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HALLEY'S COMET COMETH

by John Davis

A natural history magazine would not be complete without exploring some facets of astronomy and the return of Halley's Comet is an event that most of us are not likely to witness more than once. Dr John Davis, affiliated with the Chatterton Astronomy Department of the University of Sydney, takes us through the history of Halley's Comet and explains this fascinating phenomenon.



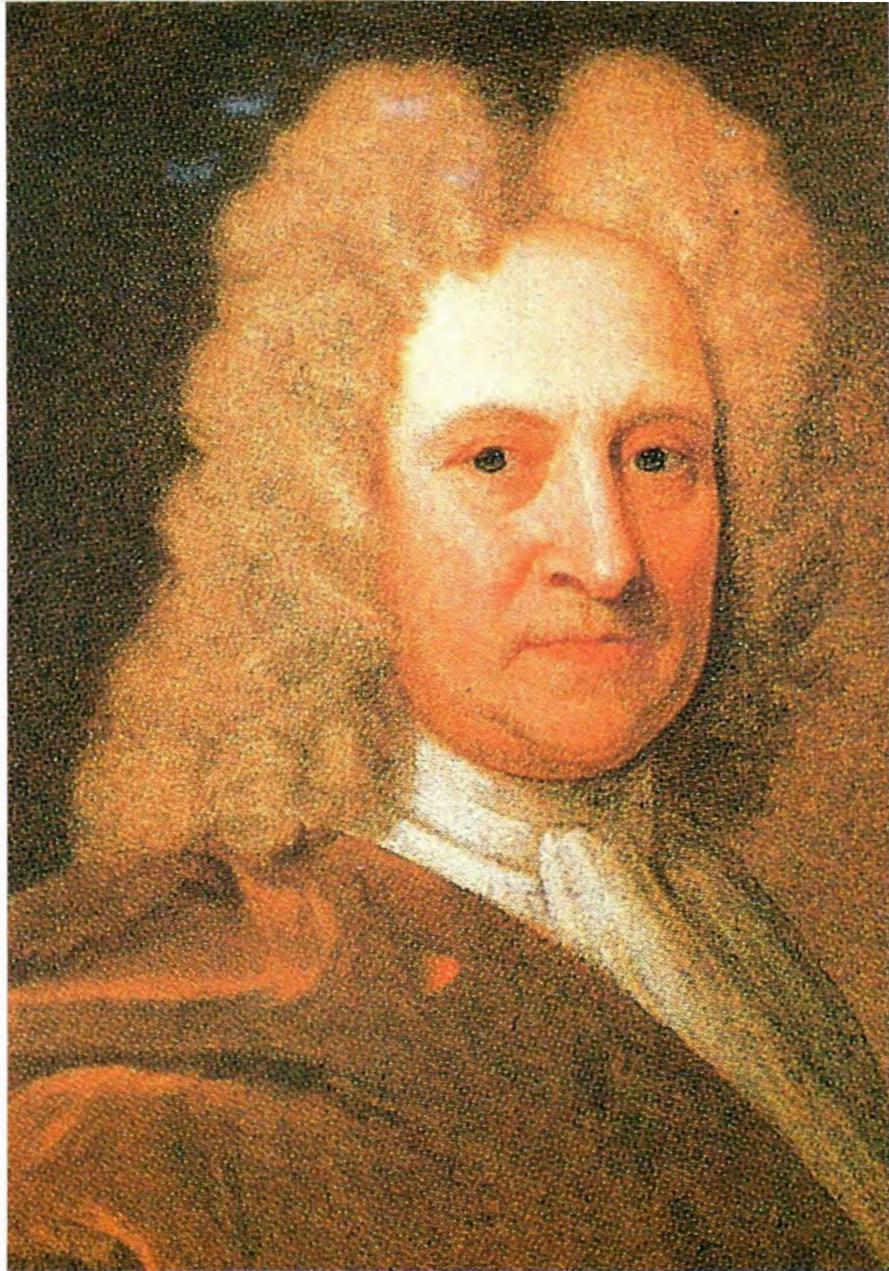
The return of Halley's Comet to the vicinity of the Sun in 1986 is being heralded by wide coverage in the media, reflecting the enormous public interest generated by this event. Lectures on the Comet are being given, books are being published and a variety of expeditions to dark sites in the country to view the Comet are being advertised. The contrast with the general attitude towards comets before Edmond Halley came on the scene is stark indeed. Before Halley, comets were regarded as evil omens. Their sudden unheralded apparition in the sky and unusual changing appearance struck fear into the hearts of superstitious people. If a king or emperor were to die or lose an important battle soon after the appearance of a comet, their fear was apparently justified! Shakespeare summed it up when he wrote in *Julius Caesar*: "When beggars die there are no comets seen: the heavens themselves blaze forth the death of princes."

The Roman Emperor Vespasian (79 AD) was another believer and proclaimed, on the appearance of a bright comet, that: "This hairy star does not concern me: it menaces rather the King of the Parthians for he is hairy and I am bald". (The word 'comet' comes from the Greek *kometes aster*, literally meaning 'hairy star'.) Unfortunately for poor Vespasian, he got it wrong—he was the one to die that year. Of course, upon reflection, it would always be possible to find some apocalyptic event to associate with the appearance of a comet. Historically it seems that is exactly what people did.

The Man Behind the Comet

It was Edmond Halley (1656–1742) who removed the mystery surrounding comets. A contemporary of Sir Isaac Newton and Sir Christopher Wren, he made major contributions to many diverse subjects. Halley became a Fellow of the Royal Society at the age of 22 for his achievement of producing the first catalogue of stars in the

An artist's impression of a cometary nucleus, described as a 'dirty iceball'. As a cometary nucleus approaches the Sun, its irregular surface is heated by the Sun's rays. The gas and dust that are released form a cloud or coma around the nucleus. Painting: Christine Bruderlin.



Portrait of Edmond Halley.

southern sky, based on observations made with a telescope. He plotted the first meteorological chart and the first magnetic charts of the Atlantic and Pacific areas. He drew up the first-ever mortality tables and devised the Venus transit method for determining the distance of the Sun from the Earth. He seems to have dabbled in anything that took his interest and advanced the current knowledge and understanding in the process. But despite his many significant contributions to science, he is generally remembered today only for the Comet.

Halley's interest in comets apparently stemmed from his attempts at working out the orbits of the planets. Along with Robert Hooke, he worked out the type of force required to keep the planets in their orbits around the Sun but was unable to deduce the actual form of the orbit. He went to see Newton in Cambridge for help and found that Newton had worked it all out but had mislaid his notes! Nevertheless, it seems that Halley's

visit triggered Newton to renew his study of celestial mechanics with the result that Newton produced his monumental *Principia*—a milestone in the progress of science. Halley played a major role in the publication of the *Principia* with the Royal Society deciding that "Mr Halley undertake the business of looking after it, and printing it at his own charge"—which he did. Furthermore, Halley computed the orbit of the comet of 1680 with the aid of Newton's mathematics and a drawing of the orbit of this comet appears in the *Principia*.

In 1705, Halley published *A Synopsis of the Astronomy of Comets*, containing the orbits of 24 comets, which he had computed largely from historical records of observations. He noted that the orbit of the comet of 1682, which he had observed himself, and the orbits of the comets of 1531 and 1607 were remarkably similar. He came to the bold conclusion that these were one and the same comet and, in his own words, wrote: "I may,

therefore, with confidence predict its return in the year 1758. If this prediction is fulfilled, there is no reason to doubt that other comets will return". He also wrote, modestly, that if he were proved right, "candid posterity will not refuse to acknowledge that this was first discovered by an Englishman". Halley died before the Comet returned, but return it did. In honour of his prediction the Comet was named after him, thus fulfilling both his predictions.

Although all comets move in orbits around the Sun, many take so long to return to the vicinity of the Sun that previous visits to our neighbourhood were made before existing records started, or their next return is so far off in the future that they are of no immediate interest. Some comets return regularly every few years and are known as periodic comets. The periodic comets are those with the smallest orbits and they are also generally faint. Halley's Comet is an exception—it is the brightest of the periodic comets and returns on average once every 77 years. Its returns have been traced back to at least 240 BC and records of every return since then have been found.

Because it has generally been a bright comet, Halley's has often been regarded as ominous and consequently has been blamed for a fair share of disasters. For example, the *Nuremburg Chronicles*, published in 1493, give an account of the events of the year 684 AD when Halley's Comet appeared. The Comet caused three months of rain, thunder and lightning; people and flocks died and grain withered in the fields. Finally, eclipses of the Sun and the Moon were followed by a plague—clearly it was not a very good year! The Comet's appearance in 1066 was regarded by the Saxons as a bad omen for the Battle of Hastings—although presumably the Normans must have looked upon it as a good omen. Either way, the event is recorded for posterity in the Bayeux Tapestry.

There are many other events in history that have been associated with Halley's Comet but mention should be made of the 1301 return. This inspired several artists including Giotto di Bondone who used the Comet as a model for the Star of Bethlehem in his painting of the Adoration of the Magi. We now know that Halley's Comet did not appear at the currently accepted time

of the birth of Christ but the European Space Agency has named the spacecraft they despatched to rendezvous with Halley's Comet 'Giotto' in honour of the famous painting.

What's in a Comet?

It is generally accepted that a comet has a nucleus, which is best described as a 'dirty iceball'. It is thought to be a conglomeration of frozen gases (ices), dust and gravel-like particles of solid material. Cometary nuclei are thought to have been formed when the solar system condensed from a dense cloud of interstellar gas and dust some 5,000 million years ago. As the density of the condensing cloud increased, gas molecules froze to dust particles in collisions and 'snowballs' were formed. Collisions of 'snowballs' produced larger bodies.

In the outer regions of the solar system, the collisions were fewer, because the density was lower, with the result that a very large number of small, icy bodies were formed with diameters ranging from a few metres to a few kilometres. There are thought to be as many as one billion of these cometary nuclei in the outer reaches of the solar system with a total mass of only a few per cent of the Earth's mass. This enormous swarm of cometary nuclei, known as the Oort Cloud (after the Dutch astronomer who first suggested its existence) moves in a roughly circular orbit around the Sun at a distance at least a thousand times greater than that of the outermost planet. Every ten million years or so it is thought that a passing star comes close enough to disrupt the orbits of some of the cometary nuclei in the

Comet Halley photographed with the 3.9 metre Anglo-Australian telescope near Coonabarabran, New South Wales on 9 December 1985. The picture was constructed from three separate exposures in red, green and blue light which were combined in the darkroom. The telescope accurately followed the comet, leaving the star images elongated. The outermost parts of the round head are tinged blue by the action of ultraviolet sunlight on gases such as cyanogen that boil off the icy nucleus. The yellow-white streaks in the tail result from miniscule grains of dirt that reflect sunlight after being shed from spots on the nucleus. Photo: D.F. Malin; © Anglo Australian Telescope Board, 1985 ▶

Oort Cloud. Some nuclei are deflected away from the Sun and are lost to the solar system forever but others are directed inwards towards the Sun. Some of the latter become bright enough in the vicinity of the Sun to be visible from Earth.

Away from the Sun, cometary nuclei are icy cold and too faint to be seen from the Earth. However, as a nucleus approaches the Sun, its surface is heated by the Sun's rays and the frozen gases near the surface are transformed into gas. In the process, dust particles are also released into



the space surrounding the nucleus. The nucleus is typically five kilometres in diameter but the cloud of gas and dust surrounding it as it approaches the Sun grows to form a head or coma, which may be 100,000 kilometres in diameter! The solar wind, a stream of charged particles streaming away from the Sun at speeds of 400 to 500 kilometres per second, together with solar radiation, carry and push the gas molecules and dust particles in a direction away from the Sun to form the characteristic tail of the comet. The tail may grow to several tens of

millions of kilometres in length but it always points away from the Sun. Therefore the direction of the tail does not indicate the direction in which the comet is moving—as the comet approaches the Sun, its tail will be streaming out behind it but as the comet recedes from the Sun, its tail will precede it.

The Return of Halley's Comet

The last return of Halley's Comet occurred in 1910 and on that occasion the Earth actually passed through the comet's tail. It had been discovered

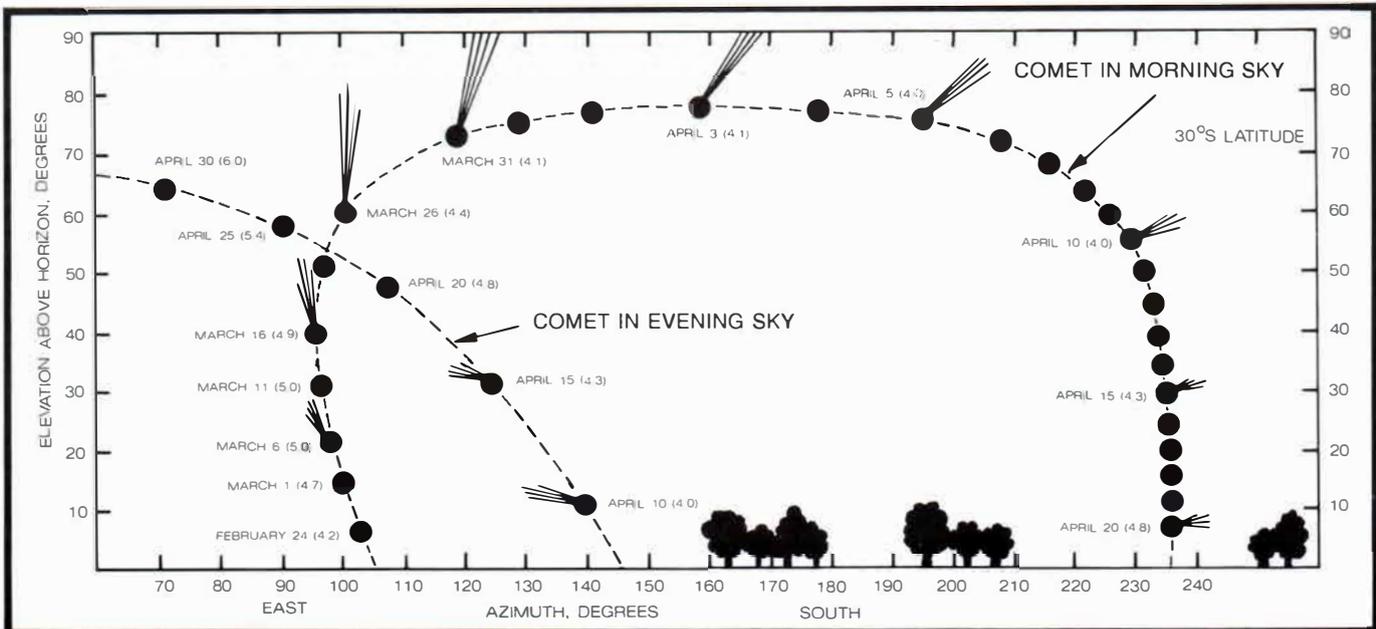
from studies of the light emitted by atoms and molecules in the comae and tails of comets that, as well as innocuous atoms such as hydrogen, carbon, iron, nickel and copper, and molecules such as water, there were also toxic molecules like cyanogen and hydrogen cyanide. This worried many people and led to headlines such as the one in a Chicago newspaper that proclaimed: "Chicago is terrified: women are stopping up doors and windows to keep out cyanogen". However, the density of the gas in comet tails is so low that





A panel from the Bayeux Tapestry depicting the 1066 appearance of Halley's Comet. As the people on the left gaze at it in bewilderment, an astrologer tells King Harold that it is an omen.

Observing conditions for Halley's Comet in 1986 for observers at latitude 30° South. The positions of the Comet are given for the end of evening astronomical twilight and the beginning of morning astronomical twilight. Approximate visual magnitudes (a measure of brightness) are given in parentheses following the dates. Drawing: Sue Oakes.



there is really nothing to worry about. Imagine exhausting all the air from the Sydney Opera House and then allowing a fly to breathe out in it—once. That would give the sort of gas density that exists in comet tails!

On this return, Halley's Comet will unfortunately not be in such a favourable position as when last seen in 1910. In fact, this return is possibly the least favourable of all the 29 recorded returns. It is simply a question of the geometry of the orbits and the relative positions of the Earth and the Comet. When the Comet is at its intrinsic brightest, which is just after its closest approach to the Sun (known as perihelion), the Earth is on the far side of its orbit, just about as far from the Comet as it could be.

Since this return is not particularly favourable, one might well ask why so much interest is being shown by scientists around the world. There are two reasons. Firstly, Halley's Comet is intrinsically bright, making it relatively easy to observe and, secondly, its reappearance can be accurately predicted, making it possible to plan a

comprehensive observational program well in advance. This is particularly important for spacecraft missions since there is inevitably a long lead time in preparing space-borne experiments for launch. In fact, five spacecraft have been dispatched to rendezvous with Halley's Comet early in March 1986. These include the European Space Agency's Giotto spacecraft, which is aimed to pass within approximately 500 kilometres of the nucleus. All the spacecraft carry numerous experiments to study different aspects of the cometary phenomenon, including the composition and structure of the coma and tail. They will also study the composition and properties of the solar wind. In addition, a comprehensive program to observe and monitor the Comet's behaviour, involving some 43 participating countries, is being co-ordinated by an organisation called the International Halley Watch. Involving over 800 professional and 3,000 amateur astronomers, this program will ensure that the Comet is observed continuously using all the available in-

struments and techniques. At the end we should know a great deal more about comets in general, about the origin of the solar system and about the environment in which the Earth orbits the Sun.

The closest that Halley's Comet will come to the Earth this time is 60 million kilometres as it passes the Earth on its journey away from the Sun on April 11, 1986. The Comet will be at its brightest as seen from Earth on this date and, fortunately for those of us in the Southern Hemisphere, it will appear high in the southern sky. In fact, the best time to see it will be the week or so around the new moon of April 9. To see it at its best, it will be necessary to get away from city lights and pollution—undoubtedly the best chance of clear skies is to go inland, away from the coast. When and where to look? The best advice is to watch the newspapers. They will no doubt publish up-to-date information, star charts and finding guides for this once in a lifetime (for most of us anyway) event. □

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W Australian WILD FOODS S

Text and Photos by Tim Low

Wild foods grow best along edges—on fringes of rain-forest, margins of streams and the seashore. At these edges, Aborigines once gathered fruits, dug for roots, netted fish and hunted.

The seashore was the most favoured of the edge environments. Apart from its bounty of fish and shellfish, fruits and leaves, it provided a pleasant place to live. Sandy beaches made travel easy and gave relief from the gloom of the forest.

Seashore vegetation is especially rich in wild fruits. In the north, Aborigines feasted on the hefty fruits of lady apples, pandanus, lolly berries and yellow plums. In the south, the seashore fruits are smaller but just as tasty. One of the most common and widespread of these is Coast Beard Heath (*Leucopogon parviflorus*). Its tiny, yellowish fruits have a delightful lemony taste.

Coast Beard Heath grows on southern seashores between Perth and Fraser Island. It is a common shrub of beaches, dunes and headlands, sometimes forming dense thickets. The stiff leaves are one to three centimetres long and the flowers are tiny

Goats-foot *Convolvulus (Ipomoea pes-caprae brasiliensis)* has edible tubers but they sometimes taste bitter and burn the throat.



The fruits of Coast Beard Heath (*Leucopogon parviflorus*) were apparently popular with southern Aborigines and also early settlers who dubbed them 'white currants'.

and white, with five furry petals. The fruits are produced almost any time of year, but ripen mostly in summer and are relished by seagulls. In 1792 the French botanist Riche was lost for 54 hours on the coast of South Australia with nothing to eat but these fruits.

Coast Beard Heath belongs to the heath family Epacridaceae—one noted for its many shrubby species with sweet, edible fruits. The heaths are identified by their small, stiff leaves without obvious veins on the upper surface and by their small fruits containing a single stone. The leaf tips are often spiny and the undersides are pale. Other heaths that grow by the sea include the five corners (*Styphelia*).

Ripe fruits of five corners are green—an unusual colour in fruits. They are eight to ten millimetres long and are half-covered by five scaly bracts—hence the name. The fruits of *S. viridis* were gathered by Stradbroke Island Aborigines, for they are deliciously sweet and succulent.

Styphelia viridis is a scrawny shrub of southern Queensland and eastern New South Wales. Although usually encountered by the sea, it also grows on inland heaths near rocky outcrops. The little fruits ripen in winter and

spring, and are one of my favourite bush foods.

Around Sydney, in the sandstone heaths, the more common species of five corners is *S. triflora*. This heath bears close resemblance to *S. viridis*, but the flowers are usually a shade of pink or yellow, not green.

One of the few tuber-bearing plants of the seashore is Goats-foot *Convolvulus* or Coast Morning Glory (*Ipomoea pes-caprae brasiliensis*). This creeper is common on beaches and dunes in northern and eastern Australia, as far south as Sydney. Its seeds are carried by ocean currents and the plant also occurs on beaches between India and Hawaii. Its bell-shaped flowers are purple or pink and the folded leaves are shaped like cloven hooves, hence its name *pes-caprae*, meaning 'foot of goat'.

Goats-foot is closely related to Sweet Potato (*I. batatas*), but its chewy, tasteless tubers are a poor substitute for the cultivated vegetable. Groote Eylandt Aborigines roasted and ate them only in times of food shortage, for they sometimes tasted bitter and burned the throat. The roots were a famine food used by Hawaiians, who considered large amounts poisonous.

The leaves of Sweet Potato are eaten as a vegetable in developing nations. So, too, are the cooked leaves of Goats-foot. They were eaten by the Indians and Japanese, but not by Australian Aborigines who ate few kinds of leaves. The succulent young leaves are a handy vegetable for beachside campers, although older foliage becomes chewy and bitter.

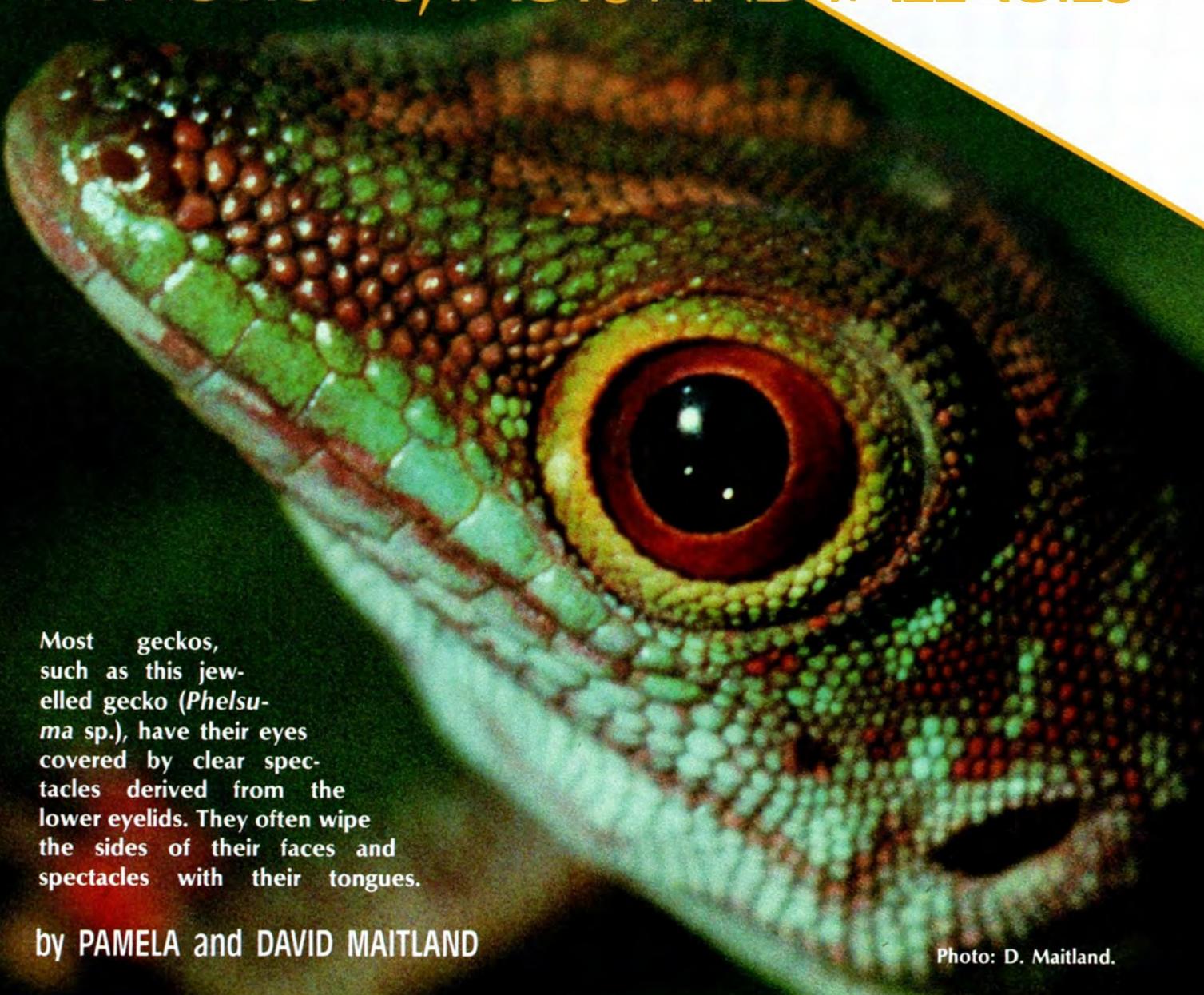
Northern Aborigines used the leaves as poultices on animal stings, boils and aches, a practice that may have been learned from visiting 19th century fishermen. The leaves are also used as a poultice in Indonesia and Indochina.

Happy eating...



EYES

FUNCTIONS, FACTS AND FALLACIES



Most geckos, such as this jewelled gecko (*Phelsuma* sp.), have their eyes covered by clear spectacles derived from the lower eyelids. They often wipe the sides of their faces and spectacles with their tongues.

by PAMELA and DAVID MAITLAND

Photo: D. Maitland.

Have you ever wondered why babies are born with blue eyes; or why veins look blue, rather than red? Why do birds have such gangly necks? Why is it wise not to wear blue clothes when bushwalking? Do carrots really help us see in the dark? These are just some of the questions Pamela and David Maitland from the School of Zoology at the University of New South Wales ask about eyes. Read on and discover more.

As humans, we think we pretty much have the best of everything and that, as far as animals go, we're at the top of the heap. That we can even entertain such a thought is justification enough for this—we have a superb brain. However, it is sobering to consider that much of the rest of our body is an improvisation of firstly, the basic vertebrate plan and secondly, the mammalian one.

Putting Our Eyes in Perspective

The human eye, for example, is complex because the vertebrate eye in general is complex. But, of all the vertebrates; reptiles and birds have it over us and, in fact, over all mammals. This is because mammals evolved from small nocturnal ancestors whose eyes, although they worked well in dim light, lacked the ability to see fine

detail like those of an animal active during the day (diurnal). Diurnal mammals have not regained the perfection of the eye structure found in diurnal reptiles and birds. For example, virtually all reptiles and birds can see colour—but we are one of the few mammals that can.

The Vertebrate Eye Rods, Cones, Carrots and Black Holes

All vertebrates share the same kind of eye—the lens eye. Light enters the eye through the cornea, the transparent bulge at the front, which in terrestrial vertebrates does most of the focusing. Because of its backing of water (the aqueous humour) the cornea in aquatic vertebrates loses this function and has little effect on the light coming in from the water out-

side. Behind the cornea is a pigmented diaphragm called the iris which is supported by muscle. Light passes through the hole in the iris: the pupil. The iris contracts or relaxes to regulate the amount of light entering the pupil. The light then passes through the lens, also supported by muscle. The lens is made of a fibrous, jelly-like material and is flexible; its shape is controlled by the surrounding muscles. In terrestrial vertebrates the lens supplements the cornea and varies the focus. In aquatic vertebrates the lens does *all* the focusing and, for example, in fish is virtually spherical: the greater the curvature of the lens, the more powerful it is.

Light is focused by the lens onto the retina after passing through the clear jelly (vitreous humour) in



between. The human retina is most sensitive at a small retinal depression called the 'yellow spot' or 'macula'. In the centre of this region, the 'area centralis', there are only densely-packed cones. (We move our eyes while we read to keep the fine print focused here.) Surrounding the area centralis are rods which, without forming a sharp image, are used to size up moving objects and to see in conditions of dim light. It is easier to see a star in the sky if we look slightly to one side of it because we are moving its image from the area centralis onto the rods.

Nocturnal animals have large eyes. That is, the proportion of the eyeball that is actually exposed is much greater than in diurnal animals (hence the endearing pop-eyed look of the bushbabies or lorises of eastern Africa). These animals have relatively large corneas in order to catch as much light as possible. Additionally, the pupil opens up very wide and the lens is large and positioned close to a small retina. This has the same effect as that of a slide projectionist, who gets a brighter image by placing his projector close to a small screen.

We've all heard the old wives' tale 'eat carrots to see in the dark'—but it's true! The rods, which are so important for night vision, contain a pigment called 'visual purple' or rhodopsin. Without rhodopsin the rod is no longer sensitive. Vitamin A is essential in the synthesis of rhodopsin and is itself derived from another pigment, carotene, which is responsible for making carrots orange. If there is not enough Vitamin A in the diet, then little rhodopsin is made and the condition known as night-blindness occurs. During World War II, every effort was made to keep a high concentration of rhodopsin in the retinae of night fighter pilots by providing them with carotene- and Vitamin A-rich foods (within limits, of course!).

Pupils come in basically two shapes: slits and circles. Round pupils do not open and close as far as slit pupils because the sphincter muscles

The eye of the Cane Toad, like most terrestrial vertebrates, has a curved cornea which aids the lens in bending the light as the eye focuses. For this reason, the lens does not need to be nearly as spherical as it is in fish, for example. The pupil in this case is a horizontal slit. Photo: D. Maitland.



The Common Brushtail Possum's highly sensitive eyes, adapted for seeing well even in very dim light, are protected from glare by pupils that close down to pear-shaped slits. Photo: D. Maitland.

in the iris are so arranged that its tissue bunches up when the pupil closes. Therefore, most nocturnal animals that are also active during the day have slit pupils to protect their sensitive retinae.

Marsupials generally have round pupils but the Koala's pupil shuts right down to a sliver. Koalas are not very active during the day, becoming far more ambitious about life towards sunset. The leaf edges of the gum trees they inhabit turn towards the sun to avoid dehydration. Because a minimum of shade is thus cast, Koalas must protect their eyes in this novel fashion.

The possums are also largely nocturnal but they aren't totally flummoxed by bright light either. Their pupils are drop-shaped and can also contract to mere slits, thus protecting their eyes from glare.

While on the subject of pupils, have you ever wondered why they are black? At the very back of the eye, behind the retina, is another layer called the choroid. This contains blood

An artist's impression of what we would look like if humans had compound eyes with the same resolving power (ability to see fine detail) as our own eyes. Each facet represents 10,000 actual facets. Drawing: Sue Oakes.





◀ This march fly is about to feast on human blood. The compound eyes of insects have corneas made of the same tough material that covers the rest of the body so there is no need for protective eyelids. Photo: D. Maitland.

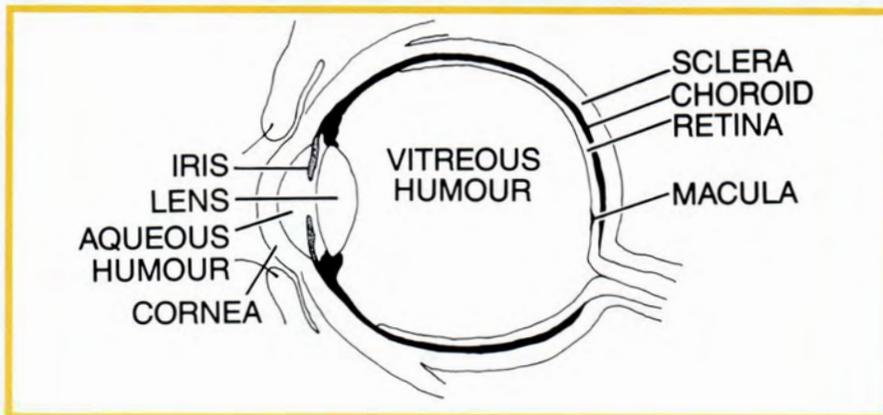


Diagram of the human eye. Light passes freely through the cornea, aqueous humour, pupil, lens and vitreous humour to the image-forming retina. Drawing: P. Maitland.

vessels and black pigment. The pigment absorbs any light not already absorbed by the rods and cones, and so, in the absence of light, the pupil appears black. True albinos lack pigmentation of any sort, including that in the choroid. Consequently their pupils are not black—just a darker shade of pink than the iris. The pink colour is due to the unmasked blood in the vessels. Albinos, therefore, have very poor vision because of the abundance of stray light in their eyes.

The Trick Behind Blue Eyes

The iris is made up of three layers: an inner muscular layer, a middle layer containing blood vessels and an outer layer which may be pigmented to a greater or lesser degree. The only pigment in all eyes is brown; it's just that blue-eyed people have a negligible amount and brown-eyed people have a lot. Babies' eyes, even if destined to be brown, are blue because the pigment has not yet formed. The reason that unpigmented irises look blue involves the same optical trickery responsible for veins just underneath the skin looking blue, even though they contain dark red

blood. The transparent outer layer of the iris that overlies the blood vessels, or the skin that covers the veins in an arm or leg, acts as a filter and absorbs all colours but blue. Blue is reflected and this is what the observer sees.

Socket To Me

The eyes of vertebrates are housed in the skull by the orbits, to which the eye muscles are attached. Birds' eyes, however, are usually so enormous (they almost touch in the middle of the skull) that there is no room in the skull for eye muscles. Hence most birds have no eye movement. This explains why birds have such flexible necks. The wise old owl, whose head only appears to be glued to its body because of all those feathers needed for soundless flight, actually has one of the most flexible necks of all. It can turn its head 270° and bend it back until it is upside-down!

The orbits of frogs and toads, however, have no bony floor. When a frog or toad swallows, its eyes disappear into its head. What's actually happening is that the eyes are being pushed down into the throat and used as ramrods to get the food down.

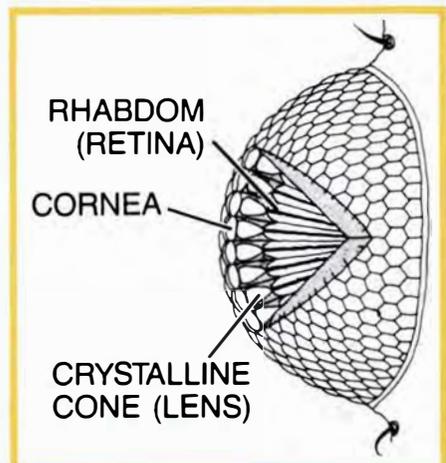
The actual position of the eye sockets is important to an animal's particular lifestyle. When an animal has eyes on either side of the head, each eye receives a separate large

field of view which enables it to see practically all the way around itself. The brain interprets two completely different images, one from each eye. A foraging herbivore needs to have this broad, sweeping view of its surroundings to keep a lookout for approaching predators. On the other hand, having eyes well forward means that each eye sees virtually the same image, that is, stereoscopic vision. This allows for the judgment of distances—vital to a jumping or striking predator.

Put a Lid on It!

Eyelids evolved in terrestrial vertebrates as protection against wind-borne dust, abrasive walls of burrows and vegetation, as well as too much light. Most importantly, however, they are essential for keeping the eye moist.

The nictitating membrane (nictitating meaning blinking) is the 'first' eyelid (that is, the first to evolve—not to be confused with its often-used vernacular, the 'third eyelid'). It closes from the nasal side of the eye outwards and is present in the eyes of adult amphibians and some reptiles (such as lizards) and is most highly developed in birds. The nictitating



Schematic diagram of a typical compound eye found in, for example, insects. A slice has been taken out of the many eye units, or ommatidia. The cornea and crystalline cone focus the light onto the retina (called rhabdom), which contains the light-sensitive cells. Each 'sees' an image which is part of the whole. Drawing: P. Maitland.

membrane in migrating birds is kept closed while they fly to prevent the cornea from drying out. Consequently, the nictitating membrane in such birds has a transparent window in it. Ducks and diving birds have a similar window which is used when swimming under water.

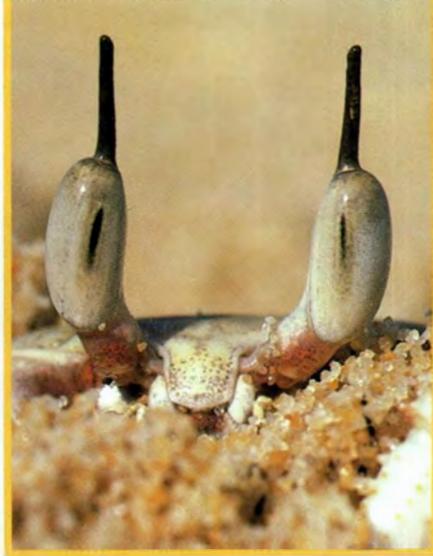
The nictitating membrane is also present in—and is important to—many mammals. The Platypus, for example, while swimming, uses the nictitating membrane to protect its eyes but on land uses its other ‘true’ eyelids. The nictitating membrane is vital to most other mammals as a ‘windscreen wiper’ which blinks much faster than the eyelids can. In primates, including ourselves, the nictitating membrane is vestigial and is the tiny, triangular structure in the inside corner of our eyes.

All snakes and certain other reptiles (such as skinks) have evolved permanent, tough, transparent coverings called brilles or spectacles to protect their corneas. These spectacles are formed from a modification of the lower eyelid, which has been thinned, thus made transparent, and permanently fixed in a raised position. Reptiles with spectacles have virtually no nictitating membranes.

The Invertebrate Eye Compound, Simple and Square Eyes

Because we tend to think of invertebrates as so essentially different from ourselves, it comes as a surprise to learn that some have eyes almost identical to our own. The cephalopods, such as the octopus and squid, have eyes with a pupil, lens and retina. The evolution of cephalopod eyes is said to have converged with ours. In other words, although development has given rise to similar structures, there is no common ancestry.

If it was sobering to realise that, of the vertebrates, our eyes are not nearly as good as those of birds and reptiles, it may be more difficult to accept that even insects can see in colour. Insects can also see ultraviolet light. The blue lamps on butcher shops and takeaway joints have a large ultraviolet output that attracts moths and other insects to their electrifying doom. Mosquitoes, march flies and midges are particularly attracted to the shorter wavelengths of blue or violet light and will fly towards a person wearing these colours. So, if you’re out in the bush and don’t want to be at-



The adult Ghost Crab, *Ocypode ceratophthalma*, often escapes predators by burrowing into the sand and peering out with its two huge, stalked compound eyes. These stalks are the pseudopupils and are found in most compound eyes. They are not, in fact, pupils like our own, but simply the image of the black pigment of the light receptors in the ommatidia that share a common line of sight with the observer. The pseudopupil has no significance for the animal but does tell us much about the way in which the eyes function. Photo: D. Maitland.

tacked by mosquitoes, wear *anything* but blue!

Most insects cannot see red. How then, you might be wondering, is a bee attracted to a red flower, especially one that is not scented? The red colour of the flower is usually made up of at least two pigments: one red, the other blue. Humans see only the red but the bee sees blue.

Insects and other arthropods have multifaceted eyes. They consist of hundreds of hexagonal facets, creating a honeycomb effect. Each facet is a lens, which focuses light down a column onto about six light-sensitive cells lying beneath it. Each column, or ommatidium, is a self-contained eye; hundreds make up the compound eyes of insects. Because there are so few light-sensitive cells per ommatidium, a complete image is not formed. Instead, each miniature eye sees a fragment of what is being viewed, so that, like tiny tiles in a mosaic, the fragments form an image. The more ommatidia there are, the finer the image. In insects where such acuity is important, the compound eyes are huge and are made up of thousands of tiny eyes. For example, dragonflies, the hawks of the insect world, have enormous eyes. Each is made up of over 20,000 ommatidia and together they occupy most of the head. The construction of the

compound eye means that it is highly suitable for the detection of movement as the image of the moving object shifts from facet to facet.

Many shrimps, lobsters and crayfish have compound eyes that are very different from those of fellow crabs and insects. The facets are square rather than hexagonal and there are no lenses. Lining the inside of each box is special tissue containing guanine crystals. These reflect light, just like a mirror, onto the light-sensitive reticular cells at the base of each ommatidium. In these mirror eyes, light is not refracted as in a lens eye, but bent by reflection.

Many insects and other arthropods have simple eyes, or ocelli, as well as compound eyes. An ocellus is made up of only one lens and usually only a few light-sensitive cells in the retina. There are three ocelli on the heads of most flying insects. Ocelli have been found to be important for navigation in ants but generally their function is unclear.

Perhaps the most complex ‘simple’ eyes are found in the spiders. Each of the six or eight eyes can contain up to 10,000 light-sensitive cells. The jumping spiders, which stalk their prey, have exceptional vision. They have four pairs of eyes: the large principal pair at the front and the smaller lateral eyes. The principal eyes resolve the nature of the object and its distance away while the lateral eyes are movement detectors. When an object moves within the lateral eyes’ field of view, the spider turns to look at it with its large principal eyes. When looking down at a jumping spider, it will tilt its body back to direct its gaze up at you—a somewhat disconcerting habit!

The Eyes Have It

Of course it’s impossible to know exactly what an animal sees and how it perceives it. We can only infer this sort of information from studies of eye structure, position, the environment in which it lives and experiments designed to examine what the animal reacts to and how. What we can be sure about is the fact that there are many different types of eyes in the animal kingdom and that each animal is equipped with just the sort of eyes it needs. □



Densey

The more I learn about slugs and snails, the more amazing I find them. The basic facts are impressive enough. Imagine having your teeth on your tongue. Imagine having your sexual apparatus on the side of your head. Yes, there's more to gastropods than crunchy shells and slimy trails and mayhem in the lettuce patch.

Speaking of shells, it's often thought that a slug is just a simple sort of snail that hasn't had the sense to grow one. But it's really the other way around. Slugs are sophisticated. Slugs have been there, done that. They've tried the shell experience, got tired of carrying their houses and opted for flexibility.

So it's tempting to define slugs as snails that have discarded their shells. But this isn't quite right either and here's another surprise: many slugs still have a shell, if only a rudimentary one tucked away inside them. The introduced slug *Testacella haliotidea*, for instance, has a small, disc-like shell sitting rather comically right on its rear end, like a cap about to fall off.

Then there are the helicarions—the little semi-slugs you find feeding on some of the big rainforest fungi. These are snails with a delicate shell worn on the back like a saddle, one too shallow to retreat into completely and often covered by the attractively-patterned

***Helicarion* sp. from northern Queensland, with mantle lobes partly covering the much-reduced shell.**



mantle flaps. They're thought to be on the way to slugdom.

Let me explain what a mantle is. It's a fleshy covering or fold, often with lobes or flaps, that all slugs and snails have on the upper part of the body near the front. In snails it secretes the shell that covers it, as well as other useful functions. In slugs, the mantle may cover most of the body or be so small as to be unnoticeable. Highly modified, it can be a useful clue to slug identity.

It must be said against slugs that they mostly come in drab colours—brown or grey or, at best, yellowish. Even the introduced Leopard Slug with its striking pattern of spots and stripes is sombrelly dressed. But now to a slug of a different colour—and perhaps a different flavour, too, if nature's use of red as a warning to predators holds good for gastropods.

The brightest colour form of *Triboniophorus graeffei*, from Mt Kaputar, northern New South Wales.



Triboniophorus graeffei is a native Australian slug found along the eastern coast and Great Dividing Range, from Sydney's heathland and dry sclerophyll to the tropical rainforest on top of Thornton Peak in northern Queensland. What a surprising variety of habitats for a single species! Another surprising thing is the number of colour forms it comes in.

On damp nights or rainy days I can usually find a few of these slugs out feeding on the sandstone outcrops around my Sydney garden. Although they're big—12 centimetres or more—the slugs are hard to see because they match the colour of wet sandstone and blend so well with the shapes of fallen gum leaves.

I look for a leaf shape with a thin scarlet border all around and a small triangular patch outlined in scarlet towards the broad end. The skin has

Elyne looks at.....

SLUGS OF COLOUR AND CHARACTER

an overall pattern of 'veins' rather like a leaf and a dense sprinkling of small tubercles that gives it a bubbly texture. Just inside the scarlet triangle is the breathing hole or pneumostome, which opens and shuts as the slug breathes.

In other parts of Sydney, a cream or pinkish-grey form appears, with a much smoother skin matching the smooth-barked bluegum trunks you find the slugs on.

The name *Triboniophorus* means literally 'cloak-bearer', but in fact their mantles are very small—just the triangular area outlined in red. It's this colour pattern that has given Sydney forms of *T. graeffei* the common name of Red Triangle Slug. To the north, the slug may be more highly coloured. Some are rose-pink all over or yellow with a solid scarlet triangle—or plain pillarbox red.

Triboniophorus is a fungus feeder, but it doesn't eat mushrooms, toadstools, bracket fungus or any of the more obvious kinds. Like a cow in a meadow, the slug grazes on crops of minute fungi that quickly appear on rocks and tree trunks in damp weather. Too small to see individually, the fungal growths and lichens are sometimes visible as a kind of surface bloom. But the slug's presence is perhaps best revealed by the absence of these growths.

Have you ever seen a set of scalloped tracks criss-crossing the face of a

rock or patterning the trunk of a smooth-barked tree? This is the characteristic feeding track of *Triboniophorus* slugs. They eat on the move and each scallop marks a mouthful, scraped up by that remarkable, rasp-

***Triboniophorus graeffei*, one of the colour forms from Sydney.**



like tongue with its thousands of teeth, called a radula.

Like virtually all native slugs and snails, these slugs are incapable of doing any harm to garden plants or crops. As with domestic cockroaches and most other pest species, we brought most of the harmful gastropods with us to Australia, either deliberately or by accident. Generally, the native kinds haven't the slightest interest in us.

But of course *they* are fascinating to *us*, both scientifically and aesthetically. *Triboniophorus* belongs to a family of slugs called the Athorocophoridae, confined to the Australasian region and of great scientific interest. In many ways, these slugs are unique. For one thing, they have a rather more advanced kind of lung than other molluscs. For another, they have only one pair of tentacles instead of the usual two pairs.

But to non-scientific eyes, the outstanding thing about *Triboniophorus* slugs is their colour. For that alone, even the most ardent gastrophobe among us might admit to their charm and forgive them their sluggish ways. □

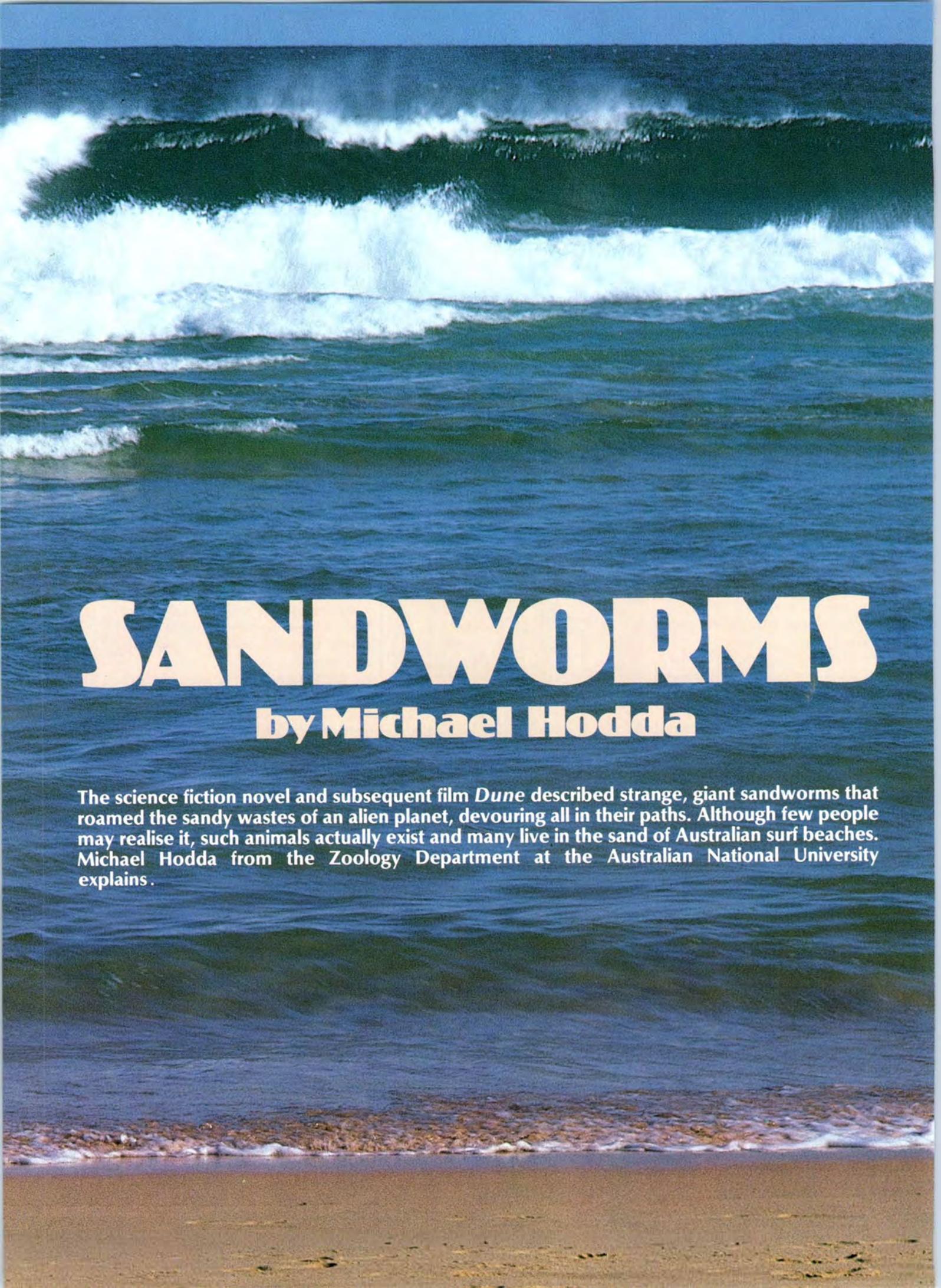
***Triboniophorus graeffei*—a New England colour form, with breathing hole open.▼**



◀***Triboniophorus graeffei*, the Red Triangle Slug—a Sydney sandstone colour form.**



Photos: Densley Clyne.



SANDWORMS

by Michael Hodda

The science fiction novel and subsequent film *Dune* described strange, giant sandworms that roamed the sandy wastes of an alien planet, devouring all in their paths. Although few people may realise it, such animals actually exist and many live in the sand of Australian surf beaches. Michael Hodda from the Zoology Department at the Australian National University explains.

Before panic starts and people flee Bondi Beach in terror, it should be pointed out that these 'monsters' are less than two millimetres long with jaws not even large enough to swallow this full stop.

The animals in question are roundworms or nematodes (phylum Nematoda). Nematodes superficially resemble other worms in that they are long, thin and have a head and tail. But here resemblance ends. Nematodes are simple animals, each comprising a straight tube with a hole (the gut) down the centre. The gut is not branched or blind like that of flatworms, nor are nematodes divided into segments like earthworms or seaworms. There are no appendages of any sort.

The mouth or buccal cavity opens at the end of the tubular body. Basically just an enlarged section of the gut, it may be equipped with vicious teeth, cutting plates, a spear or jaws to scrape, crush, puncture or bite food. Behind the mouth is a muscular pumping oesophagus, which may be up to a third as long as the entire body. The oesophagus pumps food from the mouth with a peristaltic motion through a valve into the intestine. Here food is absorbed before being passed out through the anus at the rear.

Nematodes rely on a hydrostatic skeleton for body movement. Instead of muscle contractions pushing, pulling or swinging a rigid rod, the hydrostatic skeleton works like a long, thin balloon. Pinch one side and the pressure inside forces the other side to bend. Four strips of muscle run along the nematode's body—one in each quadrant of the cylinder. Nematodes wriggle their bodies and move by sending waves of contraction alternately down the two adjacent muscle blocks along the ventral, then dorsal, side of the body.

This elegantly simple system needs only two nerves to function. Impulses to these nerves are controlled by a nerve ring near the head. This ring is the closest thing that nematodes have to a brain. There is another, smaller nerve ring around the gut near the tail.

Around the mouth are three con-

centric rings of sensory hairs, four hairs or setae in the outer ring and six in each of the inner two rings. There are also openings on either side of the head, which detect the concentration of various chemicals. These sense organs process sensory stimuli and feed information to the nerve ring, although exactly how this is achieved remains unknown. That's not surprising considering that the head of most free-living nematodes is less than one tenth of a millimetre across!

Nematodes are among the most numerous and ubiquitous multicellular animals on Earth. As many as 5,000,000 may occur in one square metre of beach sand and 30,000,000 in the same area of pasture or mangrove mud. As parasites, the number may be enormous—5,500 pinworms were once passed by a man after a single treatment and 90,000 plant parasitic specimens were recorded from a wheat gall. They occur wherever there is any sort of sediment with a water film—from Antarctica to the tropics and in deserts, lakes, seas, meadows, jungles, as well as in or on dead or live animals, plants and fungi. As free-living and parasitic forms they clothe the globe. To occupy this incredible range

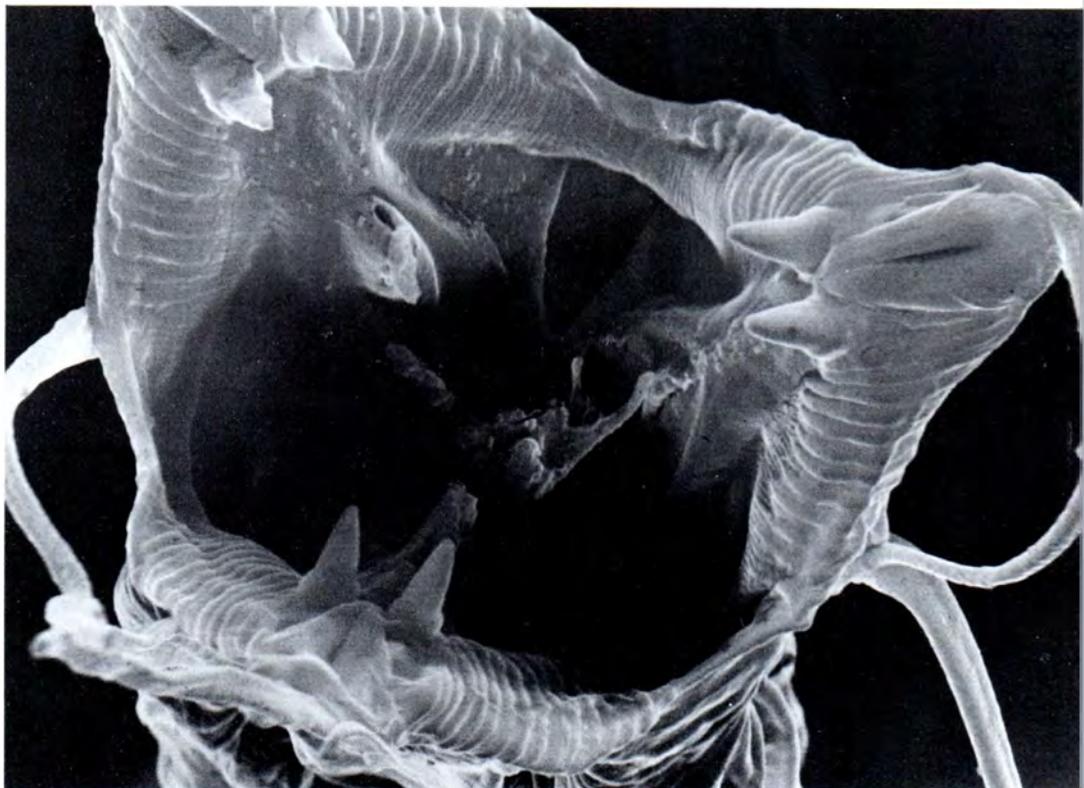
of habitats, nematodes have developed some fascinating adaptations. Those inhabiting surf beaches are among the most interesting.

Anyone who has been dumped by a big wave knows how powerful and turbulent the surf can be. Sand is stirred up and you and the sand are deposited some distance from your original location. To the nematode, however, the beach is a very different world. The sand grains aren't just annoying grit, they are huge boulders, some as far across as the nematodes are long. The boulders aren't all round, either. Some are like cubes, some like pyramids and others resemble large, flat plates.

Because of these odd shapes there is plenty of room between the particles and long, thin animals like nematodes can move around easily. The writhing propulsion of nematodes is perfect for this kind of obstacle-ridden habitat.

Food is plentiful, for there is a constant flow of water down through the sand, bringing with it small single-celled algae, and organic and inorganic debris (detritus). Some nematodes have mouths like vacuum cleaners, with a large, powerful pumping

***Enoploides* sp., a predaceous nematode with a mouth armed with vicious teeth, eats very small invertebrates. It may reach a length of two millimetres. Photo: A. Stewart.**



The violent surge of the ocean continually deposits and removes huge quantities of sand and, along with it, nematodes. Photo: F. Doig.

oesophagus, designed to suck up small algae and detritus trapped between sand grains. One has a mouth like one of those three-jawed cranes that pick up car wrecks.

Another common food is bacteria. It forms a thin film around many sand grains, rather like moss on human-sized boulders. Many nematodes scrape or suck this film off the grains. Some use a big tooth that resembles a can opener, some are chisel-like and others have teeth more like a plank of wood with a nail through it.

Then there are the predators, with huge mouths armed with enormous piercing teeth or crushing plates. These are the biggest of the surf beach nematodes and may reach a length of three millimetres. They prowl between the sand grains ready to snatch and devour any smaller animals.

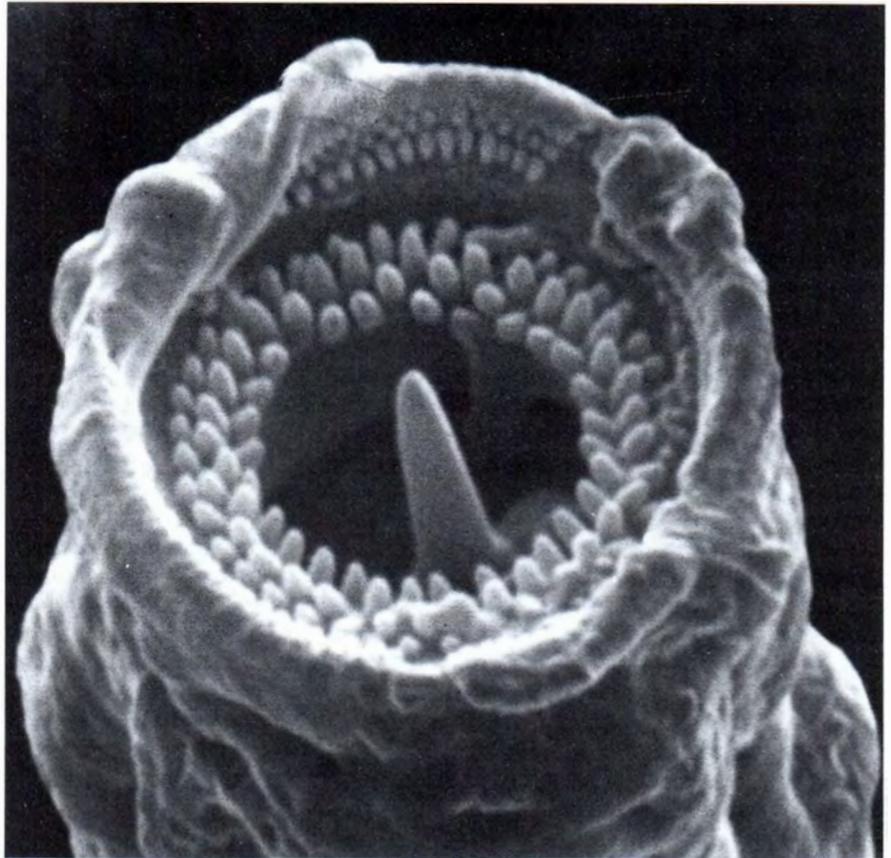
Nematodes that live on the beach are superbly adapted to the rigours of the surf. Most have a thick, rigid outer skin or cuticle, strengthened by rings or hoops around the body. This system of strengthening allows the nematode to wriggle its body while having the strength to resist being crushed by sand 'boulders'. Other beach nematodes are covered in plates, which probably work in a similar way but allow more flexibility. Some also have cuticles thickened in ornate patterns but the reason for the complexity of these patterns remains unresolved.

Some species of nematodes have long hairs or setae all over their bodies. These may have a protective function—bumping off sand grains stirred up by the surf. Just as sand grains are boulder-sized to the nematode, these hairs are as thick as tree branches.

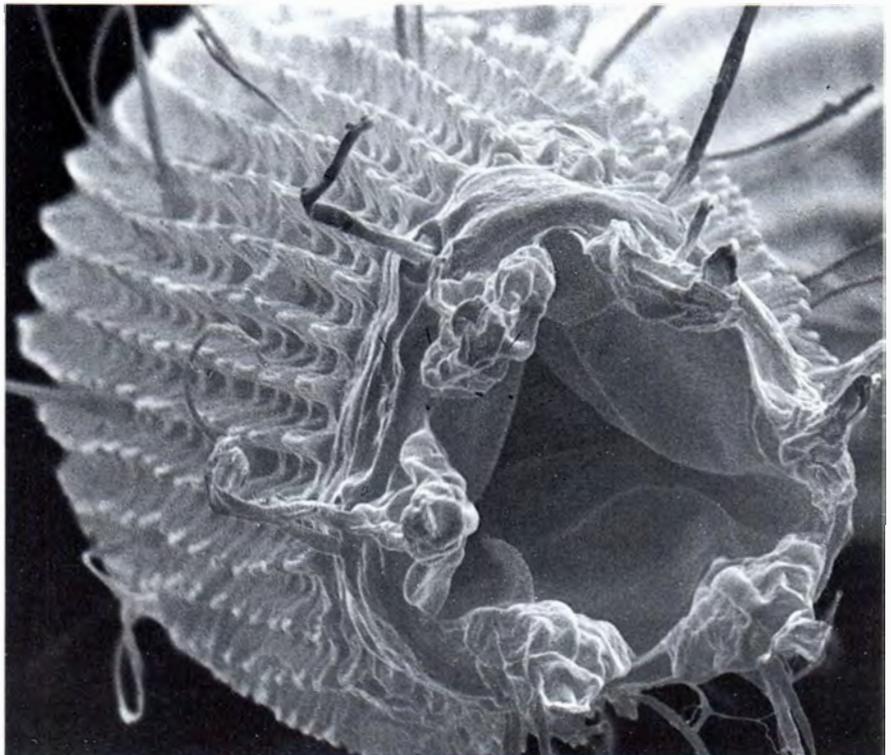
The boundary layer of water also provides protection for nematodes. This is the thin film of still water, only a fraction of a millimetre thick, surrounding all objects in moving water. To a nematode, this fraction of a millimetre is enough to act as a buffer.

Of course, any amount of protection won't prevent these sandworms from being moved about to some degree. But winding up high and dry in the dunes away from the beach or being washed far out to sea would be fatal due to lack of suitable food. So how do nematodes manage to stay in the vicinity of the beach?

In some less-turbulent beaches, such as those occurring in estuaries, nematodes move deeper in the sand



***Symplocostoma* sp.** has a tooth like a can opener to pierce algal cells. The ring of small finger-like projections are small teeth, which probably hold the food while being opened and sucked in. The buccal cavity measures eight microns across. Photo: A. Stewart.



***Xyala* sp.** uses spikes to bump off sand grains in the surf. This genus lacks teeth but sucks in edible particles of organic debris or small algae, which are swallowed whole. Buccal cavity measures 13 microns across. Photo: A. Stewart.

as breaking waves approach. Only after the turbulence has passed do they return to the surface. Surf beaches, however, present a unique problem. Sometimes surf can scour metres of sand from a beach in as little as a day and, for an animal that is only a millimetre long, moving deeper into the sand has little effect. These nematodes must adopt a different approach.

Many surf beach nematodes have a gland on their tail enabling them to 'stick' to sand grains. Coupled with their habit of coiling around the parti-

cle, they are very difficult to shake off. This clinging ability incurs several advantages. Because most sand eventually ends up on or near the beach, so too do the clinging nematodes. Also, because sand sinks quickly in the water after it is stirred up, the nematodes don't remain in the surf for very long. If nematodes are deposited far up the beach they must wait for the next high tide to wash them passively back down the beach.

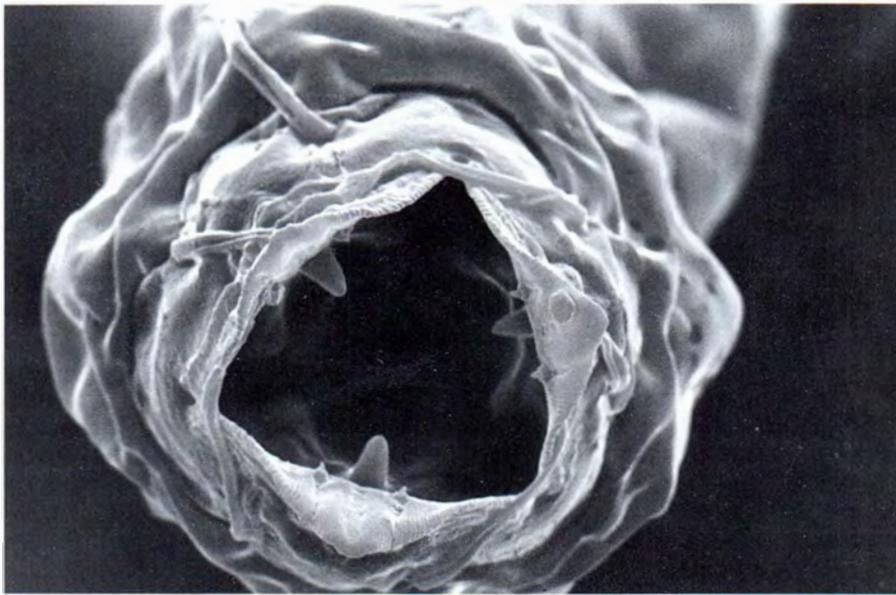
The fact that nematodes are so adept at staying on beaches raises the

question of how they colonised beaches all around the world. Without a pelagic larval stage, common to many marine invertebrates, nematodes may have crossed the oceans by accidental rafting—inadvertently attaching themselves to a piece of floating shell or seaweed, perhaps, or being carried on the feet of seabirds or even in ships' ballast. Another—possibly most important—mode of nematode dispersal may have been as passengers on the drifting continental plates.

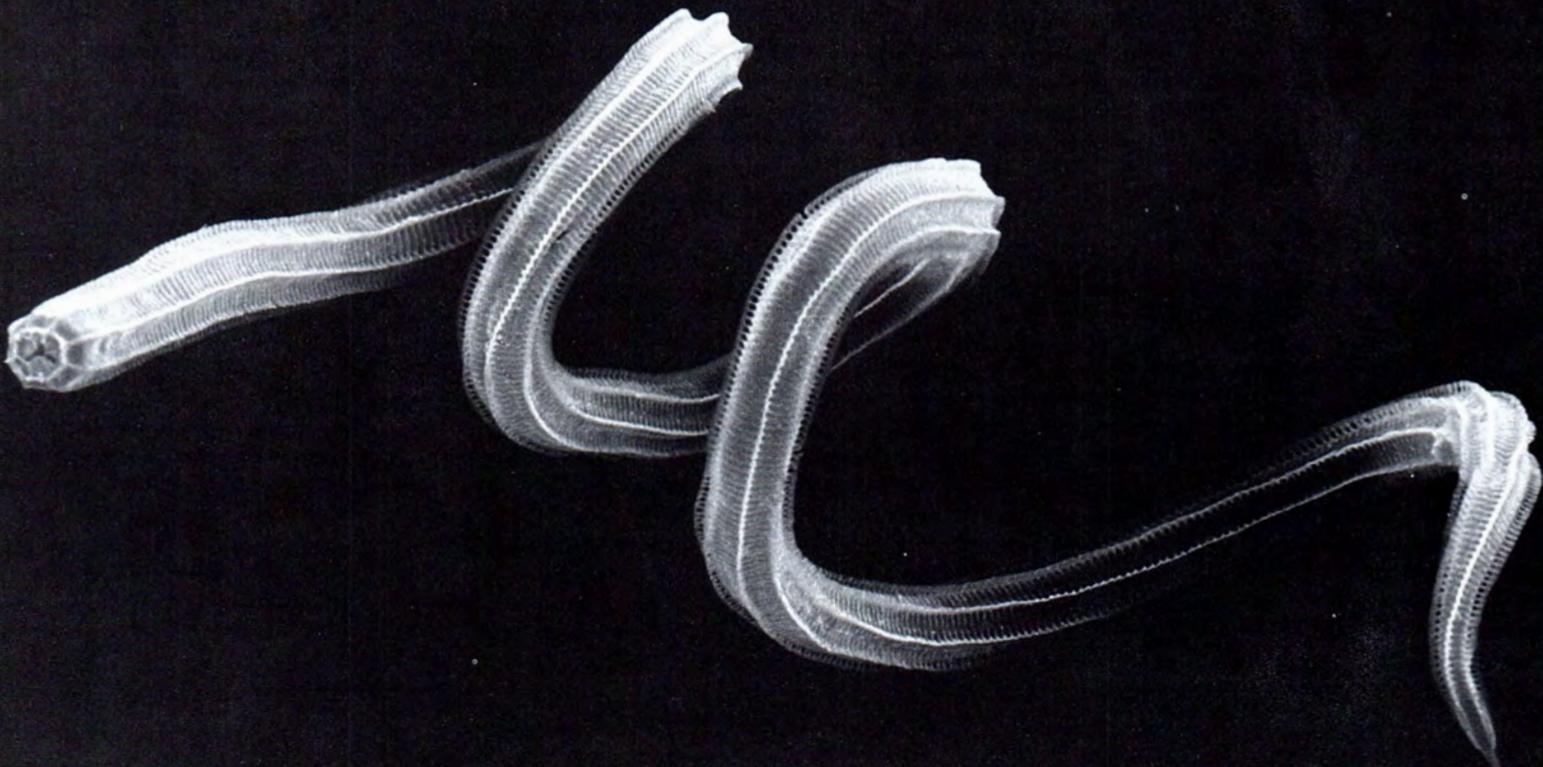
Apart from being fascinating in their own right, the beach nematodes are significant for another reason. They filter enormous volumes of water that pass through our beaches. This is important if we consider the amount of sewerage and other pollutants that our coastal cities and rivers pour into the sea.

So next time you swim at the beach, remember that you are not alone. . . those gaping 'jaws' are lurking in the sand. □

***Ceramonema* sp.** is protected from the grinding of the surf by a cuticle thickened in plates. The plates form rings around, and longitudinal ridges along, the body and are arranged to allow bending movements as well as to help grip sand particles. The long, thin shape of nematodes is ideal for moving between sand grains. This species is about 1.5 millimetres long. Photo: A. Stewart. ▼



***Mesacanthion* sp.** is an omnivorous nematode. It feeds by crushing larger food particles between three crushing plates, each shaped like an inverted 'Y' with a tooth, the stalk of the Y at the front and an inverted 'V' behind. Buccal cavity measures 65 microns across. Photo: A. Stewart.



Letters

Attitude Born of Guilt

In *Forum* (A.N.H., Spring 1985) Dr Flannery describes ignorant, vegetarian, guilt-ridden greenies opposing animal research. Even researchers admit to cruelty and overzealous collecting (killing) of rare species. Like Dr Flannery I, too, find the tactics of animal liberationists disagreeable. But it has taken such measures as theirs to bring some aloof researchers to account, in their zealous quests to publish papers. Politics is shunned in this quest: to become politically involved interferes with 'paper production' and risks upsetting sources of funding and employment. Too many disasterous projects have been approved due to both 'lack of scientific evidence' and inconclusive reports by Australian researchers. It is Dr Flannery's attitude that is born of guilt, not 'urban dwellers' as he states.

Although many glossy articles are written about Australian wildlife, original research is published in a bewildering number of journals. Most of this research fails to address the management or status of the animals or systems it deals

with. It is not even summarised into language that would make it useful to the formulation of such management. It is left to those people that Dr Flannery ridicules to track down and translate such work and fight for better management.

The quest for knowledge of Australian systems and the living things that make them work is essential to their maintenance. Yet, too few researchers involve themselves in the conservation of the same wildlife and ecosystems that provide them with jobs. Dr Flannery talks of the maintenance of natural diversity. Admirable sentiments, but meaningless without action—even to his much-loved New Guinean hunters who themselves face extinction, particularly in Irian Jaya.

—Bob McDonald
South Gippsland Natural
History Museum, Vic.

Crocodile Capers

How well-timed your article on crocodile conservation was! (See A.N.H., Summer 1985–86). The controversy and panic arising from recent attacks by Saltwater Crocodiles is

ridiculous. Anyone who willingly enters crocodile-infested waters should be aware of the consequences. As the author of the article, Grahame Webb, so correctly pointed out, there are plenty of crocodile warning signs around that are there to be heeded.

The panic this incident caused, inciting people to go out shooting crocodiles in trigger-happy groups, is not the answer. Certainly the short-term result may appear effective, but in the long term it would be disastrous. Careful management of crocodile populations, education and common-sense when in crocodile territory should see an end to these problems.

—Chris Roche
Townsville, Qld

Once Bitten . . .

Among other topics in the Winter 1985 issue of A.N.H., I was particularly interested in John Freeland's article on bulldog ants.

Being particularly sensitive to the bite of what are locally known as 'jumpers', I felt that, apart from saying beware of their painful stings and powerful bites,

the author could have suggested an antidote.

An antihistamine, taken as soon as possible after the bite, is a rapid and effective relief. The medication may be taken in the form of readily available tablets such as a well-known brand of travel sickness pills, Avil. I have these in the car, caravan, photography bag, kitchen and bathroom.

There are not many lethal things in our Australian environment, but there are some that can be extremely dangerous to many people. Perhaps at some future date an article could be prepared by a suitably qualified person pointing out some of these things . . . this is part of our natural history, especially if we want to survive to enjoy it!

— R.J. Fletcher
Cape Paterson, Vic.

Great idea, but we beat you to it! A.N.H. will be publishing an article in a future issue on deadly Australians and recommended first aid for bites and stings —Ed.



Also available from the Unwin Animal Library —

The Encyclopaedia of Underwater Life \$59.95 hc rrp
and previously published

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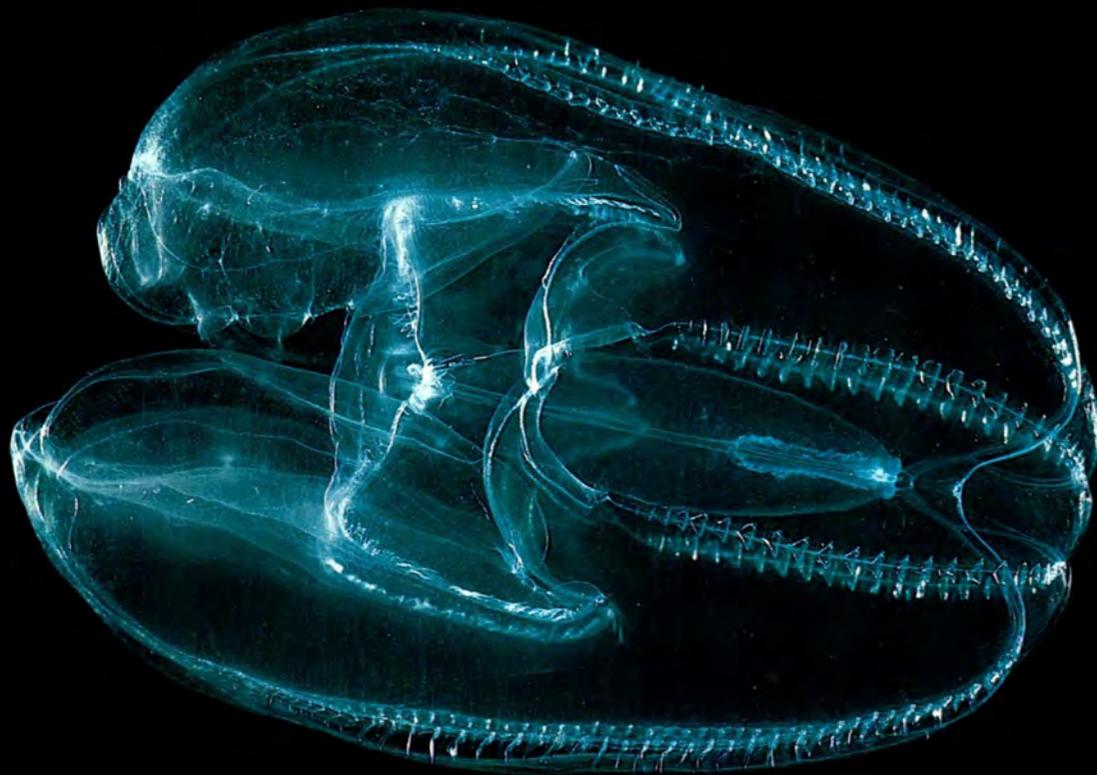
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ALLEN & UNWIN AUSTRALIA

▼ The transparent Comb Jellyfish (*Bolinopsis chuni*).



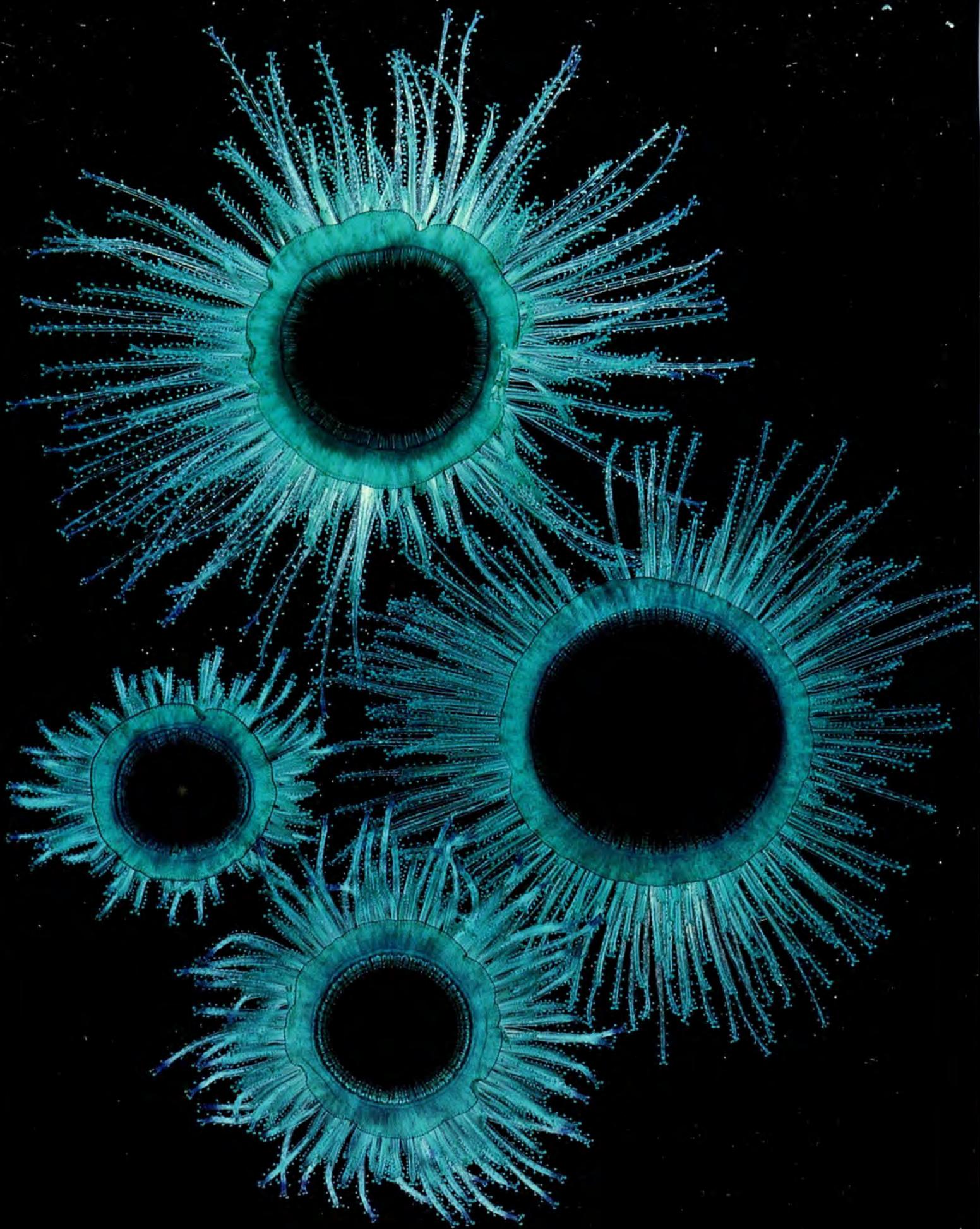
▼ The Purple Stinger (*Pelagia noctiluca*) displays its graceful, ribbon-like tentacles.



photoart

A regular gallery of portfolios
by talented Australian photographers whose
work relates to the natural sciences.

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A mantis shrimp, photographed at Lizard Island in far northern Queensland.



KATHIE ATKINSON

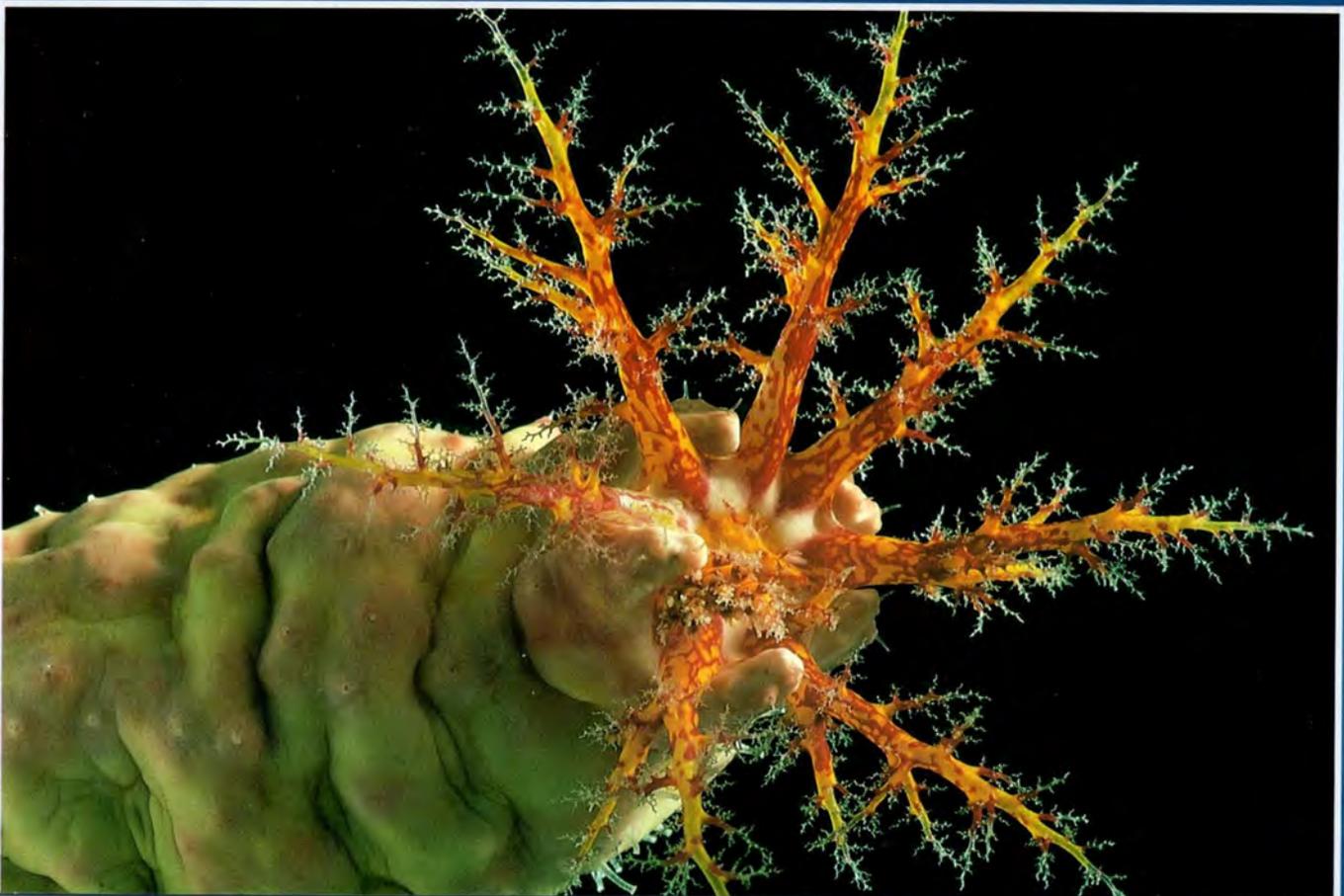
The decision to turn away from an interesting job to freelance wildlife photography was, for Kathie, "a passion that got out of control".

Extensive travel throughout Australia as a still photographer for the ABC indulged her love of nature and the outdoors. But it was not until she was assigned to a wildlife series with Harry Butler that Kathie found her direction.

What began originally as an assignment became a pastime. "I have always been drawn to the sea so I suppose it was natural that I should start exploring the rock pools for new subjects to photograph. Marine invertebrates are visually so exciting; their shapes and colours are quite unbelievable".

Kathie took up SCUBA diving and began filming under water but was continually frustrated by the cumbersome equipment and lack of control over the subjects. She began taking live specimens home to a studio situation. "After much experimenting (and a lot of film) I developed the techniques that gave me the opportunity to interpret the wonderful forms of these animals. I wanted to use my art to give others a glimpse below the waves; a chance to see the beauty of the creatures that live there".

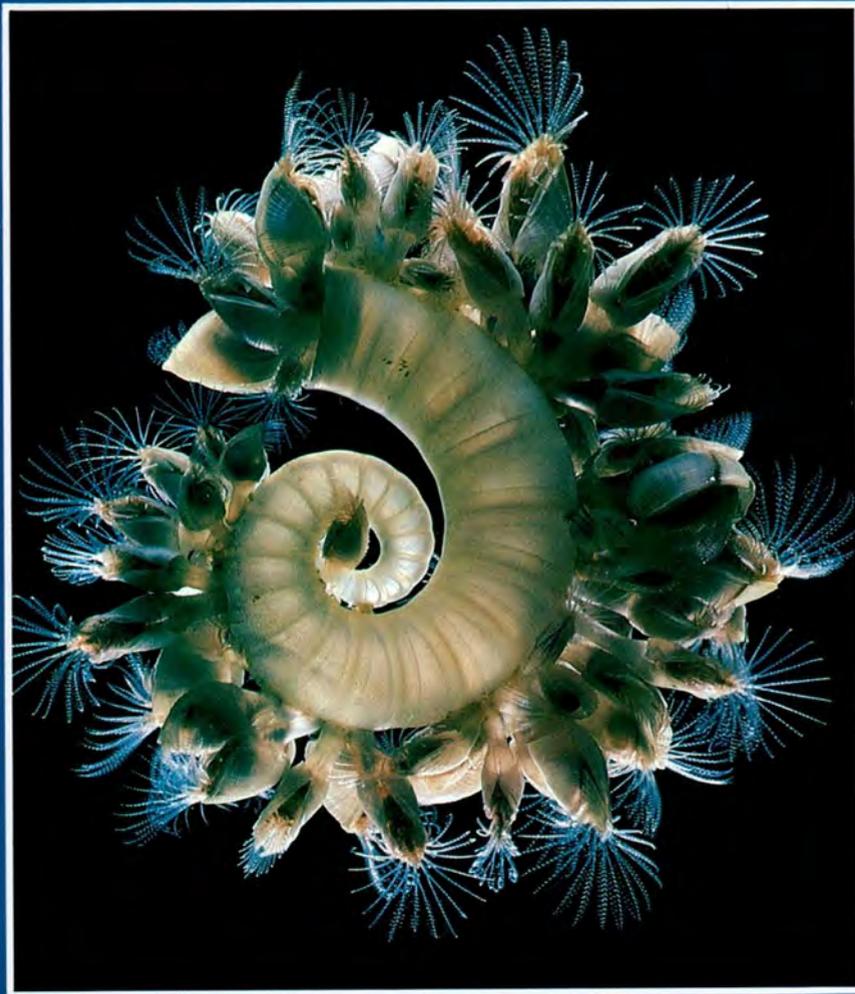
A sea-cucumber (*Pentacta anceps*) displays a splash of colour. ▼



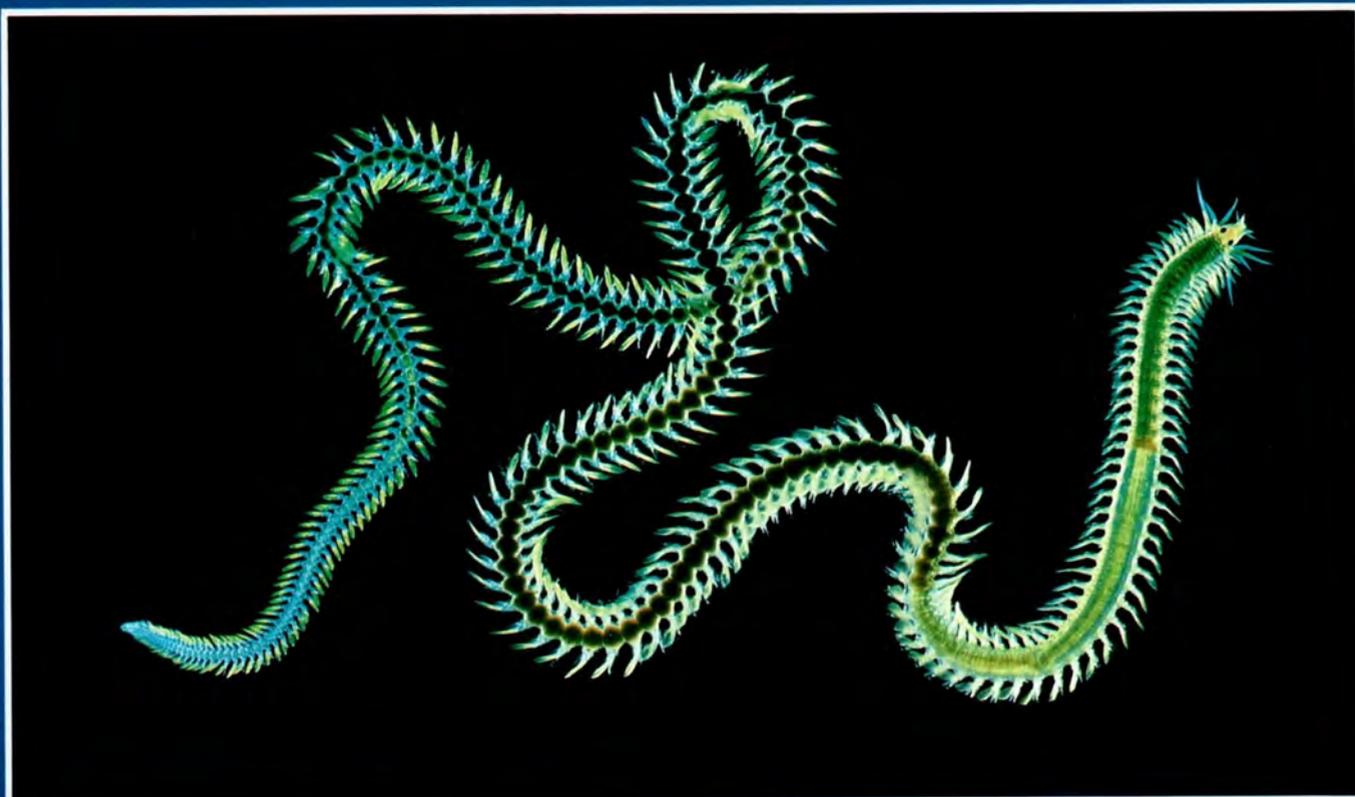
A marine worm (polychaete) of the family Flabelligeridae.▼



Gooseneck barnacles have attached themselves to a disused Ram's Horn Shell (*Spirula spirula*).▼



This polychaete (family Phyllodocidae) is reminiscent of an Aboriginal painting.▼



Sugar Glider

POSTER

The Sugar Glider, *Petaurus breviceps*, is a member of the marsupial glider family, Petauridae, and weighs 100–170 grams. The species is distributed from south-eastern South Australia, along the eastern Australian coast to north-western Northern Territory and Papua New Guinea and surrounding islands. It is also found in Tasmania where it was apparently introduced. Sugar Gliders are nocturnal and are found mainly in sclerophyll forest or woodland. Here they nest in hollow, leaf-lined branches.

Principal food items include plant exudates of eucalypts (sap and nectar), wattles (gum) and arthropods. Breeding occurs at various times during the year but mostly during winter–spring. After a gestation period of 15–17 days, between one and three young are born, although there are four nipples in the pouch.

All *Petaurus* species (there are four) are accomplished gliders. Gliding is achieved by a parachute of skin (the patagium) that extends from the Sugar Glider's fifth finger to first toe. When not in use, the membrane is visible as a wavy line alongside the body. The Sugar Glider manoeuvres gracefully between trees, volplaning easily for up to 50 metres, and lands with precision by turning upwards in order to reduce speed.

Gliding is an efficient way of exploiting a patchy food resource in open forests and may have developed at the end of the Miocene (15 million years ago), when the central Australian closed forests were beginning to open out. The earliest record of a fossil *Petaurus* specimen comes from Pliocene (4.5 million years old) deposits near Hamilton in Victoria.

Sugar Gliders, although preferring to forage alone at night, are highly social animals and nest in groups of up to seven adults plus their young. Such nesting groups are found during winter and are thought to improve energy conservation through huddling.

Group members disband into smaller groups during summer. Population densities of 2.9–6.1 per hectare have been recorded in Victoria where the average life span is between four and five years.

Selective pressures exerted during competition for mates has led to the prolific development of scent-marking glands. In male Sugar Gliders these oc-

cur in the forehead, chest and anal regions. Members of a group are identified by the scent of the dominant male, which is secreted by the glands on his forehead. Such scent-marking behaviour plays an important role in the maintenance of group cohesion. □

—Georgina Hickey



The Sugar Glider, *Petaurus breviceps*, seen here feeding on the nectar of a eucalypt blossom. Photo: Kathie Atkinson.

RARE & ENDANGERED

World's Only Strictly Marine Sea Cow Threatened

BY GEORGE HEINSOHN

The Dugong (*Dugong dugon*) is the only living herbivorous mammal that is exclusively marine. Adult Dugongs can grow to over three metres in length and weigh between 300 and 420 kilograms. They feed almost exclusively on seagrasses but occasionally algae and some invertebrates may also be eaten.

Dugongs have a tropical and subtropical distribution along the coasts of the Indian and western Pacific Oceans. They frequent the warm, shallow waters of bays, channels, island areas and reef flats—areas that are protected against strong winds and heavy seas and where beds of seagrasses grow. In Australia Dugongs range around the northern coast from Shark Bay, Western Australia, to Moreton Bay near Brisbane but occasionally

they have been sighted as far south as Sydney.

The Dugong is one of four remaining species of sea cows or sirenians (order Sirenia) and is the only existing member of the family Dugongidae. The Dugong's closest relative and only other member of the family was the giant (up to eight metres long) Steller's Sea Cow (*Hydrodamalis gigas*), which fed on large algae, mainly kelp, and weighed up to around 6,000 kilograms. It was hunted to extinction within 30 years of its discovery in the Bering Sea in 1741.

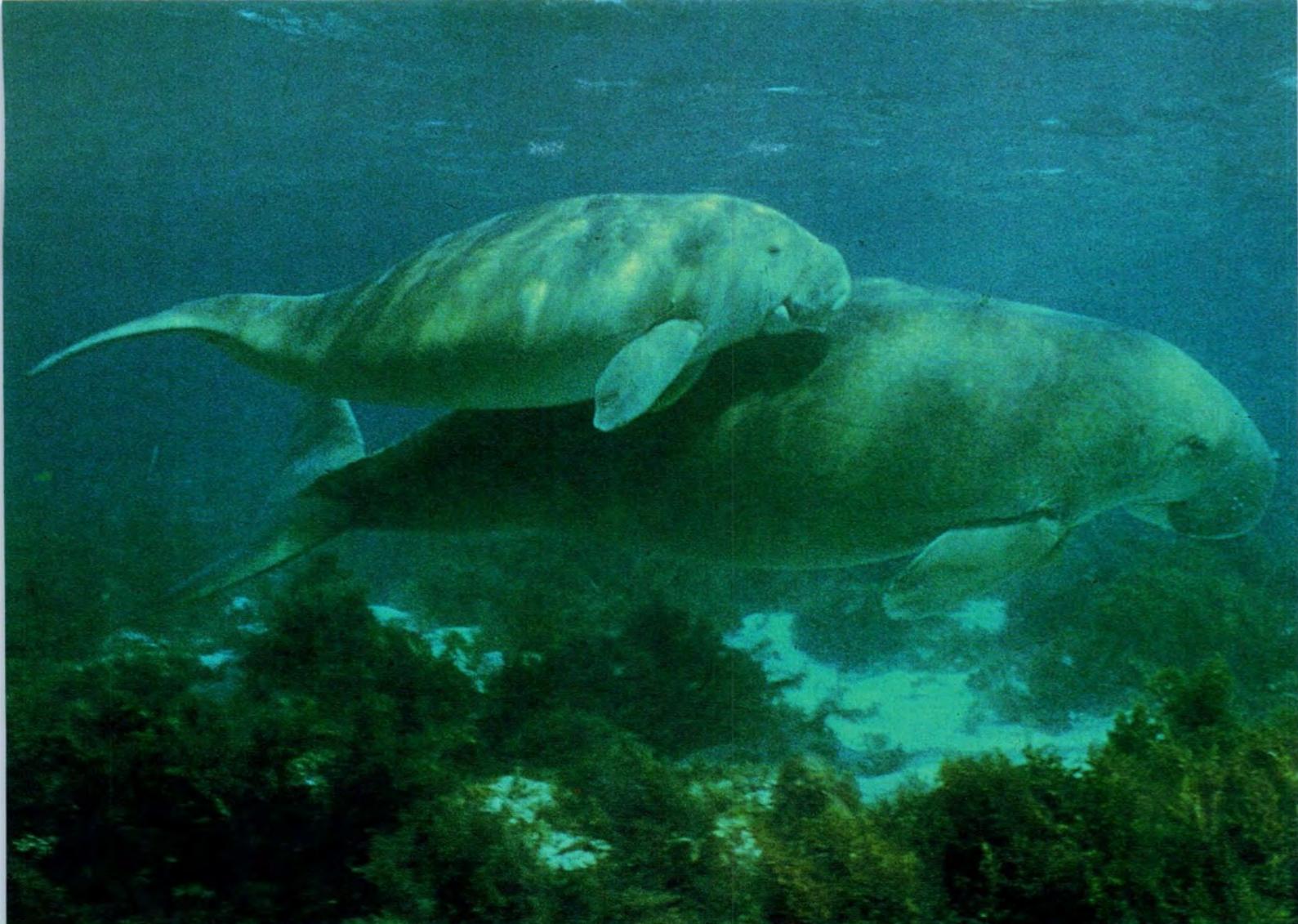
The Dugong is particularly vulnerable to extinction because it is a very long-lived (potentially 60 to 70 years), slowly reproducing mammal. Indeed it can only sustain a very low adult mortality rate (five per cent or less)

for population maintenance. Females bear their first calf at a minimum age of ten years after a gestation period of about one year. The interval between calving times ranges from three to seven years in which time a strong bond develops between mother and calf. Although a calf begins to eat seagrasses soon after birth, lactation can last up to two years.

Large sharks, Killer Whales and Saltwater Crocodiles prey on Dugongs, particularly young ones, however humans are the most significant predators. Direct hunting and netting of Dugongs for meat, plus accidental captures in nets have been the major causes of decline over most of their range. In Australia Dugongs are legally protected except for 'traditional' subsistence hunting by Aborigines and

Three Dugongs accidentally caught and drowned in shark nets set at Magnetic Island, Qld. Photo: G. Heinsohn.





Dugong mother and large calf. Photo: B. Cropp, N.P.I.A.W.

Torres Strait Islanders. In the Torres Strait, however, Dugongs are under threat from overhunting by the indigenous Torres Strait Islanders and Kiwai People of Papua New Guinea. Torres Strait Dugongs have been commercially sold in Papua New Guinea and illegal sale of Dugong meat has been reported in northern Australia. Other human activities, such as use of power boats, deliberate harassment and military activities, threaten some Dugong populations.

Pollution is another potential threat in Australia. In the Arabian Gulf a large number of Dugongs (at least 38), along with many other marine animals, were killed in 1983, now thought to be coincident with a massive oil spill, caused by the destruction of off-shore Iranian oil wells during the Iraq-Iran Gulf War. Oil pollution is a continuing problem in that region and an ever-present threat in most marine areas.

Dugong habitat destruction, such as reclamation for coastal developments, dredging, seagrass bed damage from trawling, and sedimentation from dredge spoil, mining activities

and erosion on land, is another potential threat to Dugongs and other marine life dependent on seagrasses. In particular the Ok Tedi gold and copper mine, in the Highlands of Papua New Guinea at the headwaters of the Fly River, may seriously increase heavy metal loads in the Torres Strait and northern Great Barrier Reef marine environments.

The most effective means of conserving Dugongs would be to establish a series of marine reserves in areas that are known to support large numbers of Dugongs. Net fishing must be excluded from these reserves. Some areas of the Great Barrier Reef Marine Park have been zoned for the conservation of Dugongs. However, parts of Hervey Bay, Moreton Bay, Shoalwater Bay and Port Clinton in Queensland; the McArthur River Delta in the Northern Territory; various places in the Gulf of Carpentaria; as well as Shark Bay (one of the most important Dugong areas in the world) and Exmouth Gulf, both in Western Australia, should also be declared marine national parks.

Commercial exploitation of Dugongs should be banned world-wide.

Public awareness and education programs on the biology, significance and conservation of the Dugong should be initiated, especially in regions where traditional subsistence hunting of Dugongs by indigenous peoples occurs. Methods need to be devised and appropriate legislation passed to lower their accidental mortality in net fisheries. In Queensland, alternatives to shark netting as a means of protecting swimmers should be established. Protective legislation should have sufficient powers and penalties to provide deterrents to illegal hunting, disturbance, habitat destruction and pollution, and laws should be rigorously enforced.

Dugongs are important. In indigenous societies that hunt Dugongs, the animal is not only a source of high quality meat, but has great cultural significance. For other people, Dugongs are of educational, scientific, tourist and aesthetic value. The long-persecuted Dugongs are active and gentle animals and, if not hunted or harassed, show curiosity toward swimmers and divers and can be readily observed and photographed. □

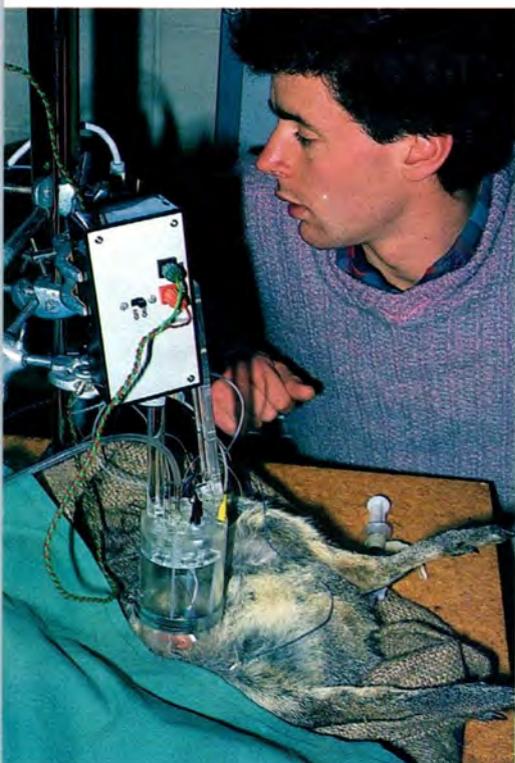
QUIPS, QUOTES & CURIOS

Baby Kangaroos and Human Disease

A team of scientists at Flinders University in Adelaide is using an artificial kangaroo pouch to understand some of the processes involved in the development of kangaroos. The young marsupials may also be used as 'models' in understanding some aspects of human physiology and disease.

The scientists are using a laboratory colony of Tammar Wallabies. Their gestation period is 28 days after

PhD student Peter Frapell observes the artificial kangaroo pouch containing the joey. The mother is lightly anaesthetised. A rubber seal (designed by Frapell) fits over the mother's nipple. It allows the joey to feed normally while its responses to a variety of conditions are monitored. The joey is later returned to its real pouch unharmed. Photo: courtesy Russell Baudinette.



which the young enters the mother's pouch and remains for about 200 days. Here, however, oxygen levels may be 20 per cent lower and carbon dioxide levels significantly higher than room air. Fungi and bacteria in the pouch ('pouch flora') have also been found to use up more oxygen in the first 50 days than the joey. How, then, does the joey live in such an oxygen-starved environment?

The Flinders group has been examining the properties of haemoglobin (red blood cells) in the Tammar joey. This is the pigment which binds with oxygen in the lung and releases it again at organs and tissues. It seems that the lower the oxygen concentration in the pouch, the greater the oxygen carrying-capacity of the joey's haemoglobin. Joeys apparently have the ability to change the binding characteristics of haemoglobin with oxygen using organic phosphate molecules in their blood.

The Flinders group has also discovered that kangaroo lungs are functional at an early age. They don't rely completely on cutaneous respiration, as previously thought. A lipid compound (pulmonary surfactant), necessary for lung function, is produced at an earlier stage than in other mammals. It is the lack of this material that causes respiratory distress in some premature human babies, and Russell Baudinette, a member of the group, suggests that understanding the initiation of surfactant production in joeys may provide a tool for its understanding in man.

Australia's Oldest Mammal

Australia's oldest mammal, whose discovery was reported in an article by Dr Alex Ritchie in A.N.H. (Vol. 21, No. 9) and which was tentatively reconstructed by artist Peter Schouten and mammalogist Dr Tim Flannery in the same issue, has since been formally described and named *Steropodon galmani* in *Nature* (1985, Vol. 318, No. 6044) by Drs Archer, Flannery, Ritchie and Molnar.

The description is based on a 28 millimetre-long, opalised jaw fragment containing three molar teeth from Early Cretaceous (100 million years old) rocks at Lightning Ridge, New South Wales. It was part of a large fossil collection, compiled by opal miners Dave and Alan Galman, and sold to the Australian Museum for \$80,000.

The jaw appears to belong to a monotreme (egg-laying mammal) and contributes significantly to our understanding of mammal phylogenetics. It is particularly important because it extends the fossil record of terrestrial mammals in Australia back from 23 million years to 100 million years; and it reveals that monotremes and marsupials are more closely related than previously thought.

Steropodon is derived from the Greek word *sterope* meaning 'flash of lightning' and *odon*, 'tooth'; and *galmani* refers to its original owners.

Legless Birds of Paradise

Two types of naturalists existed in the Victorian Era: the field naturalist, who studied living organisms in

their natural environments, and the closet naturalist, who studied dead organisms within the confines of a museum or 'closet'. Closet men relied on the field men to bring them new species for analysing, but beyond that there was almost no contact between the two groups—a situation that inevitably led to some confusion as the case of the Legless Birds of Paradise proves.

The first birds of paradise sent to England for identification had their legs cut off to facilitate packing. Leglessness thereupon became enshrined as a characteristic of the species and popular writers went into rhapsodies at the thought of these creatures spending all their lives in the air. Only the eventual arrival of a bird of paradise complete with legs put an end to these ethereal fantasies.

Frank Buckland—19th Century Naturalist and Zoophagist

While most naturalists of his time merely observed natural history, Frank Buckland ate it. His gastronomical likes (and dislikes) included squirrel pie, mice cooked in batter, hedgehogs, frogs and garden snails, earwigs (which were bitter), baby rats, panther (which apparently did not taste nice; the fact that it had been buried for a couple of days before being eaten would not have helped!), numerous British bird species, a washed-up whale and, from the London Zoo, elephant trunk (rubbery), rhinoceros (baked in a pie), porpoise and giraffe, the latter having been cooked on the hoof as a result of a fire in the giraffe house.

No doubt Frank inherited the skills of zoophagy from his father, Dean Buckland, who claims to have eaten King Louis XIV's pickled heart.

Buckland's study of zoophagy led, indirectly, to the opening of the Acclimatization Society in 1860. Its principal aim was to further the search for new food, by introducing and domesticating foreign animals into the country. Another aim of the Society was to improve Britain's fisheries and experiment with artificial fish-hatching.

Bridal Beds

Anthropomorphism (the ascription of human characteristics to non-human things) seems to be taken to the extreme in Linnaeus' truly erotic description of plant reproduction:

"The actual petals of a flower contribute nothing to generation, serving only as the bridal bed which the great Creator has so gloriously prepared, adorned with such precious bed-curtains, and perfumed with so many sweet scents in order that the bridegroom and bride may therein celebrate their nuptials with the greater solemnity. When the bed has thus been made ready, then is the time for the bridegroom to embrace his beloved bride and surrender himself to her." (Quoted in Barber's *The Heyday of Natural History*, Jonathan Cape, 1980.)

Meteorite Impacts on Humans

Researchers in the Herzberg Institute of Astrophysics in Canada have developed a formula that predicts the frequency of meteorite falls on Earth. In a

recent issue of *Nature* (1985, Vol. 318, No. 28) they extended the formula to predict the frequency of impacts on people in North America. Various assumptions were required, of course, among them being that one person occupies 0.2 square metres; only fragments larger than 200 grams will penetrate a roof and ceiling; North American residents spend five per cent of

ing on a couch, badly bruising her left thigh. The fact that only one case has been recorded in the last 30 years suggests, as the formula predicts, that the chances of a person being struck by a meteorite are extremely thin.

There have been other records of people and animals being struck or near-missed by meteorites, some



Victim of a 3.9-kilogram meteorite that penetrated a roof and ceiling of this woman's house in Alabama on 30 November 1954.

each day outside; and the total roof area of buildings averages 50 square metres per person. They predicted an annual rate of 0.0055 impacts on people (or once in 180 years). On a world scale this extrapolates to one person being hit every nine years.

According to the article the only documented case of a person being hit by a meteorite was on 30 November 1954 in Sylacauga, Alabama. A fragment weighing 3.9 kilograms penetrated the roof and ceiling of a house, bounced off a radio and struck a woman sleep-

quite authentic but others rather doubtful. Two authentic near-miss reports include an 18-kilogram meteorite that hit a house in Braunau, Bohemia on 14 July 1847, some parts falling on a bed where three children lay sleeping; and a fragment from the Chicora, Pennsylvania, meteorite of 24 June 1938, which tore the hide of a cow in a field. One of the doubtful cases, involving a prehistoric animal, was listed by LaPaz in a 1951 issue of *Popular Astronomy* (Vol. 59; in which, incidentally, he predicts one person to be struck every 300 years). Ap-

parently a stony-iron meteorite was found below the remains of a Megatherium (giant South American sloth) which may have been killed by it. Another doubtful (but amusing) tale is told of a farmer who was ploughing when a shower of meteorites began falling around him. He rushed into town and called the sheriff to protect him from his enemies, whom he believed were ambushing him. And, during World War I, a man who observed a meteor shower concluded that the Germans had opened long-range artillery fire on the United States!

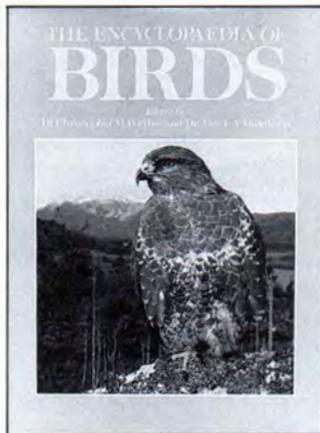
In medieval annals there are several accounts of people being killed by what may have been direct hits from meteorites. But there does not appear to be any reliable modern record of a meteorite-induced human death.

Calculations and predictions, based on such small sample sizes, are difficult to test and may prove to be more an exercise in statistical trivia (albeit an entertaining pursuit). The fact that many so-called reported cases turn out to be feigned (because of their sensationalism and, therefore, newsworthiness) only adds to the problem. Such an example closer to home includes the ten year old boy from Warwick (Queensland) who, while gazing at the stars one night in 1979, was hit on the leg by "hot, flying rocks" that consisted of "meteorite-like material". When sent to the Queensland Museum for identification, the meteorite was found to be a welded mass of nuts and bolts and the Warwick boy probably a subject of a school-boy prank. □

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The Encyclopaedia of Birds

Edited by C.M. Perrins and A.L.A. Middleton. George Allen and Unwin, London, Sydney, 1985. xv + 447 pp. \$49.95.



Eighty-seven ornithologists, including 12 from Australia, have contributed to this account of the birds of the world. Approximately eight per cent of the 8,800 odd species of birds recognised throughout the world occur in Australia, so one would expect that as nearly 14 per cent of the contributors are Australians, this work would give fair treatment to our beautiful birds. Indeed, I am pleased to see that Australian birds feature prominently in this publication.

Like similar books that have appeared in the past, *The Encyclopaedia of Birds* looks briefly at each family, including those known only from fossils. The sequence is based on the order used in *Checklist of Birds of the World* by J.L. Peters et al. (Museum of Comparative Zoology, Cambridge, Massachusetts). Two early pages are devoted to explanatory notes, which detail some of the major differences of opinion on classification. A short section titled 'What is a Bird?' outlines the evolution of the class Aves and looks at the physical charac-

teristics, senses and patterns of breeding among birds. The remainder of the book is divided into three parts which cover all the world's 180 or so families of living birds.

An information panel precedes the textual discussion of each family or group of families. This provides a quick reference to the main features of distribution, habitat, sizes, plumage, voice, nests, eggs and diet. A map shows the natural global distribution of each family and a scale drawing of a representative species is shown as a silhouette against a 1.8 metre human or 30 centimetre human foot.

The text itself is both an interesting and informative account of each family group. The results of specific studies of certain groups or individual species have been included in many of the essays to provide further insight into evolutionary processes, social organisation, foraging behaviour, breeding biology and conservation. Some of these brief special features, which may be of particular interest to Australian readers, include nomadism in Emus, lead poisoning in waterfowl caused by the ingestion of shotgun pellets, the song of the lyrebird, and honeyeaters as pollinators. These articles add immensely to the general discussion of each family of birds. Some attention is also paid to endangered species. Species listed as threatened in the International Council for Bird Preservation's *Red Data Book*, which are discussed in this book, are highlighted by a symbol system.

Almost every page has a colour photograph, colour illustration or, in some cases, a series of black and white line drawings to illustrate an interesting feature

such as feeding or courtship behaviour or other quaint habits (for example the Australian Fairy-wren's rodent run).

A valuable glossary of terms is provided together with a comprehensive index. Unfortunately, the book does not contain references, but this will not be missed by most readers.

This book is aimed primarily at the general public rather than serious ornithologists and I have no criticisms to offer which would be of any significance to the average reader. It is my view that the book achieves its objectives of providing a readable basic outline and understanding of the diverse bird families of the world and the ecological niches they occupy. Prospective purchasers should not expect to find an account of all known bird species. The book is not intended as, and does not pretend to be, a complete checklist or dictionary of the birds of the world.

Anyone who has an interest in birds and their lives should enjoy the informative and interesting text and illustrations. One can only look at *The Encyclopaedia of Birds* as succeeding in its objectives and being a valuable addition to any bird enthusiast's library.

—J.W. Hardy

A Field Companion to Australian Fungi

By Bruce Fuhrer. *The Five Mile Press*, 1985. 162pp. \$14.95.

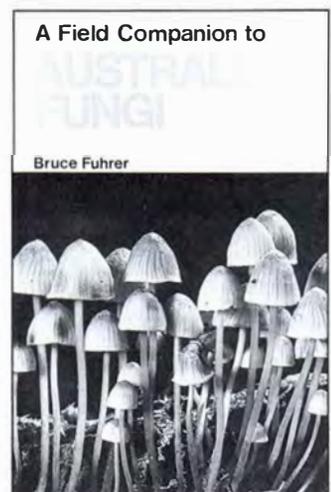
Weighing up to 29 kilos, with caps a metre or more across, the bolete *Phaeogyroporus portensis* is probably Australia's biggest mushroom. On a smaller scale, but equally impressive, is *Pleurotus nidiformis*, a luminescent green forest

fungus and little *Mycena interrupta*, with its bright blue caps.

Australian fungi, like fungi everywhere, are a fascinating but mostly ignored element of the flora. Bruce Fuhrer's superbly illustrated guide should help strike interest in this neglected group. Fuhrer's photos are excellent. Crisp, colourful and thoughtfully composed, they represent a veritable feast of exotic (and oft times erotic) colours, textures and shapes.

The same cannot be said for the skimpy text. Fuhrer says little at all about distribution. Very few common names are given. The text amounts to little more than captions to the photos.

The author has photographed most of his fungi in Victoria, so readers from further afield may be disappointed by the selection.



Also disappointing is the paucity of information on edibility. Fuhrer seems unaware that several of his illustrated species—like beefsteak fungus (*Hepatica fistulina*) and stalactite fungus (*Hericium clathroides*)—are good to eat. He does not depict important poisonous and hallucinogens.

This is a very beautiful and well-designed book but

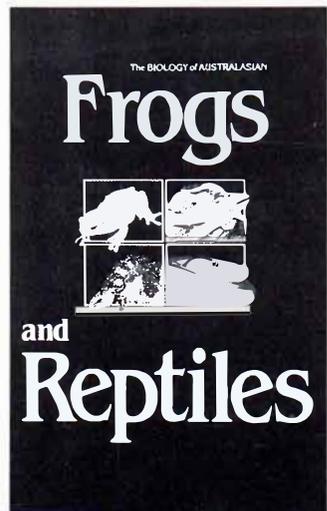
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its text is altogether a disappointment.

—Tim Low

The Biology of Australasian Frogs and Reptiles

Edited by G. Grigg, R. Shine and H. Ehmann.
Surrey Beatty and Sons,
Sydney, 1985. 527 pp.
\$56.00.



The Biology of Australasian Frogs and Reptiles is quite a milestone in Australian natural history. It represents the emergence of Australian herpetology from what has often been regarded as a part-time and somewhat 'inferior' branch of vertebrate zoology, to a status on par with mammalogy or ornithology. The history, format, content and range of the book represents an excellence in publication that any scientific field would be proud to accept.

This book contains papers presented at the Australasian Herpetological Conference, held in Sydney in August, 1984. The conference, one of a recent series of high-standard, scientific forums that have been sponsored by the Royal Zoological Society of New South Wales, further endorses the

support that this society has given to Australian zoology. All of this makes the book sound like dull reading but it is quite the reverse. Anyone with an interest in Australia's fauna will lap up the details, natural history secrets and glory of these underrated animals.

The book is divided into seven major sections: population ecology, ecological biogeography, phylogeny of elapid snakes, reproductive biology, physiological ecology, rare and endangered species, and husbandry and snakebite. Each one contains a treasure trove of valuable and curious information about our herpetofauna, as well as dealing with our near neighbours' (New Zealand and Oceania) reptiles and frogs. A number of the chapters have been penned by some very eminent names in Australian zoology, others by up-and-coming natural historians.

The level of achievement in Australian herpetology is soundly advanced by this publication. See for yourself by taking the time to thumb through some of the pages of this book. Although expensive, it represents good value for money. Snake, lizard and frog lovers will certainly covet this book as an essential addition to their collection.

—Dr Arthur White

Lands in Collision; Discovering New Zealand's Past Geography

By Graeme Stevens.
Science Information
Publishing Centre,
Wellington, N.Z., 1985.
129 pp. \$NZ18.95.

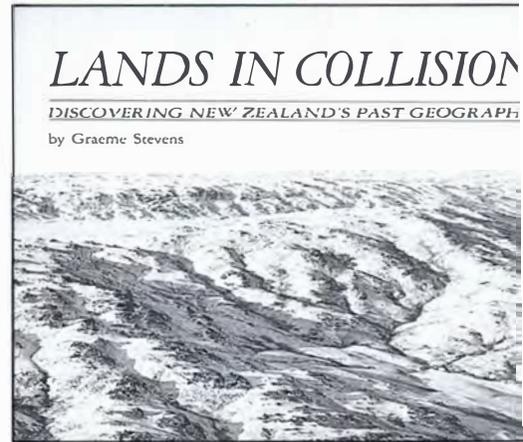
Lands in Collision provides an excellent coverage of the geological history of New Zealand from Cambri-

an times (570 million years ago) to the present. Indeed, predictions as to the shape and position of New Zealand over the next 50 million years add a further valuable dimension to this work.

Yet this volume covers much more than that. Early chapters give easily-understood overviews of major geological discoveries that are related to our modern understanding of continental drift. This will be particularly valuable to students of the earth sciences.

However, while geology is covered excellently in this volume, the treatment of biology is appalling. I was indeed surprised to learn that up until 40,000 years ago, the Australian mammal fauna consisted solely of monotremes and marsupials (page 78). Australia's unique rodents and bats, which make up fully one half of the fauna, must have been spontaneously generated from vapours or some such at that time! I was also astounded at the revelation that Wallace's Line ceased to exist in the Pleistocene as "the myriad islands in Indonesia were all connected by land and linked to South-East Asia" (page 104). One wonders then, why rhinos, tigers, Orang-utans and tapirs failed to cross this dry land from Java to Irian Jaya (western New Guinea) and why kangaroos did not infest Asia!

Apart from the major rearrangements of the fauna and zoogeography of the Australasian region, the book is marred by a number of lesser errors in its biological and palaeontological sections. For example, New Zealand's only dinosaur fossil is 70–65 million years old on page 73 but ages remarkably to 85–70 million years by page 74!



Overall, though, I must recommend this book for its excellent treatment of the geology of New Zealand and for its well thought-out structure. The technical notes at the end of the book are very useful, particularly for students and a number of useful references are given. The illustrations, however, are amateurish. Just one final warning to university students who may be taking courses in both geology and biology—make sure you *don't* take this book into your final biology exam!

—Dr Tim Flannery





ROBYN WILLIAMS

Enlightenment vs Luna Park: A New Kind of Museum Gallery

A.B.C. RADIO SCIENCE SHOW

It was the very last day of our trip overseas. In the eight weeks that I'd bounced my two young children (Tom was 11, Jessica eight) from London to Paris, on to Florence and Rome, Frankfurt, New York and Los Angeles, they had enjoyed (or endured) countless museums, cathedrals, galleries and historic places. They were understandably cross, therefore, when I announced that our final hours abroad were to be spent at yet another worthy institution of learning—the Exploratorium.

"Bet that's just another museum!", they wailed.

"Wait and see", I hedged grimly. "This one is different".

I shanghaied the two sullen victims to the park near the Golden Gate Bridge where Professor Frank Oppenheimer had established his scientific adventureland in an old arts building the size of a jumbo hangar. We were initially taken aback by the pseudo-Grecian statues and giant columns. But the real astonishment was inside: scores, perhaps even hundreds, of experiments, bursts of colour, explosions of sound—even displays designed specially for the experience of touch—seemed to go on forever.

Domes with electric guitars, domes with noise machines, tanks with electric fish, strobes giving visual illusion, computer screens with cosmic challenges... on and on they went, with kids intently preoccupied at each station.

My kids charged off to join in. It took hours to extract them. I thought we'd miss the flight home.

Can one adapt Oppenheimer's vision for natural history displays? Well, not in the same way as a museum concentrating on the physical sciences might. Sydney's Power House Museum will have scores of 'hands-on' displays and the National Science Centre, developed from Michael Gore's brilliant Questacon in Canberra, will take such schemes further. But I think we can explore techniques that allow direct, even physical, involvement in a natural history museum. This I have no doubt of, but it is worth asking why one should bother.

Firstly because, it seems to me, nature is not static and closed off in a box. Nor is it stuffed! So to allow interplay is not to misrepresent. Secondly, the traditional way to display knowledge is as if it came without struggle. There is the bird; that is its name (Latin and common); this is its taxonomy and relationship to other beasts; here is its distribution... so there!

Just like that. All neat. All sewn up.

But the sciences, even biology, are full of doubt, disputation, re-appraisal, exploration. To represent this in a museum wouldn't be misleading.

Imagine entering a large hall. Basic in both decoration and design, it allows flexibility and robust treatment. In the centre might be a workshop area (protected but fully visible) where equipment of interest is being fixed or prepared—fossils cleaned, bones moulded, displays painted. In the corner are live animals: a seashore tank where starfish and molluscs can be picked up and examined, a giant piece of living coral with lots of fish and anemones, an electric fish like that in the Exploratorium with an audio-amplifier of the signal made when the fish is approached, and some bottom-living polychaetes showing feeding mechanisms.

In a second corner are computer screens. One can be programmed to show how dramatically the environmental parameters of a forest change as you chop the trees down—how the wind increases and the temperature goes up. On another you can follow the pentadactyl (five-fingered) limb from its beginnings in fish through to the various forms in seals, elephants, apes, whales and people. On yet another, one can see a scene as, we imagine, would a bird (like a film slowed down ten times), a bee (in thousands of images at once), a dog (without colour), a hippo (poorly), or a baby (in simple patterns). Select your example and the picture changes.

In a third corner are our enthusiastic amateurs of the month. This time we may have the rock-choppers with their collections of ammonites,

meteorites, stalactites and gold: well, perhaps it isn't gold. And the main attraction might be experts on hand who could examine and identify their treasures. Next month the ornithologists could take over (with games involving the identification of bird calls or eggs or feathers), then gemstone people (polishing and identifying), then ichthyologists, froggos, shell-collectors, snake-lovers, book-merchants, ethnographers, Aboriginal sand-painters and so on. Why, even musicians could be there—teaching people to play the didgeridoo.

In the fourth corner are some fairly sophisticated scientific instruments of a more traditional nature. One is a microscope with overhead projector, which will show your cheek cells or the living content of pond water. One is an indestructible apparatus on which youngsters can view slides they prepare themselves. Another is a display showing relative size which can be multiplied or reduced from the global (Earth seen from a satellite) to the microscopic (shown by scanning electron micrographs) as participants zero in on a specific point, getting closer and closer with each stage. Participation is limited by the cost of the apparatus or the preference of the on-lookers.

This imaginary hall would be ever-changing as lessons are learned and gifts are made; and as varied and as active as science itself. It would not be a substitute for the natural history museum we know, but complementary to it.

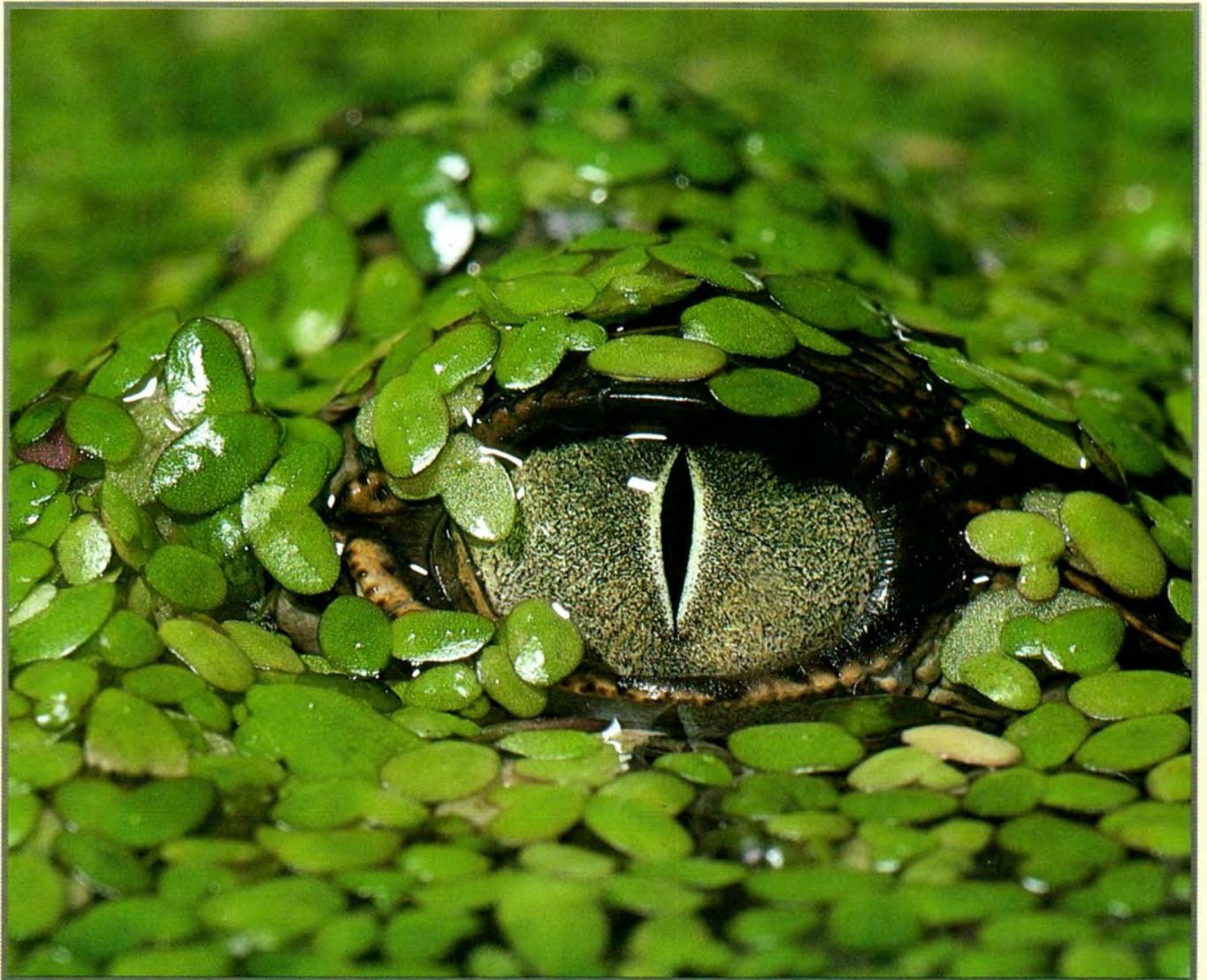
If it does a little to further the inspiration of the remarkable Professor Oppenheimer (who, like his brother Robert, once worked at Los Alamos on the Manhattan Project), then I would be delighted. The old man died, not long ago, of cancer. The Exploratorium lives on. □

CROCODILE TEARS

Salt Glands and the Evolution of Crocodiles

by Laurie E. Taplin

Crocodile tears—which are supposedly shed by crocodiles over those that they devour—have long been a symbol of hypocritical grief. They have, however, recently emerged from their literary closet to play a tantalising role in a scientific investigation that promises to radically change our understanding of crocodile zoogeography and evolutionary history. Laurie Taplin, from the Queensland National Parks and Wildlife Service, explains how.



Eye of the Saltwater Crocodile, *Crocodylus porosus*. Photo: D. Maitland.



◀The ancient Egyptian crocodile god, Sebek (Suchos in Greek), from whom the scientific name of the modern crocodilians is derived. From E.A.W. Budge, *The Gods of the Egyptians*, Dover Publications Inc., New York, 1969.

prominent in Alexander Neckam's 13th century Latin poem *De Naturis Rerum*, which (loosely translated) records:

"It [the Cocodrillus] sometimes eats human flesh but, as if sympathizing, bathes its face with tears."

Neckam was one of the prominent natural philosophers of the Middle Ages and, like many scholars of his time, relied for his information on the works of the classical scholars of Greece and Rome. There is mention of crocodile tears in a sermon by Asterius, Bishop of Amasia in 400 AD, and an oblique reference in Claudius Aelianus' biological miscellany *De Natura Animalium*, written in the 2nd or 3rd century AD. Aelianus records:

"... the people of Apollinopolis, a district of Tentyra, net the Crocodiles, hang them up on persea-trees, flog them severely, mangling them with all the blows in the world, while the creatures whimper and shed tears; finally they cut them up and eat them."

Tearfulness, in this context, is not associated with hypocrisy. Rather, the crocodile is portrayed as something of a cowardly brute. The anecdote gives the impression that the crocodile-tears association derives from fairly long established folklore but here we come to a dead end. No evidence of its origins can be found in the earlier writings of Oppian, Aristotle, Strabo, Pliny the Elder or Herodotus, in whose works much contemporary natural science was recorded. Nevertheless, there can be little doubt that the myth has its origins in ancient Egypt, whence virtually all the early natural history of crocodiles was derived.

The crocodile played a major role in Egyptian mythology, even in pre-dynastic times before 3000 BC. The crocodile god Sebek (Suchos in Greek—hence Eusuchia, the suborder containing the modern crocodilians) was worshipped in parts of Egypt, especially at Arsinoe (known as Crocodilopolis for some of its history) and Thebes, but detested elsewhere. Sebek was one of the earliest local gods of pre-dynastic times and was regarded as the personification of evil and death. In later times Sebek became associated with Set (Seth, Typhon), the god of the sky by night, and

it is from this association that the myth of crocodile tears may have evolved.

In the legends of the first and second millennia BC, Set waged war against the Sun god, Ra. In these legends, Set took the form of Apep, depicted either as a giant crocodile or as a giant serpent accompanied by a crocodile. Apep had swallowed the Moon, the left eye of Ra, so Ra thrust his lance into Apep who vomited forth the Moon and, according to some authorities, wept.

It is possible, however, that the association of tearfulness with crocodiles may go even further back to the Egyptian legends of creation. In one version of *The Book of Knowing the Evolutions of Ra and of Overthrowing Apep*, recorded about 312 BC, the god Osiris in the form of Khepera (both forms of the Sun god, Ra) created the gods Shu and Tefnut from the watery abyss known as Nu, and the Sun, Nu's eye, came into being. However, the Sun was shrouded by mist and cloud, which proceeded as tears from Khepera (Ra). These tears seem to be personified as the god Rem, about whom little is known except that *rem* means 'to weep'. However, *The Book of the Dead* refers to a god Remi who appears to be identified with Sebek (the crocodile god) and personification of Nu. Elsewhere we learn that Apep was originally the thick darkness that enveloped the watery abyss of Nu and formed a serious obstacle to the Sun's emergence. Thus the association of Sebek and Apep (both represented as the crocodile) with the creation of the world is manifest—and there are several hints of an ancient connection of tears with crocodiles.

Unfortunately for the crocodile, the days of veneration and worship are long since gone, even in Egypt. The ancient legends have largely been lost and crocodile tears have lingered on as one of the few enduring crocodilian contributions to western culture, ranked a poor second to alligator-skin shoes and disappearing from even the literary scene.

In an odd twist of fate, however, crocodile tears have recently emerged from their literary closet to play a tantalising role in a scientific investigation that promises to change the way we think of crocodiles and their evolutionary history. Before looking at these recent events we should look briefly at what is known of the history of this remarkable group, which has survived

Of the many myths surrounding crocodiles, the idea that they shed tears of hypocritical grief over their victims is undoubtedly one of the most colourful and venerable. Crocodile tears as symbols of hypocrisy appear to be a European institution, drawn from ancient Egyptian culture and passed on for centuries. There is little to connect them with other continents or cultures. They were popular in Elizabethan England where Shakespeare used them in several of his plays, hence:

"Gloucester's show
Beguiles him as the mournful
crocodile
With sorrow snares relenting
passengers."

Henry IV, III: 225 (AD 1590–91),

while Samuel Bacon in his *Essays* of 1612 AD notes: "It is the wisdom of crocodiles, that shed tears when they would devour."

The theme is developed in several of the medieval bestiaries and is

little-changed since before the Age of Dinosaurs.

Crocodile Evolutionary History

The first crocodiles, the protosuchians (from the Greek *pro-* = first and *Suchos* = Sebek, the Egyptian crocodile god), are found in Upper Triassic sediments of North and South America and Africa, some 200 million years ago. They were small animals, about a metre long. Some may have been terrestrial but others shared the amphibious freshwater habits of their modern descendants. From this inauspicious origin arose the dominant Mesozoic crocodylians of the suborder Mesosuchia. The adaptive radiation of the crocodylians reached a peak during the Mesozoic with the emergence of truly terrestrial and highly aquatic forms, in addition to characteristically amphibious crocodylians like those we see today. Thus the Jurassic Metriorhynchidae were highly specialised marine crocodiles with well-developed flippers and a rather shark-like tail fin. Presumably they either crawled ashore like turtles to lay eggs or bore their young live like most of the sea snakes. Somewhat later in the Mesozoic, perhaps 70 to 100 million years ago, the Libyosuchidae and Notosuchidae appeared. Almost certainly terrestrial, they ap-

pear to have occupied a niche similar to that of modern goannas. The Mesosuchia thrived until the late Mesozoic when, at about the time of the great extinctions of the late Cretaceous, they were largely displaced by a new group of crocodylians, the Eusuchia.

The evolutionary history of the eusuchian crocodiles is poorly understood, despite the fact that crocodiles are among the most abundant vertebrates in many fossil-bearing strata. The reasons for our ignorance are quite straightforward. The crocodylians have, throughout their history, been remarkably conservative in body form. While there have been small crocodiles and giants over 15 metres long, terrestrial and aquatic forms, narrow- and broad-snouted types, there have been very few that would not be readily recognisable to the layman as crocodiles. Because similar skeletal characters have arisen independently in many distantly related species, there are few characters of value in determining which species are most closely related to one another. Additionally, neither soft tissue nor ecological characteristics of the living species have proven very useful in clarifying their relationships. Hence, various authors have divided the Eusuchia along different lines according to the

weighting they give to the few characters that do separate them.

Perhaps the most distinctive eusuchians belong to the family Gavialidae—large crocodiles with inordinately long, thin jaws, represented today by only one species, the Indian Gharial (*Gavialis gangeticus*). The other extant crocodiles belong to three subfamilies: the Crocodylinae or true crocodiles; the Alligatorinae, which includes alligators and caimans; and the Tomistominae with a single species, the Asian *Tomistoma schlegelii*. The tomistomines and gavialids reflect the narrow-snouted line of crocodylian evolution, while the alligatorines are almost exclusively broad-snouted. The crocodylines, however, include both narrow-snouted species like Australia's Freshwater Crocodile (*Crocodylus johnstoni*) and the remarkably similar African Sharp-snouted Crocodile (*C. cataphractus*), and broad-snouted species such as the Saltwater or Estuarine Crocodile (*C. porosus*) and the African Dwarf Crocodile (*Osteolaemus tetraspis*). Many of the Crocodylinae bear a remarkably close resemblance to one another, but whether this reflects close evolutionary relationships or parallel evolution has not been determined.

With so much uncertainty over



Representative living eusuchian crocodylians showing the conservatism of body form in the group and the broad- and narrow-snouted lines of evolution that have characterised the eusuchians throughout their history. A: Indian Gharial (*Gavialis gangeticus*; Gavialidae). B: Freshwater Crocodile (*Crocodylus johnstoni*; Crocodylinae). C: Nile Crocodile (*C. niloticus*; Crocodylinae). D: Spectacled Caiman (*Caiman crocodilus*; Alligatorinae). Photos: L. Taplin.

the phylogeny of crocodylians it is not surprising that little progress has been made in understanding their zoogeography. In recent years, however, the application of biochemical and immunological techniques to the problem of crocodylian phylogeny has changed dramatically the traditional picture of crocodylian evolution and raised some intriguing zoogeographical questions. At the same time, unrelated advances in the field of crocodylian physiology have provided a possible answer to at least some of these questions. Together, these independent pieces of work have led to a radically revised view of the evolution and zoogeography of the living

neys of limited concentrating ability, marine reptiles should have salt glands.

Over the next 20 years, salt glands were found in nearly all marine and estuarine reptiles and several different types were shown to have become modified for salt excretion. The sea snakes have sublingual salt glands secreting into the sheath surrounding the tongue, the Galapagos Iguana and Rusty Monitor have nasal salt glands comparable to birds, while the sea turtles and estuarine Diamondback Terapin have lachrymal glands secreting salty tears into their eyes—hence the doleful appearance of the nesting turtle.



The white plastic device on the crocodile's snout was specifically designed to collect nasal salt secretions from Saltwater Crocodiles. However, attempts to do so proved singularly unsuccessful. Note the firmly tied jaws! Photo: L. Taplin.

crocodylians. In pursuing these developments we must turn to a problem of crocodylian physiology and, in doing so, we find crocodile tears coming back into the picture.

Those Elusive Salt Glands

About a quarter of a century ago, Knut Schmidt-Nielsen, the founding father of environmental physiology, discovered that the fluid that drips from the nostrils of marine birds is extremely salty and is secreted by specialised excretory organs, the salt glands. He demonstrated that the salt glands were, in effect, accessory kidneys specialised for the excretion of inorganic salts and crucial to the bird's survival at sea on a salt-rich diet. The need for salt glands derives from the inability of a bird's kidney to produce urine more concentrated than its blood and hence to excrete salt at a sufficiently high concentration to keep its blood diluted. Schmidt-Nielsen reasoned that since reptiles also have kid-

neys of limited concentrating ability, marine reptiles should have salt glands. By 1980, 22 years after Schmidt-Nielsen's discovery, the only major group of reptiles in which salt glands had not been found was the Crocodylia. This fact was not entirely surprising, however, as it had long been held that modern crocodylians were essentially freshwater animals with only limited sea-going capabilities. Only in recent years has this view been seriously questioned.

The observation that some species of crocodiles, especially the Saltwater and American Crocodiles (*Crocodylus porosus* and *C. acutus*), spend much of their time in saltwater habitats and are capable of crossing substantial marine barriers, led to speculation that they, of all the eusuchian crocodiles, should have salt glands akin to those of other marine reptiles and birds. But, because none could be found, it was argued that these 'marine' crocodiles were really more or less estuarine in habits, having

periodic access to fresh or brackish water. Together with their large size and impermeable skin, this might explain their survival in the wild. However, observations of the Saltwater Crocodile in northern Australia showed that many small animals, even hatchlings, live in highly saline waters, often far more concentrated than sea water, in areas where no fresh water is available and months at a time can pass without rain. These crocodiles eat salt-rich invertebrates and yet excrete very little of the principal salt, sodium, in their urine or faeces. If the sodium wasn't to be found in urine or faeces, then it was most likely excreted by salt glands. But where were they? This was a problem that vexed my colleagues and I at the University of Sydney for several years.

Because salt glands are secretory organs, it seemed sensible to confine the search to those glands and organs capable of secreting salt to the outside of the body. The tears of turtles flow directly to the exterior. The nasal secretions of birds and lizards either drip from the beak or are expelled by 'sneezing'. The sublingual salt glands of sea snakes secrete into the tongue sheath inside the mouth but are expelled as the snake slides its tongue in and out. Now the Saltwater Crocodile has quite well-developed nasal and lachrymal (tear) glands so these were obvious candidates for investigation. There are few other glands in the head apart from some small and very obscure oral glands described last century by German anatomists. These included small glandular masses on the palate and simple tubular glands on the tongue, both of which were assumed to be salivary glands of one sort or another. Neither type was described as having remotely the size or structural complexity of other reptilian and avian salt glands and so were dismissed from our considerations early on in the piece.

Nasal secretions are not much in evidence in crocodiles and attempts to collect salt from the nose were amusing but singularly unsuccessful. Crocodile tears, on the other hand, can flow quite readily from freshly captured animals and were, without doubt, the most probable route for salt secretion. Yet, despite our best efforts to stimulate secretion, they proved neither sufficiently saline nor copious to account convincingly for the salt that had to be excreted. Numerous excre-

tory routes were then investigated but rejected one by one, including the possible presence of a rectal gland like that in sharks and rays.

It was, therefore, rather a last-ditch effort that led us to closer examination of that most unpromising area—the crocodile's mouth. Yet there, to our complete astonishment, were the salt secretions we'd been chasing for so long—all over the tongue and secreted by those obscure little lingual glands. It needed only a little reflection to realise that the glands were nevertheless excretory, as the oral cavity of a crocodile is effectively part of its external surface, sealed off from the interior by the palato-hyal valves and the secondary palate. Analysis of the secretions and electron microscopic examination of the glands left no doubt that they were indeed salt glands, secreting sodium chloride three to five times more concentrated than their blood.

Here, then, was the secret of the crocodile's salt glands. Nothing to do with crocodile tears at all; these had been a red herring all along. But the pleasure of solving one physiological puzzle was soon followed by perplexity over another, for the lingual salt glands of the Saltwater Crocodile were not unique as we expected. They turned up in a variety of crocodiles, including some that were, to all intents and purposes, restricted to fresh water. There seemed no sensible physiological reason for freshwater crocodilians to need salt glands in a salt-poor environment, especially as they share with other freshwater reptiles the ability to reduce urinary salt loss by reabsorbing sodium and chloride from their urine. It was in searching for an explanation of this paradox that the biochemical and immunological studies of Llew Densmore and Herbert Dessauer in the United States provided essential clues.

Protein Clocks and a Revised Crocodile Past

Densmore and Dessauer had spent several years attempting to unravel the phylogenetic relationships of the living crocodilians by comparing blood proteins using a variety of sensitive techniques. Their results for the alligator-caiman lineage (Alligatorinae) were fitted readily into existing schemes of crocodilian evolution. The Alligatorinae separated readily in their tests from the Crocodylinae; and they

were able to date this divergence to the late Cretaceous or early Tertiary, basing their calculation on average rates of evolutionary change in the proteins they examined (the so-called 'protein clock'). The various alligatorine genera and species segregated readily, with the basic split between the North American-Eurasian alligators and South American caimans dating to the early Tertiary. Datings of both the alligator-crocodile and alligator-caiman divergence fitted well with fairly good fossil evidence.

The results for the crocodile lineage, however, were not so readily understandable. Densmore found amazingly little variation in proteins between members of the genus *Crocodylus*, while the only other member of the Crocodylinae, *Osteolaemus tetraspis*, had diverged only minimally from the *Crocodylus* stock. Protein clock calculations pointed to the appearance of all extant crocodylines within only the last five million years or so. This was totally at odds with the accepted view of crocodyline evolution, in which the extant species were regarded as relicts of a group that appeared and radiated throughout most of the continents in the late Cretaceous or early Tertiary, some 65 million years ago!

Now, an early Tertiary dispersal of the crocodylines is feasible for a group of freshwater animals because, among other things, the continents at that time were only beginning to break apart. The Laurasian and Gondwanan landmasses were still largely intact and there is little need for trans-oceanic crossings to explain the occurrence of crocodiles on all the major landmasses. A more recent post-Pliocene radiation and dispersal of the crocodylines is, however, quite a different kettle of fish. The continents were in much their present positions by the middle Tertiary and, by the Pliocene, formidable oceanic barriers to crocodilian dispersal existed. Nor was there opportunity in the post-Pliocene period for dispersal between America and Eurasia via major land bridges like the Bering Strait, which had allowed alligators to pass between North America and Asia during periods of low sea levels and warm sub-Arctic climates. Two possible explanations suggested themselves. The calculated protein clock date of the crocodyline radiation could be wrong but this would imply that rates of protein evolution differed



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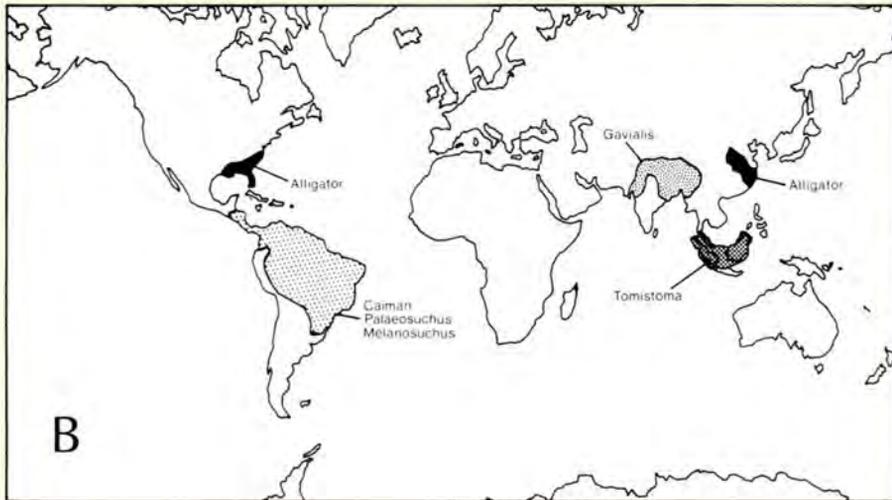
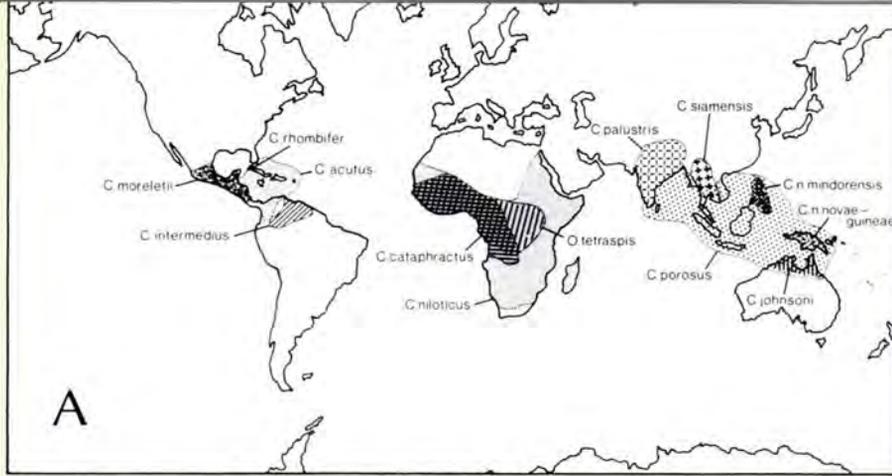
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Geographical distribution of the living crocodylians. It is argued that the high diversity of the Crocodylinae in the island archipelagoes of Asia, Australasia and the West Indies (A), and the restriction of the Alligatorinae to the continental landmasses of Eurasia and the Americas (B) are, in part, consequences of the differences in the physiology of their lingual glands.

remarkably between the Crocodylinae and the Alligatorinae. Alternatively, the post-Pliocene radiation could be real but, in this case, dispersal must have required the crossing of major oceanic barriers.

Here the accumulating physiological evidence provided, for the first time, a feasible mechanism for such dispersal. The Saltwater Crocodile had been shown to be remarkably tolerant of very high salinities and not dependent on fresh water for survival at sea. Large crocodiles are known to take to the sea and cross substantial barriers. Even small one-metre crocodiles are seen commonly on islands of Australia's Great Barrier Reef. Adult crocodiles should be capable of surviving many months at sea without feeding or drinking. This marine capability is combined with the ability to survive and reproduce not only in estuaries but also in permanent fresh water, hundreds of kilometres from the sea. It is not difficult to envisage an animal with these capabilities being able to cross substantial seaways, disperse through island chains and establish breeding populations. Combined with the marked sea level fluctuations of

the past few million years, opportunities for periodic isolation of freshwater populations and subsequent reinvasion by saltwater populations may have been common. The Saltwater Crocodile may not be the ancestor of other living species but its physiological capabilities are precisely those we might expect to see in the ancestral stock.

If, indeed, the freshwater and saltwater crocodylines are derived recently from sea-going ancestors, then the presence of salt glands in many of the living freshwater species is less paradoxical than at first thought. The glands may have retained some of their salt-secreting ability (which is significantly lower in all species than in Saltwater Crocodiles living in sea water) through some dependence of oral sense organs or membranes on such secretions. Alternatively, the glands may function in maintenance of salt balance during periodic bouts of aestivation, which appear to affect most freshwater crocodylians living in hot, dry climates. But, if the lingual salt glands of the crocodylines are relicts of a recent marine ancestry, then what of the lingual glands of the alligato-

rines? Here we find quite a different picture. Only the American Alligator (*Alligator mississippiensis*) and the Spectacled Caiman (*Caiman crocodylus*) have been examined to date, but both lack the complex, lobulated salt glands of the crocodylines. Instead, they have relatively simple tubular glands of quite different appearance. These seem to be fairly ordinary salivary glands incapable of the copious and concentrated secretions of salt glands. The apparent absence of salt glands in the Alligatorinae may explain their historical restriction to the continental landmasses of North and South America and Eurasia. Dispersal between North and South America, and between North America and Eurasia, could have been possible for these freshwater animals in the early to middle Tertiary across land bridges or short island chains in the Bering Strait and central America. It is notable that never in its long history has the Alligatorinae colonised any of the archipelagoes of Asia and the West Indies, unlike the Crocodylinae, which has achieved its greatest diversity in precisely these areas.

We can see, then, that our perception of the evolutionary and zoogeographical history of the crocodylians is likely to be altered greatly by recent developments. If these ideas gain acceptance, the familial classification of the group may need changing to give the Alligatorinae and the Crocodylinae full status as separate families. The relationships and origins of the Gavialidae and Tomistominae will remain unclear for the present, as there is insufficient knowledge of their biochemistry or physiology. But acceptance of these ideas will also create a further evolutionary puzzle. Fossils belonging to the genus *Crocodylus* are known from the earliest part of the Tertiary, 60 million years or more before the living Crocodylinae are supposed to have appeared on the scene. If all our living species are new ones, then where did all the old species go and why should they have disappeared so completely? As in most sciences, the solution to one puzzle raises another batch to tantalise us. At least with this one we'll be restricted to dealing with fossils and won't have any mythical crocodile tears to lead us astray. □



Actively secreting lingual salt glands of the Saltwater Crocodile. The secretions are three to five times more concentrated than the blood plasma and are the major excretory pathway for excess sodium. Note the palatal valve at the back of the tongue, sealing off the mouth completely from the throat and internal organs. Photo: L. Taplin.



A▲

▼B



Comparison of the tongues of A, the Indian Muger (*Crocodylus palustris*) and B, the South American Spectacled Caiman (*Caiman crocodilus*). Note the prominent lingual salt glands in the Muger and their absence from the Caiman. *Alligator* and *Caiman* have small, relatively simple lingual glands, which lack the ability to secrete concentrated sodium chloride solution. Photos: L. Taplin.

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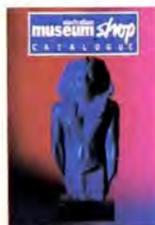
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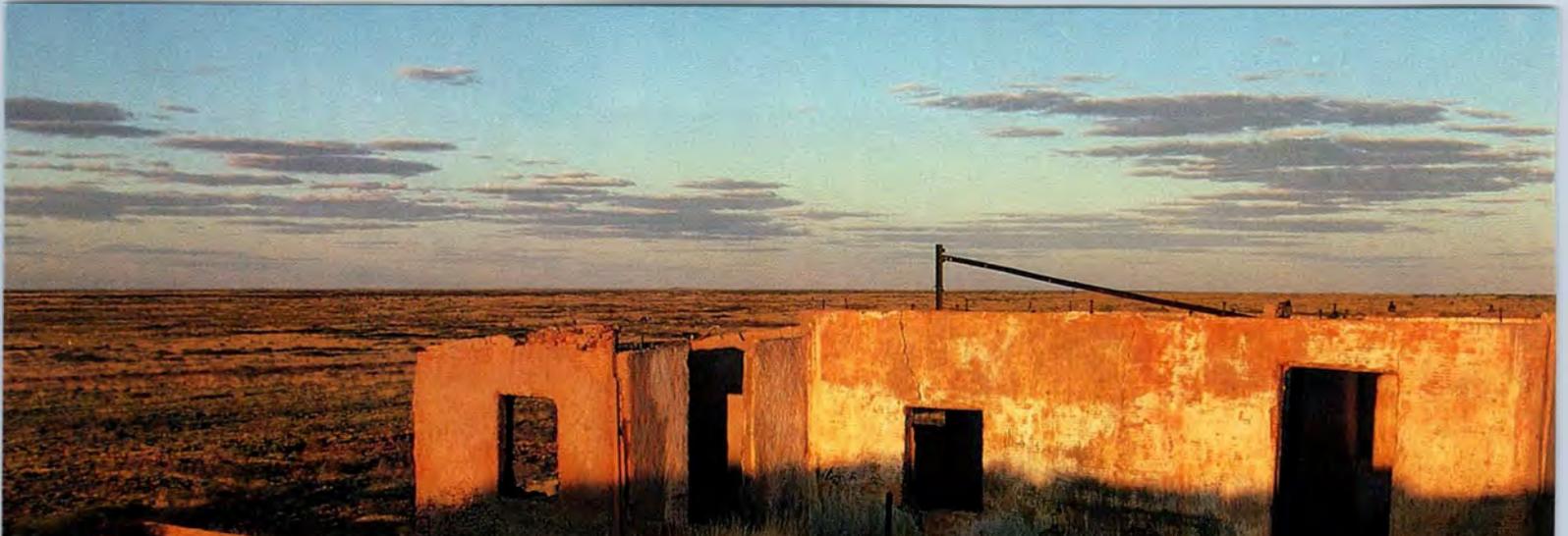
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THE TANAMI DESERT

Research on Aboriginal Land

BY DAVID F. GIBSON

In recent years the Tanami Desert has been the focal point for a number of wildlife research programs carried out by the Conservation Commission of the Northern Territory (C.C.N.T.). This vast region covers an area of over 160,000 square kilometres, more than twice the size of Tasmania. David Gibson of the C.C.N.T. explains the biologically unique and pristine nature of the area and the conservation measures that are being taken to preserve it.

Found in the central western portion of the Northern Territory, the Tanami Desert is largely unknown to most Australians. The Simpson Desert, in fact, is probably better known by virtue of the many 'first' crossings reported from time to time.

History and Exploration

The early history of European exploitation in the Tanami generally followed the trend found in most other parts of Australia: exploration, then mining, followed by pastoralism. However, Aboriginal occupation has been of overwhelming importance and to this day exerts a major influence on the ecology of this sandplain region of spinifex and shrubs.

The first European explorers travelled in the Tanami Desert as early as 1873 and, even in the 1930s, it was still being explored. Men such as W.C. Gosse, A.A. Davidson, W.R. Murray and M. Terry are unknown to the majority of Australians, yet their journeys rank them in stature with such notables as Sturt and Mitchell. Our knowledge of early Aboriginal occupation of the Tanami, its landscapes, mineralogy, flora and fauna would be severely limited but for the endeavours of these explorers.

Following exploration came the miners and prospectors who eventually established workings on the Tanami and The Granites goldfields. Attempts were also made to run stock in several parts of the Tanami Desert but neither pastoralism nor mining were very successful. Today the Tanami is unique in that it is one of the largest areas in Australia virtually unaffected by mining, pastoralism and European exploitation as a whole.

Conservation

Interest in the Tanami for conservation purposes dates back to 1964 when the Tanami Desert Wildlife Sanctuary was established, covering an area of 37,529 square kilometres. A number of wildlife surveys were carried out within the sanctuary and these confirmed the almost pristine nature of the country as well as the presence of a number of rare animal species. The status of this sanctuary, however, was soon to change.

In 1976 the Federal Government passed the Aboriginal Land Rights (N.T.) Act and in 1978 the Warlpiri people, who have traditionally lived within the Tanami, were granted freehold title to an area of 90,000 square kilometres. This grant included the Tanami Desert Wildlife Sanctuary

Ruins at the abandoned Granites goldfield. The goldfield was discovered in August 1900 by A.A. Davidson. The area was an important wildlife habitat in the past and, even though many of the medium-sized mammals are now extinct, it remains an important region for small mammals. It is also a significant mythological site for Warlpiri Aborigines, being related to a possum dreaming. Photo: I.R. McCann, A.N.T.

which later, in 1982, had its sanctuary status dissolved. During those years of change, active wildlife survey work was continued, confirming the Tanami as a unique biological area worthy of more intensive research. However, much of the region remained unknown and, in fact, had never been traversed by anyone other than Aborigines. Even Aboriginal activity in many parts of the Tanami had been absent for 40 or more years as their traditional nomadic hunter-gatherer way of life gave way to the more sedentary lifestyle of Europeans.

Faunal Survey

Between 1981 and 1984, two researchers contracted to the C.C.N.T. were engaged full-time to survey the entire Tanami Desert. Their main

objectives were to determine what wildlife inhabited the region and to define areas of biological significance that were important for establishing conservation areas. Aborigines participated in the survey work. The older men and women, especially, had much to contribute to our knowledge of Tanami wildlife—particularly those species now regarded extremely rare or extinct.

The three-year survey was both rewarding and disappointing. Together with historical accounts and previous wildlife surveys, they revealed a rich and abundant wildlife comprising the following assemblage of vertebrate species: two species of fish, 17 amphibians, 90 reptiles, 188 birds and 41 mammals. A total of five new species were recorded for the Northern Territory—the Lesser Hairy-footed Dunnart (*Sminthopsis youngsoni*), the skinks *Ctenotus greeri*, *Lerista ips* and *L. aericeps*, and an undescribed frog of the genus *Cyclorana*. Significant species in terms of, for example, their isolated populations or recent invasions, include the Western Chestnut Mouse, Delicate Mouse, Long-tailed Planigale, Pheasant Coucal, Red-chested Button-quail, Painted Snipe and Grey Falcon. The Tanami is also home to two endemics—the skink *Ctenotus tanamiensis* and frog *Uperoleia micromeles*.

Several rare and endangered species were located during the survey work. The Greater Bilby, Spectacled Hare-wallaby and Northern Nailtail Wallaby were quite common in some areas. A small population of the rare central Australian form of the Common Brushtail Possum was located and an egg, considered by experts to be that of the elusive Night Parrot, was found. The Tanami is also home to the only extant continental population of the Rabbit-sized Rufous Hair-wallaby. Known to the Warlpiri as the Mala, it once had a wide distribution throughout much of South Australia, Western Australia and the Northern Territory.

Local Extinctions and the Effects of Fire

The disappointing aspect of this work was finding that many species of mammals about the size of the Mala had become locally extinct. Aboriginal informants related the past occurrence of a number of medium-sized mammals that were no longer found in the area. These included the Bur-



The Greater Bilby was found to be common in many parts of the Tanami Desert. However, its continental range has been drastically reduced during the past 100 years. Here, a female suckles its young. Photo: D.V. Matthews, A.N.T.



A number of Warlpiri men have been employed to help manage the critical habitat of the endangered Rufous Hare-wallaby or Mala, mainly through the practice of controlled burning. Photo: D.F. Gibson.

rowing Bettong, Brush-tailed Bettong, Golden Bandicoot, Western Quoll and even a small and apparently passive wallaby known to the Warlpiri as the Yamarri. Only reported to be the size of the Mala, this wallaby has not been positively identified by scientists and will probably remain unidentified forever.

It appears that about 58 per cent of the medium-sized mammals have disappeared. This figure compares to less than 19 per cent for small mammals (such as the Long-tailed Hopping-

mouse, Short-tailed Hopping-mouse and Central Rock-rat), while none of the large mammals have vanished. Only one bird, the Malleefowl, is now absent from the Tanami. These species represent a significant loss not only to conservationists but also the Warlpiri. Many aspects of Warlpiri culture involve these animals in songs, dances, dreaming tracks and dreaming sites.

So, what caused these extinctions over such a large slice of Australia? Traditionally accepted reasons for

extinctions, such as European exploitation (particularly pastoralism) and the introduction of exotic animals, do not fit with the Tanami experience. It was clear that the extinctions were rapid and had taken place over a period of only 30 to 40 years as many species were abundant when the survey informants were children.

The current theory is that fires (or a lack of them) may have had a major influence on these local extinctions. With the decrease in traditional Aboriginal hunting methods, which is directly related to the increase in European occupation in the last 30 to 40 years, came the decrease in the number of small, periodically-lit fires. This meant that fires caused by lightning, for example, instead of being checked by limited plant growth, could spread for thousands of kilometres. Large animals, because of their inherent



The fence-trap technique was used intensively during the survey of wildlife in the Tanami Desert. Many species of frogs, lizards and small mammals, which would otherwise be difficult to document, were captured by this means. Photo: D.F. Gibson.

mobility, could avoid these fires. Small animals might burrow underground and afterwards gain nutriment from the soil. But medium-sized animals, even if able to escape death from the fire, would probably die from lack of food.

Research in the Tanami is currently directed towards determining exactly what effect fire has on the ecology of



Particular emphasis was placed on the search for medium-sized mammal species, many of which appear now to be locally extinct in the Tanami Desert. Here a Greater Bilby has been successfully obtained from a large termitaria by a Warlpiri informant. Photo: D.F. Gibson.

this region. Controlled mosaic or patchwork burning is successfully being used to manage the Mala colony. It helps maintain the protective spinifex cover for this medium-sized animal, while providing food in the form of regenerating grasses and forbs. This use of fire will also, hopefully soon, be used to manage the habitat for the only known location of the Common Brushtail Possum in the Tanami.

The Tanami survey also identified areas potentially suitable for the reintroduction of rare animals. A colony of Mala has been established in one of these areas with the help of Aboriginal people who have traditional affiliations with the species and the reintroduction site. However, it will be some time before it is known whether or not the program is successful.

The survey also established that five areas in the Tanami have significant conservation potential. It is hoped that, in the near future, national parks will be established in the Tanami Desert and that, clearly, Aboriginal people will have a major input into the delineation and future management of these areas.

The Tanami Desert is an immense area of land but it is by no means self-protecting. The disappearance of so many mammals from this vast wilderness area is a fair indication that the land cannot be left to manage itself. After all the work undertaken in the Tanami Desert and the data base that has been established, conservation areas would not only protect the flora, fauna and landscape but also many aspects important to the culture of the Warlpiri people. □

ANIMAL RIGHTS—A CONSERVATION DILEMMA

The great modern conservation issues are fought on complex ideological grounds, not all of which are necessarily rational or even in the best interests of a stable environment. Because some of these issues are of great importance to our tenure in the world, it is worth examining one or two of the major battles, to see if their eventual outcomes have lived up to the expectations of the conservationists involved.

The battle to stop the Canadian seal cull has been one of the longest and most passionately fought conservation issues of our time. The battle was fought for 20 years and effectively terminated in 1982 when the E.E.C. banned the import of white-coat seal pelts (primarily the pelts of baby Harp Seals). This was hailed at the time as a great victory for conservation. It has now become clear, however, that this was actually a great disaster—one that has adversely affected many conservation issues around the world.

When world attention was first focused on the Canadian seal hunt in the early 1960s, it was clear that something was awfully wrong. The seal herd had declined to one and a half million from the 19th century total of about three million. By 1964 the hunting had become wasteful and unnecessarily cruel. However, due to conservation lobbying and increasing biological awareness, the Canadian Government began to regulate the cull with an aim to eliminate unnecessary cruelty and, more importantly, to protect the seal stocks from overexploitation. By the early 1970s the legislation was clearly working. Experts sent by the 'Save the Seal Fund' and State Government veterinarians to the hunt areas could say by 1967 that sealing was being carried out in a humane fashion. Also, seal numbers were recovering and, by the late 1970s, stocks had expanded from the 1960's low by 25 per cent to over two million. Most beneficial to conservation in the long term, however, was the fact that Harp Seals, due to the international interest shown in them, had become one of the best studied of the world's mammals. The industry could thus be managed on a truly scientific and rational

basis. It should have been clear at this stage that a great conservation victory had already been achieved. However, many animal rights groups persisted in calling for an end to the seal cull and were making more and more strident and, by necessity, less rational pleas. After all, their case could not now be based on a rational conservation policy: the best had already been achieved in this direction.

With the E.E.C. ban on white-coat seal skins in 1982, these groups achieved their end. However, the result was a disaster: thousands of Inuit (aboriginal peoples of Canada and Greenland) lost their sole or major

source of cash income. Money for gasoline, cartridges and snowshoes was simply not available to them, so that their ability to live off the land in a hunter-gatherer existence was destroyed. It seems that the animal rights groups managed to destroy the last vestiges of traditional Inuit way of life—something that government and industry, through many years of contact, could not do. People who do not use their land lose much of their right to it. What grounds will these people have now to oppose the building of pipelines and other ecologically disastrous projects in Canada's north? Reduced largely to dependence on



For many Inuit (aboriginal people of Canada and Greenland) seal hunting is their sole or major source of income.

government handouts, their plight is truly tragic. They have had their very means of understanding and interacting with their world cut off in a similar way that Aborigines herded onto reserves in Australia last century had.

But this is only one implication of the cessation of sealing. It is reasonable to assume that high fashion coats will still be made of something, now that seal skins are *passé*. One wonders whether they will be made of fine-grade wool grown in inland Australia. Or perhaps synthetics made from non-renewable products. If wool be the option, then the outcome is worse. Grazing of large ungulates on Australia's inland plains has contributed greatly to one of the great ecological disasters of modern times; problems of salination and soil erosion have already reached alarming proportions in Australia, largely due to land clearance and introduced animals such as cattle and sheep. Many mammals of the Australian arid zone are now extinct for the same reasons. The ecological cost of producing wool in Australia is thus clearly very high. In comparison, there was virtually no ecological cost for the seal skins taken in Canada in the 1970s. The industry was well-regulated and, in ecological terms, one of the cheapest ways to produce clothing.

So, for conservation a victory was won, then lost. We can only hope that elegant ladies will wear their seal skin coats with pride, as badges that should read 'thoughtful protector of the environment', and that one day this great tragedy can be undone.

There are obvious parallels between the seal cull of Canada and Australia's kangaroo cull. We are now at the stage that Canada was at in the 1970s. We have won a great victory in producing our well-regulated and well-run industry. But will further pressure from animal liberationists turn this into defeat? What will happen if the kangaroo cull stops? No doubt our leather and pet food will still have to come from somewhere. More cattle and sheep for the inland plains? And perhaps an even greater long-term battle will be lost. Kangaroos are clearly less ecologically costly to our inland plains than sheep and cattle. Rather than trying to ban their use, shouldn't those truly interested in conservation be trying to find better ways



We should be utilising more ecologically costless species, such as the kangaroos, rather than sheep and cattle, which cause damage to our inland plains.

to utilise these ecologically appropriate species, so that we can lessen our dependence on our northern European animal husbandry heritage, which is clearly inappropriate here? Compared to cattle and sheep, even large numbers of kangaroos would appear to do little environmental damage.

Perhaps we can look forward to the day when many of our needs will come from such well-adapted species. This would go much further towards solving many of Australia's conservation problems, such as soil erosion and arid zone extinction, than if the kangaroo industry was destroyed. However, I fear greatly that we will lose our victory. I only hope that, in contradiction to the views expressed daily by 'conservation' groups in the media, a rational approach to conservation is growing in this country and that such a tragedy can be avoided. □

—Dr Tim Flannery

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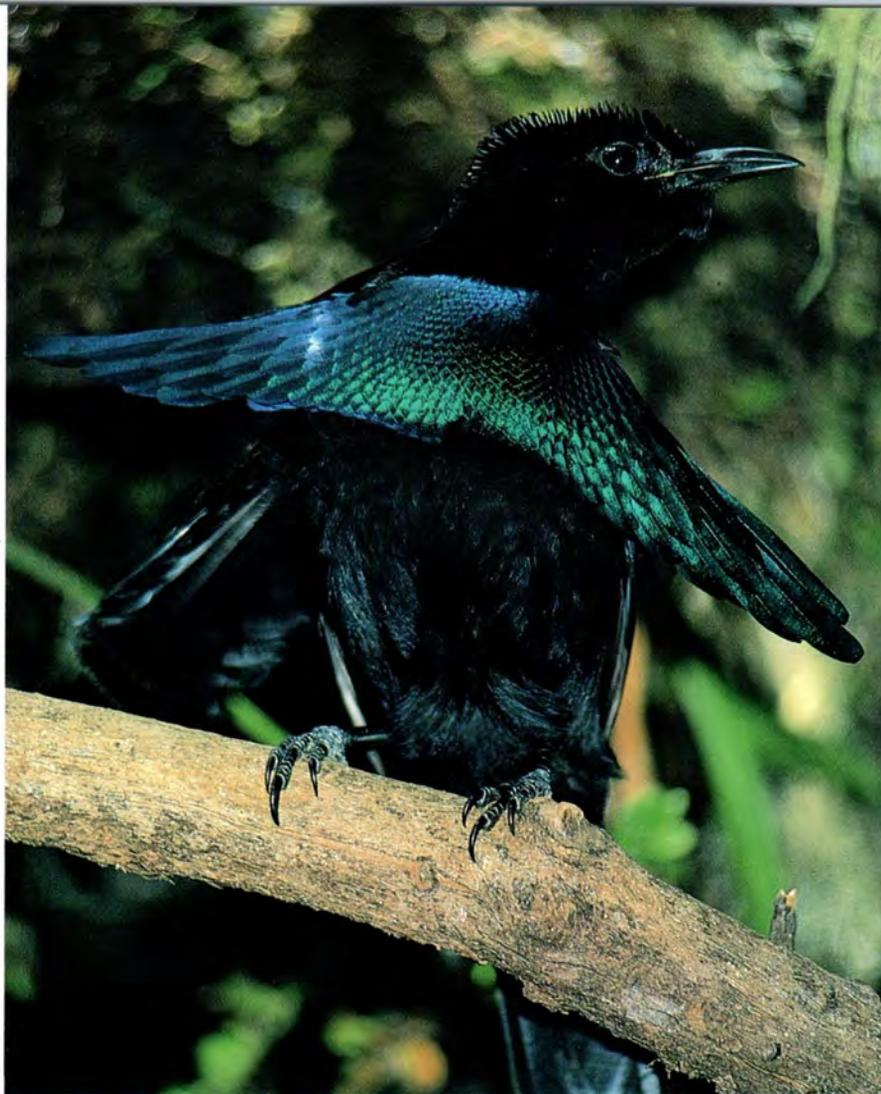
DOING THE BIRD...

**Dance Routines
in the
Papua New Guinea
Highlands**

by
PAUL SILLITOE

There are many spectacular birds in Papua New Guinea. To the Wola people of the Highlands, certain birds provide inspiration for their ceremonial dances. They mimic the birds whose plumes they don, not only in visual splendour but also in their movements, habits and cries. This mimicry, however, is not limited merely to dance routines. It pervades many aspects of Wola life and there are remarkable lifestyle similarities between birds and people. In this article, Dr Sillitoe unravels the mysteries of 'doing the bird'.

His wig topped by a magnificent Enamelled Bird of Paradise headdress, a man parades, chanting in a dance. Photo: P. Sillitoe.



The people of Papua New Guinea are renowned for their majestic, colourful *singsings* or dances. In the Highlands, the Wola people are no exception. Here men dance like birds. As one Wola man expressed it:

"The dancing of those birds and of men is the same, like they've 'joined'. Birds and men have come together. When we shoot birds carrying plumes, we 'spear' these, imitating them, [putting the plumes] onto our heads. . . when we decorate [ourselves], we are somewhat like birds."

When they dance, the Wola imitate the birds whose plumes feature in their headdresses. There are five birds, in particular, that they imitate—all of which display or 'dance'. They are the Enamelled Bird of Paradise (*Pteridophora alberti*), Macgregor's Gardener Bowerbird (*Amblyornis macgregoriae*), Superb Bird of Paradise (*Lophorina superba*), Black Sickle-billed Bird of Paradise (*Epimachus fastosus*) and Princess Stephanie Bird of Paradise (*Astrapia stephaniae*).

There are countless similarities between displays of these magnificently plumed birds and the Wola dance rou-

tines. For example, some of the birds build and maintain an arena or 'dance ground'. The name for this arena, *howma*, is also given to the grassed clearings on which the Wola dance. Not only do the birds have a dance ground, but others congregate there to watch those performing, just as people come, the Wola say, to watch their own dances.

These similarities reach their zenith with the Enamelled Bird of Paradise—its delicate, iridescent feathers are valued above all others. The bird comes down from the forest canopy to a springy branch or vine in the understorey, bouncing up and down by flexing its legs. According to one witness:

"Here's a small branch or length of vine. . . it [the bird] perches quietly with its plumes flattened down its back. . . then it waves its plumes to and fro—those two plumes the Enamelled Bird of Paradise has growing out of its ears. When it has them coming out of its ears, it tosses its head up and they stand erect. When they stand erect like this [demonstrating with his hands], it dances making its 'shshshsh,

shshshsh' cry. It does this [tossing his head up and down in imitation] and they [the plumes] wave beautifully, back and forth."

In their dancing, Wola men imitate this bird explicitly. They often chant 'shshshsh, shshshsh'. Also, when participating in drum dances (where they stand in one spot and wave their plumes by bobbing up and down), the men flex their knees in the same way that the bird bends its legs as it displays.

With the Black Sickle-billed tail feathers in their headdresses, the Wola men not only imitate the majestic waving of this bird's tail plumes, but they also mimic the bird's display call—a 'brrrr, brrrr, brrrr' sound. When that bird dances, it attracts one or two spectators—the plain-feathered, dowdy-looking females and immature birds. It displays in an open situation, often perched atop a dead tree, its long tail feathers hanging vertically. It bounces rhythmically up and down, puffing up its feathers. This is copied by the men, who also bounce at dances with their chests pushed out. The bird makes a booming sound at irregular intervals as it displays, which is imitated by the men who liken the sound to the beating of a drum.

The Superb Bird of Paradise also makes a thumping sound as it displays, reminiscent of clapping, produced—the men think—by flapping its wings. It makes this regular beat while bouncing up and down along a branch.

Unlike the other birds, the Princess Stephanie Bird of Paradise performs no static dance according to the Wola. Instead, it just flits about the trees, again with two or three spectators. It makes the imitated 'shshshsh' sound but with its tail (not head) plumes.

The display of the Macgregor's Gardener Bowerbird has never been witnessed by the Wola, for its fellow spectators always warn of potential intruders. Nevertheless, all agree that the dancers are the birds with the orange head crests and it is these birds that the Wola men catch to obtain crests for headdress fringes.

Men wear bunches of fresh, oiled, brightly-coloured, variegated palm lily leaves over their buttocks. These stick up their backs and bob up and down during the dance—just like the birds' long tail feathers during their display.

The Wola acknowledge they are imitating these magnificent birds' dis-

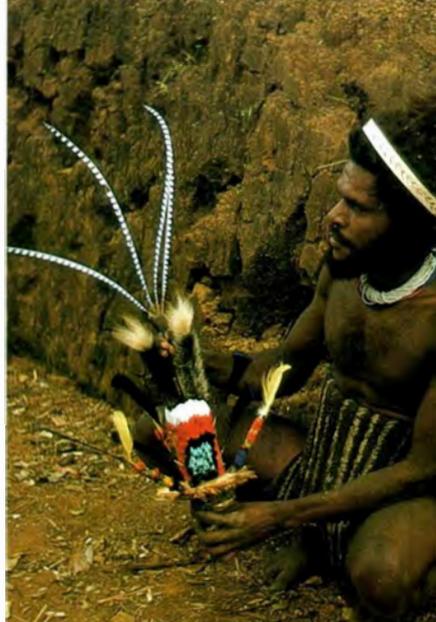
plays by referring to their own dances as *iysh mol menay* (literally 'tree drum lift'). Drum refers to the noise that some dancing birds make and 'tree lifting', initially puzzling in regard to human dancing, refers to the way some birds' bounce up and down on small branches, making them wave about.

Another parallel between the bird world and Wola society is evident when comparing the females. The female birds, whose job it is to lay and sit on eggs, are small, plain, unobtrusive and do not display. Wola women, the bearers and rearers of children, are likewise dowdy and less prominent in public affairs and, if married, cannot decorate themselves and participate in dances. Indeed, the only time they decorate themselves is in mourning and even then they make themselves less attractive, smearing their bodies with white clay. So, as a rule, only males 'preen' themselves and 'display'. Exceptions include nubile girls (although infrequently) and brides. During the marriage ceremony, a bride's decoration plays an important symbolic role in the bride-wealth distribution—a major ceremonial wealth exchange, in which context men frequently don their finery.

Ceremonial exchange is a central institution in the political structure of Wola society and self-decoration is inextricably linked with it. Full-dress decoration not only features in the dances that accompany some ceremonial exchanges, but several of the accoutrements that comprise the decoration are valuables used in exchange, such as sea shells, feather headdresses, ornamental axes and tigas oil.

Parallels also exist between decoration (notably feather headdresses) and exchangeable wealth. The Wola saying *kwiysh gemb ombuwkiy njuksiy bay* epitomises this (literally: Enamelled Bird of Paradise headdress foundation mounted give?). Men throw this taunt into the faces of those who are slow in making an exchange payment. The implication is: "judging by the long time you're taking to honour your exchange obligation to me, are you going to repay me with such splendour as a fully mounted Enamelled Bird of Paradise head-dress?". Such jibes cut deep where men's reputations depend on them meeting their obligations promptly and generously.

A noteworthy association is that between the Macgregor's Gardener Bowerbird and pigs, the latter being creatures the Wola regard highly as exchangeable wealth. The Bowerbird makes a range of ventriloquial calls during its display, mimicking other bird calls, humans talking, twigs snapping and even babies crying. But the call that fascinates them most is its imitation of pig squeals. The Wola even claim that the Bowerbird reproduces the sounds of a pig kill, mimicking the squeals of animals followed by thudding noises that replicate their being clubbed to death. This acquisitive bird carries its interest in pigs even further, decorating the rim of its circular moss bower with pigs' droppings. It also places here small pieces of charcoal and round, black berries from a melastomad shrub, which the Wola men assert the bird mistakes for pigs' droppings, maintaining that its object is to surround the bower's perimeter with pig faeces.



Having just assembled an Enamelled Bird of Paradise headdress, a man tests its springiness by waving it back and forth. Photo: P. Sillitoe.

Regarding the Superb Bird of Paradise, the Wola liken its iridescent, crescent-shaped feather plaques to pearl shells which, together with pigs, are the most highly esteemed wealth items used for exchange. Some are worn around the neck for decoration. As one Wola observed:

"The Superb Bird of Paradise's chest plaque is just like a pearl



A male Macgregor's Gardener Bowerbird crest plumage in display position. Photo: Frithfoto, A.N.T.

shell, worn here, around the neck... just so, like a pearl shell. Very good. It's excellent if it's [the back of the neck plaque] somewhat like a pearl shell, and it's [chest plaque] similar to a bailer shell."

A myth told by the Wola (see separate section) describes how birds came by their beautiful plumes and underlines the connections between finery and display, and ceremonial exchange—the foundations of their stateless polity. The myth implies that objects used as finery came out of chaos to reaffirm social order. For, without ceremonial exchange to which finery so closely relates, the leaderless political order of the Wola would collapse into anarchy, as happened (according to the myth) in primeval times when dogs rounded on marsupials.

Birds flaunt brightly coloured crests or plumes in display for the same reason that men don finery—that is, to allure the attentions of females.

How the Birds of Paradise got their Plumes—a Wola Myth

Many animals, including cassowaries, marsupials, pythons, birds and dogs, met one hot day at Siniyphowma to stage a dance. The python decided to decorate himself magnificently for the event and put Enamelled and Black Sickle-billed Birds of Paradise plumes on his head, together with many other colourful feathers from a range of brightly feathered birds like parrots and lorries. He painted himself with designs using red, white and yellow earth. He put on a new apron and hung a Hornbill's beak around his neck. And so on, he put on all the things men decorate themselves with today.

While all the animals were dancing, a Long-fingered Striped Possum became sick with the heat and went to a nearby stream for a drink. He wandered along the stream, drinking occasionally, until he came to the spring that was its source where, tired out, he expired. Meanwhile, one of the dogs at the dance also felt thirsty and went to the stream for a drink, too. He found the water extraordinarily tasty and wandered upstream drinking it, unknowingly following the possum. When he arrived at the spring he found the dead possum and sniffed him. He smelled good. The dog saw his long grub-winkling finger and bit it off and ate it. The finger was very appetising and the dog ate all the deceased animal's paw. His appetite now whetted by the delicious taste, he made a meal of the entire possum.

The dog returned to the dance, smacking his lips and related his ex-

perience to his canine friends, telling them how rare-flavoured he had found possum flesh. Until this time, dogs and marsupials had been friends. This was the first occasion a dog had eaten a marsupial. But when the possum-eater told his dog friends how tasty his meal had been, they turned hungrily on the other marsupials at the dance. An almighty fight erupted, the dogs killing and eating marsupials.

The fighting and bloodshed frightened the highly decorated python who fled in terror beneath the litter on the forest floor. All his ornaments fell off as he ran away. Today, as a result, pythons only have a dull black and white skin. However, all the finery he dropped was picked up by those creatures which have these things now. The Enamelled, Superb, Black Sickle-billed and Princess Stephanie Birds of Paradise came by their majestic plumes and the Macgregor's Gardener Bowerbird, his orange crest. The Shovel-billed Kingfisher obtained his silver-blue back feathers and the Hornbill, his enormous beak. The Grey Honeyeater, Schlegel's Whistler and Dusky Orange Lory shared out the yellow paint among themselves, and the Reichenow's Honeyeater, Black Butcher Bird and Short-tailed Paradigalla shared out the white. The Yellow-fronted Blue-eared Lory, Fairy Lory and Papuan King Parrot took the red paint. And so on, everything was distributed between those having today. That's how these creatures came by them, the objects we use to decorate ourselves. □

As one Wola man put it:

"When, from time to time, we decorate ourselves with Enamelled Bird of Paradise plumes and so on, then—oh, we're very big, big men. Women's thoughts are excited: 'I'll marry that man', they think to themselves... girls think to themselves that they'll sing courting songs [with the finely decorated]."

For many of those who decorate themselves, courting and showing off to members of the opposite sex is their main concern. It is also for this reason that the Wola prevent married women from decorating and participating in full-dress events for, unlike the polygynous males, they may not be married to more than one man. When they marry, their courting days cease and for them to flaunt themselves in full decoration would be immoral.

Here is yet another parallel with the bird world—the bird of paradise dances imitated by the Wola are male courting displays. Interestingly, however, the Wola are unaware of this for they believe these magnificent birds are celibate. They maintain that they reproduce in an earlier stage of development—as the dowdy-plumed female and immature members of the species, all of which, the Wola believe, turn eventually into magnificently plumed adult males.

So here are five beautiful birds that are believed to have nothing to do with reproduction, an activity that Wola men maintain is enfeebling and dangerous. They believe the sexual act gradually drains away their vitality and essential life juices. A foolhardy man who engages in frequent sexual intercourse hastens his own demise, reducing himself prematurely to the dry and wrinkled condition of old age. The abstemious, on the hand, are supposedly healthier and live longer.

Small wonder the Wola are attracted to birds that supposedly have nothing to do with sexual matters and reproduction! They show their admiration for these beautiful birds by personifying them in self-decoration and dance—in other words, by 'doing the bird'. □

The massed ranks of plume-bedecked dancers present an awe-inspiring spectacle. Photo: P. Sillitoe.

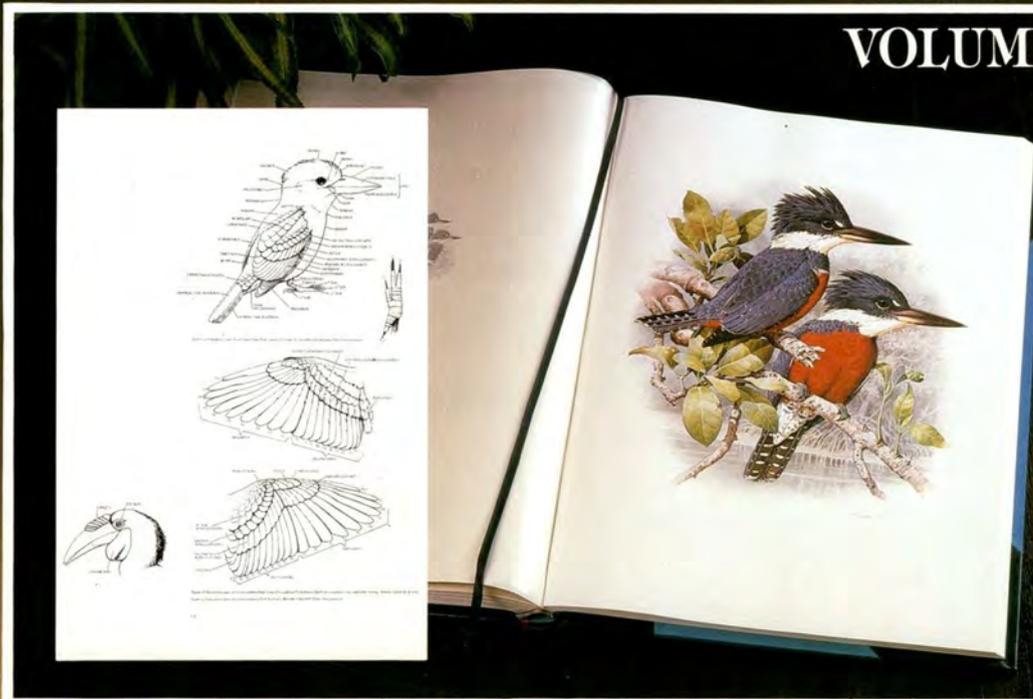


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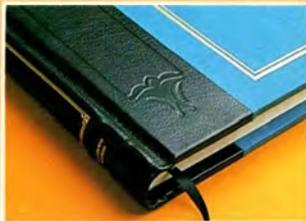
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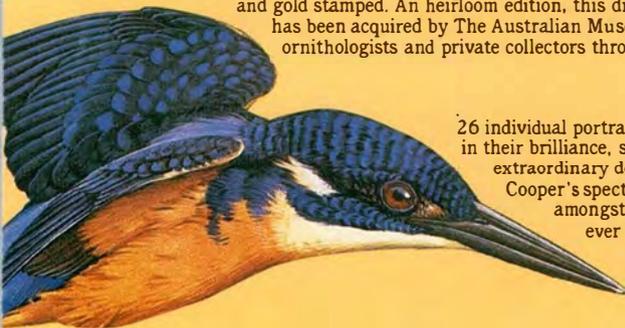
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