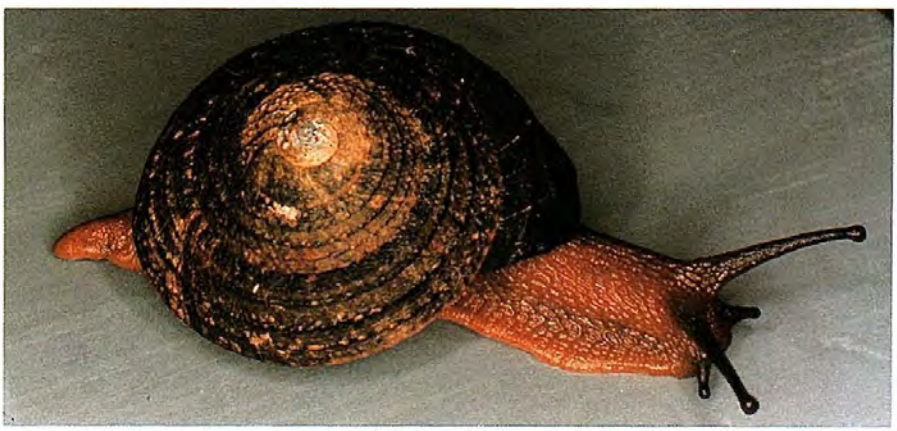
Little has yet been learnt about the life cycle of the Granulated Snail. Juvenile snails, which live in the litter, are miniature replicas of adults with, of course, fewer whorls. The most active adults seen were crawling amongst moss and may have been grazing on the moss or associated minute plants. But a consistent behaviour pattern has not emerged except the indisputable habitat preference for rainforest.

The rainforest habitat may include a sprinkling of large eucalypt trees but the environment is consistent with high rainfall probably in excess of 1,400 millimetres per annum. The ground may be well covered with ferns, low shrubs, rotting logs and a litter (if present) of typical small rainforest leaves. The overhead cathedral-like canopy may give a dense shade. It is unusual for these snails to be seen in open forest in daylight. A great deal of searching may be required to find more than one or two live specimens. Empty shells do occur in favourable areas where fire has cleared the undergrowth of the otherwise impenetrable understorey with its hidden moss-covered logs. The environment becomes accessible to the student but the snails are dead. However in one locality a former large population thus revealed indicated that good drainage, high reliable rainfall and shelter are important.

Hedley's 1891 description of a fern gully near Scottsdale where the Granulated Snail was plentiful suggests that there were more large populations at that time. He expressed his concern for the future survival of the species even then under threat from development. Naturalists already knew of the limited rainforest distribution and habitat. Recent field research has concentrated on establishing the extent to which the snail has survived. In this respect the help of Forestry Commission officers has been invaluable. Several new localities have been recorded. Nevertheless the snail has remained hard to find in most localities. Populations are too often limited in numbers of individuals and they are widely scattered. Clear evidence of a viable population was difficult to obtain for most localities.

At present, exploitation of the rainforest is not part of future plans. There are several reserves within the area of distribution of the Granulated Snail. One of these is part of the nominated type locality, that is the area within which Ronald Gunn probably found the first shells. Live snails have been found in these reserves. There is evidence of good recovery from fire in a favourable locality. A range of suggestions has been made for future management of the species and a more detailed investigation of the animal is proposed. Provided that a low fire frequency together with respect for this environment is maintained, then there is strong hope for survival of this species. ■

Maintenance of a low fire frequency in the snail's rainforest habitat should ensure survival of the species.



RON C. KERSHAW

Mr Ron Kershaw is an amateur naturalist whose interests lie in the Mollusca, especially Tasmanian land snails. He is an Honorary Research Associate at the Queen Victoria Museum and Art Gallery in Launceston, Tasmania.

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

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"The only desert sand these ancestral moles ever experienced was that which blew 20 million years later over the grey limestones that contained their bones."

THE SCIENCE OF BEING WRONG

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

IT HAS SOMETIMES BEEN SAID THAT palaeontology, the study of prehistoric life and its changing environments, is a 'soft' science rather than a 'real' one like physics or physiology. ('Real scientists don't play with dirty old bones'.) To these 'real' scientists palaeontology does not appear to involve the testing of predictions such as the hypothetical existence of mesons or mutated mitochondria.

If true, this devastating slur could justify the defrocking of palaeontology as a science because the vulnerability of ideas to falsification through testing is to most scientists a key part of the procedure. If it were impossible to test hypotheses, how could we decide which of two theories competing to explain the same natural phenomenon was the more plausible? *Are* the ideas and activities of palaeontology unfalsifiable poppycock like those that comprise, for example, Creation 'science' (ANH vol. 22, no. 4, pp. 160–164, 1987)?

As one of the breed under siege here, I admit that most palaeontologists are discovery junkies who would practice palaeontology whether or not it had a single scientific bone in its body. Many join the guild simply for the thrill of the chase; after all, no modern safari could produce such stunning quarry at the end of the day (which is why we can be hired for such lousy pay!).

Most start out as kids lured by the intrigue of lost worlds, haunters of museums or consumers of books peppered with nightmarish creatures and impossibly long names. Some day-dreamed of breaking a rock to discover the jaw of a new meat-sucking dinosaur, wing bone of a jagged-toothed flying reptile or shell of a sable-eyed, predatory ammonite that once streaked through the green waters of a Cretaceous sea to an appointment with oblivion.

For me, it was trilobites—extinct, beautiful and tantalisingly rare creatures hidden among the tangles of crinoid stems and brachiopod shells that stuffed the rocks in the paddock behind my house. I wanted to know everything about them; to trace their stone eyes and cheeks with my warm fingers, to link my flesh with theirs and raze the trivial 400-million-year gap that separated our lives. In fact, I confess, for as long as I can remember I have loved to touch fossils, to tear down barriers that blind us to beginnings. Each time we split a Riversleigh rock, the 'snap' of stone is a violent incantation that hurtles into our world a part of some extraordinary ancestor, something that basked in the light of a younger sun on a changeling Earth. But are discoveries of this kind the stuff of science?

There are at least four kinds of palaeontological discoveries: the stunning, the redundant, the predicted and the bubble-burster. Contrary to popular opinion often fed by Hollywood horror flicks, few palaeontological discoveries are of the first kind—the 'My God Professor, what on Earth *is* that Thing!?' type. Certainly gasp-worthy 'hyperweirdos' do turn up, such as the 16-metre-high dinosaur *Ultrasaurus*, the tiny but appropriately named *Hallucigenia* from Cambrian rocks in Canada, and 'Thingodonta' from Riversleigh (now formally known as *Yalkaparidon*[1]), which represents a bizarre new order of mammals never before seen here or on any other continent. While discoveries of this kind frequently provoke widespread interest, they rarely shed much light on previous understanding—because they are simply *too* strange. In this sense, although 'hyperweirdos' are important in helping us comprehend the timeless splendour of life, they are often impotent arbitrators on the battlefields of science.

In contrast, the majority of palaeontological discoveries represent the second kind: repeat encounters with creatures already known from particular times and

MICHAEL GILLAM

***Notoryctes typhlops*, the living Marsupial Mole.**

places. For example, since Sir Thomas Mitchell excitedly blew the Wellington Cave dust off the first-known fossil jaw of an extinct Tasmanian devil (*Sarcophilus laniarius*) in the 1830s, each subsequent discovery of this species in other Pleistocene cave deposits became just a bit more 'ho-humish'.

The third kind of palaeontological discovery is that of 'evolutionary links'—creatures predicted, on the basis of previously known organisms, before they were actually discovered as fossils. Finds of this kind are delightful support to evolutionary biologists who expect intermediate creatures, but a nightmare to Creation 'scientists' who 'know' in advance that such evolutionary links *could* not exist because they are committed to the view that God's Creation was 'complete' the moment it was zapped into existence a mere 6,000 years ago.

As an example of this third type of discovery, recent studies of molecular biology and skeletal morphology reported in 1982 led to hypotheses that thylacinids (for example, the Tasmanian 'Tiger', *Thylacinus cynocephalus*) and dasyurids ('dasyures' such as antechinuses and their relatives) were close relatives[2]. Therefore, if one evolved from the other or both from a common ancestor, intermediate 'links' should have existed at some time in the past. However, nothing was known from the fossil record to support or refute. these hypotheses—until now. From the rich local faunas of Riversleigh have come several creatures intermediate in size and form between 'primitive' dasyurids and thylacinids. For Jeanette Muirhead, the University of New South Wales palaeontologist studying these creatures, they have clearly materialised the predicted 'missing links'[3]. In fact, one of the Riversleigh beasts is so intermediate in shape that she cannot with confidence place it in one or the other of the two families that it links. As a found 'missing link' it provides support for current hypotheses that thylacinids were highly specialised descendants of archaic 'dasyures'.

Could the 1982 thylacinid–dasyurid hypotheses have been refuted rather than supported? Most certainly! If, for example, the fossil record had produced a 'half-thylacinid–half-bandicoot', it would have severely challenged the 1982 hypothesis, which in turn would have prompted the gathering of yet more data in an effort to resolve a very stimulating problem!

The fourth and last kind of palaeontological discovery is of a creature that, although previously known in kind, turns up in a time or place *not* expected. Which brings us by way of an example to moles, holes, the stuff of science and the point of this essay.

Do Marsupial Moles (notoryctids; the living *Notoryctes typhlops* being the only known species) live in desert holes because old sandy holes 'made' those wriggly moles? I for one certainly used to think so and in 1984 even said so[4]. The living creature, which is about the size of a very large mouse, is blind, lacks external ears, has spade-like hands and feet and, as far as we know, is confined to the central Australian sandy deserts through which it burrows in pursuit of juicy, yummy invertebrates. So what could be more reasonable than to conclude that these attributes so obviously suited to life in desert sand evolved in response to the demands of that arid habitat? I remember thinking in 1984 that, although the hypothesis was plausible, it would be very difficult to test because desert habitats with their scarcity of water are among the worst places to preserve fossils.

The unexpected debunking of this hypothesis came from a beautiful row of teeth in a vat of dissolving Riversleigh limestone—tiny, primitive but unmistakable notoryctid teeth. The once wriggling, furry body that used this jaw to gobble grubs lived on or in the floor of a tropical rainforest in north-western Queensland. The only desert sand these ancestral moles ever experienced was that which blew 20 million years later over the grey limestones that contained their bones.

To Miranda Gott who studied these first fossil moles, for her UNSW Honours project in 1988, every new piece of evidence became another nail in the coffin of the old hypothesis. When limb bones turned up, these displayed many of the same 'digging' features so effectively used by the modern moles to burrow through sand. Of what possible use would evolution of such features have been to these ancestral moles in a rainforest? Perhaps they burrowed through thick mosses and root mats of the kind that develop today in some of the montane rainforests of New Guinea. In this way, although the verdant rainforests gradually gave way to spinifex as Australia dried out, the tiny moles secure in their subterranean holes may have been serendipitously pre-adapted for tunnelling through the sand that slowly replaced the moist forest floor.

Anyway, it's not the *fact* that I was wrong about the ancestral mole hypothesis that makes this debunking important; it is the fact that I could be *shown* to be wrong—unexpectedly and totally wrong—that delights me, for it demonstrates that palaeontological ideas *can* be as readily uprooted as any of the worst generated by physicists or physiologists! ■

[1] Archer, M. Hand, S., Godthelp, H., 1988. A New Order of Tertiary Zalambdodont Marsupials. *Science* 239: 1528–1531.

[2] Szalay, F.S., 1982; Sarich, V., Lowenstein, J.M. and Richardson, B.J., 1982; Archer,, M., 1982. In *Carnivorous Marsupials*. Royal Zoological Society of New South Wales: Sydney.

[3] Muirhead, J. and Archer, M., 1989. *Mem. Qd Mus.* (in press).

[4] Archer, M., 1984. The Australian Marsupial Radiation. Pp. 633–808 in *Vertebrate Zoogeography and Evolution in Australasia*, ed. by M. Archer and G. Clayton. Hesperian Press: Perth.

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

CHANCE MUTATIONS

BY RALPH MOLNAR & GLEN INGRAM
VERTEBRATE FOSSILS, QUEENSLAND MUSEUM
VERTEBRATE ZOOLOGY, QUEENSLAND MUSEUM

THE IDEA OF NATURAL SELECTION, AS discussed in the last issue of ANH, pre-supposes the existence of individual differences ('variation') in any population. The question of how this variation originates, while interesting and significant, is nevertheless irrelevant to the operation of natural selection. What *is* critical to the role of natural selection in the modern, neo-Darwinian theory of evolution is that the variation is said to be random.

This randomness is a point often attacked by creationists (and even scientists such as Sir Fred Hoyle) who are not closely acquainted with the modern theory of evolution. The question—and it is a valid if often misconstrued one—is: how do well-organised and well-structured organisms arise at random? The answer is that they don't; they arise by evolution, which is not the same thing. Natural selection is a far-from-random process; indeed it is the antithesis of randomness. The mistake is the assumption that, because those features subject to natural selection are said to arise at random, this randomness must permeate the whole selective process. This simply isn't true.

At the heart of the confusion is the word 'random'. Evolutionary biologists do not use this term in the same way as everyday folk or mathematicians. In fact, it may be fairly said that 'random' is not the ideal word to use here at all. So what does it mean to be random? There are several, interlinked concepts involved. (1) An event that happens without a cause, or at least without any perceptible cause, is surely what most of us mean when we use 'random' in everyday conversation. (2) A related meaning is that a random event is one that is not predictable. This is what economist Richard von Mises meant when, referring to games of chance, he described a random game as being one that cannot be beaten. In order to beat the game you must predict what is going to happen next. A sequence of events that displays no pattern allows you no way to predict what events will happen next. Consider a computer printing out a sequence of random digits: the sequence contains no redundant information and so there is no way to describe the sequence of numbers in any shorter fashion than by reading them out. But if you have 'one thousand numbers each twice its predecessor', such as 1, 2, 4, 8, 16, 32, 64, 128, ..., then you can describe the sequence simply in seven words and deduce what the next digit will be. This is impossible for random sequences. (3) Scientists and mathematicians may also use the word random in another sense, such as 'imprecise' or even 'simple', but these are definitely minority usages. (4) In everyday conversation we can also use the word to mean 'without regard for the consequences'. Someone who plays a game randomly, for example, does so without regard for whether she wins or loses.

"... which of these concepts is meant when we say that natural selection acts on random variation?"

Now, which of these concepts is meant when we say that natural selection acts on random variation? Do we mean that the variation has no cause? Well, no we don't, for we are sure that when the nucleotides, and other biochemicals that make up the genes, change and cause mutations, they do in fact change in accord with the laws of chemistry—not at random. A detailed knowledge of this chemistry, we think, allows one to predict in chemical terms just what the change in the genes will be. So 'random' mutations and 'random' variations are, at least in principle, neither without cause nor unpredictable. Do these 'random' mutations lack redundant information? Well no: they can certainly be described in much shorter terms than by detailing what happens to each individual atom when one nucleotide sequence changes to another. One can, for instance, simply say that one nucleotide (such as guanine) was replaced by another (say cystosine) and this is clearly shorter than detailing what happened to each atom.

So what does 'random variation' mean? It means without regard for the consequences; the last of the definitions given previously. In evolutionary terms it means that there is no necessary connection between the biochemistry (or chromosomal structure) of a mutation and the effect that the mutation has on the survival or reproductive ability of the animal. Changing guanine to cystosine does not invariably result in longer legs or purple polka dots. And this is ***all*** that it means. It does ***not*** mean that a gene has an equal chance of changing (mutating) or remaining the same. It does ***not*** mean that the chance of a gene mutating cannot itself change. It does ***not*** mean that mutation is unpredictable (after all we can predict that exposure to hard radiation, as from nuclear weapons or cosmic rays, will cause mutations). And it does ***not*** mean that any mutation has an equal probability of being beneficial or harmful. What it ***does*** mean, as the American philosopher of science Eliot Sober put it, is that mutations do not occur simply because they would be helpful. The mutations occur first, then their helpfulness or harmfulness determines whether or not they will be selected. Given such 'random' variation, natural selection can result in evolution, as Charles Darwin showed.

However, are mutations ***really*** random in this sense? Recent work has called this into question. In the 8 September 1988 issue of *Nature*, John Cairns, Julie Overbaugh and Stephan Miller from the Harvard School of Public Health suggest that some bacteria can direct the process of mutation. This does not simply mean that they can speed up or decrease the rate of mutation: that phenomenon has been known for decades. What these bacteria—the colon bacterium, *Escherichia coli*, beloved of bacteriologists—seem to do, is to produce mutations that are appropriate to enhance survival and reproduction in the face of specific environmental stresses. These are termed 'direct mutations'. Cairns and his colleagues used a very specific environmental stress, the presence of lactose. The bacterial strain used does not metabolise lactose, and hence did not reproduce on the lactose-containing medium. Only those mutants that could 'digest' lactose could reproduce to form colonies. The experiments were designed to

distinguish between any mutations that arose prior to being on the lactose-containing medium, and those that appeared after contact with the medium. Conventional wisdom suggests that only the first kind of mutations would be found. In fact, apparently both kinds were found.

What are the implications of this for evolutionary theory in general? The genetic machinery of bacteria differs considerably from that of animals. For one thing, animals develop from zygotes to adults; bacteria simply grow and divide. For another, the germ (or reproductive) cells of animals are effectively insulated from changes that occur to body (or somatic) cells. Also, the only gene in *E. coli* that seemed to mutate 'on demand' was that which coded for the enzyme that 'digests' lactose. If lactose in some way affected the structure of this gene, for example by causing 'faulty' replication of the gene, there would be a simple, one-step link between the environmental stress and mutation. This is rarely the case for multicellular organisms. Escaping from a tiger (if you are an animal) or a cow (if you are a plant) involves much more than the production of a single enzyme.

If this effect is confirmed, and even the authors suggest that more evidence is needed to confirm it, it presumably applies only to bacteria and related life forms. However, if it is confirmed, multicellular organisms should be tested for it, just in case.

If such directed mutation *is* found in multicellular organisms, what would *this* imply for evolution? In regard to natural selection, not much. Cairns and his colleagues, after all, did not show that the so-called random mutations are nonexistent; they merely showed that there might also be non-random mutations. Natural selection will act on both. If the directed mutations differ in their effects, selection will distinguish between them. If not, it won't. The origin of the variation is, after all, irrelevant to the process of selection.

In regard to molecular biology, however, plenty would be implied; for then there must exist some mechanism (other than natural selection) of matching the biochemical (or chromosomal) changes to their effects on survival and reproduction. As we implied previously, this is not too difficult to imagine for bacteria (although it is yet to be demonstrated), but for multicellular forms considerable complexity would be involved. It would require some dictionary to translate environmental stresses into chromosomal structure or biochemistry. This raises further questions. How common or rare are the stresses that can be met in this way? Certainly not all stresses can be so met: the prevention of being vapourised by a falling meteorite would seem beyond the bounds of any reasonable mutation. How did this mechanism of directed mutations arise? Presumably it was not a property of the biochemicals that gave rise to the bacteria (and other living things), or else it should be much easier to create life in the laboratory. Such problems could provide (and, indeed, have already started to provide—see Stahl's reference) years of entertainment for molecular biologists.

"... these directed mutations do have an air of Lamarckism about them."

A letter to the Editor of *Nature* (3 November 1988) by Linda Partridge and Michael Morgan suggests, however, that such speculation may be premature. They point out that there seems to be a statistical error in the procedure of Cairns and colleagues. Basically they may have overestimated the mutation rate following introduction of the bacteria to the lactose-containing medium. If so, then the evidence for directed mutation occurring with 'chance' mutation, after the introduction of lactose, is suspect and, at the very least, the whole experiment needs to be done under stricter conditions before any conclusions can be reached.

Cairns and his colleagues' work is also controversial in another respect. In the late 1970s Dr Ted Steele, a native of Darwin, proposed that there was evidence for Lamarckian evolution in the immune system of mammals. The work at Harvard is said to be simply an application of Steele's ideas. In the sense that both refer to environmentally directed evolution this is true. But the proposed mechanisms, which are after all quite important, are distinct. Steele proposed that 'random' mutations occurred in the body cells of mammals, and that these mutated genes could then be transferred to the germ cells. The Harvard mechanism involves non-random mutations and being in bacteria does not involve any kind of transfer of mutated genes.

However, these directed mutations do have an air of Lamarckism about them. They bring to mind the inheritance of features acquired by the efforts of indivual animals, such as the Giraffe evolving a long neck from generations of stretching (never mind that this is not precisely what Lamarck himself thought). However this is not so. Bacteria do not strive to produce lactose-digesting enzymes as a Giraffe might strive to stretch its neck to a tasty leaf. A better analogy would be the leaf beyond the reach of the Giraffe altering the Giraffe's genetic read-out so as to enable the Giraffe's offspring to grow a long enough neck to reach the leaf. In the Lamarckian scheme it is the Giraffe's exertion that affects how long the neck will be in its offspring; in directed mutation the environment (the presence of lactose in the case of the bacteria) influences the genes to produce a modified offspring. A revisionist kind of Lamarckism, perhaps, but not what was originally meant by the term. One thing seems certain, however: organisms with directed mutation would be strongly favoured by natural selection! ■

Suggested Reading

Benson, S.A., 1988. Is Bacterial Evolution Random or Selective? *Nature* 336: 21–22.

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Sober, E., 1984. *The Nature of Selection.* MIT Press: Cambridge, USA.

Stahl, F.W., 1988. A Unicorn in the Garden. *Nature* 335: 112–113.

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

QUESTIONS & ANSWERS

A regular column where *your* questions about our natural world are answered by experts. Readers are invited to submit brief questions.

Ant Battles

Q: Recently I saw a battle between what appeared to be groups of similar ants. They were what we laypeople refer to as sugar or meat ants. The battle occupied two days and left thousands of ants dead. Usually individual engagements were quickly over—the loser quickly collapsed. I would like to know why such battles occur.

—J. Norberry
Address unknown

A: Ants are often aggressive to other ant colony members, whether they are the same or an unrelated species. Competition for food resources, seeking slave ants for their own nest, or taking the pupae and larvae from a nest for food, are the usual reasons for this behaviour. An ant of one species that enters the wrong nest of the same species will more than likely be killed.

Several species of ants will raid other ant species nests to remove the pupae and larvae for food. Yet other species of ants are known to make raids from which they bring back the pupae of other species of ant. Some of these are eaten but the rest emerge in their captor's nest and take part in the social life there, especially in rearing the brood of the captor. These raids can be made at night or by day, either underground or on the surface and often last for several days.

—Geoff Holloway
Australian Museum

Do All Animals Yawn?

Q: I have just read Georgina Hickey's quip on the role of yawning in humans. Can you tell me please, whether all animals yawn.

—David Browne
Alice Springs, NT

A: According to Robert Provine (*Ethology* 72: 109–122, 1988), the gaping component of the yawn is widespread in the animal kingdom (fish, reptiles, birds and mammals). However, because there aren't many ways to open a mouth wide, these 'yawns' may just superficially resemble human yawns. No tests have been done on these animals to determine a function for the gaping mouth (that is, whether respiration or cerebral blood flow is affected) or whether they are infectious. Fish have been observed yawning when changing from one activity to another; and dogs when they are on the threshold of aggression or are being forced to participate in an aversive activity. It seems, like humans, they do it when they're bored. But this is purely subjective.

—G.H.

Meat ants feeding on scale insect

JIM FRAZIER/MANTIS WILDLIFE

Microwave Cockroaches

Q: During a recent cockroach invasion, I noticed that cockroaches had, horror of horrors, invaded my microwave oven. Yet even after several had been microwaved on high for four minutes, they escaped supposedly unharmed. Why don't they get cooked?

—Matthew Feierabend
Kirribilli, NSW

A: Our resident entomologists are unable to suggest any reason why these cockroaches are exempt from the normally debilitating high-frequency waves. Certainly one would expect their certain death. Perhaps the cockroaches you saw weren't actually 'zapped' and were emerging from behind the oven, or from an area not subject to the waves? It seems unlikely that the chitinous exoskeleton would reflect the waves, as do shiny metal surfaces. All I can suggest is you thoroughly clean the oven (inside, underneath and behind), thereby removing any cockroach lure. On the other hand, if you can be sure that the cockroaches *were* subjected to the high-frequency waves, and indeed survived the ordeal, I'm sure our entomology department would be interested in receiving further information.

—G.H.

Garden Havens

Q: As a keen gardener and enthusiast of all our natural wonders, I love to create a garden that is a haven not only for my family and friends, but also for all the wonderful creatures that frequent it. Is there any way to attract ladybirds and butterflies to my little oasis?

—Jill Reid
Deakin, ACT

A: Many insects can be induced to frequent the garden simply by supplying the appropriate food. Many of the ladybirds, both adults and lar-

vae, feed on aphids, scales and other small insects. If a suitable and ample supply of food is available, the insects will remain in your garden; for this reason the planting of a host plant will attract the appropriate butterfly.

—Geoff Holloway
Australian Museum

Butterflies can be attracted with the correct host plant.

DENSEY CLYNE/MANTIS WILDLIFE

Upside-down Flies?

Q: One lazy Sunday afternoon, while chatting with a group of friends, we became fascinated with the movements of blowflies in our kitchen. An argument ensued about their flight abilities but one question that no-one could answer was how they can land upside-down. It didn't matter how long we watched them, we just couldn't figure it out—they never seem to actually fly any way other than the right way up. So how do they do it? Can they fly upside-down?

—G. Thompson
Adelaide, SA

A: Blowflies and house flies cannot or do not fly upside down except for a moment of adjustment. This moment is significant for landing or taking off from a ceiling. When landing on the ceiling the fly does a half loop which brings its body to a feet-up position facing in the opposite direction to its original one. Many insects can commence flight from a ceiling by simply dropping into the air. The position in which they hold the legs and wings results in their falling right way up. Flies, however, often give themselves a quick take-off from the ceiling by flying forwards and, by a half roll, quickly becoming the right way up.

—Geoff Holloway
Australian Museum

Bird Names and Why

Q: Could you please supply the meanings of the following scientific names: MacCormick's Skua, *Catharacta maccormicki* (who was MacCormick?); Saunder's Tern, *Sterna saundersii* (who was Saunders?); Swamp Quail, *Coturnix ypsilophora* (what does 'ypsilophora' mean?); and White's Thrush, *Zoothera dauma* (what does 'dauma' mean?).

—E.L. Hamonet
Speers Point, NSW

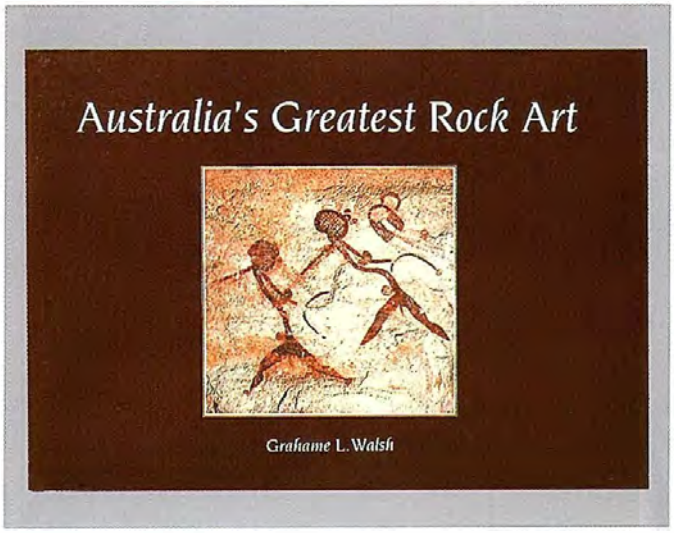
A: Dr R. MacCormick (1800–1890) was a surgeon with the British Antarctic Expedition in 1839–1843. Saunders was *probably* Howard Saunders who worked extensively on gulls and terns in the late 1800s. 'Ypsilophora' derives from the Greek word *Upsilon* meaning the letter U and *phoreo* meaning I bear, in reference to the markings on the back, which resemble the Greek capital U (Ω). *Zoothera dauma* was named by John Latham as the Dauma Thrush. No meaning for the word 'dauma', however, was given; and neither I nor my colleagues are able to offer further suggestions.

—Walter Boles
Australian Museum

The species name of the Swamp Quail refers to markings on the feathers.

ANTHONY FARR

REVIEWS



Australia's Greatest Rock Art

By Grahame Walsh. E.J. Brill and Robert Brown Associates (Australia), Bathurst, NSW, 1989, 324 pp. $129.95.

Australia's Greatest Rock Art is the first book to cover the Aboriginal rock art of every Australian State and every major rock art region and style. Many of the art sites in the 339 colour plates have never been published before. It is also a book written by one of Australia's greatest characters.

The book depicts rock paintings that may be some of the oldest in the world. There is evidence to suggest that delicate red ochre figures in northern Australia, preserved with natural silica coatings, may be up to 25,000 years old. There are mythological figures such as rainbow serpents that recur all over the continent. The brightly contrasting desert art is illustrated together with the more sombre dry pigment drawings found north-east of Sydney. No doubt some of the art had special meaning, such as the sorcery art of northern Queensland; while other figures, such as the running figures shown on the front cover of the book, bear an uncanny resemblance to the bushman paintings of South Africa.

Grahame Walsh lives and works in a remote part of the Central Highlands of Queensland. He founded a Rock Art Research Centre known as Takarakka, which is an example of privately funded decentralisation at its best. Grahame could be described as a rock art fanatic. Born and bred on a property near the remote country town of Roma in central Queensland, he developed a fascination for the Aboriginal culture and prehistory. His intense interest led him deep into the heart of the Carnarvon wilderness—an area that he probably now knows better than any other living Australian. From there Grahame's interest in photographing and recording rock art spread to cover the rest of Australia.

DAVID LAMBERT

Grahame Walsh at a site at Mt Moffat National Park in central Queensland.

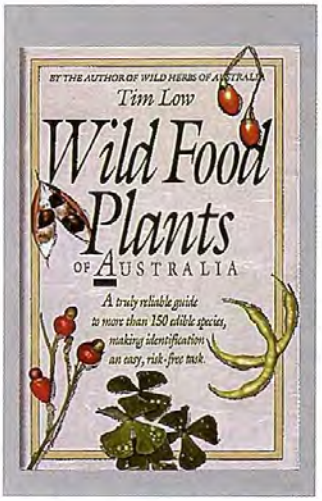
Grahame's great passion for rock art has been mainly confined to northern Australia. It was no mean feat to get him to venture down to the southern States and it was on one of these rare visits that I was fortunate enough to be able to take Grahame to some of the sites around Sydney. I was delighted to see that a number of the sites we visited are featured in the book and, in my view compare well with the more famous sites of Kakadu and northern Australia.

Time is an important commodity to Grahame. Get him to a rock art site and he'll go like there's no tomorrow. Supreme effort is injected into every photograph. He uses only large-format cameras with an array of flash units to illuminate each site. He'll take several shots at each angle varying the exposure to get that one photograph with perfect light and contrast. "Immortalised again" he'll say when pleased with a particular shot. Then the gear gets put back into the knapsack ready for the long haul out, but not before exhaustive notes on site detail and measurement are taken.

The setting up of Takarakka Rock Art Research Centre in the remote Carnarvon Gorge was in itself a feat few people could have accomplished. Property around Carnarvon Gorge is either dedicated as national park or used as cattle stations hundreds of square miles in area. Be it foresight or foolishness, Grahame bought a station looking back into the Gorge. Securing the property with a ten per cent deposit, Grahame frantically lobbied politicians to allow him to excise part of the property for the Rock Art Research Centre. Flo Bjelke Petersen helped him win the day. For once bureaucracy bowed to the individual. A small area on the Carnarvon River was annexed and Takarakka Rock Art Research Centre was born. In the meantime a buyer for the cattle station had been found and Grahame managed to unload the property before being required to find the remaining 90 per cent of the value set out in the contract.

This book draws on more than ten years solid work. Countless kilometres have been travelled, each time returning to the Research Centre to process film and write up the areas visited. When you realise the time and effort that have gone into producing this book with its attention to fine detail, it lessens the blow for the $130 outlay. But then you've got to pay for quality and that's exactly what you'll get.

—David Lambert
National Parks and Wildlife Service of NSW



Wild Food Plants of Australia

By Tim Low. Angus and Robertson, Sydney, 1988, 236 pp. $39.95.

Yet another book on Australian native food plants! First, in the mid-70s we had the Cribbs' excellent *Wild Food in Australia*; although sparsely illustrated this was well written and soundly based, and has been freely available in paperback form. Then there was Jennifer Isaac's beautifully illustrated *Bush Food*, which appeared in 1987 and became an instant best-seller. It was based largely on the author's first-hand experience in Aboriginal communities in the Northern Territory. Other books include Dulcie Levitt's *Plants and People*, relating to Groote Eylandt, and the small but valuable *Mayi—Some Bush Fruits of Dampierland* by the Broome Aboriginal communities.

Despite this wealth of material, I would still strongly recommend purchase of Tim Low's book to anyone with a genuine

curiosity about native plants or an interest in bush survival, or even to the more adventurous gourmet. Like all these books it is based largely on the millennia of experience accumulated by Aborigines, but its scope is nonetheless wider than Aboriginal food plants. The author, who has contributed fine articles on food plants to this magazine, is a talented writer and photographer; his enthusiasm for the plants shines through every sentence, although tempered by a refreshingly sceptical and empirical approach to questions of palatability and food value. It is no mere compilation but in many places a personal account of his own researches.

The main part of the book is the long chapter headed "The Plants", with one or two colour plates on almost every page. The photographs, mostly by the author and T.J. Hawkeswood, are of a high standard and clearly show features that should enable identification. The distribution of each plant described is indicated on a miniature map of Australia. No botanical inaccuracies were evident except for a misidentification of the prickly pear species illustrated on page 173. There are six introductory chapters, all of which I found absorbing reading for the fresh perspectives they gave, not to mention the numerous interesting facts and quoted opinions they bring together. I found especially interesting the discussion in Chapter 4 on relationships between various fruit types and their dispersal by birds, bats and even lizards. Chapter 6, on the Aborigines, likewise reveals an enquiring approach as well as a wide acquaintance with previously published work. In summary: highly recommended, despite the rather high price for a modest-sized book.

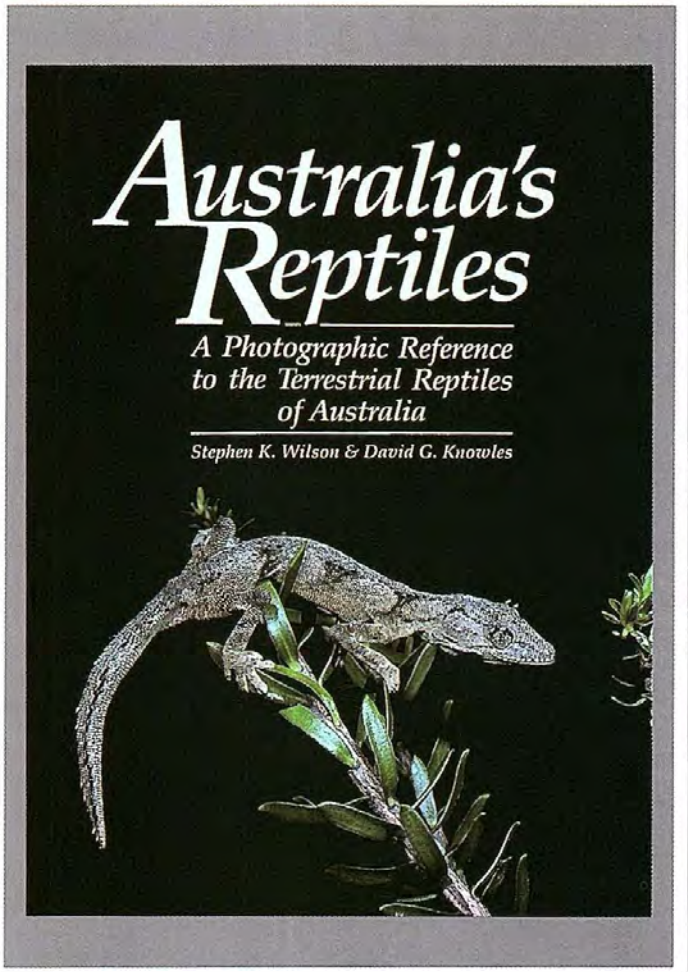
—**Tony Rodd**

Australia's Reptiles

By David G. Knowles and Steven K. Wilson. Collins Publishers, Sydney, 1988, 447 pp. $75.00.

For the past 15 years Cogger's *Reptiles and Amphibians of Australia* has been the foundation volume for many herpetologists and naturalists requiring an Australia-wide guide to the continent's reptile and amphibian fauna. While the quality of photographs in Cogger's publication are excellent, the ratio of 1:4 for colour to black and white representation was the obvious shortcoming upon which future publications would target. This is exactly what David Knowles and Stephen Wilson have done with the publication of *Australia's Reptiles*, providing almost 850 colour photographs of approximately 650 terrestrial Australian reptiles.

In content, this book has an account of each described species of terrestrial reptile comprising size, a colour-oriented description, diagnostic comparison with selected congenors, distribution (including a map), habits, and a colour photograph of a live individual or preserved museum specimen. The written accounts are presented as slabs of continuous text broken into two sections by the median placement of the 55 x 88mm-format photographs. In this regard the publishers have failed to take the initiative and tackle the problem of text and photo placement any differently to Cogger's volume. Placement of the appropriate photographs and maps with the individual species account would have simplified use of the book. Further, the more-or-less uniform size of the photographs has limited presentation of the more spectacular photographs of animals in their natural habitat. Photographs that portray either the habits or a reasonable representation of the habitat in which the animal occurs offer the reader an insight into aspects of the biology of the species often not available in the text. Such photographs, like the Water Python (*Bothrochilus fuscus*) feeding on a Masked Plover (Fig. 687) or the Monitor Lizard (*Varanus panoptes panoptes*) in defensive response (Fig. 662), where the animal photographed occupies a relatively small proportion of the photograph relative to the background, suffer loss of detail. To appreciate the degree of detail lost, reference need only be made to the cover-piece photograph (approximately half an A4 page) and the smaller (by one sixth) presentation of the same photo (Fig. 113).



Inconsistencies in the treatment of supposedly undescribed species occur too often. Photographs labelled with their generic name followed by "sp." are treated variably in the text; some (such as the five *Lampropholis* sp. pictures) have no corresponding species accounts or diagnoses, yet others (such as *Sphenomorphus* sp. 1) do. Another criticism concerns the resurrection without explanation of names formerly thought to be synonyms. For example, *Carlia aerata, C. laevis* and *C. macfarlani*—none of which appear in the editions of Cogger—are listed as three separate species. No reasons or references as to their recent recognition as separate species are offered. These criticisms are only some I have identified in the areas of Australian herpetology with which I am familiar.

The strength of this publication lies in the extent of the photographic coverage, particularly interspecific variation in colour patterns, and uncommon species or those with restricted distributions. It should, in most instances, serve as a ready reference for people who simply want to identify species of reptile they have observed, while naturalists and professional herpetologists alike will welcome the photographs of live specimens of species not previously illustrated.

The authors of *Australia's Reptiles* must be credited for the accumulation of so many top-quality photographs in the one volume, enabling them to present pictorially the diversity of our reptile fauna of which many people will have previously been unaware.

—**Ross Sadlier**
Australian Museum

The Contented Botanist: Letters of W.H. Harvey

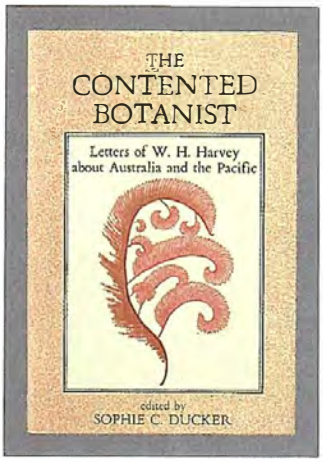
Ed. by S.C. Ducker. Melbourne University Press, Melbourne, 1988, 413 pp. $65.95.

Intrepid botanists have not been rare on the continent of Australia. Since the advent of white men there has been a steady flow of curious, cultured, scientific minds to the 'new' territory. But on the evidence of his letters alone, the engaging William Henry Harvey, Professor of Botany from Dublin, leads the field as a chronicler of places, people and species.

Dr Sophie Ducker, herself an eminent botanist, rediscovered Harvey's letters in the Asa Gray Herbarium at Harvard University and has reproduced those relating to Harvey's travels in Australia and the Pacific. The result—*The Contented Botan-*

ist—is a book of rare pleasure, one that absorbs and amuses a lay reader as much as it interests the contemporary botanist. Harvey's specialty was marine plants, the algae, as it is Ducker's. He was also able to identify the higher species, having improved his knowledge of exotic plants during the six years he was Colonial Treasurer and self-appointed botanist in Capetown. During this period (1836–1842) he published his first major works, *The Genera of South African Plants* and *A Manual of the British Algae.*

In her introduction, Ducker points out that Harvey's only formal education was at the Quaker schools of Munster and



Ballitore, Kildare, where the headmaster was a keen naturalist. At 16 he returned home to Summerville in Limerick and was apprenticed to his father in the family business. Harvey senior understood his son's need for the Irish countryside and, since the family fortunes did not depend on William, he was able to undertake "a lot of meandering". In 1830 at age 19, Harvey acquired a microscope. A year later he discovered a moss, *Hookeria laetevirens*, not previously recorded in Ireland and which he sent to Sir William Hooker, Regius Professor of Botany at Glasgow. Hooker befriended and encouraged the young man and asked him to write parts of the new edition of the *British Flora.* Harvey welcomed the chance. "I rise every morning at five and work till breakfast, examining or describing algae for the 'British flora'. If I do five species a day I think it good work."

Harvey's dream was to botanise in foreign lands. After his parents died he considered going to New South Wales where a family friend, Sir Richard Bourke, was Governor. However his South African appointment intervened, followed by his election as Keeper of the University Herbarium at Trinity College, Dublin, and his appointment to the Chair of Botany of the Royal Dublin Society in 1848.

Between 1847 and 1849 Harvey completed his Nereis australis and was invited to deliver 12 lectures before the Lowell Institute in Boston. During this stay in America his friendship with Asa and Jane Gray developed, resulting in much of the correspondence found in *The Contented Botanist.* Asa Gray was Professor of Botany at Harvard and an early supporter of Darwin. His influence did much to sway Harvey towards a later tolerance of the evolutionary theory.

Harvey saved and planned for his trip overland to Australia and finally arrived in January 1854 in Albany, Swan River Colony. . ."when you land. . . you are up to your ankles in white sand in the streets. . ." His hunt for algae was poorly rewarded most of his time in Western Australia. But on Rottnest Island in June he described to his sister Hannah some of his more satisfying finds: ". . .the rock pools are of the most magnificent dimensions & often 10 or 12 feet deep—The water [in the rock pools] is invariably as clear as crystal (I had almost said as Air) & when the surface is calm, the view therein is extremely beautiful. . .Some [algae] are like ostrich feathers, as big & as soft—others like Persian-Cats' tails, or rather Squirrels, others like a string of beads. . ."

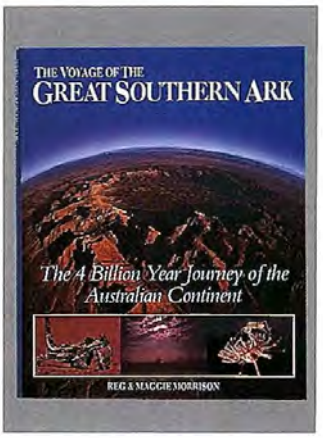
Harvey's adventures in Australia, recorded in his letters to his sisters, covered several areas near Melbourne and in northern Van Diemen's Land. He also visited Sydney, travelling north as far as Newcastle and Ash Island, and spent almost six months in the Pacific where he sailed round the Friendly Islands on the *John Wesley*, a brig belonging to the Wesleyan Methodist Missionary Society. Never robust, this journey left him ill and exhausted.

But W.H. Harvey, as his letters illustrate, was always aware of his own good fortune in doing what excited him most. His humour and acceptance of each day's lot stemmed as much from his own nature as from his Quaker faith, and he mixed with convicts and governors as easily as he walked the beaches in search of his seaweeds.

Harvey's letters describe an Australia long changed but still familiar. They are specific, informed and entertaining. When he died in Torquay in 1866, his old friend Asa Gray noted that he was one of the few botanists of the time who excelled both in phaenogamic and cryptogamic botany. "He was a keen observer and a capital describer. . . Handsome in person, gentle and fascinating in manners, genial and warm-hearted but of very retiring disposition, simple in his tastes and unaffectedly devout, it is not surprising that he attracted friends wherever he went. . ."

Excellent biographical notes and several botanical appendices accompany the letters. Ducker has produced a work of inspired and scrupulous research that has both historical and scientific significance for Australians and international readers.

—Marion Ord



The Voyage of the Great Southern Ark
By Reg and Maggie Morrison. Landsdowne-Rigby, Sydney, 1988, 334 pp. $59.95.

"A cautionary word to intending travellers. . ." Not your usual way to begin a book on the evolutionary history of the Australian continent, but then this is quite an extraordinary one. Reg and Maggie Morrison have combined interesting, informative text with stunning photography and produced a book for anyone fascinated by Australia.

The 4.6-billion-year evolutionary time span. has been scaled down into a 24-hour period for easy comprehension; and it works well. Each chapter deals with a major evolutionary event and carries a clock symbol showing the respective amount of time passed. We are therefore able to understand an incomprehensibly long period of time by making relative comparisons between major evolutionary events. For example, the landmass of Australia existed for over 18 of the 24 hours before multicellular animals were present, and humans came into the picture with only five minutes remaining on the clock.

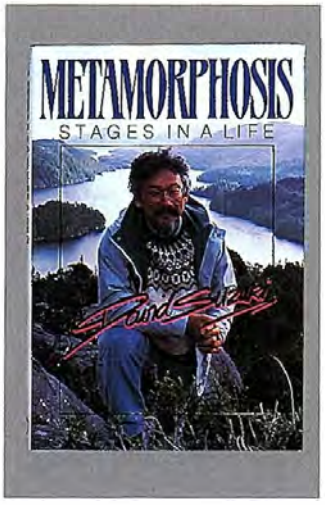
The author has utilised the assistance of many scientists in the production of the text and the result is a large amount of technical information presented in a simple and coherent form. In fact, so much time was spent working here at the Australian Museum that Reg Morrison has been made an Honorary Associate of the Museum.

The photography is simply superb, especially in the presentation of geological formations, which are represented here in all their fascinating glory. In recognition of his outstanding photography Reg Morrison was

presented with the Bronze Medal in the 1987 Nikon Photographic Awards.

I have nothing but praise for this outstanding work. It is the first attempt at putting together a comprehensive account of Australia's evolution and it will prove a hard one to beat.

—Jennifer Saunders
Australian Museum



Metamorphosis: Stages in a Life
By David Suzuki. Stoddart Publishing Co., Toronto, Canada, 1987, 304 pp. $15.95.

I'm almost certain it was a winter evening (in Canada they usually are). It was CBLT, Channel 6 Toronto; that much I *do* remember. I was just out of art college, apprentising in my first magazine design job. It was 1974.

In Canada, as I suppose in Australia, things were changing. A man on the moon, heart transplants, fuel shortages, a state-of-the-art war in Vietnam, and suddenly science was no longer something that happened only in a laboratory but on the front page or prime-time TV.

I turned on my television that evening to see for the first time "The Nature of Things with David Suzuki"—a very different kind of science program. He was instantly likeable, very much at home with his science and, as I watched Suzuki, I realised he was special.

Week after week he would appear and somehow manage to convey, combined with beautiful photography, the most obscure scientific notions simply, clearly and most enthusiastically. Today, some 15 years on, the program still airs in Canada as well as 55 other countries around the world.

David Suzuki is a geneticist by trade, although he is equally comfortable in a lecture hall, laboratory or in front of a television camera. Having already written a best-selling series of science books, at the age of 50 Suzuki decided to write about his own experiences.

"This book is an attempt to explain the factors that shaped my personality and influenced my priorities, aspirations and career. It tries to shed light on why I believe and act as I do, why I left the security and prestige of teaching and research for the turbulence of reporting."

"My life in retrospect has been marked by a series of transformations. It's interesting to note that in the rest of the biological world, profound change in the lives of many organisms is a natural and necessary part of their development. Often these changes involve dramatic transitions in physical makeup, behaviour and habit. This process is called metamorphosis."

From his Japanese roots, his childhood in western Canada, World War II warcamp internment, schooling in both Canada and the United States, Haight-Ashbury's flower power, a teaching post at the University of British Columbia, a failed marriage and remarriage, and on to television and print, Suzuki has definitely had his share of "profound change".

As a Canadian-born citizen of Australia, I felt at home with Suzuki's writing style. Paradoxically this is probably the only area of the book I can fault. Although a personal account, it *is* a book about a Canadian living in Canada and, as such, is littered with references to very specific politicians, places and personalities. Under other circumstances the Australian reader would probably be bogged down with these specificities but, after recent guest appearances on ABC radio and television, Suzuki's easygoing style and demeanour has ingratiated him with the Australian public.

"My real hope", he writes, "is to provide a different angle from which the reader may see her or his own experiences, values and beliefs". Sitting in my lounge room in Australia on a comparatively warm winter evening, Professor Suzuki's book has certainly done that.

—Stephen Costello

"We must replace the mouths of long extinct plant-eating giants with a sensible fire policy."

AUSTRALIAN WILDERNESS: AN IMPOSSIBLE DREAM?

BY TIM FLANNERY

HEAD OF MAMMAL DEPARTMENT, AUSTRALIAN MUSEUM

MANY CONSERVATIONISTS WOULD like to see large areas of Australia put aside as 'wilderness', or areas left totally uninterfered with by humans. However, as one who has studied both Australasian biohistory and ecology, I have come to the sad realisation that Australia is one of the few continents that cannot afford wilderness. In brief, this is because we (*Homo sapiens*) are the last of Australia's megafauna. We are the ecological equivalents of *Diprotodon, Thylacoleo* and all the rest. Removing us from the environment is equivalent to having a megafaunal extinction all over again. Such disruption leads to trophic cascades that cause the extinction of many small animal and probably plant species.

Our perception of this problem is clouded by the devastation of the Australian environment that has occurred over the past 200 years. We have come to see people, particularly Europeans, as a negative force in the environment. In fact, I am now convinced that much of the damage of the last 200 years was not so much the result of what Europeans did, but of what the Aborigines could not continue doing. The real damage to Australia occurred thousands of years ago, with the extinction of the continent's megafauna, including almost all of the 60 largest animals. Aborigines replaced in part those giants, preventing a potentially devastating trophic cascade; until 1788.

Imagine the African savanna today if all large animals were removed from it. Within a few years, vast amounts of vegetation would build up. Sooner or later, that vegetation would be consumed, not by animals' mouths, but by fire. Those few species that are adapted to the occasional fire previously would proliferate. With the build-up of fuel they could ensure vast blazes, to the detriment of the less fire-adapted plants. Very soon, the smaller animals dependent upon such plants, and those unable to recolonise after the widespread blazes, would follow the large animals into extinction.

The first part of this scenario was played out in Australia some 40–20,000 years ago, when we lost 60 of the largest animal species found on the continent. In Australia, we had many fire-adapted plants, so why did we not experience a trophic cascade, with the extinction of many smaller animal species and fire-sensitive plants? The answer lies in the Aboriginal land management practice of firestick farming. Throughout the length and breadth of Australia, Aborigines constantly lit small, relatively cool fires, so consuming in a relatively harmless way the tinder that otherwise would have gone up in a spectacular, hot conflagration. This provided a mosaic of habitat that supported many small mammals, protected pockets of fire-sensitive plants (such as those in rainforests) from hot burns and, most importantly, prevented the vast fires of the inland that scorch hundreds of square kilometres.

We can gain some impression of the prevalence of firestick farming, and its drastic effects, from the journals of early Australian explorers. Giles saw so many small fires during his explorations that he called the Aborigines the sons of Prometheus. Banks, in 1770, described the area around Kernell and other parts of Botany Bay as a "very barren place without wood. . .very few tree species, but every place was covered with vast quantities of grass. . .the trees were not very large and stood separate from each other without the least underwood". It would be hard to imagine a greater contrast with the dense tangles of Kernell and other national parks nearby as they are today, which presently support large and devastating blazes. Firestick farming maintained these open parklands that Banks was able to traverse so easily. When the practice stopped with European settlement, species that depended upon open conditions, such as the White-footed Rabbit-rat (*Conilurus albipes*) and Tasmanian Bettong (*Bettongia gaimardi*), disappeared forever from the Sydney area.

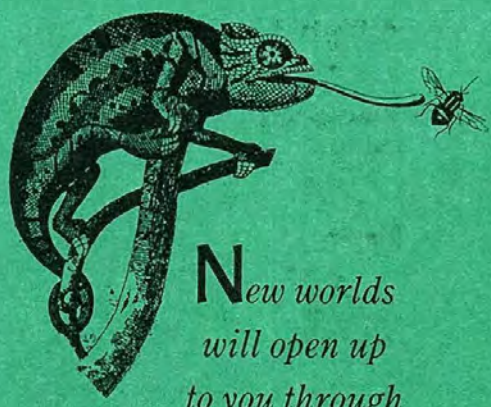
Research in central Australia is showing just how dependent many medium-sized Australian mammals were on firestick farming. The disappearance of perhaps as many as 17 such species from the arid and semi-arid zones correlates with nothing but the removal of the traditional Aboriginal way of life in an area. When the Aborigines left, the large blazes started, reducing a diverse, relatively rich environment to a uniform, unstable, simplified and often plague-species-ridden ecosystem. Concommitently, the large species such as the Red Kangaroo—first controlled by native predators, then by Aboriginal hunting—built up numbers. In areas without Dingoes their vast numbers further threaten the devastated system.

So, where does this sad history leave wilderness areas? If we are happy to watch as biotic diversity is gradually lost from our wilderness areas, making them unstable and susceptible to invasion, then perhaps we should just let them be. However, if we wish to see them remain in their complex grandeur, we must accept that humans have been an integral part of the Australian landscape for 40,000 years. If we fail to manage the system, and withdraw the last of the megafauna, collapse will follow. Specifically, we must replace the mouths of long extinct plant-eating giants with a sensible fire policy, and those of the carnivores with effective culling and species management programs. ■

Can we really afford to have large areas of untamed wilderness?

WELDON TRANNIES

Dr Tim Flannery is head of the Mammal Section of the Australian Museum. He has a deep concern for the future of the Australian environment.



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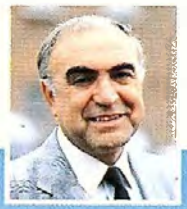
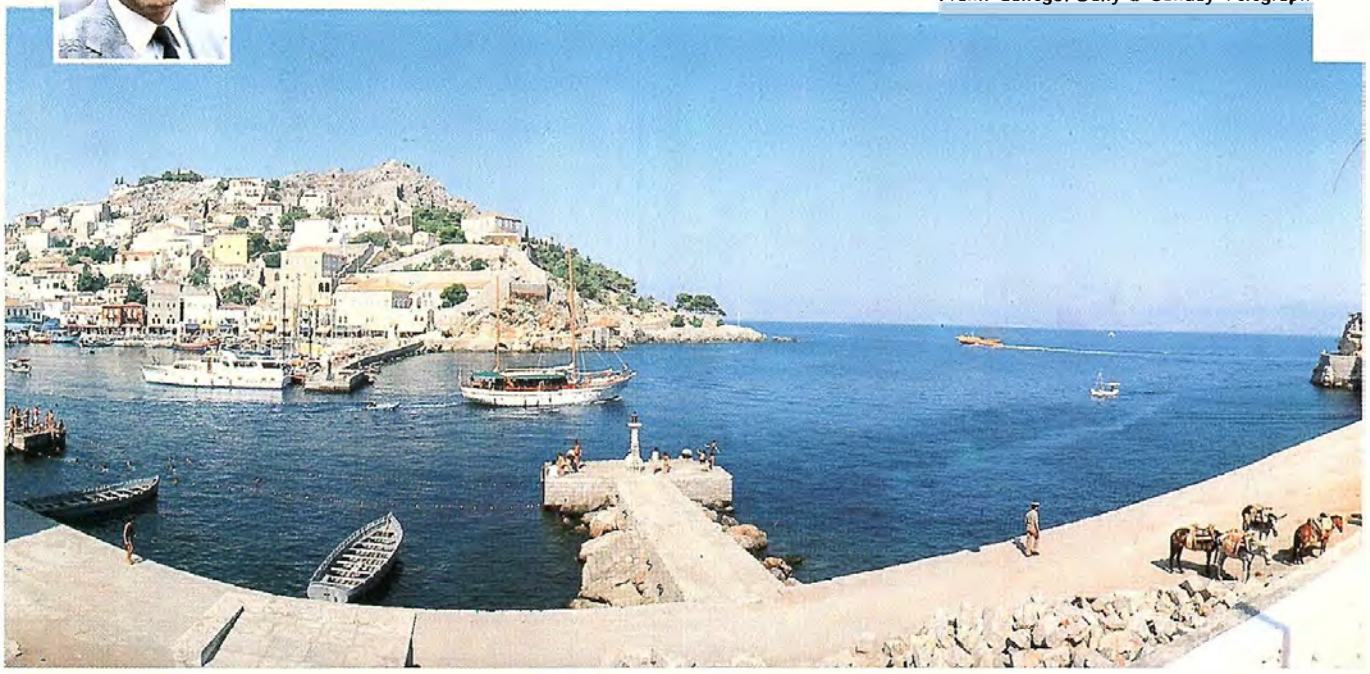


Frank Gallego, Daily & Sunday Telegraph



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