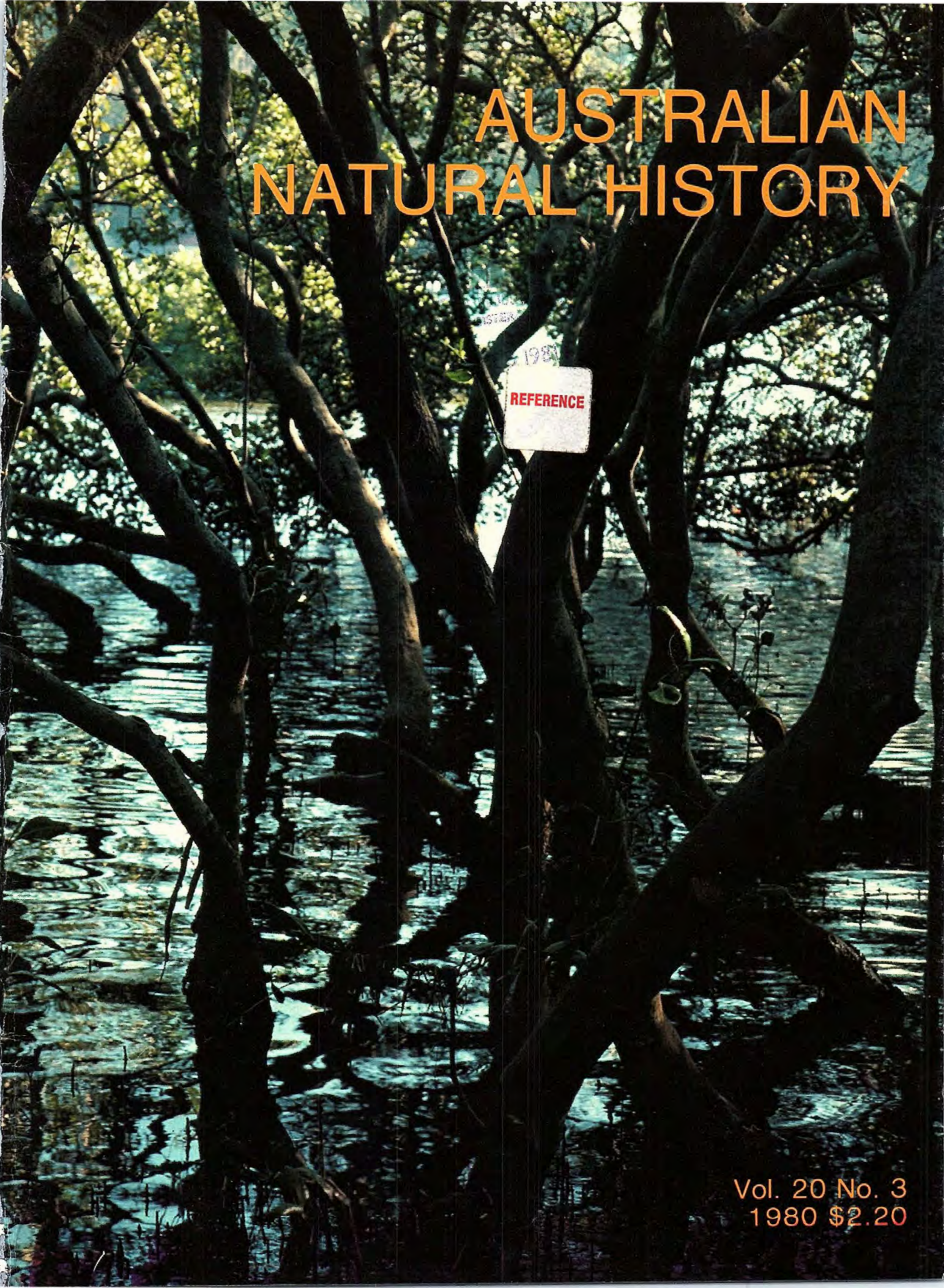
AUSTRALIAN NATURAL HISTORY



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AUSTRALIAN NATURAL HISTORY

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A newly settled seedling of *Bruguiera*, a wide ranging mangrove of the tropics and subtropics. Photo by David Stoddart.

Some of the tools of a museum taxidermist's trade. Photo by John Fields/The Australian Museum.

The cheerful cackle of the laughing kookaburra, *Dacelo novaeguineae*, is often heard in the suburban gardens of Sydney. Photo by Jim Frazier.

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* Deceased, 24 October, 1980

FROM THE INSIDE

Unloading gear and materials at Seal Rocks, Victoria, The Australian Museum team of preparators get set to study seal life in the raw as part of their work in creating a marine mammals diorama. The exhibit, and the work that goes into it, is but one part of the final mammals gallery which will be finished in mid-1981. Photo by John Fields/The Australian Museum.

Well! Here is number three of *Australian Natural History* Volume 20, and its successor is certainly on its way. All of which gives an added zest to the prospect of festive celebrations at this year's end, particularly for the editorial workers who set this publication target—we hope readers share our satisfaction.

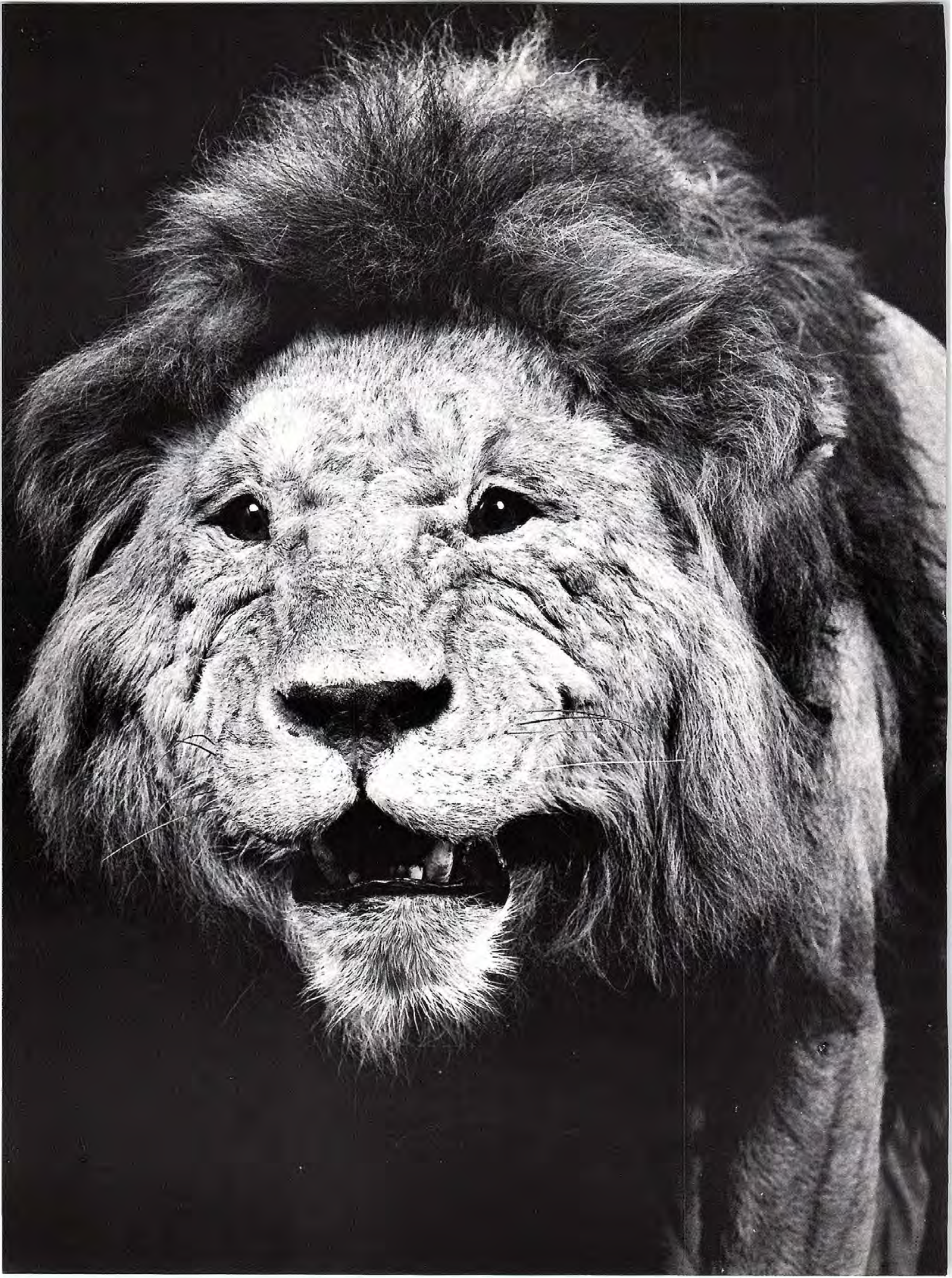
Before coming to work at The Australian Museum I was firmly convinced that behind the exhibits museums comprised quiet, hallowed corridors, smelling of camphor and peopled with softly spoken scholars, solemnly going about the business of immortalising dead things—I received a sharp, but joyous, awakening when I got on the inside; the only truth remaining of my preconceived image is the smell of camphor, and that but faint.

The Museum is concerned with the whole canvas of life, the past, the present and the future, and with the changes great and small in man's natural environment and cultural development. The great collections, animals, rocks, minerals and anthropological artefacts, represent the dedicated, intensive activity of many men and women, directed by top administrators, backed up by artists, photographers and sculptors, clerks, typists and accountants, engineers, artisans and attendants, all working to one end—to increase and disseminate knowledge of life.

It is the function of this magazine to reflect that great canvas within the limits of its covers. The variety of subjects in this issue begins to do so. Readers will be introduced to the intricacies of preparing specimens for display in George Hangay's article, and the picture on this page gives a further glimpse of the effort behind the exhibits visitors see—life on the rocks with seals can be tough, exhilarating and rewarding in terms of presentation of facts. The fascinating story of mangroves represents hours, days and weeks, clambering around the swamps, camping all night in primitive conditions plus detailed organisation of expeditions by its authors Drs Pat Hutchings and Harry Recher, who, typical of the Museum's scientific staff, interface their researches and surveys with decisive, sometimes controversial, support for conservation. Diamonds have other functions to serve than that of a 'girl's best friend' as Dr Julian Hollis shows in his article on this much misunderstood, long exploited and beautiful carbon. The world shortage of energy resources continues to agitate the public mind and Dr Hans Coster reminds us to look at commonplace sources—such as the ubiquitous cow pat—in his informative contribution on bioenergetics. Two contributors to this issue—Densey Clyne and Geoffrey Prestedge show the value of inter-change between the scientific community and that of the lay naturalist.

All these subjects have been gathered into this issue, not without difficulties; we were all very saddened by the sudden death of a new addition to the editorial staff—Jan Nesbit, whose enthusiasm played a not inconsiderable part in the production. But sadness has been softened by many letters from readers who expressed their appreciation of the new format and offered suggestions for further improvement. Some will note the modifications effected as a result. Such lively interest from the outside is most rewarding to hard-pressed editorial workers who all join with this writer to wish readers the compliments of the season 'from the inside'.

Barbara Purse
Editor



STUFFED WITH LIFE

The Australian Museum's popular slogan 'Stuffed With Life' reflects modern day museums' emphasis on interjecting realism into formally 'stuffy' exhibitions. A taxidermy department is a key component in any natural history museum, and the technical and artistic skills, dexterity, patience and dedication of taxidermists have brought life back into these institutions. At an early age George Hangay worked as a taxidermist in Hungary, and since 1973 The Australian Museum's Preparation Section has benefited from his skills. In the following pages he presents the interesting history of taxidermy from its earliest known days in Ancient Egypt to the complex science of today.

by George Hangay

Here George Hangay rejuvenates 'Belmont British', a prize-winning bulldog in 1922, for a new exhibition. The owner of the living dog wanted his deceased pet preserved, if possible, forever. This was the first specimen in The Australian Museum to be mounted on a sculptured papier mâché manikin. Photo by John Fields/The Australian Museum.

This magnificent lion (left), which belongs to The Australian Museum and was most probably mounted by Carl E. Akeley, glares proudly, as lifelike as ever, testifying to the skills of its preparator. Photo by John Fields/The Australian Museum.

Taxidermy—the word is derived from two ancient Greek words, a literal translation of which signifies "the arrangement of skins"—appears to have been practised ages ago.

Primitive man preserved some of his prey to be used as decoys, charms or trophies. In tombs of ancient Egyptians hundreds of preserved animal bodies were found. The people of this ancient race possessed the skill to arrest decay even in such huge carcasses as that of the hippopotamus, bull, crocodile and other large animals. These preserved bodies had one thing in common: apart from the viscera and brain most other matter of the anatomy was conserved in one piece. The entire body was cured with salts, spices and minerals until it was rendered decay-proof. A lifelike appearance could not be retained with such techniques. The flesh shrank and the skin wrinkled on the dehydrating body until it became dry and hard like a piece of wood. Like human mummies hardly resembling a living man, these animal mummies bore very little resemblance to their living counterparts.

A *Natural History*, published in Paris by the Royal Academy in 1687, mentions a collection of "stuffed" birds. These birds were collected by the Dutch on their first voyages to the East Indies in the early fifteen hundreds. The collection was exhibited in Amsterdam and seemingly well remembered 160-170 years later by the French. Unlike the mummies, these specimens were skinned and the spice-preserved skins filled with some material until the birds regained their natural lifelike appearance. Thus the birds mentioned here could be classified as the first known true taxidermic specimens. From the later years of the sixteenth century more stuffed animal specimens are recorded, even larger ones such as the famous Rhinoceros of Ulysses Aldrovandus' Museum in Bologna.

The first major publication dealing with the mounting and collecting of vertebrates is Abbe Manesse's *Treatise on the Manner of Stuffing and Preserving Animals and Skins.* It was printed in 1786 in Paris. At this time France seemed to be the land of taxidermy. Many known taxidermists worked in this country. A number of them published treatises and set up collections of fame.

One of them, Monsieur Becoeur of Metz, is certainly worth mentioning. This gentleman, who was the best apothecary of his city, was also the inventor of the taxidermist's Arsenical Soap. Unlike his predecessors and contemporaries who employed the preserving qualities of spices, herbs, powdered tobacco, etc., he treated his skin with a mixture of soap, arsenic, camphor, salt of tartar and powdered lime. This was an ingenious innovation since arsenic does not break down with time and thus the skins treated with it become insect-proof practically forever. Becoeur was a good taxidermist who practised his craft with the greatest precision. He skinned the birds through a single cut of the skin of the belly, removed all flesh by cutting it away from the bones. While doing this he took great care not to harm the ligaments inasmuch that the skeleton stayed as a whole. The carefully cleaned skeleton was then replaced inside the treated skin. With a system of elaborately jointed wire armature the specimen was posed and the flesh replaced with chopped cotton or flax. Once the belly was sewn up the bird was re-posed for absolute lifelikeness and the plumage painstakingly groomed.

Although the craft of preserving animals became more and more appreciated in Europe it took a while for its fame to spread across the La Manche. The ability of the French, German and Dutch taxidermists was admired by the Englishmen. Soon the first English taxidermists began to show their works—sometimes earning a little less than admiration from their critics.

C. Waterton, who is described by many of his contemporaries as an eccentric genius, had a very sad opinion about his taxidermist colleagues. He writes in his *Wanderings in South America* published in 1825: ". . . As the system of preparation is founded in error, nothing but deformity, distortion and disproportion will be the result of the best intentions and utmost exertions of the workman. . . . This remark will not be thought severe when you reflect that that which was once a bird was probably stretched, stuffed, stiffened and wired by the hand of a common clown. Consider likewise, how the plumage must have been disordered by too much stretching, drying and perhaps sullied, or at least deranged, by the pressure of a coarse and heavy hand—plumage which, ere life had fled from within it, was accustomed to be touched by nothing rougher than the dew of heaven and the pure and gentle breath of air." However, he was criticised by others who were not impressed by his methods. He invented a technique which permitted him to mount birds without wires. He also decried the use of arsenic. A

talented and skilled worker, it is known that he had great patience. He could spend days in scraping out the hands and feet of a large ape until he got the skin paper thin. His invention of a kid-glove substitute of a peacock's face is also known, besides many other virtuoso taxidermic achievements.

Many other taxidermists tried to match or surpass Waterton's work. Most of the specimens were exhibited, not only in museums but also in private exhibits. Of course, all these works directed the public mind to the contemplation of natural history.

The Great Exhibition of 1851 in Paris marks the proper beginning of modern taxidermy. Peculiarly enough, a considerable impetus to the more correct and artistic delineation of animals came from an odd contributor: the so-called *Grotesque School* instituted by the Germans. This trend in taxidermy was denounced by most serious taxidermists, however even today the public is often fascinated by its product.

The oldest works from the *Grotesque School* illustrated fables with appropriately posed and dressed mounted animals in fairy-tale settings. Although such exhibits could almost be called sacrilegious by misrepresenting nature, they taught a special lesson by the increased care necessary to prepare them. To render the facial lines of an animal so that they create the proper half-human, serio-comic impression required by the setting is no small task for any taxidermist. To present something unnatural in the most natural way was the main goal for the old masters of the *Grotesque School*. Many examples of this 'art' are still to be seen, especially in South Kensington. One of the most famous is the 'Tea Party', a number of cats dressed as ladies of the period, sipping tea from fine china cups.

Another great achievement of the Great Exhibition was the introduction of mounted animal groups in their natural habitat. Roland Ward's taxidermy studio exhibited a number of these groups which became famous in their time. One of them was the *Lion and Tiger Struggle*. This and some other similarly dramatic group exhibits captivated the public's imagination. Taxidermy became a very popular craft.

Hunting, especially for big game in the colonies, was popular too. Soon the proud hunters were not satisfied with just a pair of horns or elephant tusks—they wanted to see and show their trophies as lifelike as possible. Roland Ward, whose taxidermy studio was the first big scale commercial studio of the world, had the sense to employ foreign craftsmen as well as his English taxidermists. Under an immense workload the taxidermists had to be quick and efficient to satisfy rich and fussy customers. England soon became the country of high class taxidermy. The public acquired a taste for exquisite, quality work. New exhibits of mounted specimens in museums received widespread publicity in newspapers and private collections represented huge values in artistic as much as in monetary terms.

A toad orchestra—an interesting example of the German *Grotesque School* of taxidermy. Photo by John Fields/The Australian Museum.

Roland Ward's taxidermists developed a technique to which they adhered until recent times. An artificial body was made of woodwool by wrapping the material around a steel armature. Anatomical detail was worked into the body by forming surface muscles of bundles of woodwool and by stitching through it with long needles and string. The tanned or pickled skin was tried on many times until the body fitted it perfectly. Before the final fitting and sewing on, the artificial body was coated with a layer of wet clay or papier mâché. On this wet and mouldable surface the skin was mounted. Fine detail was modelled by pushing and squeezing the clay under the skin until it assumed the living animal's appearance. By this technique the skills of the sculptor were just as important as the tanner's and the preparator's.

Real, modelled taxidermy as we know it, however, was invented in America. Carl Ethan Akeley—naturalist, taxidermist, sculptor, artist, inventor, photographer—was probably the most famous taxidermist of all time.

He was born in 1884 near Clarendon, New York. At sixteen he was a competent bird and small mammal taxidermist. His natural artistic talent helped immensely to set up specimens in a most lifelike manner. During his comet-like career he worked for Professor Henry J. Ward's Studio (no connection with Roland Ward) for the Milwaukee Public Museum, the Field Museum and the American Museum of Natural History. While working for these museums he also ran an active commercial studio. His group exhibits, all classified as the true masterpieces of taxidermy, are still part of these museums' exhibits. Many of them were prepared in his private studio. His technique for large mammal mounts was revolutionary. Fortunately he was able personally to collect specimens from the wild and so secure accurate field notes, body measurements and moulds. To skin most mammals through a dorsal cut was his invention. By this method the legs were not split open, therefore unsightly seams were avoided. Once the skins were secured he made small models of the specimens, preferably of the whole group and then the life-size sculptures were prepared. To achieve accuracy in stance and appearance he used motion pictures as records. From the life-size models, which were made of modelling clay, hollow casts were made. Plaster of paris and burlap were used for this purpose and the result was a strong yet lightweight manikin. On this the skin was mounted. The hard, anatomically and artistically perfect manikin ensured good results. The tanned skin was pasted on it and since it was held in position by the paste and hundreds of pins, it could not change during the slow process of drying.

Unlike the large mammals mounted prior to the invention of this technique, his specimens retained their lifelike expressions.

Akeley's most famous achievements are his successes in the field of elephant taxidermy. This animal presents a difficult task for the preparator, not only because of its size but also because of the problems occurring during modelling and handling the skin. The lack of hair will not permit the slightest imperfection in the modelling of the body. The many wrinkles and folds of the living skin would fast disappear during the drying process.

Akeley's elephants, still on exhibition, do not show any of these imperfections. They are just as perfect as they were in the African bush when Akeley collected them more than seventy years ago. As modelled taxidermy gained its deserved status many other talented men learned taxidermy. America seemed a very fertile land; most giants of the taxidermy world were citizens of the United States.

Although the most famous taxidermists were known as Americans, not all were born there. Coloman Jonas was Hungarian by birth and learned his trade in Hungary and Germany. He and his brothers established a commercial studio in Denver, Colorado, in 1908 and soon dominated the taxidermy business in America. They were the first to form a supply house for other taxidermists. Apart from commercial success they contributed greatly to present day sophisticated taxidermy methods. The Jonas Brothers Taxidermy Supply was a product of the time. By the second decade of the twentieth century taxidermy became so popular in America that most outdoorsmen, amateur naturalists, science teachers, etc., wanted to learn. Glass eyes, scalpels, modelling tools and other taxidermy items were sought after by thousands of hobbyists. Jonas Brothers met this need and created the most outstanding supply house.

Leon Pray, another American, was the first to use borax instead of arsenic to preserve and insect-proof skins for the purpose of collecting. The use of borax as a preserving agent gave another boost to the popularity of taxidermy. Dangerous arsenic could be omitted from the taxidermist's workshop. Opinions about this differ; some preparators love the good old arsenic. It is dangerous but reliable, they say. Others won't touch it; they would rather take a chance with the moths and silverfish.

Today's taxidermists are divided into two large groups: the museum men and women and the commercial operators. In a museum where quality is more important than quantity, the taxidermist has a more interesting and satisfying career than in commerce. A commercial taxidermist must produce sufficient work each day, otherwise the business cannot survive. In countries like the USA or Canada, the taxidermy business is extremely competitive and good technicians are very much sought after by the various firms.

In a modern museum the taxidermist's life can be very gratifying. With enough work and suitable equipment, materials and information, a preparator can gain immense knowledge of the subject. Today's techniques are varied and the taxidermist chooses his own methods for each task.

Birds are mounted on the same principle in most museums or in private practice. The body is removed through a ventral incision of the skin. The main bones of the limbs and the skull are retained, cleaned, preserved and used in the construction of the artificial body. This is often made of woodwool or carved in rigid plastic foam. A wire armature keeps the mount upright, and once the skin is mounted on the artificial body, the plumage is carefully arranged. After a period of drying the faded colours of the fleshy parts are restored.

The famed American taxidermist Carl E. Akeley. Photo by American Museum of Natural History.

The preparation of small mammals is very similar to that of birds. The skin of these animals being a little thicker, it often may require more attention. In many instances the cleaned hides are pickled or even tanned before mounting.

Large mammal mounting is the most complicated, most difficult aspect of taxidermy. To practise this, the taxidermist must have sufficient knowledge of anatomy plus extensive knowledge of the animal's behaviour. The commonly used technique is based on Akeley's method. However, with the advancement of technology, more and more plastics and other modern materials are used by museum preparators and commercial taxidermists. Tanning methods were greatly improved in preceding decades and the up-to-date taxidermist employs tanning agents which give a better tannage for his hides than the materials of bygone days.

The initial modelling of the animal's body is also improved with new techniques. In many instances the actual moulds taken from the skinned carcass can be used as a basis for

Fur seal pups (left) are being mounted for a new mammal gallery in The Australian Museum. Photo by John Fields/The Australian Museum.

Freeze-drying machines (below) allow more delicate specimens such as rats, reptiles and amphibians to be prepared and preserved with precision and ease. Photo by John Fields/The Australian Museum.

modelling. This method greatly improves the work of any taxidermist. It was perfected in the Jonas studio. Henry W. Inchumuk of the Denver Museum of Natural History practises this technique and through his generosity we now have this knowledge. Most mounts for the new Mammal Gallery of The Australian Museum are prepared this way.

Despite all advancements in the craft, the taxidermist often meets tough opponents in his practice. Some species of birds or mammals are extremely difficult to handle. Many problems start on the skinning table. To mention a few examples, pigeons or some small passerines have extremely thin skins, others have very loose feathers. The slightest mistake, a little heavier pressure on the skin or nick of the scalpel and the delicate specimen can be damaged, sometimes beyond repair. The skin of a cuscus is likewise very delicate, just like the skin of the American cotton-tail rabbit. Some species, including many frogs, change colour after death, inasmuch that restoration may become impossible. The translucency of the nose of a sugarglider, for example, is a lost battle for the taxidermist.

Again, the aid of modern technology is invaluable. In the course of preparing specimens for the new Mammal Gallery of The Australian Museum, a new technique was developed for the preparation of rats. Although it is not the easiest of tasks, the mounting of rats does not cause problems to a skilled taxidermist. However, we want perfectly preserved detail around the nose and mouth as well as around the eyes and ears. The specimens are too small for conventional large mammal mounting techniques where all fleshy parts are split and filled with modelling materials to prevent shrinkage. Therefore the rats were mounted in the regular manner, but lips, noses, ears were left intact. Before the skins could dry they were placed in the freeze-drying machine where they were slowly cured in vacuum on a low temperature. Shrinkage and distortion was thus avoided, something which could not be done before the invention of the freeze-dryer.

Some species—sometimes entire orders —cannot be prepared successfully with the traditional taxidermic methods. Frogs are especially difficult subjects. Their delicately detailed anatomy would lose its lifelike appearance through the normal taxidermy process. Prior to the development of the freeze-dryer the specimen was placed in a bath of alcohol. The strength of the alcohol was increased until the entire body was thoroughly dehydrated. After it was removed from the alcohol the water was replaced in the tissues by molten paraffin wax. The specimen prepared this way had a lifelike appearance and was durable, but the time-consuming, labour intensive technique was somewhat cumbersome.

The freeze-dryer can do the job faster and probably better. The specimen is pinned out in a lifelike pose on a piece of timber and deep frozen. After it is placed in the refrigerated vacuum chamber of the machine the ice from the tissues slowly sublimates until the specimen is completely dry and so retains its original lifelike shape.

Fishes represent different problems. Because of their high fat content they cannot be freeze-dried successfully. Their often translucent skin makes them difficult subjects for taxidermy. Here the taxidermist must call upon an allied craftsman, the plasticworker. With plastic workshop methods very lifelike fishcasts can be prepared. In most cases these casts are more lifelike than a mounted fish. The effect of the frequently translucent skin is lost through the conventional taxidermy procedure. Reptiles are also difficult subjects for the taxidermist. Plastic or rubber reproductions are often more lifelike than mounted specimens.

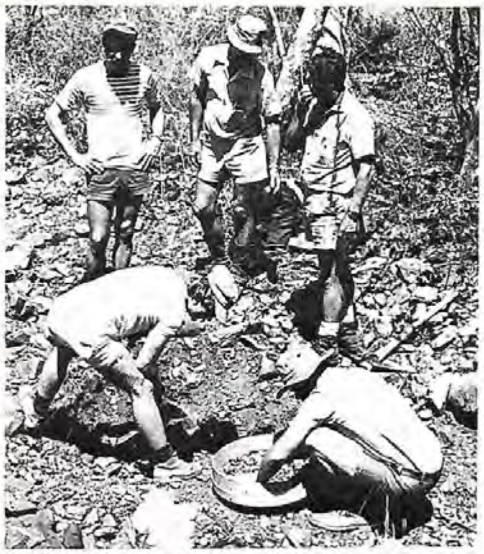
With ever advancing technology, the art of taxidermy likewise progresses. The present day taxidermist can make use of the knowledge of taxidermists of past generations, but is also fortunate enough to be able to improve the old methods with modern technology.

Although there are no educational institutes where an interested person could receive formal training as a taxidermist, the number of keen amateurs in Australia is steadily growing. Some of these people are willing to put all necessary time and effort into their work and are achieving excellent results. With the help of the many conscientious taxidermists past and present, the craft of taxidermy is becoming recognised as a truly professional art.

DIAMOND, Carbon's Cinderella

The remarkable success of diamond exploration in the Kimberleys of Western Australia has stimulated interest in diamonds, both as investments and as minerals of great geological interest. It may surprise some people that the greatest diamond production to date in Australia has been in northern NSW. Julian Hollis of the Department of Mineralogy and Petrology at The Australian Museum is actively engaged in research into the rocks and minerals of the upper mantle of eastern Australia. His article describes the geological aspects of diamonds—where they are found and how they got there.

by Julian Hollis



An Ashton Joint Venture field team samples gravels in Smoke Creek, WA. Photo by Conzinc Riotinto of Australia Limited.

The element carbon is unusual as it can occur as the mineral graphite, which is one of the softest minerals known, or as diamond which is by far the hardest naturally occurring substance. Under natural conditions at very high pressures, carbon atoms form dense cubic crystals whose extreme hardness is due to their tight atomic packing. In spite of this, diamond crystals cleave readily in four different directions—an important property when they are cut as gems. Ideally, diamonds are water-clear and when cut, extremely lustrous. They are most highly prized when free from flaws. Traces of impurities or defects produce a range of pale-coloured varieties; particularly shades of yellow, but also pink, blue, green, brown, red and orange. About 80% of diamonds are unsuitable as gemstones due to their small size, poor colour and the presence of inclusions or flaws. These are used as industrial abrasives.

South Africa is the largest producer of diamonds and also holds the record for the largest stone. This was the Cullinan, which came from the Premier Mine, Transvaal, in 1905 and weighed 3,106 carats (621.2 g). The DeBeers Group at present produces over six million carats of diamonds per year from its three main workings: the Finsch Mine, the Premier and the Kimberley Mines. During the last decade the USSR has become the world's second largest producer, with major diamond sources in Siberia, the Urals, the Ukraine and the Kola Peninsula. Diamonds are widely scattered across the continents with primary sources concentrated in the ancient continental cores. These areas are composed of thick granitic rocks and are termed shields.

The first Australian diamonds were discovered in the Bathurst area, NSW, in 1851 during the gold rush. Diamonds occur in the alluvial deposits of old rivers at numerous points along the highlands of the eastern states. At the present time the most significant prospects are in the Kimberley area of northwestern Australia. Here, diamonds have recently been discovered as alluvial concentrations and in the broken rock and ash infillings of ancient volcanoes. These features known as pipes were the conduits through which materials ascended from great depths during eruptions. Our Australian discoveries are similar to the classic South African occurrences and Australia looks like becoming a major producer before the end of the decade. Past diamond production has been mainly from the Copeton and Bingara areas of northern New South Wales where rich alluvial deposits were worked.

Experimental work has shown that high pressures are normally required before diamonds can develop. A pressure of at least 35 kilobars (35,000 atmospheres) coupled to a temperature of about 900°C can be considered a normal minimum requirement. In nature, such high pressures are established at depths of over 100 km, that is in the upper mantle regions. Very high pressures are also briefly achieved during the impact of giant meteorites and where large sections of the Earth's crust slide against each other along fault lines. Although diamonds have been found in the Canon Diablo meteorite fragments in Arizona, there is as yet no evidence of diamonds having been formed in either impact or fault zones. Practically all diamonds are found in volcanic pipes or in detritus derived from the erosion of such features. Due to the inaccessibility of the Earth's mantle, an understanding of the actual conditions and reasons for diamond formation is proving to be a challenging enigma for geophysicists.

A peculiar volcanic rock called kimberlite is the normal host for diamonds. It is only the few volcanic pipes filled with this material that can be considered candidates for exploration as primary sources. Even when a kimberlite pipe is located, there is still a less than one per cent chance that it will yield diamonds in commercial quantity. Kimberlite is a heavy, bluish-black rock like basalt, but it is richer in magnesium and chromium and has less silica and iron. Both kimberlite and basalt are formed from molten magma that generates volcanic eruptions. There is substantial evidence that kimberlite magmas form at depths of over 150 km by the partial melting of garnet-bearing peridotite rock. Garnet peridotites are most attractive looking mixtures of deep purplish-red garnets (the gem variety pyrope), set in a mosaic of clear green olivine (the gem variety peridot) and rich green chrome-diopside. These and related rocks are known to contain diamonds in some South African and Siberian pipes, hence some or all of the diamonds could have been released by the breakup of these rocks. The kimberlite magma is probably only the vehicle that transported the diamonds to the surface. Eruptions involving kimberlite magmas generated large quantities of gases, mainly carbon dioxide and steam, which blew the magma into fragments rather than it being erupted as lava. The volcanic pipes were filled with a jumbled mass of fragments known as breccia. Such eruption conditions probably destroyed the diamonds except in rare cases, increasing the element of luck in their discovery.

A selection of diamond crystals from northern NSW showing typical crystal shapes (between 3 and 5 mm in diameter). These specimens are from The Australian Museum's collection. Photo by John Fields/The Australian Museum.

Kimberlites usually contain a fascinating assortment of rocks that have been acquired accidentally by the magma as it punched its way upwards through some 150 km of other rocks. Fragments of the upper mantle are of the greatest interest as they provide samples from far beyond the range of drilling. These 'foreign' rocks, or xenoliths, also provide clues as to the origin of diamonds. By complex geological detective work on the constituent minerals, one can estimate the temperatures and pressures of formation for the original rock masses. Over most of eastern Australia the xenoliths of mantle origin found in volcanic rocks contain the opaque black mineral spinel, rather than garnet. It has been shown experimentally that garnet is only stable at the pressure equivalent of around 75 km and at shallower depths its place is taken by spinel. The spinel peridotite xenoliths indicate that magmas in eastern Australian volcanoes were generated at depths that were quite unsuitable for the occurrence or formation of diamonds. On this theory alone, likely looking volcanic pipes in many parts of eastern Australia may be discounted as diamond sources.

Prime targets for exploration programs are promising volcanic pipes. Those most likely to contain kimberlite infillings can be expected in ancient continental shield areas. Kimberlite breccias are soft in comparison with the surrounding granitic rocks and they are usually deeply eroded. With little or nothing to be seen on the surface these pipes are almost impossible to locate by ordinary field traverses. Sophisticated geophysical prospecting techniques now provide a new 'seeing eye'. Chief amongst these aids are geomagnetic and gravity measurements that show up anomalies sometimes associated with volcanic pipes. Promising areas can also be recognised from a careful analysis of fault and other structures. It has been shown that there is a greater possibility of finding kimberlite pipes where two faults intersect. Such points provided natural weaknesses that allowed easy escape of magma. Ground traverses subsequently evaluate any promising structures and anomalies. Sampling of soils, called 'loaming', and searches of river deposits are systematically carried out in the hope of finding tell-tale kimberlite indicator minerals. Chief amongst these are magnesian garnet (pyrope), chromium-rich spinel and pyroxene (Cr diopside), perovskite and, of course, diamond. By careful elimination, the origin of such mineral grains may be located, and hopefully a kimberlite pipe discovered.

A typical diamondiferous kimberlite in South Africa contains about 25% gem-grade stones. With transport by rivers gem quality diamonds are very durable, but flawed industrial stones do succumb to abrasion and are destroyed. For this reason, alluvial diamonds found a considerable distance from their source show a much greater percentage of gemstones. When this situation is recognised indications are that their source may be a long way off.

In many ways, diamond exploration is an even more chancy business than searching for petroleum. Even when a diamond-bearing pipe is found, it takes time-consuming and highly specialised evaluation work to establish its viability. The diamond yield of any kimberlite or alluvial deposit varies widely and an average yield can only be determined on a large sampling program. As diamond grades also show great variation, detailed grading is needed to determine the proportion of gems to industrial stones.

Being a continent, Australia possesses an ancient shield area as its geological core. This area covers much of Western Australia and includes some of the oldest rocks in the world, well in excess of 3,000 million years old. As in South Africa, India and Siberia, this is a most suitable situation in which to find primary diamond sources. The WA shield areas provide a wealth of minerals, notably gold, chromium, nickel, uranium, copper and rare metals. As they are much thicker than other continental areas, the crustal shields extend to greater depths and hence higher pressures. Being stable, temperatures at depth are lower than for comparable depths around the continental margins. Any volcanic activity through the shields involved magma that was generated at greater depths than that responsible for volcanoes elsewhere. Magmas are much more likely to have come from deep zones that contained diamonds, hence the attraction of Western Australia for diamond hunters.

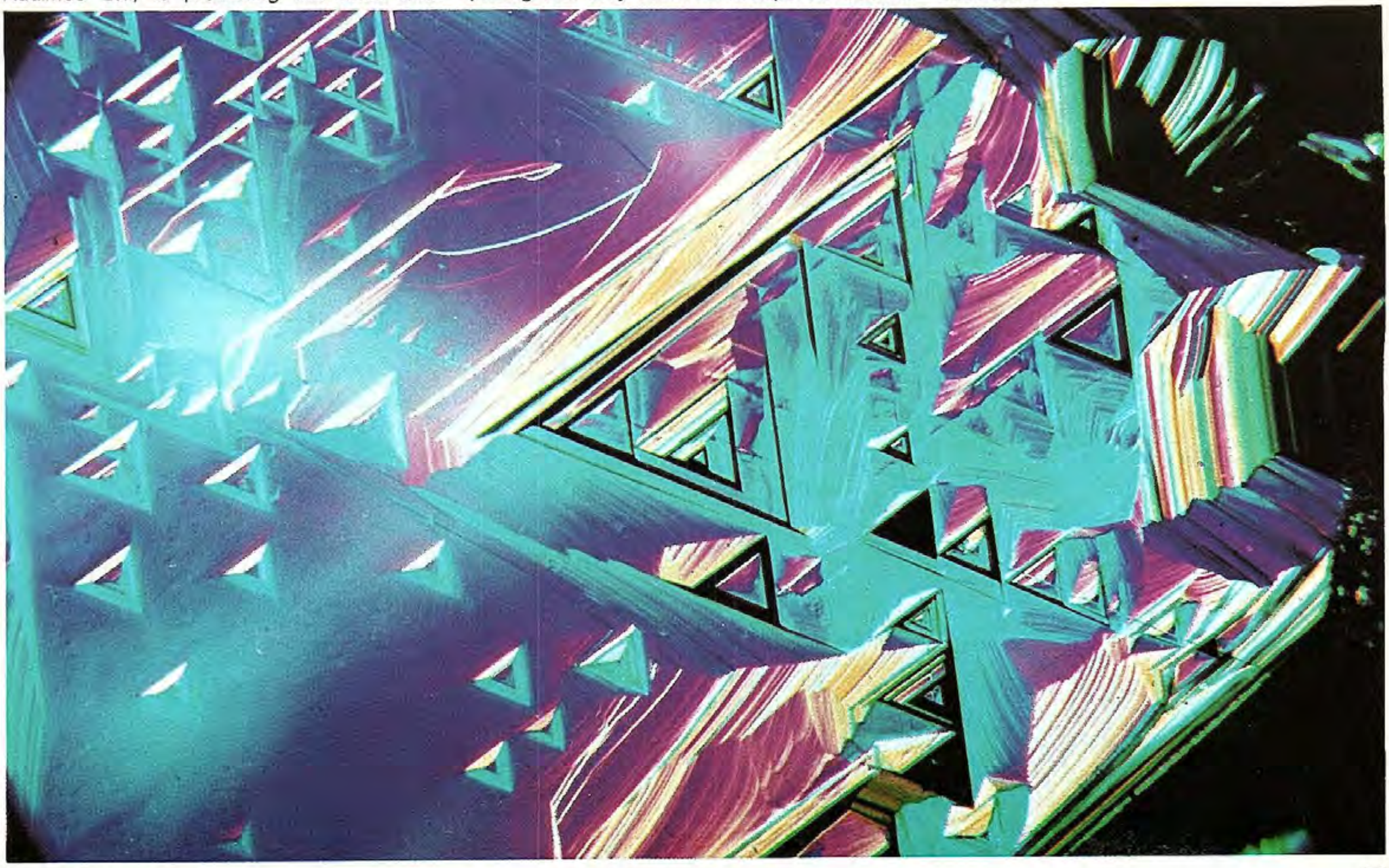
In northern New South Wales, although it is geologically unsuitable for diamond-bearing pipes, alluvial diamonds have been successfully won in many areas. Volcanism involved magmas generated at less than 60 km that were not kimberlites and were thus unlikely diamond sources. However, Australia's chief production of diamonds has been from the alluvial deposits around Copeton and Bingara in northern NSW. Deposits were very rich in these parts. In fifty years up to 1922 the total recorded production in these fields was approximately 204,000 carats, although much of the production may have been unrecorded. The largest stone weighed 7.5 carats, but the majority of stones were less than a carat. About 10% of stones were of gem quality and many showed well-developed octahedral crystals. To this day it is not too difficult to pan for small diamonds in fossicking areas around Copeton; and one company, Audimco Ltd, is producing diamonds from alluvial deposits in that area. Unfortunately, many of the former rich prospects are now deep beneath the new Copeton Dam.

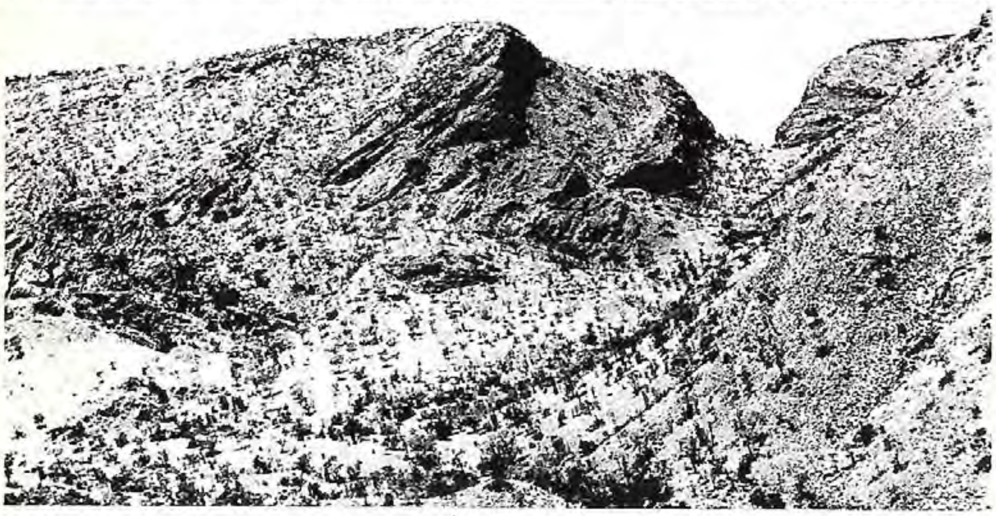
The origin of these diamonds is a challenging problem. The scattering of breccia pipes known in New South Wales all contain materials of relatively shallow origins. One of these is Ruby Hill, some 19 km south of Bingara and close to the rich alluvial fields. This is a well-known fossicking area for clear, deep red pyrope garnets and also shows chrome-spinel and chrome-diopside. All these are kimberlite indicator minerals but the magma associated with them is an ordinary basalt, albeit in breccia form. Diamonds were reportedly found in shallow excavations at the foot of Ruby Hill in 1900, but further exploration has failed to reveal any more. The alluvial diamonds could have been transported long distances from sources in the shield areas to the west. However, the dense, localised concentrations of stones characterising the Copeton and Bingara fields would suggest a local origin. This lack of scattering and the high proportion of 'industrials' points to a source that was perhaps covered by lavas during the past 50 million years, and is thus no longer accessible.

There was a most peculiar record at Oakey Creek, Copeton, which may provide a valuable clue. Here an adit tunnel encountered an intrusion of dolerite—a crystalline igneous rock related to basalt—which yielded several small diamonds. The diamonds must have been foreign crystals in the rock and it is surprising that they survived transport in such a

Alluvial diamond in ironstone conglomerate matrix from Inverell, NSW. Photo by John Fields/ The Australian Museum.

A diamond crystal face in polarised light (below). Just as fingerprints of people are distinctive between individuals so too are the colour patterns of diamonds produced by polarised light. Photo by Rod Brightman / Diamond Grading Laboratories.





Aerial view of an Ashton Joint Venture bulk testing plant beside a kimberlite pipe, east of Derby, WA (top). Bulk sampling of the weathered kimberlite is being carried out, marked by the whitish trenches in the left corner. Photo by Conzinc Riotinto of Australia Limited.

The Argyle Kimberlite No. 1 pipe (above) is believed to be the source of diamonds found in the Argyle Prospect. Photo by Conzinc Riotinto of Australia Limited.

Unusual diamond crystals recently acquired by The Australian Museum (above right). Photo by John Fields/The Australian Museum.

medium. There are many other dolerite intrusions in the area but these have escaped critical searches. The Oakey Creek occurrence was a world curiosity, but it too was inundated by the Copeton Dam. The questions raised are whether the NSW diamonds come from dolerites rather than kimberlite pipes, and whether the dolerite magma acquired diamonds from normal mantle depths (i.e. over 150 km) or were they from some shallower source?

Recently, USSR scientists have succeeded in producing artificial diamonds at relatively low temperatures and pressures. This indicates that it is quite possible for diamonds to be generated in the upper mantle as shallow as 50 km, and current theories will need critical examination.

Diamonds have been known in WA since 1895 when diamonds in conglomerate were recorded from Nullagine area. In the remote Kimberley region of WA it is not surprising that the first alluvial diamond was discovered only in 1973. Since then, exploration has progressed with increasing intensity and the Kimberleys appear promising as host for Australia's first diamond-pipe mine. Already Conzinc Riotinto of Australia's joint partner, Ashton, has discovered at least three diamondiferous kimberlite pipes and rich alluvial deposits that may be producing by the end of 1980. Diamond ventures have by tradition and necessity been excessively secretive groups and geological facts about the occurrences are scanty.

Late in 1978, Ashton Joint Venture discovered two large breccia pipes at Ellendale. Both turned out to contain commercially significant diamonds. Although small, about 60% of stones were graded as gem quality. Ellendale 'pipe B' has the third largest surface outcrop in the world, of 84 hectares and sampling has yielded an average of 13.5 carats of diamonds per 100 tonnes of kimberlite. Late in 1979 very rich alluvial deposits were encountered in Smoke Creek near Lake Argyle. Soon a third and much richer pipe was discovered as their probable source. Tests of kimberlite from this pipe showed average yields of 95 carats per 100 tonnes which compare with the best South African yields. The largest stone discovered by January, 1980, weighed 7.03 carats and came from Smoke Creek.

It will be most interesting to see if further discoveries will be made in what is still largely an unexplored area. Activities are exciting world-wide interest, but the element of risk for investors is high. As remarked recently in the 'Sunday Times' of London, "If discovering copper ore is like sending a blindfold man to find a haystack, unearthing diamonds is like searching for the needle inside." With such attractive results so early in the exploration program, the future for Australian diamonds looks bright indeed.

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THE WATERLOGGED FOREST

Because of their situation in estuaries, and thus having affinities with both terrestrial and aquatic environments, mangroves provide an interesting natural laboratory for ecologists. Harry Recher, Curator of Vertebrate Ecology, and Pat Hutchings, Curator of Marine Invertebrates (Worms), have combined their expertise at The Australian Museum in an investigation of mangrove and estuarine management. The economic importance of mangroves is considerable in a large number of underdeveloped countries within SE Asia. In a country like Australia where the national economy is not dependent upon these trees, an opportunity exists for an appreciation of the role of the mangrove in estuarine ecology to be extended to conservation and management. In this article we are taken into the very heart of these waterlogged forests and given the opportunity to feel the pulse of a threatened environment.

by Harry Recher and Pat Hutchings

Straddling two environments—land and sea —the frontal edge of this mangrove (*Rhizophora*) stand is characterised by thick vegetation, tangled roots and glutinous mud. Photo by Pat Hutchings/The Australian Museum.

Portuguese sailors called them 'mangue'. To Malays they were 'manggi-manggi' and 'mangin'. We know them as mangroves; trees which grow between land and sea. In southern Australia, stunted and warped in form, mangroves straggle along the shores of estuaries. In the tropical north, mangroves form forests as tall and rich as those of the land.

Mangroves are an important part of Australia's estuaries and a source of conflict. The role of mangroves in the cycle of nutrients and energy which makes estuaries among our most important sources of seafood, has been recognised only in recent years. Too often mangroves are viewed as obstacles to development, a source of pollution and a breeding ground for mosquitoes and biting midges. As a result, mangroves have been extensively cleared and the land they occupied claimed for houses, industry and port facilities.

For over a decade The Australian Museum has fought for the protection and management of mangroves. It has done so because of the importance of mangroves to the ecology of estuaries. Although there is a now a wider recognition of the value of mangroves and a more sensible approach to the use of mangrove habitats, mangroves and mangrove communities lack effective protection throughout Australia. In this article we describe the natural history of mangroves and explain their role in the ecology of estuaries. We hope that better conservation will follow.

Mangroves are trees or shrubs which grow along the shores of estuaries, tidal creeks and sheltered bays. Alternately flooded and exposed by the tides, the intertidal habitat of mangroves is harsh with wide variations in salinity and temperature. Yet there is an abundance of water and nutrients so that under optimal conditions mangroves form extensive forests with trees 30 to 40 metres tall. In southeast Asia mangroves are an important source of timber and fuel.

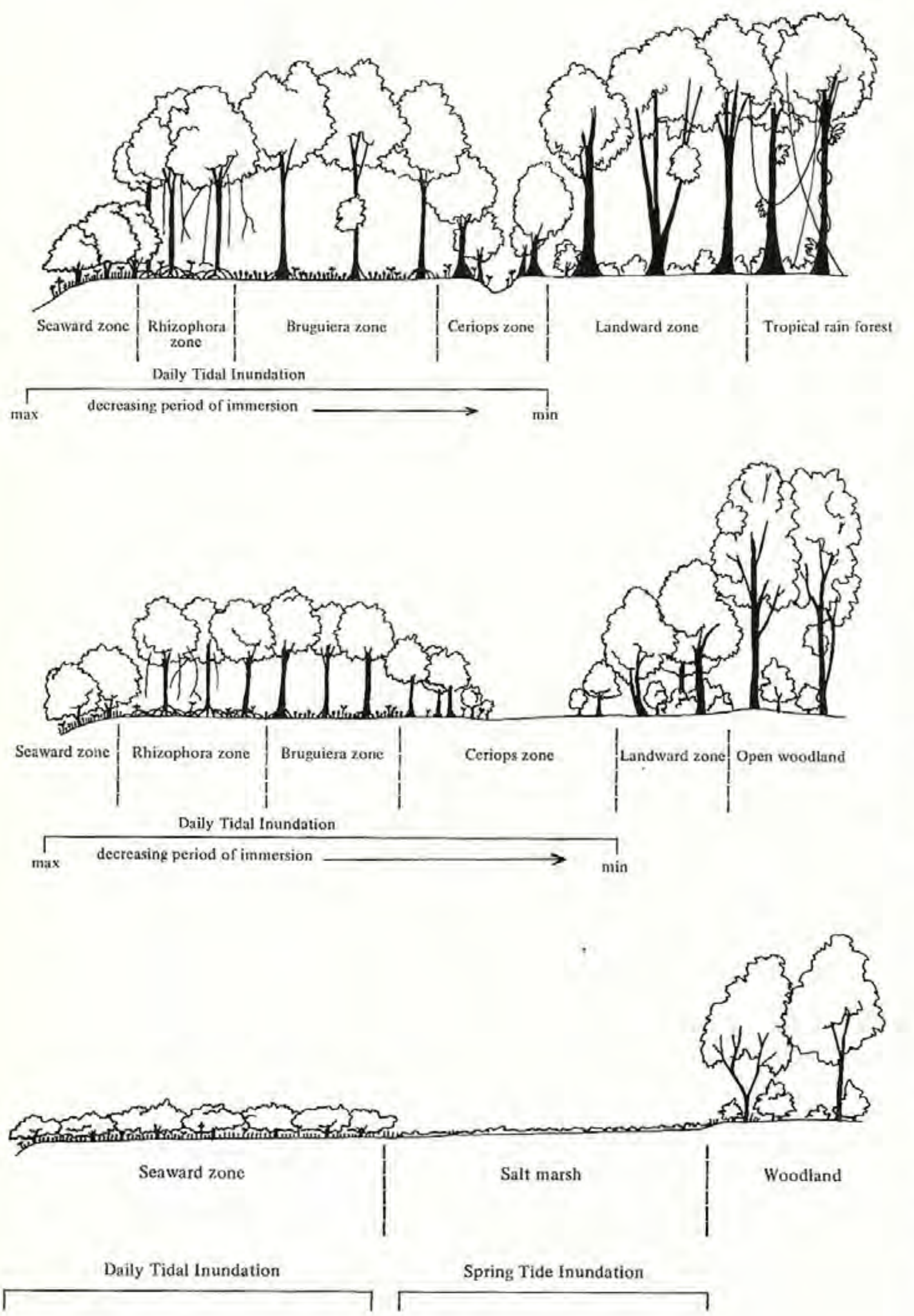
In Australia, there are 29 species of mangrove representing 15 different families of plants. Most of these are closely allied to trees of tropical rainforests and are considered to have evolved in southeastern Asia. Mangroves belong to the tropics and subtropics, and the richest and most extensive mangrove forests in Australia occur along the broad estuaries of the tropical north.

Mangroves only grow where the shore is sheltered and the water is shallow. Under these conditions nutrient-rich silts accumulate and young mangroves establish themselves. The distribution of mangroves along the Australian coast is therefore patchy, with the arid coasts of the south and northwest devoid of suitable habitat. In general, the number of mangrove species declines from north to south. All 29 species occur north of 12°S latitude, but only half of these extend to the Tropic of Capricorn (23°S). Proceeding south, seven species occur near Brisbane (28°S) but only two species reach the NSW south coast (Merimbula). Only the grey mangrove, *Avicennia marina*, occurs in Victoria, South Australia and southwestern Western Australia. No species of mangrove has been found in Tasmania, but *Avicennia marina* occurs around Auckland in New Zealand.

Traversing a mangrove swamp in the tropics is like climbing a steep mountain; it is physically difficult and one passes through a series of different plant communities or zones of vegetation. As on a mountain, the zones in a mangrove forest differ in plant species and in the structure of the vegetation. In places one walks easily through a tall shaded forest with widely spaced trees and in others, pushes with difficulty through thickets of massed foliage, tangled roots and glutinous muds. In such cases it is easier to swim through at high tide.

On a mountain, the change in plants is related to altitude but a mangrove swamp appears flat. But here, appearances are deceptive. Mangroves are flooded by saline waters during high tide and are uncovered at low tide. These requirements restrict mangroves to the intertidal zone between mean sea level and the limits reached by the highest astronomical or spring tides. Each species of mangrove grows best at some point between these limits. In fact, mangroves respond as much to changes in elevation as do plants on the slopes of a mountain. The intertidal change of elevation is simply more subtle.

Zonation in a mangrove forest is a response to changes in the duration of tidal flooding, soil salinity, available sunlight, cur-



Schematic representations of transects through tropical, subtropical and temperate mangrove systems. The first diagram shows a tropical mangrove system typical of northern Queensland. The seaward zone to *Ceriops* zone is inundated on each tidal cycle, with the sea water zone inundated for the longest period of time. A tropical rain forest, which is never inundated by sea water, abutts the mangrove zone. The second diagram shows a subtropical system of southern Queensland. Daily tidal inundation occurs from the seaward zone to the *Ceriops* zone as well; however, between the *Ceriops* and terrestrial area a salt pan devoid of vegetation is often developed. The third diagram in the series is of a temperate mangrove system in Victoria. The seaward zone is entirely composed of *Avicennia marina* which forms dense shrubs rather than trees. An extensive salt marsh occurs between the mangroves and the woodland which may be represented by sheoak, *Casuarina*, and paperbark, *Melaleuca*. Diagrams modified from Lear and Turner, 1977.

rents and fresh water run-off. Each of these factors changes along a transect from the water's edge to the land. They also differ from place to place within an estuary or tidal river system. At sites where the soil drains poorly or is very salty or where the river tends to be fresh fewer kinds of mangroves occur and zonation is simplified. This occurs in Spencer Gulf, South Australia, where salinities reach 60 to 80‰, temperatures exceed 40°C in summer and virtually no land run-off takes place. Recent work in the Northern Territory shows that the height and girth of mangroves is strongly influenced by the freshwater run-off during the wet season.

Zonation is most noticeable in tropical estuaries where the number of mangrove species is greatest. Each zone is identified by an individual species or group of species and takes its name from the dominant or most abundant species. At the water's edge is a narrow fringe of pioneering species. The two most common species forming 'pioneer' zones in the tropical north of Australia are *Avicennia marina* and *Sonneratia alba*. Seedlings and saplings extend seaward, but mature plants seldom form more than a band two or three plants deep. Grey mangroves and pornupan mangroves, *Sonneratia* spp., are dominant. Proceeding towards land, the next zone is the *Rhizophora* zone. *Rhizophora* is also characteristic of the edge of tidal creeks where their prop roots hold them against the current. They are the classic mangroves of tropical shores with tangled arching roots and dark green leaves. Next is the *Bruguiera* zone. It is often the tallest and may form a closed forest 30 metres high. Here the mangroves are dominated by species of *Bruguiera*. Cannonball and cedar mangroves, *Xylocarpus granatum* and *X. australasicus*, and looking-glass mangrove, *Heritiera littoralis*, may occur in association with *Bruguiera*. Spurred mangroves, *Ceriops* spp., form the fourth zone in this series. Thickets of spurred mangroves up to 5 metres in height occur along tidal waterways where the soils appear to be well-drained. But here also occur bare, highly saline areas devoid of vegetation. The final zone merges into the land vegetation. Although this 'landward fringe' may be narrow it is richest in species. This ordered zonation occurs only where there is a uniform slope from low water to high water mark. However, normally variations in the slope spread throughout the tidal area so that the five zones may be considerably confused within a mangrove stand.

Moving from north to south, the number of mangrove species decreases and in consequence there are fewer zones. In temperate climates a traverse through a mangrove forest commonly passes through a seaward, pioneering fringe of young *Avicennia* into a taller and wider zone of mature trees. In well-developed stands these form a closed canopy and dense shade obscures the forest floor. If the waters of the estuary are clear, the mangroves may grade into beds of sea grasses (e.g. *Zostera* and *Posidonia*). Sea grasses are also abundant in tropical estuaries and bays wherever the water is clear and the bottom is stable. Between the mangroves and dry land there is often a salt marsh dominated by samphire, *Salicornia*, and the coach grass

Sporobolus virginicus. On well-drained and higher soils or where there is freshwater seepage, the river mangrove, *Aegiceras corniculatum*, often borders *Avicennia marina* in estuarine situations.

The grey mangrove grows around the coast of Australia. It dominates the seaward fringe of mangrove forests on the Daintree River in northern Queensland, withstands pollution along the Parramatta River in Sydney, tolerates cold winters at Corner Inlet in Victoria (the southernmost occurrence of mangrove in the world), thrives in seawater and grows up river where the water is virtually fresh. It is the mangrove most Australians see whenever they look at mangroves and is one of the five dominant mangrove species in Australia.

The environment in which *Avicennia* grows is harsh. The soil is periodically waterlogged, rich in organic matter and therefore low in oxygen. Water and nutrients are abundant, but the water is salty. To grow, a mangrove must cope with each of these problems. To reproduce, it must produce seeds or propagules capable of lodging in shallow water that can take root before being swept away by winds and tide. To colonise new shores, the propagules must float.

Walking in an *Avicennia* forest is hampered by a dense growth of short, woody pegs projecting from the soil. These are 'pneumatophores'—aerial extensions of the mangrove's roots. Literally, they are the root's lungs through which the roots obtain the oxygen they need to live and grow. The prop roots of *Rhizophora* and the meandering buttresses of *Xylocarpus granatum*, like the pneumatophores of the grey mangrove, also serve to supply the roots with oxygen. Air is taken in through the pores (lenticels) in these specialised roots during low tide and a supply stored for high tide. This need for aeration of the roots is why mangroves cannot grow where their roots are continuously covered by water.

Mangroves cope with salinity in several ways. Some species tolerate considerable salt concentrations in their tissues and may excrete salt through special glands in their leaves. Other species largely exclude salt from the water they take in through their roots and may excrete salt through these glands in their leaves. In general, mangroves are considered as either excluders or excretors of salt. For example, *Aegiceras, Avicennia* and *Aegialitis* excrete salt, and *Rhizophora* and *Ceriops* largely exclude salt.

Avicennia actively excretes salt through its leaves. The ability of *Avicennia* to excrete salt is easily demonstrated by floating a leaf upside down in a bowl of salty water. (The salt excreting glands are most numerous on the under surface of the leaf.) In a few hours, the leaf will be coated by glistening crystals of salt. Mangroves which exclude salt from the water they use cannot do this perfectly and deposit salt they take up in the tissues of their older leaves. This makes the leaf appear fat and turgid. The salt is removed from the plant when the leaf if shed.

Many mangroves are viviparous. That is, the seed germinates on the tree before falling. *Rhizophora* is viviparous, and its long cigar-shaped seedlings are common along the shores of estuaries. The propagules of all mangroves are buoyant and when the *Rhizophora* propagule falls it floats. The elongated stem trails down into the water and if it is carried by wind or tide into the shallows it is perfectly positioned to catch on the bottom. Roots rapidly develop to anchor it in place. Seedling *Rhizophora* may develop a stem more than a metre in length before dropping from the parent tree. Floating favours dispersal and enhances the chances that the young mangrove will lodge in a place suitable for growth. Some species such as *Avicennia marina* require several weeks' immersion in seawater for successful growth. Almost all mangroves require full sunlight for growth and it is an advantage for the young plant to drift away from the shade cast by its parent. Yet the young plant must be able to root quickly if it is to avoid drifting into deep waters or to shores where conditions are unfavourable for growth.

Falling between land and sea, the mangrove forest belongs to both worlds. Birds, mammals, reptiles and insects enter it from land, and with high tide fish swarm through the submerged portions of the

The prop roots of *Rhizophora* (top) stabilise the mangrove in soft muds and hold it against currents. *Rhizophora* occurs in mangrove forests throughout tropical and subtropical parts of the world. Photo by Pat Hutchings/The Australian Museum.

The pneumatophores of *Bruguiera* (above left) and other mangrove species are aerial extensions of roots and provide the tree roots with oxygen. Photo by Pat Hutchings/The Australian Museum.

The developing fruit of *Rhizophora* (above right). The seeds within the fruits will germinate before falling from the tree. Viviparity, as this phenomenon is called, enables the young mangroves to root quickly. Photo by Pat Hutchings/The Australian Museum.

Young grey mangroves, *Avicennia marina* (top), rapidly colonise new habitats if the water is shallow and the substrate stable. Here the 2-3 m high plants are invading an area of shallow water at the edge of the salt marsh at Careel Bay in Pittwater near Sydney. Photo by Harry Recher/The Australian Museum.

Mangroves provide a solid substrate for oysters, barnacles and seaweeds (above left). More active animals such as crabs and snails live among the encrusting organisms, but the entire community is limited to the height reached by the tides. Photo by Harry Recher/The Australian Museum.

In many places a salt marsh develops between the edge of the mangrove forest and dry land. Pat Hutchings (above right) examines the dominate plant species of the marsh, samphire or pickleweed, *Salicornia*. Photo by Harry Recher/The Australian Museum.

Although mangrove forests support relatively few kinds of animals, each species tends to be abundant. Many mangrove animals are small and can be collected only by screening mud (right). Photo by Harry Recher/The Australian Museum.

swamps feasting on crustaceans, worms and molluscs which inhabit the forest floor. This is a unique assemblage of life and its abundance reflects the productivity of the forest.

Estuaries are among the world's most productive ecosystems. In Australia, nearly 80% of fisheries are based on estuaries or on shallow coastal embayments. In oceanic waters small single-celled plants called phytoplankton are the main primary producers. That is, they use solar energy to produce organic compounds (sugars) which can then be used by animals and the plants themselves for growth and reproduction. In Australian estuaries, sea grasses and mangroves are important primary producers. This is because they occupy the largest areas; salt marsh is equally important in cooler climates.

With an abundance of water, nutrients and sunlight, an average mangrove forest produces a kilogram of dry organic matter each year for every square metre of forest. The most productive tropical mangroves produce as much as 28 tonnes of dry organic matter per hectare/year. For the Sydney area dry litter production of up to 5.8 tonnes/hectare/year have been obtained for *Avicennia marina*. Although mangroves are not wonder trees and the mangrove forest is not as productive as the most productive forests on land, the organic matter produced by them and sea grasses forms the basis of many estuarine food chains. Work carried out by the Australian Institute of Marine Sciences at Hinchinbrook, N Queensland, suggests that some of the productivity previously attributed to mangroves comes from freshwater run-off from terrestrial systems. In Florida (USA), workers have shown that after heavy rain, a pulse of organic matter is washed from the adjacent sawgrass areas (equivalent to our salt marshes) into the mangroves. Such work stresses the inter-relationships between these ecosystems, which must be managed as one system.

When the leaves, fruits and woody parts of the mangroves fall they enter the estuarine detrital system. Sinking to the bottom, the leaf of a mangrove is colonised by bacteria, fungi and small animals such as nematodes. Bacteria and fungi possess the enzymes needed to break down and digest the leaf, but studies from Florida have shown that it may be a year before a leaf is completely degraded and all of its energy and nutrients released. The process is assisted by crabs, prawns, worms and snails. These animals break the leaves into small pieces and feed on the micro-organisms coating the leaf. The pieces of leaf and the wastes of these marine detritus eaters can then be colonised by micro-organisms and again ingested by crabs, prawns, worms and snails. In turn the animals which feed on detritus are food for larger crabs, fish and birds. Ultimately the solar energy captured by the mangrove finds its way into the fish, crabs and prawns served in Australian restaurants.

The economic value of mangroves is not easily measured. Ten years ago the Head of Fisheries in Queensland estimated that each acre of mangroves on Moreton Bay produced

Continued on page 95

CENTREFOLD NO. 6
Nankeen Night Heron

by Walter Boles

The nuptial plumes on the back of its head indicate that this nankeen night heron is in breeding condition. Photo by Harry Recher/The Australian Museum.

The descriptive name of the nankeen night heron, *Nycticorax caledonicus* (Gmelin) 1789, is derived from its colour, which resembles that of a naturally buff-coloured cloth that was popular before the age of permanent dyes. As this material could be obtained only from the Nanking district of China the colour came to be known as nankeen. It has been suggested that the name of the bird should be changed to rufous night heron, as this is a more accurate description of its colouration, but this would lose an attractive piece of Australian bird lore.

The white nuptial plumes trailing from the crown are present only during the breeding season. Sexes are similar. The immatures are brown with buff and white streaks and spots and are often misidentified as the brown bittern, *Botaurus poiciloptilus*, a much shyer and less common species.

Breeding is concentrated in the October–March period, but if conditions are suitable it may take place at any month of the year. The basic requirement is a permanent body of water close to the nesting trees.

The courtship display and role of the sexes in building the nest and raising the young have not been reported for the nankeen night heron. In the very closely related black-crowned night heron, *N. nycticorax*, which is probably very similar in behaviour, the male selects a site and begins to build the nest. He also uses it as a display platform for performing his swaying courtship dance. Once attracted, a prospective mate must display in response before she is accepted. The male will then join her in display and conclude the ceremony with the ritual presentation of sticks to his new mate. Material for the nest is gathered by the male but the female carries out the actual construction.

Nankeen night herons usually place their nest on a horizontal branch near or overhanging the water. It may be as high as 30 metres from the ground. These birds are usually colonial nesters, up to 250 nests having been recorded in one colony, although solitary breeding pairs have been observed.

The eggs of the nankeen night heron, like those of most other herons, are greenish-blue. Two or three eggs are usual but clutches of up to five are known. Incubation takes about three weeks.

The name 'night heron' reflects the nocturnal habits of these birds. By day they roost quietly in thickly leaved trees bordering the water. When evening comes, they fly to their feeding spots to replace the diurnal (active in daylight) herons. Although dominated by these other species at this time, the night herons are soon left by themselves as night falls. Food consists of almost any small aquatic animals such as fish, crustaceans, frogs, molluscs and insects. Nankeen night herons are known to raid goldfish ponds and are not above robbing the occasional nest.

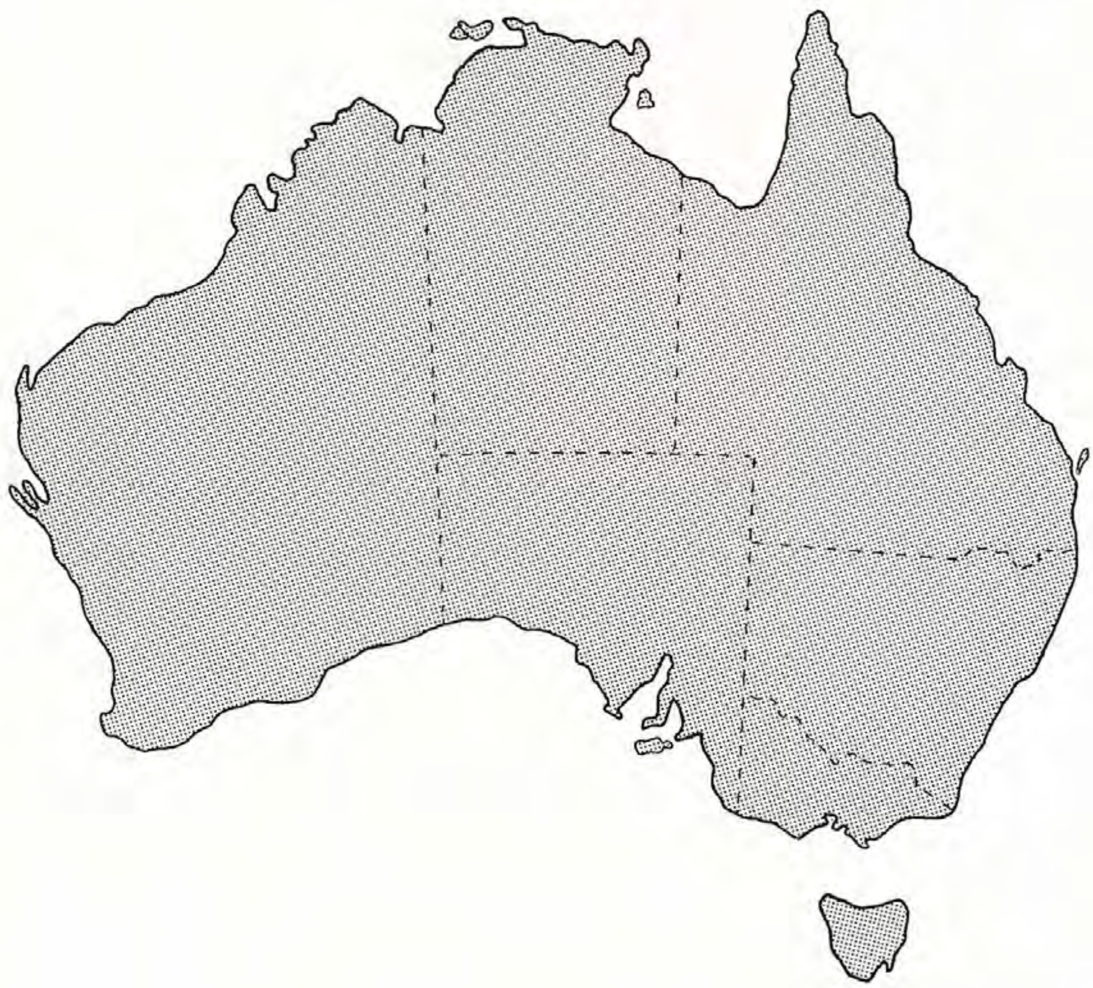
Because of the close association with water, as a breeding and feeding area, nankeen night herons if necessary will wander to follow this resource. The little information from banding studies, however, indicates that by and large this species is sedentary.

The nankeen night heron is Australia's only representative of the night herons, a group of squat, short-legged herons. It is found throughout the continent wherever suitable water is available. The first specimen was collected in New Caledonia in 1789, hence the name *caledonicus*. This locality is at the eastern edge of its distribution; it ranges west to Java and north through the Philippines to the Bonin Islands, less than 900 kilometres south of Japan. Attempts to introduce it to New Zealand have been unsuccessful.

The nankeen night heron's geographical replacement, the black-crowned night heron, meets it on several islands around Wallace's Line. Together these two species form a superspecies of nearly worldwide distribution.

An adult nankeen night heron, *Nycticorax caledonicus*, at the nest with a pair of recently hatched young. Photo by Peter Slater.

The nankeen night heron is fairly common in certain Pacific regions and is found wherever suitable habitat occurs throughout Australia, as the distribution map indicates.



Class: Aves
Order: Ciconiiformes
Family: Ardeidae
Genus: *Nycticorax*
Species: *Nycticorax caledonicus*
Subspecies: *N. c. halli*
Common Name: Nankeen Night Heron

Continued from page 90

The Canterbury Municipal Council claimed mangrove land for a rubbish tip on Salt Pan Creek of the Georges River (left). Large areas of mangrove forest and salt marsh have been destroyed by land fill operations. The loss of these plant communities deprives the estuary of some of its most productive habitats and must ultimately reduce catches of fish, crabs and prawns. Photo by NSW Littoral Society.

Although pleasant, it is not necessary to live at the water's edge. The destruction for houses of such precious and limited resources, as this salt marsh at Careel Bay (below left), illustrates a lack of appreciation of the role that these plants play in the estuarine ecosystem. Photo by Harry Recher/The Australian Museum.

Mangrove forests make good classrooms, but access is often difficult. Boardwalks, such as on Hinchinbrook Island in Queensland (below), allow movement through the forest and facilitate the use of the mangroves for research, education and natural history study. Photo by Pat Hutchings/The Australian Museum.

$300 worth of fish and shellfish per year. The total value exceeded 12 million dollars. Similar estimates have been made for southern Florida where much pioneering work on mangrove ecosystems has been conducted. In their classic study, Odum and Heald showed that mangrove leaves formed the base of the detrital food chain in southern Florida. They also showed that these mangrove swamps were the nursery areas for many of the region's most important game and food fish.

An acre of Florida mangroves is estimated to generate $4000 worth of fishing, tourism and recreation each year. Recognition of these values and the role of mangroves in estuarine productivity was slow in coming. In simple economic terms it pays to protect mangroves.

Although it is now considered that mangroves contribute significantly to the productivity of estuaries, the destruction of mangrove forests continues throughout the world. Australia is no exception. The growth of Australia's population is concentrated around the coast and there is every reason to believe that this will continue. Development has been greatest in and around the major cities. At Cairns, Townsville, Brisbane, Newcastle, Sydney, Wollongong and Melbourne, growth has been accompanied by the extensive destruction of estuarine environments. Large areas of salt marsh, sea grass beds and mangroves have been claimed for industry, airports, shipping, playing fields, sugar cane farms, housing or garbage disposal. Many remaining areas are threatened by air and water pollution. In New South Wales alone a significant percentage of mangrove forest has been destroyed. Most of this destruction has taken place in the last 30 years.

We can argue that mangroves are an integral part of the estuary, but are they so important that there should never be any development along our foreshores? Some people have said that such a policy is not possible and that it is not necessary to preserve mangroves everywhere. They argue that the need for land near growth centres is too great and that conservation can be served by retaining mangroves along the more remote parts of the coast. The growth of heavy industry at places such as Gladstone in Queensland and the development of extensive recreation and retirement complexes at many places along the coast shows that mangroves are no more secure away from the cities than they are on Port Jackson.

Unfortunately the legislation which prevails in most states prevents the inclusion of mangrove forests within national parks or nature reserves. National parks stop at the high tide line where the mangrove forest begins. Mangroves are protected by law in all states, but the rate of destruction shows that the law (or its enforcement) is inadequate. Inadequate, that is, if we want to protect our estuaries and conserve our estuarine fisheries.

Not everyone accepts mangrove forests as places of beauty and many will continue to insist that they are little more than the breeding ground of mosquitoes and biting midges. Some will also insist that people have a need and right to live on a waterfront block—even if that land has to be carved from the soul of the estuary. We must reject these views.

Foreshore development should be restricted to industries and port facilities which require direct access to shipping. Playing fields, houses and garbage tips have no place on the water—especially if it means the destruction of salt marsh, mangrove forest and

The encroachment of man's recreation and industry onto a mangrove forest is vividly illustrated in this NW-directed aerial photo of Careel Bay in Pittwater near Sydney. The mangrove forest, a parkland of *Avicennia marina*, and salt marsh were once more extensively distributed in this and adjoining bays, as well as along their feeder streams, but is now being quickly eroded away on all sides by housing development and land fill. Photo by John Fields/The Australian Museum.

sea grass beds. The spread of canal estates of the type developed at St Huberts Island in Brisbane Water near Sydney or Kawana Waters on the Maroochy River near Brisbane should be stopped. In the United States, the Corps of Army Engineers has acted to halt canal estate developments. The reasons: wetlands (salt marsh, mangroves and sea grass beds) are too valuable a public resource to be squandered on developments which are not clearly of public benefit. Australia must take a similar stand.

Wetlands are also valuable outdoor classrooms and in the Everglades National Park in Florida, board walks have been built allowing easy public access.

Australia is in a unique position to maintain large areas of mangrove. The majority of the world's mangroves lie in the tropics in underdeveloped countries, and mangroves are used extensively for fuel, building purposes and for the woodchip industry. Primary mangrove forests are being rapidly depleted in India and SE Asia, so that in 10 to 20 years time Australia may have the last remaining stands of mature, highly diverse mangrove forests in the world. In Florida, where mangrove species are protected, there are few species of mangrove.

Tidal wetlands mean too much to the national interest to be squandered for quick profits or political expediency. Instead, these wetlands should be declared endangered habitats and given national recognition as a critical resource. If the states cannot protect our estuaries, then perhaps there is need for intervention by the Commonwealth.

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BIRDS IN MY GARDEN

Although we frequently marvel at the diversity and beauty of the avian fauna of Australia's heathlands and forests, we too often take for granted the suburban species. Here Densey Clyne, helped by photographer Jim Frazier, introduces us to some of the more common birds in her Turramurra garden.

by Densey Clyne

Flocks of rainbow lorikeets, *Trichoglossus haematodus*, swoop daily through many gardens, alighting by the dozen on trays to quarrel ferociously over and through the contents (above right). Photo by Jim Frazier.

There must be many households besides my own around the suburbs of Sydney—and indeed along the whole east coast of Australia—where food is put out every day for flocks of rainbow lorikeets. In fact, the daily advent of these lively and spectacularly lovely birds can all too easily come to be taken for granted.

Out of the sixteen species that come regularly for food, it is the rainbow lorikeets that give character to my garden with their screeching and squabbling, and constant comings and goings at seemingly breakneck speed between gum trees and feeding trays.

These trays are filled daily, some with bread and honey mash, some with sunflower seed which is also scattered on the lawn. To be out of the way of neighbourhoods cats, the trays are either fixed to bamboo poles or swung from low branches. From time to time sliced bread and pieces of cheese are thrown out of the kitchen window. The bread is thrown at random, the cheese aimed specifically at the currawongs, which are extraordinarily adept at catching the pieces, and the kookaburras, which are less expert.

Water is supplied by an artificial pond nearby, which is *not* covered hideously with wire netting, as I don't begrudge the kookaburras an occasional goldfish.

Eight species of the parrot family visit the garden. The rainbow lorikeets greatly outnumber the rest, and they are sometimes accompanied by a few of their close relatives the scaly-breasted lorikeets. Often there appears to be hybrid colouring in one of a pair—a hint of violet about the head, a touch of flame rather than yellow bordering the breast feathers, to show the rainbow in their pedigree.

The scaly-breasted lorikeets are by no means a watered-down version of their more colourful relatives, as they have a distinctive character of their own.

King parrots come in increasing numbers every year for the sunflower seed. A male king parrot in full plumage is an unforgettable sight, the vermilion red of head and body appearing almost fluorescent against the green of wings and tail.

Both eastern and crimson rosellas come for sunflower seed, but the former have always been shy birds, preferring to feed on the lawn among the spotted doves. Crimsons, on the other hand, are bold enough to stay on the feeding trays when I walk nearby, and I get the impression that these and some other species actually wait near the windows and call for food. Certainly the rainbow lorikeets do this all the time, sometimes twittering with unaccustomed sweetness and restraint at me through my study window while I am working.

The most surprising of the parrot visitors is a male superb parrot which turned up for the first time last spring and continued visiting through the summer months. The normal range of this species is well to the west of Sydney although it does reach this area on occasion. But the bird could have been an escaped cage bird as he had no mate with him. He arrived first with a female king parrot, and all his visits coincided with those of the king parrots in the early morning and late afternoon when the trays are shaded by the house.

Galahs and white cockatoos are the remaining parrot species appearing in and around the garden. Small flocks of white cockatoos are infrequent but noisy visitors to the upper branches of the bluegums.

The galah, *Cacatua roseicapilla*, with its frequent screaming squawking as though gossiping, is a constant menace to grain growers throughout Australia but presents a rather respectable appearance when feeding on exotic shrubs in the garden (left). Photo by Jim Frazier.

The scaly-breasted lorikeet, *Trichoglossus chlorolepidotus* (right), is closely related to the rainbow lorikeet with which it often shares proffered food at the local 'swinging' diner. It occurs sparingly from Pennant Hills of Sydney to the northern suburbs and beaches. Photo by Jim Frazier.

The ubiquitous noisy miner, *Manorina melanocephala*, occurs in colonies which are of special interest to bird observers as they present well-developed social systems. The miner, one of our better known honeyeaters, has adapted well to urban living (below). Photo by Jim Frazier.

The galahs are increasing in numbers and are tame enough to feed only a few metres away from where I have my lunch on the stone terrace adjoining the house. For several springs a pair of them has been investigating a hole in one of the trees as a potential nest site. Perhaps this year it will be acceptable to them.

This year, a lone, female-plumaged satin bowerbird has found its way to the garden. From the shelter of the shrubbery where the characteristic 'bubble-and-squeak' notes give away its presence, it makes discreet visits to the seed trays.

Noisy miners are permanent residents about the garden. They are always around the feeding trays, and individuals are adventurous about coming through the kitchen window to raid the sugar bowl. Red wattlebirds are always around, too, mopping up what the lorikeets drop, pushing in nervously among the other species to pick up a hurried beakful at a time. In summer they bring along not only their own young ones, but at least one foster child in the shape of a fat baby koel that squats right down in the middle of the bread-and-honey mash. Even sitting in the middle of its food, it cries pitifully for the harassed 'parents' to feed it.

Kookaburras and grey butcherbirds come for cheese and meat scraps, and every year a pair of magpies bring their scrawny, unwashed looking offspring along on their regular ground patrols, stopping at the back door with an obvious request for cheese. Sleek currawong parents have a special dead branch outside the kitchen window where they cleverly field cheese thrown to them, an achievement the young ones try to copy with varying degrees of success as the season goes on.

Recently when I took an old copy of Cayley's *What Bird is That?* from my bookshelves, a scribbled list of birds fell out. It was a record of sightings in my garden during 1960. All but eleven of the 47 birds were either year-round residents, regular visitors, or seasonal migrants. Rarest sighting of all was a spangled drongo, unmistakable with its metallic plumage, red eye and characteristic forked 'fish-tail'. It perched for a while near the window, then took off for regions unknown, and I have never seen another one. I have heard of other sightings, though.

Like other small birds on that old list, the eastern yellow robin whose piping call used to be the first thing I heard on waking has gone from the garden. Gone with it are the blue wren, silvereye, thornbill, eastern spinebill and others that searched the foliage for insects and added their silvery sounds to the daily symphony.

Of the 25 birds shown as common on that list of 47, eight have in fact disappeared or are now only occasional visitors. But it is good to be able to record eight new species in their place (though some early omissions were probably due to lack of observation). And a few birds recorded then as 'once-only' or infrequent visitors now spend much of their time around the garden.

So—something lost, something gained, and the greatest gain to me is an increased pleasure in the bush birds that have so quickly adapted to life in the suburbs.

The black-backed magpie, *Gymnorhina tibicen*, is one of the more delightful songsters of the suburban garden but is probably better known for its aggressiveness during nesting periods. Trained eyes can tell three things about the bird pictured: 1) it has recently alighted on the branch, because of the greater amount of white showing in its wing, which, when it has settled down, shows more black; 2) the bird is adult, because of the white beak; and 3) it is a female, because of the greyish hind neck. Photo by Jim Frazier.

BIOENERGETICS

Energy—and our need to conserve and explore for alternative sources—is currently a topic of concern and will become increasingly so in the future. While the 1979 special issue of *Australian Natural History* concentrated primarily on physical energy sources and processes, the present article focuses on bioenergetics, the study of energy transformations within living organisms. Hans Coster, an Associate Professor in the School of Physics at the University of New South Wales and leader of the Biophysics Research Laboratory, has research interests in the thermodynamics of life processes, ecological and evolutionary. In his article he traces the flow of energy through the machinery of life.

by Hans Coster

To ensure efficient energy conversion and thus maximum food production, modern man promotes short, simple food chains by his agricultural practices. A cow obtains energy by eating grass which converts solar energy into biological energy through photosynthesis (above). Photo by NSW Department of Agriculture.

A diagrammatic representation of the cycle of photosynthesis and respiration in the biosphere is shown (right). The evolution of this cycle has created a gigantic store of chemical energy in the form of atmospheric oxygen and hydrocarbons. The oxygen/hydrogen carbohydrate store of materials provides a readily accessible source of energy to drive the various functions performed during respiration. Diagram by H. G. L. Coster.

The biosphere has a vast energy budget and human beings feature significantly in that overall budget. In living cells energy is derived from metabolism. A very high degree of organisation is needed to utilise the energy available from metabolism, and moreover, the metabolic processes can themselves also lead to changes in the structure which thus requires a continual replacement of the components of the cell matrix.

In animals the ingestion and oxidation (respiration) of foodstuffs provides the energy required. Ultimately, however, the source of this energy is the plant material which begins the food-chain. The plants utilise solar light energy (in photosynthesis) to manufacture materials which are subsequently used in their own respiratory pathways for the growth of the plant. The photosynthetic process leads, ultimately, to the fixation of carbon dioxide from the atmosphere and a production of oxygen and carbohydrates and other organic molecules.

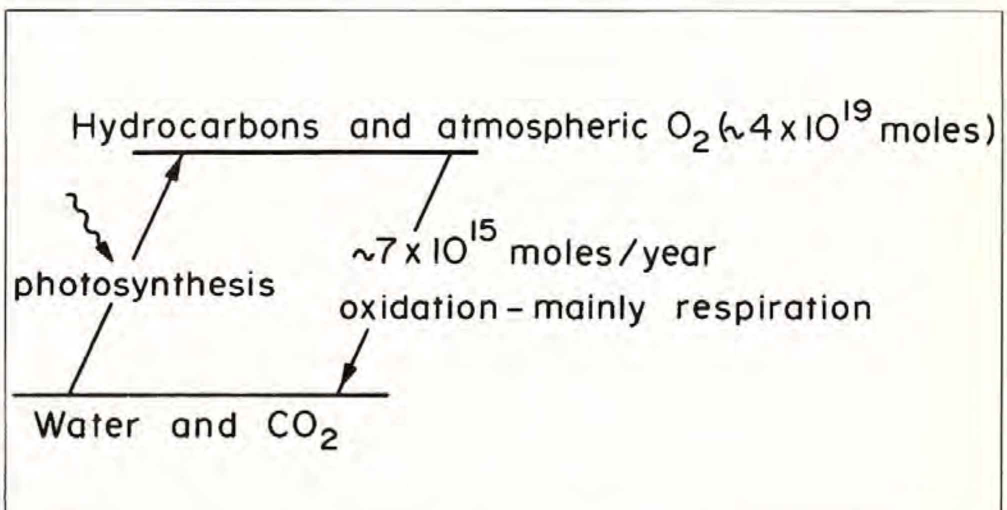
This process can be summarised by the following chemical reaction scheme:

H_2O	+	CO_2	$\longrightarrow$	(CH_2O)	+	O_2
water		carbon dioxide		carbohydrate building block		oxygen

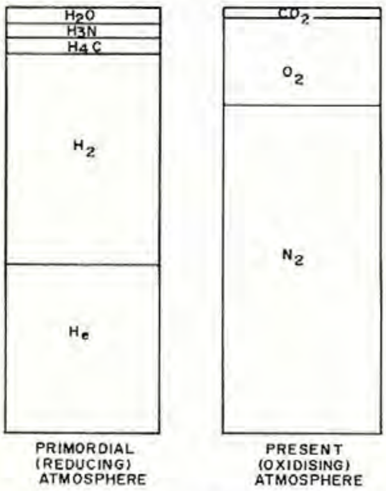
The energy required to drive this reaction from left to right is approximately 4.81×10^5 joules/mole. The joule is a unit of energy; to lift a 1 kg mass a distance of ~ 0.1 m requires approximately 1 joule of energy. 4.18 joules $\approx$ 1 calorie. A mole is that mass of the substance which in grams is numerically equal to its molecular weight. For example, 18 gms of $H_2O \equiv 1$ mole.

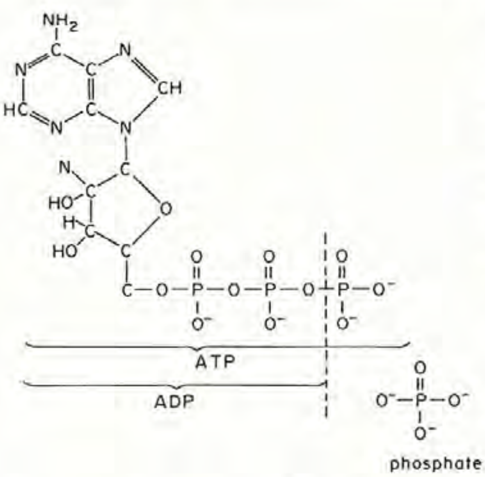
The giant cycle of photosynthesis and respiration made possible by the photosynthetic products is shown in the illustration below. Using the values for the annual turnover indicated there, we can estimate the annual energy budget of the biosphere to be approximately 3.3×10^{21} joules. The magnitude of this figure can be put into perspective by reference to the table presented on the next page.

It is clear that man features significantly in the energy cycle at present, although he made a much smaller (about 100,000 times smaller) impact, energetically speaking, at the time of Neanderthal man.



Total incident solar radiation	Energy cycling through biosphere	Energy generated artificially by man	Total energy stored as a result of biological activity
4.7×10^{24} joules/yr	3.3×10^{21} joules/yr	3.2×10^{20} joules/yr currently	1.9×10^{25} joules
		4×10^{15} joules/yr 100,000 years ago	





A comparison of the prebiotic and present composition of the earth's atmosphere (above). Nearly all of the oxygen in the present atmosphere was generated by the processes of photosynthesis. Diagram by H. G. L. Coster based on H. C. Urey in *The Planets*, Chicago Univ. Press, Chicago, 1952.

The adenosine triphosphate (ATP) and adenosine diphosphate (ADP) molecules (above right). ATP is the universal energy currency used throughout living systems.

The flow of energy in living cells (below). Energy derived from respiration or photosynthesis is used to convert ADP and phosphate to ATP which then circulates through the system to drive those life processes and mechanisms which require an input of energy for their function.

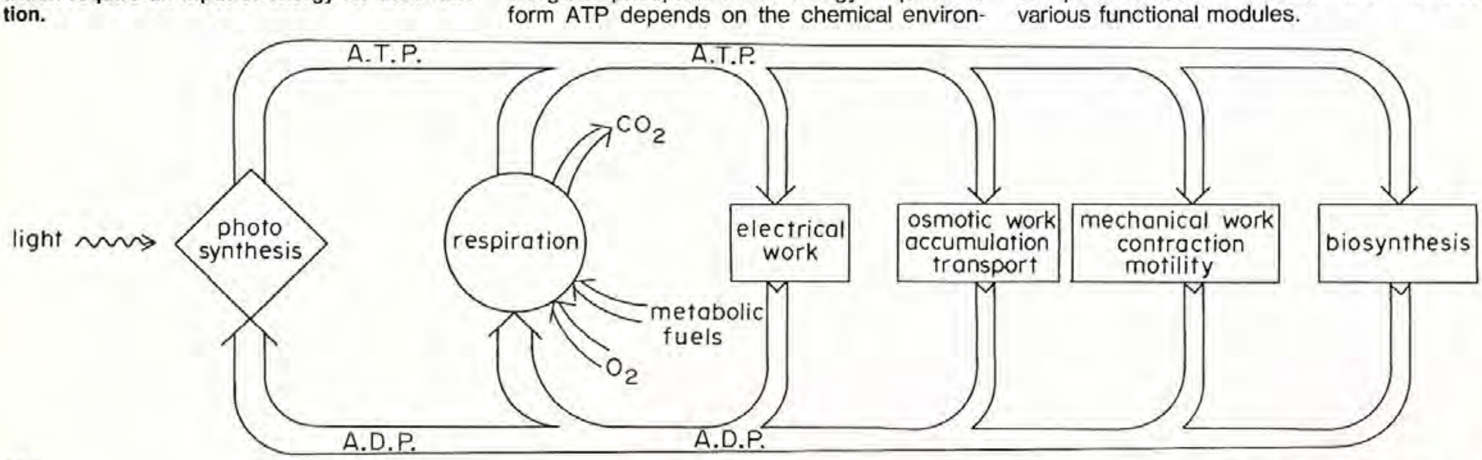
Photosynthesis, apart from fuelling the present energy cycle of the biosphere, was also responsible for the dramatic transformation of the earth's atmosphere which has taken place since the prebiotic era. The pool of atmospheric oxygen presently stored in the atmosphere and the associated pool of hydrocarbons (including the vast fossil fuel deposits) and other biosynthetic materials, represents a truly gigantic store of energy as can be seen in the last column of the table. Note that the yearly energy budget of the biosphere is only a small fraction of the total energy stored as a result of the past evolution of this cycle. This very conservative 'fiscal' policy is no doubt an important factor in maintaining stability in the whole ecosystem.

In the metabolic processes, energy released by the breakdown of metabolites (food) is generally used to synthesise adenosine triphosphate (ATP—a high energy compound) from adenosine diphosphate (ADP—a relatively low energy compound) and inorganic phosphate. The energy required to form ATP depends on the chemical environment (for example, the concentrations of ADP, phosphate and ATP) and will be different in different media (e.g. aqueous, lipid, etc.). When equilibrium concentrations of ATP, ADP and phosphate have been reached in an aqueous solution the energy required is about 3×10^4 joules/mole of ATP. Each mole of glucose ($\equiv \sim 180$ g of glucose) oxidised during respiration produces 25-35 moles of ATP, which therefore would require a total of 7.5×10^5 to 10.5×10^5 joules of energy. The complete oxidation of glucose yields about 29×10^5 joules of free energy. The energy stored in the extra phosphate bond of the ATP molecule becomes the immediately accessible source of energy and it forms the 'currency' which underwrites the host of chemical reactions and other processes in the living organism which require an input of energy to drive them. In these various processes the ATP is hydrolysed back to ADP and phosphate via enzyme mediated mechanisms (ATP-ases) which couple the energy so released to the specific function to be performed. Some of these functions involving ATP are shown in the illustration below.

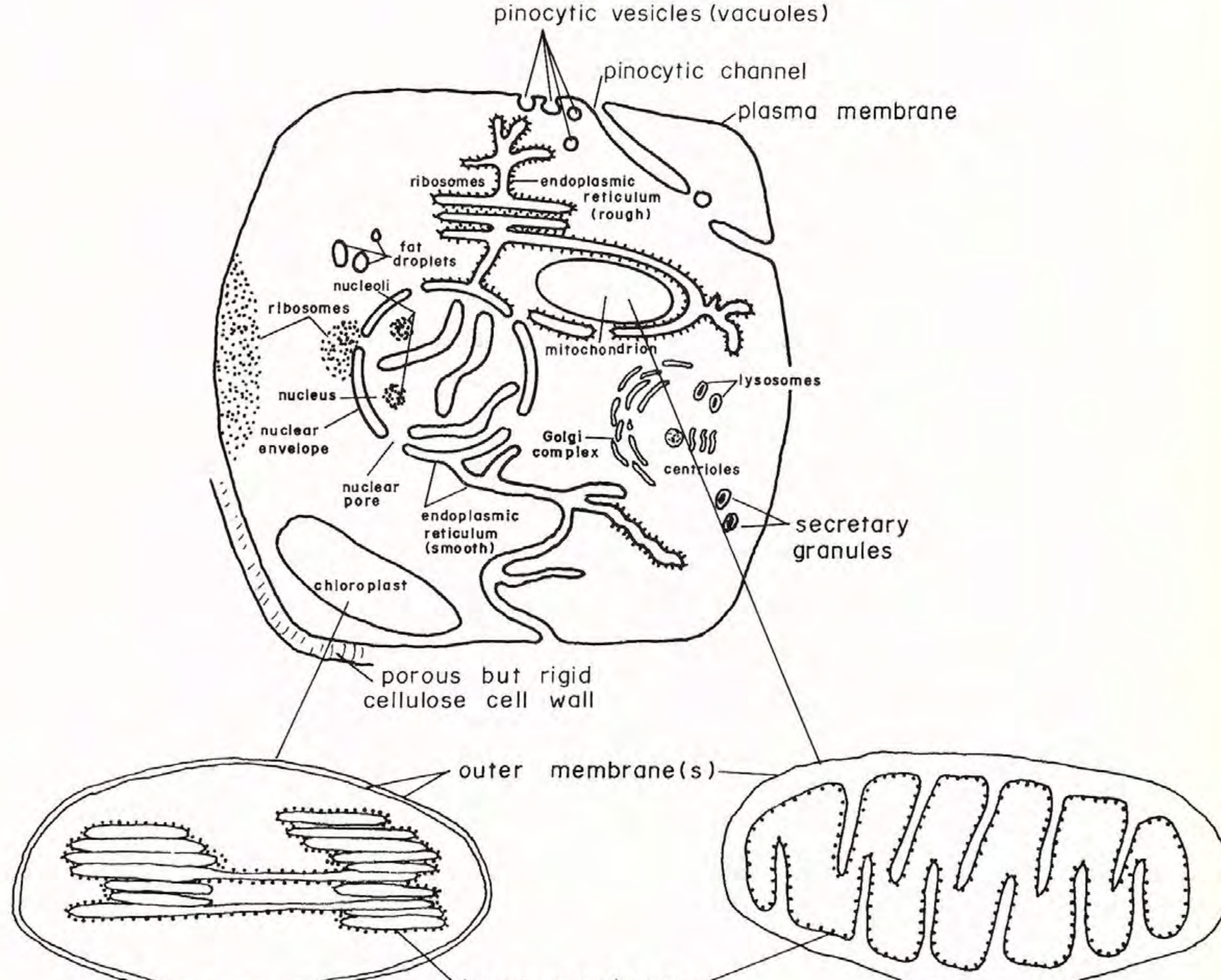
Despite their staggering diversity, living organisms do possess many common features and mechanisms. Thus all organisms have similar mechanisms for utilising chemical energy to drive the various work functions shown below. The also have similar mechanisms for the generation of the universal energy currency, ATP from ADP.

In plant cells the raw energy source is light. This is utilised in special structures called chloroplasts to manufacture ATP. In animal cells the manufacture of ATP occurs in mitochondria using energy released by the metabolism of high energy compounds ingested by the organism.

The relation of these two organelles (chloroplasts and mitochondria) to the rest of the cell can be gauged from the schematic diagram which shows the anatomy of a generalised cell. Not all cells possess all the features shown and no particular single cell species conforms to this generalisation (e.g. the cell wall may not be present typically in animal cells and chloroplasts occur only in plant cells, etc.). Both mitochondria and chloroplasts are delineated by membranes. These membranes are 7-9 nanometres in thickness and consist essentially of a bi-layer of lipid molecules in which are imbedded various functional modules.



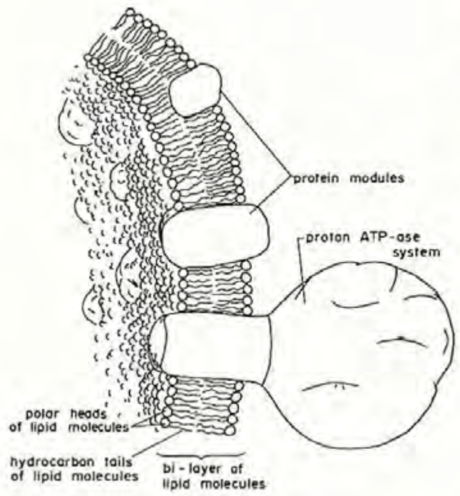
A schematic diagram of a typified cell. Not all the structures shown here are necessarily found in all living cells. The plasma membrane and the membranes surrounding organelles are about 8 nanometres thick.



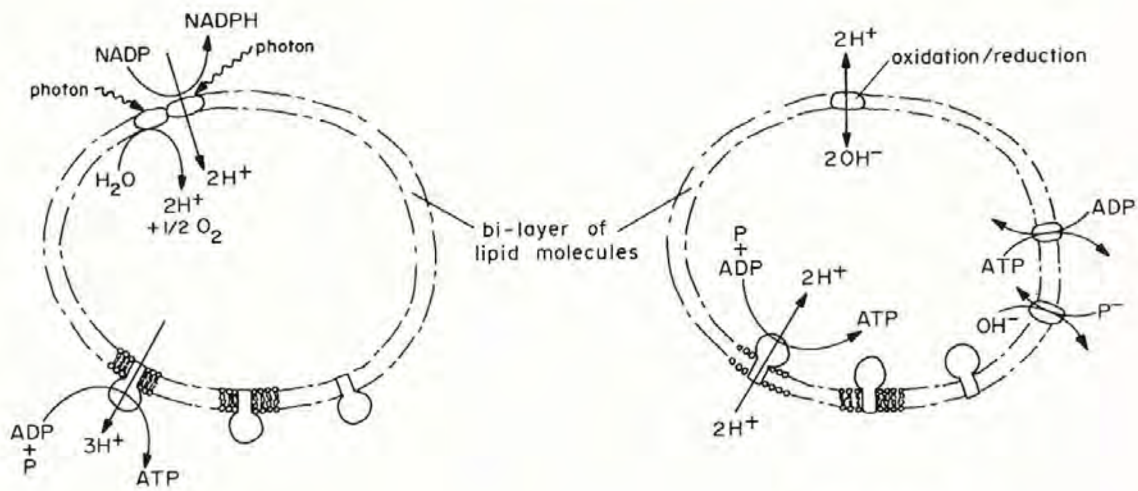
The dots represent the pretruding knobs of the ATP-ase system imbedded in this membrane.

An outline of the processes involved in the synthesis of ATP in mitochondria and chloroplasts (below). In the latter a high concentration of protons is established by light-driven mechanisms. Two photons of light have to be adsorbed for each electron transferred from a water molecule to an electron receptor (NADP—nicotinamide adenine dinucleotide phosphate).

In mitochondria a complicated series of respiratory reactions, beginning with reduced NADH (nicotinamide adenine dinucleotide), translocate protons from the inside to the outside. In both mitochondria and chloroplasts the resulting proton gradient produces a flow of protons (inwards in mitochondria, outwards in chloroplasts) through the ATP-ase complex where the thermodynamic potential energy of the protons drives the synthesis of ATP from ADP and phosphate. In chloroplasts 1 ATP is synthesised for each 3 protons that flow out; in mitochondria 1 ATP is synthesised for each 2 protons that flow in.



The structure of the membranes of mitochondria and chloroplasts (left). A bimolecular leaflet of phospholipids forms the basic fabric into which are imbedded specific protein modules. The phospholipid molecules possess polar heads (shown as round circles) which are hydrophilic and are in contact with the aqueous solution. The hydrocarbon tails face each other in this bi-layer. The large knob-like structure of the proton-ATP-ase module, which as shown protrudes into the aqueous solution, contains the site of the ATP synthesis.



Chloroplast

Mitochondrion

Synthesis of ATP in both systems occurs via the establishment of a gradient in the concentration of protons (ionised, or charged, hydrogen atoms) and/or electric potential difference (referred to as an electro-chemical potential gradient) across the inner membrane of these organelles.

Thus the energy to drive the ATP synthesis is derived from the difference in the electro-chemical potential energy of the protons across the inner membrane. The chloroplast or mitochondrion is like a proton-battery which drives the machinery (proton ATP-ase) that manufactures the ATP and which is recharged either directly by the action of light or via respiration. This scheme, which was unravelled in the last 20 years or so, is known as the chemiosmotic hypothesis of ATP synthesis. One of its chief exponents, Peter Mitchell, was awarded the Nobel Prize for his work in 1978.

Such proton-based energy systems are also found in some micro-organisms lacking chloroplasts and mitochondria. Thus in the halophytes (salt loving micro-organisms) a protein called bacteriorhodopsin imbedded in the plasma membrane (outer envelope membrane) of the bacteria translocates, under the action of light, protons from the cell interior to the external environment (salt water of the lakes in which they grow). The flow of the protons down the gradient so established, back into the cell, then provides the energy needed to drive the various (energy requiring) processes of the cell.

Much of the detail of the molecular mechanisms of the ATP-ase is not yet understood and is the subject of intensive research. On reflection it may not seem surprising that living organisms utilise the gradient of protons to drive the machinery of life, and have evolved an energy transduction system based on the splitting of water, the most abundant and physiologically universal solvent. The energy transduction mechanisms in organisms have had the benefit of evolution for a period of some 4000 million years. It is somewhat ironic that we are now only just beginning to discover for ourselves the advantages of a hydrogen-based economy for the future energy needs of mankind.

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MIDWIFE TO A SEASTAR

Of particular interest to a number of professional and amateur naturalists is *Patiriella vivipara*, one of only three known viviparous (live-bearing) seastars. Seastars are marine invertebrates of the class Asteroidea in the phylum Echinodermata. Other echinoderms include the sea urchin, brittlestar, featherstar and sea cucumber. Geoffrey Prestedge, a Prison Officer in Tasmania, has patiently recorded, from the local seashores and his aquaria, many fascinating details about *P. vivipara* and has, indeed, made a significant contribution to science with his hobby.

by Geoffrey Prestedge

An adult *Patiriella vivipara* giving birth. The juvenile (arm length approximately 2 mm) has just emerged from a split in the upper surface of its parent. The youngster will move off the parent and live an independent life. Photo by Geoffrey Prestedge.

On the south-east coast of Tasmania, in the region of Eaglehawk Neck, Roches Beach and Pittwater, there is a seastar which gives birth to live young. This species, *Patiriella vivipara* Dartnell, 1969, was the first viviparous seastar to be described. Since then two others have been found; *P. pseudoexigua pacifica* (Hayashi, 1977) from southern Japan and *P. parvivipara* Keough and Dartnell, 1978, from the South Australian coast.

Over the past three years (1976 to 1978) I have watched a population of *P. vivipara* on the shore at Pittwater and collected and watched the activities of this species in a series of aquaria built in my laboratory. *P. vivipara* is a small, five-sided, cushion-shaped seastar, reaching a maximum 'arm length' (radius) of about 15 mm. It is coloured yellow/orange on the upper, arched side but is almost white on the flat underside. The seastar can usually be found under loose rocks on the rock platform in the mid-littoral (or shore) zone, together with other invertebrates. This species is the largest of the three viviparous species with *P. pseudoexigua pacifica* reaching an arm length of about 10 mm, while *P. parvivipara* is only known to reach an arm length of about 5 mm.

According to Keough and Dartnell (1978), *P. vivipara* reaches maturity at an arm length of about 5 to 6 mm, whereas *P. parvivipara* reaches maturity at about 2 mm. The size of maturity for the Japanese species has not been recorded but might well fall between that of the other two species, i.e. between 2 to 5 mm arm length.

The gonads are placed interradially (i.e. between adjacent arms) and appear as orange-coloured spots which show through the body wall. As a juvenile develops, a lump appears on the upper surface of the seastar until the body wall splits and a juvenile emerges. Only one gonad develops a juvenile at a time, though one or more of the gonads, in the other interradial areas, may develop juveniles in random succession. I have timed birth to take anything between 10 minutes and 40 hours. The time between the release of one seastar and the birth of another varies between 10 and 12 hours. Juveniles, at birth, range in size between 0.5 and 4 mm arm length, averaging about 1.5 mm. The adults do not necessarily remain stationary while birth is taking place but may continue to move around, feeding, as though nothing were happening. The juvenile merely walks or rolls off the parent, righting itself if it lands upside down, and immediately leads an independent life.

An interesting fact has emerged from keeping four specimens isolated each in its own aquarium betweeen 1976 and 1978. I collected two of the specimens from the shore, and two were born in another aquarium. The arm length of each of the animals to begin with was 2 mm. For the first seven to nine months growth was rapid, increasing from 2 mm to 6 mm. At the end of the first year the arm length had reached 7 to 9 mm. During the second year arm length increased a little over 1 mm but in the third year barely reached a further 1 mm. The first juvenile was born in December 1977, almost two years from the time the parent had been isolated in the aquarium, and had an arm length between 7.25 to 9.00 mm. Whenever I changed the water in the aquaria I always collected the water from the shore and stored it for 48 hours before use. It would seem, therefore, that since only single specimens were kept in each aquarium, cross-fertilisation could not have taken place. Certainly Dartnall found gonads to be hermaphroditic, with eggs surrounded by sperm tissue. Keough and Dartnall (1978), however, have suggested that cross-fertilisation possibly occurs in the South Australian *P. parvivipara*.

It might be suggested, considering the largest size recorded for *P. vivipara* in the field (i.e. about 15 mm arm length), the size reached after three years in an aquarium (i.e. about 10 mm) and the reduced rate of growth after the first year, that *P. vivipara* might take between 7-10 years to reach maximum size and die!

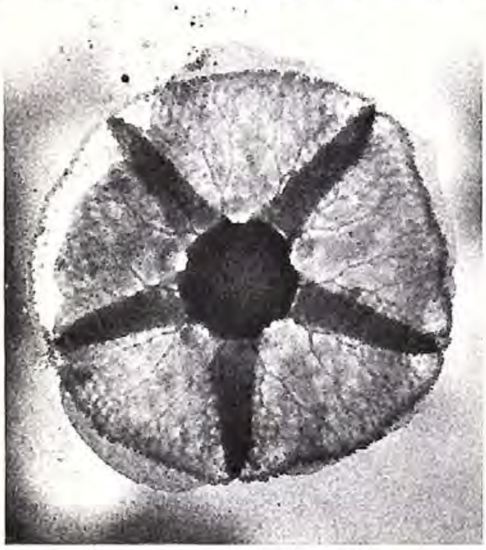
I have been unable to find anything that will prey on this seastar, even though I have introduced various crustaceans, fishes and other echinoderms into my aquaria.

Although juvenile *P. vivipara* can be found throughout the year on the shore, there does appear to be a peak, with the largest numbers being born between November and February. During this time you may find up to twice as many juveniles as adults. This contrasts with *P. parvivipara* in South Australia which reproduces only during the December-February period according to Keough and Dartnall. They have suggested that increased water temperature in the summer period increases reproductive activity in *P. parvivipara*.

A further very interesting and important comparison can be made between the Tasmanian and South Australian species. Although the Tasmanian species may be relatively long-lived, Keough and Dartnall report that the

Patiriella vivipara in its natural environment (top). The seastars are found on the rock platforms in the mid-littoral zone often in association with other marine invertebrates including snails and chitons. This seastar apparently feeds exclusively on algae and was often seen grazing on the algal mats growing on the sides of aquaria (centre left).

P. vivipara **dissected, showing gonads (centre right). The gonads are positioned between the arms within the starfish (in the photo seen as convoluted tissue at the base of the pins). At birth variations between individuals in number of arms were noted. Pictured (bottom) are 3, 4 and 6-armed seastars—deviations from the more normally encountered 5-armed individuals. Photos by Geoffrey Prestedge.**



South Australian species is short-lived, the reproduction process being fatal to the adults which are about one year old.

One of the more interesting observations to have come out of this study is the amount of morphological variation that occurs. Normally *P. vivipara* has five arms, but individuals with arm numbers ranging from two to six also occur. In two aquaria, in each of which six adults had been kept, a total of 119 and 178 juveniles were born over the period 1976 to 1978. Of the 119 juveniles born, five had three arms, nine had four arms, and one had six arms, totalling 18% of the number born. Of the 178 births, one had two arms, three had three arms, six had four arms and two had six arms, totalling 21% of the number born. On the shore Alan Dartnall found only two specimens, out of 216 he examined, to have two arms, or about 1% of the total. The two-armed specimen in the aquarium lived from November 1977 to March 1978, increasing its arm length from 2.25 to 3.50 mm. It is possible there is a high mortality rate among such abnormal specimens in their natural environment, whereas in the comparative safety of the aquarium survival rate is at least initially higher. Those variants with three, four or six arms, which became mature, gave birth only to five-armed individuals.

P. vivipara is found usually under rocks, but individuals with arm lengths over 5 to 6 mm may be found exposed on the rocks. Although these seastars are fairly mobile on the shore this depends on the proximity of the rocks. It is rare to find *P. vivipara* on the open or in sand or mud. It appears to feed on algae. I have introduced a variety of food-stuffs to the seastar in the aquaria, including steak, liver, fish, goldfish food, bread, crab-meat and molluscs. Not once did I see *Patiriella* feed on any of these. Instead, it fed continuously on the algal covering on the glass sides of the aquaria.

On the shore *Patiriella* has to withstand six to seven hour periods of exposure when the tide is low. This, of course, it does by hiding under the loose rocks. I have measured air temperatures ranging from 41 °C in high summer to −3 °C in mid winter. The temperatures of pools of water in the vicinity of the seastars ranged from 6 °C to 35 °C over the year with the highest daily range occurring in the summer (18 to 35 °C). I have recently received a grant from the CSIRO Scientific and Research Endowment Fund with which I have bought a salinity meter. I am now taking salinity readings to try to determine the effect of changes in the salt level in the water in the shore area on the seastar, particularly since fresh water washes over the shores where they live. There is still much for me to find out about this particularly fascinating and important species of seastar. In conclusion I must admit that I never imagined for one moment that my hobby would qualify me as a 'midwife' to a seastar.

FURTHER READING

Dartnall, A. J. 1969. A viviparous species of *Patiriella* (Asteroidea: Asterinidae) from Tasmania. *Proceedings Linnean Society N.S.W.* Vol. 93 (3): 294-296, plate xxix.

Hayashi, R. 1977. A new sea-star of *Asterina* from Japan, *Asterina pseudoexigua pacifica* n.ssp. *Proceedings Japanese Society Systematic Zoology* 13: 88-91, 1 figure.

Keough, M. J. and A. J. Dartnall, 1978. A new species of viviparous asterinid asteroid from Eyre Peninsula, South Australia. *Records South Australian Museum*, 17 (28): 407-416, 7 figures.

IN REVIEW

New Zealand Adrift **by Graeme Stevens, A. H. & A. W. Reed Limited, Wellington 1980, 442 pages, illustrated, $24.95.**

This book is about much more than New Zealand. The author explores the geology of the islands through concepts of continental drift and the global network of the earth's geological interactions. New Zealand is a geologist's paradise with its recent mountain building, volcanoes, earthquakes and active position on the boundary of the Pacific and Australian Plates, sufficiently varied material to illustrate many concepts drawn from the global scene.

There has been a revolution in understanding of the fundamental forces behind the geological evolution and movements of the continents and oceanic floors. This is almost a text book although written in simplified style. Ordinary people may have difficulty with the concepts contained in over four hundred pages, but they will be fascinated with the historical, zoological, botanical and climatological background woven into the geology. Biologists, teachers, mature high school students and university undergraduates will profit from this account.

Profuse black and white diagrams are repetitive even though illustrating different geological points on a similar scene. The diagrams, drawn by the author's wife, Diane, include some humorous touches. One is also grateful for the natural scale profile presented with the detailed profile of the Tongan Trench which is exaggerated by twenty times. One error noted in the diagrams involved the captions for Figs. 9.2 and 9.3 dealing with submarine trenches and volcanoes. They are reversed on different pages. The reader may also be slightly disconcerted by Figs. 8.37-8.46 which show the openings of the oceans over the last 180 million years. These are shown as facing illustrations depicting opposite sides of the globe, but the scales differ to allow for the caption on one side.

Other illustrations include black and white photographs of personalities, rock specimens, fossils and geological features. Some colour shots would have helped, but would have added too much to the cost of the book. One splash of colour, a series of Landsat colour images of New Zealand, lies in the centre of the book, and is more appropriate to the later chapter on the "Making of Modern New Zealand". Presumably they were placed there for efficiency of printing. The book includes a comprehensive reference list and glossary.

As the publishers state, "Dr Graeme Stevens has compiled a gripping account of the many exciting and far-reaching changes that have occurred in the Earth Sciences, some of them only in the last five years". The book is good value for the money.—*F. L. Sutherland, Curator of Minerals and Rocks, The Australian Museum.*

Guide to Fishes **by E. M. Grant, Queensland Department of Harbours and Marine 1978, 768 pages, illustrated, $15.00.**

This is the fourth edition of E. M. Grant's *Guide to Fishes* and deals with approximately 750 of the 1,600 or so species in Queensland waters.

The original paperback, covering 120 or so species entitled *Know Your Fishes—an Illustrated Guide to the Principal Commercial Fishes and Crustaceans of Queensland*, was written by T. C. Marshall, E. M. Grant and N. M. Haysom, and published by the Queensland Department of Harbours and Marine in 1959. T. C. Marshall then produced his own *magnum opus*, published by Angus and Robertson in 1964, *Fishes of the Great Barrier Reef and Coastal Waters of Queensland* (curiously unlisted in the bibliography of the present work).

This title, *Guide to Fishes*, is misleading, as the volume includes only Queensland fishes. However, although few Victorian fishes may be found, many species included do occur in the northern waters of New South Wales. This edition at least mentions the word "Queensland" (though inconspicuously) on the spine of the dust jacket.

The list of contents remains substantially the same as in the third edition, in which a Classification section was added immediately preceding the individual species accounts. Unfortunately, the classification system used is antiquated and not followed rigorously, species accounts being mixed in random fashion.

In an earlier review of Marshall's *Fishes of the Great Barrier Reef* (*Melbourne Age*, Literary Supplement, 27 February, 1965) I pointed out that "Considering the significance of Marshall's book as a reference on such an important section of the world's tropical fish fauna, it is to be regretted that an outdated scheme of classification (that of Regan from the 1929 edition of *Encyclopaedia Britannica*) has been used." Thirty years hence there have been at least two major revisions of fish classification. With this present work, some fifteen years later, it is again to be regretted that an outdated system of classification, this time that of Berg, 1940, has been used. The scheme of Greenwood *et al.* (*Bull. Amer. Mus. Nat. Hist.* Vol. 131, 1966) is now generally accepted, throughout the English-speaking world, and with small effort this scheme could have been used.

Preceding the accounts of each species are a preface, an introduction and "notes for students" explaining the layout and organisation, a glossary of technical terms and a list of technical abbreviations. This section includes diagrammatic illustrations showing general morphological characteristics of both sharks and bony fishes.

The arrangement of the species accounts themselves is grouped under five main headings: Sharks and Rays, Marine Fishes (General), Poisonous Fishes, Freshwater Fishes and Crustaceans.

Under a half tone or colour illustration of each principal species are given the common and scientific names and a description comprising morphological data from accounts in more technical treatises (mostly I. S. R. Munro's *Handbook of Australian Fishes* or his *Fishes of New Guinea*). The colour notes and maximum sizes are included in the natural history notes. These notes include behavioural observations, fishing techniques, edible qualities, distribution and miscellaneous information. These fascinating snippets include such facts as that in 1935 a tiger shark in Coogee Aquarium "disgorged a man's undigested arm, tattooed with a length of rope tied around the wrist: this led to the celebrated 'Shark Arm Case', involving violent death, gunfire, and a speedboat pursuit by police", and that although pikey bream "affords good sport on light tackle", in Gulf of Carpentaria rivers "it is sometimes fished for with lines breaking at 100 lb or better"! Following the principal species are brief descriptions of related species found in Queensland waters.

Species accounts are fairly accurate and informative though so-called "principal species" are often vague. The gummy shark, named a principal species, is represented by only "Occasional specimens . . ."; whereas the white-tip shark is considered as subsidiary species though the author claims that "Most underwater Barrier Reef photographs and films show it in the background". Likewise, a page and illustration is devoted to each of the black sharks (described as "rare") and the long-finned garfish (only five specimens of which are known in Queensland).

Small faults occur in species accounts. However, the giant Queensland groper, which apparently attains 12 feet in length and 1,200 lb in Persian Gulf waters and which has been reported at 634 lb in Queensland, is certainly not "the largest known fish in Australian waters" (page 285). A black marlin captured off Cairns is reported (page 209) to have been over 15 ft long and to have weighed 1,448 lb. And surely the sharks must be regarded as fish—mention is made of a tiger shark of 18 ft and 3,360 lb, a white shark over 36 ft (although this is doubtful), and whale sharks (pages 37, 43 and 55) up to 40 ft in length. It is noted that the author has not (as in the earlier edition) given the lengths and weights in metres and grams.

Only two new principal species have been included, although some 35 additional species are mentioned in the text and colour photographs have increased by about 130.

The main strengths and weaknesses of the book lie in its illustrations of which there are 440 including 326 photographs in colour and over 250 in black and white. The previous edition contained only some 300 colour illustrations. Most illustrations of principal species, in half tone or colour, are by F. Olsen and G. Coates and of a high standard. Good colour work examples are shown on pages 119, 331, 238 and 362. In several of Coates' paintings, however, the colour may be a little overdone, e.g. the yellowfin tuna on page 198. Some illustrations taken from other works are excellent, but some are poor. There must be a better colour painting of a rainbow trout than that shown on page 671!

The colour photographs are mostly credited to the author and range in quality. The best are taken against plain pastel backgrounds, such as that of the trevally in colour plate 93, the rock cod in colour plate 112, and the butter fish in colour plate 164. Blurred, washed-out aquarium shots of damselfishes, butterflyfishes, triggerfishes, etc., salvaged from earlier editions, with the very dead-looking trumpet fish draped over a cairn of rocks in colour plate 56 are less impressive. The only fault with the colour photos concerns the author's fixation on coloured synthetic rope. The use of iridescent blue, blood red or aquamarine rope backgrounds is hard on the eyes, the rope imparts a sheen of that colour to the fish displayed which hardly aids the reader in his colour identification. For instance, try the reddish-brown blackfish in colour plate 162.

The nebulous main section heading "Marine Fishes (General)" should be replaced by "Marine Bony Fishes", which is all that it includes. The preceding section "Sharks and Rays" would be more equivalent to "Marine Fishes (General)".

"Poisonous Fishes" includes stonefishes which, although they may be very venomous, are not poisonous. All poisonous fishes could be more logically included in their natural order, in a general "Marine Bony Fishes" section.

In the section entitled "Freshwater Fishes" the technical description of the lungfish (probably the most world-famous of Queensland fishes) is restricted to two uninformative lines which do not do it justice—even though it is unlikely to be mistaken by the layman for any other species.

Despite my criticisms, this is probably the best general work on northern fish fauna and good value at $15.00 from the Department of Harbours and Marine, GPO Box 2195, Brisbane 4001 (include $2.25 postage from NSW, $1.10 from Queensland and $2.60 from other states), or $18.50 from The Australian Museum Shop. (Pages 369 to 384 were missing from the reviewer's copy.)—*D. A. Pollard, Research Scientist, NSW State Fisheries, Sydney.*

Rocks and Minerals of Australia **by Oliver Chalmers, Methuen of Australia Ltd, London & New York, 1979, 246 pp, hardcover. $3.95**

Over the last couple of decades active interest in geology and the related areas of petrology and mineralogy on the part of informed laymen has grown enormously. This is due in part to the growth and facilities offered by geology and mineralogy clubs and societies and by lapidary organisations which are now spread throughout the country. Very few academics have the time or the interest to offer their services to the ever increasing number of people whose interest and activity should be nurtured and encouraged. Not so Oliver Chalmers—himself an experienced professional mineralogist. In his book *Rocks and Minerals of Australia* Mr Chalmers has offered an excellent survey of a subject on which there is not much published at a level appropriate to the layman who is prepared to spend a little time in systematic study of rocks and minerals!

Perhaps the most significant aspect of Mr Chalmers' book is that it is written in a manner that most could readily understand while, at the same time, being able to maintain technical correctness and approved scientific style.

In the initial chapters Mr Chalmers provides useful advice on matters such as gaining access to properties, statutory documents relating thereto and general field procedures including matters of safety. This is followed by an account of various rock types, including structural aspects, and notable localities where these may be observed and collected. This provides a sound background to the ensuing chapters on minerals *per se*. In doing this Mr Chalmers underlines the fact that a knowledge of rocks and rock structures is a prerequisite to a sound understanding of the mineral kingdom for without rocks there can be no minerals!

Subsequent chapters are devoted mainly to leading mineral localities together with notes on locations. Of particular interest is his description of some of the more remote localities, e.g. those in Western Australia and the interior generally. This embraces some of the more recently discovered areas whence come some quite rare minerals.

The book is of a size that can be conveniently taken into the field, it is sturdy and well bound, and the crystallographic data and determinative tables and illustrations enhance its usefulness.

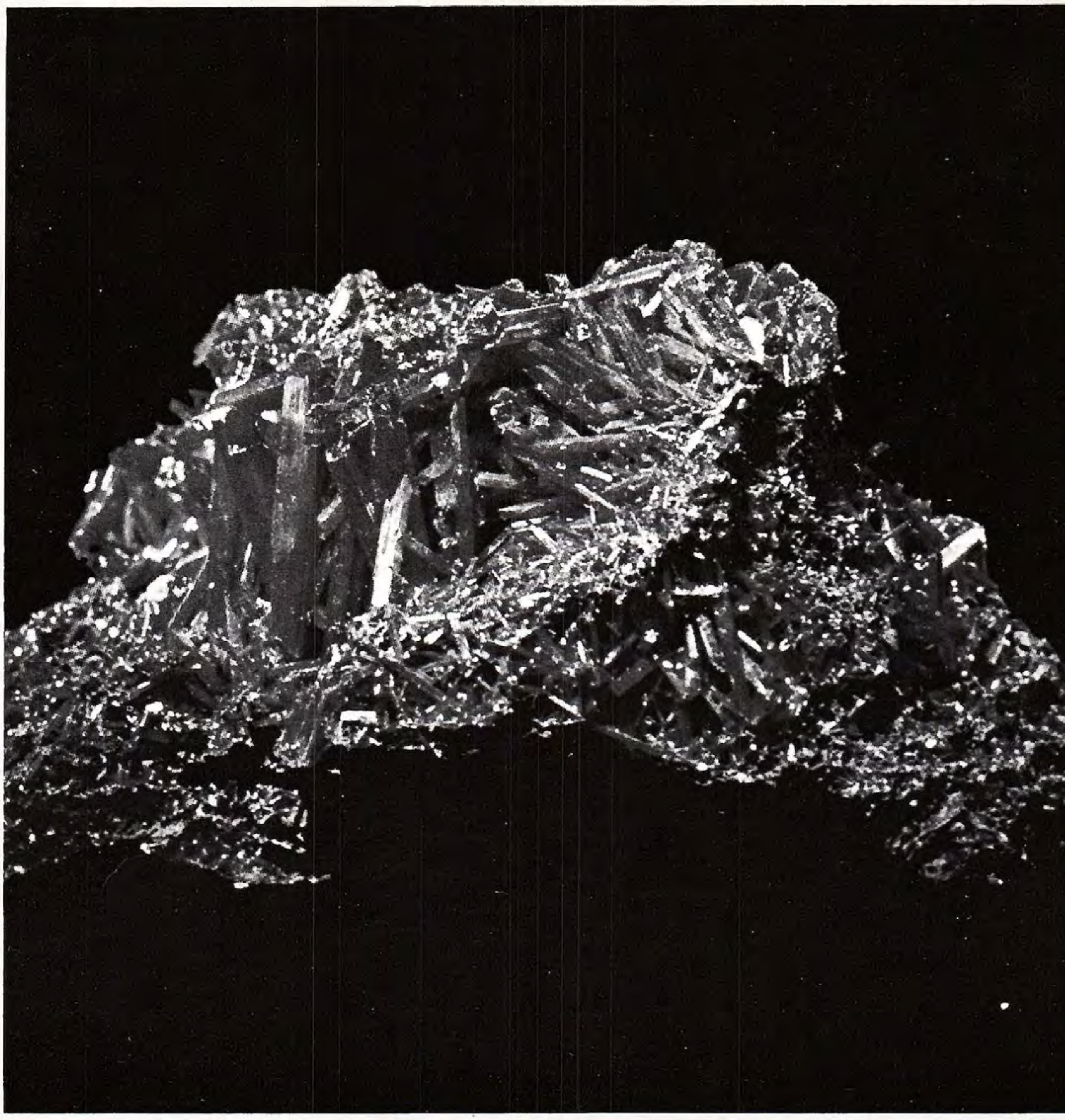
This little book will be of considerable use to all who are interested in the geological sciences at a non-professional level. It would be of use also to high school students and even to professionals who want to know something of our noteworthy mineral localities.—*Dr L. J. Lawrence, University of N.S.W., reprinted by courtesy Journal of the Mineralogical Society of N.S.W.*

All books reviewed are available in The Australian Museum Shop.

The Observer's Book of

ROCKS AND MINERALS OF AUSTRALIA

OLIVER CHALMERS



At high tide, water covers the base of a well developed stand of the grey mangrove, *Avicennia marina*, at Careel Bay, Pittwater, NSW. Such densely tangled vegetation coupled with protruding roots and thick mud at low tide and visions of pestering insects promotes a sinister image to mangrove swamps in many people's mind. Photo by Howard Hughes/The Australian Museum.