AUSTRALIAN NATURAL HISTORY

DECEMBER 1974 VOLUME 18 NUMBER 4 70c

The past year has seen many changes in the presentation of AUSTRALIAN NATURAL HISTORY and we have received many letters from readers in Australia and overseas congratulating us on the success of our new format. As with any major renovation, problems have been encountered and we apologise to our readers for the delays and inconveniences that have occurred during the changeover period.

During the first year under the new system, the Trustees of The Australian Museum have borne all the additional costs involved, including rises in postal rates. The production cost of a single copy is substantially higher than the price for which it has been sold to subscribers in 1974, and the cost of mailing a single copy locally has risen, this year, from 12c to 33c; the rate to New Zealand and New Guinea is now 45c, and to other countries, 70c (surface mail).

Because of all these increased costs and the Museum's critical financial situation, the Trustees find it necessary to raise the annual subscription rate of the magazine to $4.50—Australia; $5—New Zealand and New Guinea; $6—other countries. The single copy price will be $1 ($1.33 posted); $1.45—New Zealand and New Guinea; $1.70—other countries. The new rates will take effect on 1 March, 1975 and those whose payments are received at the old rate after that date will be billed for the additional amount, which must be paid before the subscription becomes effective. Overseas subscribers please note that rates are to be paid in Australian currency.

We sincerely regret having to pass these increased costs on to our readers, but we hope you will agree with us, and with so many others, that AUSTRALIAN NATURAL HISTORY is, more than ever, worth its price.

We appreciate your interest and support and we hope that you, our readers, will continue to express your opinions of the magazine and of the articles we publish.

—FRANK TALBOT

AUSTRALIAN NATURAL HISTORY

DECEMBER 1974 VOLUME 18 NUMBER 4 PUBLISHED QUARTERLY BY THE AUSTRALIAN MUSEUM, 6-8 COLLEGE STREET, SYDNEY
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COVER: A male Banded Iguana (*Brachylophus fasciatus*), a rare lizard whose survival is threatened by animals introduced by man into the Fijian islands. This lizard, and a close relative in the Tongan islands, are the only land animals of the western Pacific whose origins lie in South America. (Photo: H. G. Cogger)

ABOVE: View of the western crater walls of Mt. Gambier Volcano, built of volcanic scoria, cinders and ash, and enclosing Valley Lake on the right which represents the level of the regional water table. (Photo: Howard Hughes/ Australian Museum)

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CONTROLLING THE SHEEP

BY R. L. KITCHING

Larvae of the sheep blowfly on the skin of a sheep. The larvae shown in the photograph are third stage, just before they leave the sheep altogether.

Blowflies must be among the most familiar insects in Australia. They thrive in man's environment. His domestic and agricultural practices seem designed to provide breeding places ideally suited to the flies' requirements.

Scientifically, blowflies constitute the family Calliphoridae, of which there are approximately 150 Australian species, but fewer than a dozen make their presence felt to the non-entomologist. Among these, 'brown' and 'green' blowflies may be recognised. The former are species of *Calliphora* and the latter, *Lucilia* and *Chrysomya*. The notorious sheep blowfly is *L. cuprina* which may be distinguished from *L. sericata*, the only

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BLOWFLY

other Australian representative of this genus, on several points of colour and bristle arrangement. As a rule-of-thumb in Australia, *cuprina* may be thought of as a rural fly and *sericata* as an urban species.

The sheep blowfly is believed to have been introduced into Australia by accident, possibly from South Africa, during the nineteenth century. The species is now widespread over much of the continent, including Western Australia and the northern tropics. In sheep-rearing regions, blowfly 'strikes' and the damage they cause to the sheep, have been a major concern to graziers since early this century. Recently, the Bureau of Agricultural

Puparia of the sheep blowfly exposed in the soil. The puparia are tanned a reddish-brown colour and contain the pupal stage of the insect.

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biology of sheep blowflies with a view to testing and establishing new methods for their control.

Economics estimated that for the year 1969-70, the cost of the blowfly problem to the sheep industry was $28 million. This includes damage caused by species other than *cuprina* but it is generally accepted that this species is the major initiator of strikes, opening the way for the establishment of other species and the extension of the wound inflicted by the flies, sometimes, indeed, causing the death of the sheep. This, and the development of resistance to commonly used insecticides, has led to a renewed interest in the biology of the fly and a search for new control methods.

The species retains the habit of breeding in carcasses but in much of Australia it suffers heavy mortality due to competition for food and space and to predation by the larvae of other species of carrion fly. It has also adapted to breeding in rubbish tips and in northern Australia, beyond the range of sheep, this is probably its primary habitat. It is, however, associated with sheep over much of the continent and the living sheep seems to be the habitat on which the species is most successful. Eggs are laid in the fleece of the sheep on regions of the body that are moist, either due to soiling and urine-staining around the breech or, following prolonged wet conditions, elsewhere on the sheep's body. If the favourable condition of the egg-laying site is maintained, eggs hatch within twenty-four hours and the young larvae move down to the skin. Here they set up an irritation and thrive in the secretion this produces. As they grow they invade the skin itself and feed on the flesh of the sheep. The larval period may last from three to seven days. This is the stage that is usually thought of as a 'strike' and it furnishes an especially attractive site for further egg-laying. There are three larval stages, and during the last of these the larva stops feeding and drops off the sheep. It then enters a wandering phase, usually referred to as the prepupa, where it burrows into the soil and, after a variable length of time, forms the next stage in the fly's life, the pupa. The prepupal stage can go into a state of suspended animation if soil temperatures are sufficiently low. In this way, the species passes the winter. As in all Calliphoridae the pupa is enclosed in a hard case known as the puparium. The duration of the pupal stage is variable but can be as little as one or two weeks in the summer months. Females may be ready to lay eggs within six or seven days after emerging from the puparium, thus completing the life-cycle.

An adult female of the sheep blowfly, *Lucilia cuprina.*

Females show a series of cycles of egg development during their adult life. Each cycle shows a sequence of recognisable stages and each ends with the laying of a batch of from 120 to 280 eggs, depending on the size of the fly. In the laboratory, up to six such cycles have been observed, although evidence suggests that in the field there are seldom more than three. The first cycle is a little longer than subsequent ones, lasting five days at 25°C as compared with three to four days for later cycles. Each cycle, though, is alike in its dependence upon the availability of certain resources. No appreciable development of the eggs occurs until after the female fly has fed on protein. After this there is a period of egg maturation ending with the fully-developed eggs ready to be laid. Two further events must occur before egg-laying: mating and the location of a suitable egg-laying site. Throughout the fly's life it must also have access to a source of sugar which provides the basic fuel to maintain life and promote development of the eggs. Water, too, is essential to combat loss of body moisture—a constant problem for all small organisms. Following successful egg-laying, the sequence of resources—protein and an egg-laying site, together with the necessities of sugar and water—must be located and exploited for the completion of the next cycle. Mating need not occur more than once in the life of the female.

Male flies do not show cyclical development but do require sugar and water in a way similar to females. They are also attracted to sources of protein but are not dependent upon it for their development.

Protein occurs in several different forms which may be available to flies. Carrion and already established strikes are the most obvious, but adequate sources of protein are also provided by dung originating from animals grazing on nitrogen-enriched pastures. Sources of sugar are more widespread and the nectar of eucalypt blossoms is its most abundant form. Rotting fruit, and honeydew produced by aphids, psyllids, coccids and the like provide additional supplies, and some may be obtained from dung or carcasses. Water may often be obtained incidentally from the protein and sugar sources but is also available as dew and raindrops, or in mud around standing water.

The sex-ratio at emergence from the puparium is approximately one-to-one, but the problem for the female fly is contacting males. It seems likely that the attraction of males to sources of protein is an adaptation for bringing the sexes together. Following mating the female must find an egg-laying site, and carcasses of various animals and susceptible or struck sheep are available in the field.

We may consider the adult fly to be living

Honeydew, produced by various plant-feeding bugs, provides a rich source of sugar for blowflies. The photograph shows a colony of one such bug, the cabbage aphid, *Brevicoryne brassicae*.

R. D. Hughes

within a superimposed series of patterns of different resources. For female flies, these patterns and the strength with which they are attracted to particular resources will depend upon, and change with, their internal state of egg development which in turn is dependent in part upon the fly's nutritional history.

By catching flies and dissecting them, we learn much about the interplay between demand and supply of essential resources. It seems likely that sugar and water are seldom in short supply but

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the protein needed to begin egg-development may be. We detect this by noting when female flies which we believe to be quite old appear with undeveloped or only very slightly developed ovaries. The most important delaying factor, however, shows up as an excess of gravid flies—that is, those containing fully-developed eggs. This may result from a shortage of mates or of egg-laying sites, but because this build-up often coincides with a relative abundance of males and with environmental conditions adverse to egg-laying, the second explanation seems more likely.

In the past, many methods of blowfly control have been tried which have ultimately proved ineffective, uneconomical, or both. These included trapping adult flies, burning, burying, or poisoning carcasses considered as breeding sites, and the release of a European wasp, *Alysia manducator,* known to be parasitic on the larvae of blowflies. This release was unsuccessful and the wasp never established itself in Australia. Considerable effort was also directed to the breeding of sheep which were less susceptible to strike. This included selecting out those with wrinkly breeches and, to an extent, this was successful; but the popularity of the merino breed, which is particularly prone to strike, prevented the breeding programme from being fully implemented. Control methods developed early this century represent the basic techniques in use today. These were the regular shearing of the fleece around areas of likely strike, the surgical removal of part of the tail and some of the skin-folds around the breech of the sheep, and regular jet-

ting of the susceptible areas with powerful insecticides. In the early days, solutions of arsenic were used, but in post-war years these were replaced by organic insecticides, notably dieldrin. After a short period of spectacular success the blowfly developed a very powerful resistance to this chemical and it was replaced by another, diazinon, which is still used. Lower orders of resistance to this compound have developed, but it remains useful when applied correctly and regularly at intervals of several weeks.

Although more sophisticated chemical insecticides may be developed, the most exciting new prospect for blowfly control is genetical manipulation. Methods presently being developed in Australia by the Division of Entomology of the CSIRO consist of selectively breeding strains of flies in the laboratory and releasing them in large numbers in sheep-rearing regions. Two approaches are being tried. The first centres around releasing flies which introduce sterility into subsequent generations. This is often referred to as the genetic load approach. Various proportions of sterility can be achieved, and theoretically, if successful, such a method could dramatically lower the densities of fly populations. The second approach involves releasing flies in numbers and manner designed to replace the native flies. The released flies would have their biological characteristics altered in a way that would make their control possible. Using the second method, two possibilities appear promising: first, release of flies which, although active and comparable to normal flies in the summer, would be unable to survive the winter after replacing the wild flies, and second, the release of flies that would be more amenable to conventional insecticidal control than the native flies.

With a view to developing and testing these and similar control methods, intensive studies of the biology, ecology and genetics of *Lucilia cuprina* are being carried out by the CSIRO.

Sheep carcasses, a common source of protein and a potential site for oviposition for blowflies. These animals are drought victims but carcasses of one sort or another are frequent in the field.

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A common source of sugar in the blowflies' environment is the blossom of eucalypts. The photograph shows the Western Australian red-flowered gum, *Eucalyptus ficifolia*.

INSIDE THE LIFE UNIT

BY JIM FRAZIER, KINGSLEY GREGG AND DAVID POPHAM

When Robert Hooke published his *Micrographia* in 1665, he coined the term "cells" to denote the tiny cavities, separated by walls, which appeared to make up plant tissues. What he had seen through his microscope, however, were merely the thickened walls of dead cells. Succeeding microscopists found that living cells were not empty spaces at all but membrane-enclosed bodies with their own internal organisation.

The true significance of cells was not realised until the early nineteenth century when, in 1838, Matthias Schleiden pointed out that cells are the basic structural units of vegetable matter and, a year later, Theodor Schwann announced, ". . . that all organisms [plant and animal] are composed of essentially like parts, namely, of cells". These perceptive generalisations became the groundwork on which present-day cell theory is firmly established.

Cells are the fundamental units of which all living matter is composed. Their shapes, sizes and functions vary according to the requirements of the organism to which they belong. Some cells are completely independent organisms—such as *Amoeba* and *Chlorella*. Some may be loosely organised into colonies—for example, *Volvox*—that behave as single organisms, and others are aggregated in tissues such as the phloem and xylem of plants or the liver and muscles of animals. The single cell of *Amoeba* carries out the entire range of processes necessary to the life of that organism; the activities of cells grouped into tissues of multicellular organisms are far more circumscribed. Nevertheless, all cells possess most of the prerequisites for life—growth, reproduction, irritability (response to stimuli), nutrition, movement, excretion and respiration. To meet these requirements, they are equipped with organelles (the cell's equivalent of a body's organs) to perform specific tasks within each cell.

Before the advent of the electron microscope, with its capacity to magnify to well over one hundred thousand times original size, much of the structure and function of organelles remained speculation. Over recent years, however, despite certain limitations inherent in electron microscopy, sufficient information has become available to permit construction of reasonably accurate models of cells and their internal components.

One such model—of an animal cell—is displayed in the Australian Museum's Hall of Life. Built entirely by the Museum's Preparations Section, the model is 1.65 metres in diameter—a linear ratio of more than two hundred thousand to one. Because the model is intended to instruct as well as to attract, it shows only those organelles common to most animal cells. It does not represent a specific cell type and its spherical shape is an idealised condition within which the organelles can be displayed to their best advantage.

The first task confronting the team that made the model was that of researching and interpreting all the available information about cells in general. From this information, the preparators extracted enough basic facts to enable them to visualise a composite cell whose components, when assembled, would satisfy the requirements of both scientific accuracy and aesthetic and popular appeal.

The visualisation had then to be translated into actual methods of production, based on available materials and known (and yet-to-be-devised) techniques. The internal composition of a living cell is an aggregation of differing and often highly complex structures, and inclusions of various densities. Accordingly, each item had to be treated as a separate problem, with techniques and materials calculated to enhance its final appearance and to accentuate its difference from other components.

Techniques included vacuum-forming, blow-moulding, conventional moulding and casting, rotary casting and several new and often unconventional methods of production. Materials were

Preparators put the finishing touches to the cell model in The Australian Museum's Hall of Life.

JIM FRAZIER is Chief Preparator in The Australian Museum's Exhibitions Department and was responsible for the construction of the cell model in the Museum's Hall of Life. KINGSLEY GREGG, an Artist at the Museum, was responsible for the display explaining the structure and function of cells. DAVID POPHAM, a cytologist in the Department of Anatomy at the University of Sydney, was the principal scientific advisor for this section of the Hall and worked closely with Museum staff during the entire time the exhibit was being assembled. His valuable assistance and unceasing enthusiasm are gratefully acknowledged.

C. V. Turner/Australian Museum

Preparators working on the plaster mould of the model's cell membrane.

many and diverse. During the preliminary modelling and moulding of parts, vast quantities of plasticene, plaster and rubber were used. In its final, assembled form, the giant model consists of a wide range of the most recently developed plastics—epoxy and polyester resins, acrylic rods and sheeting, P.V.C. tubing, polyurethane foam—together with more than a million glass beads. Some plastics manufacturers, when contacted for advice about their products, expressed astonishment at the unusual uses to which these were being put and at the obvious successes which followed.

Features of the finished model include the cell membrane, membranes of smooth and rough endoplasmic reticulum, ribosomes and polyribosomes, mitochondria, a Golgi apparatus, lipid globules, lysosomes, glycogen particles, vacuoles, nuclear envelope, a nucleolus and centrioles. Different structures inside a living cell generally appear colourless under a light microscope and are not readily discernible. To overcome similar problems with the huge replica, several of these structures were coloured.

Cytoplasm is that material, excluding the nucleus, which is enclosed by the cell membrane. It consists of cell organelles (e.g. mitochondria, lysosomes, etc.) and inclusions (ribosomes, glycogen granules, etc.) suspended in a matrix of protein and salt solution, commonly called the ground substance. This viscous, semi-transparent substance that occurs in all living cells and makes up much of the internal bulk of animal cells, was excluded from the model. This was partly because of the vast quantity and sheer weight of the material that would have been needed and partly because of the problem of displaying several more or less transparent objects, which were not coloured, in a medium of similar refractive properties.

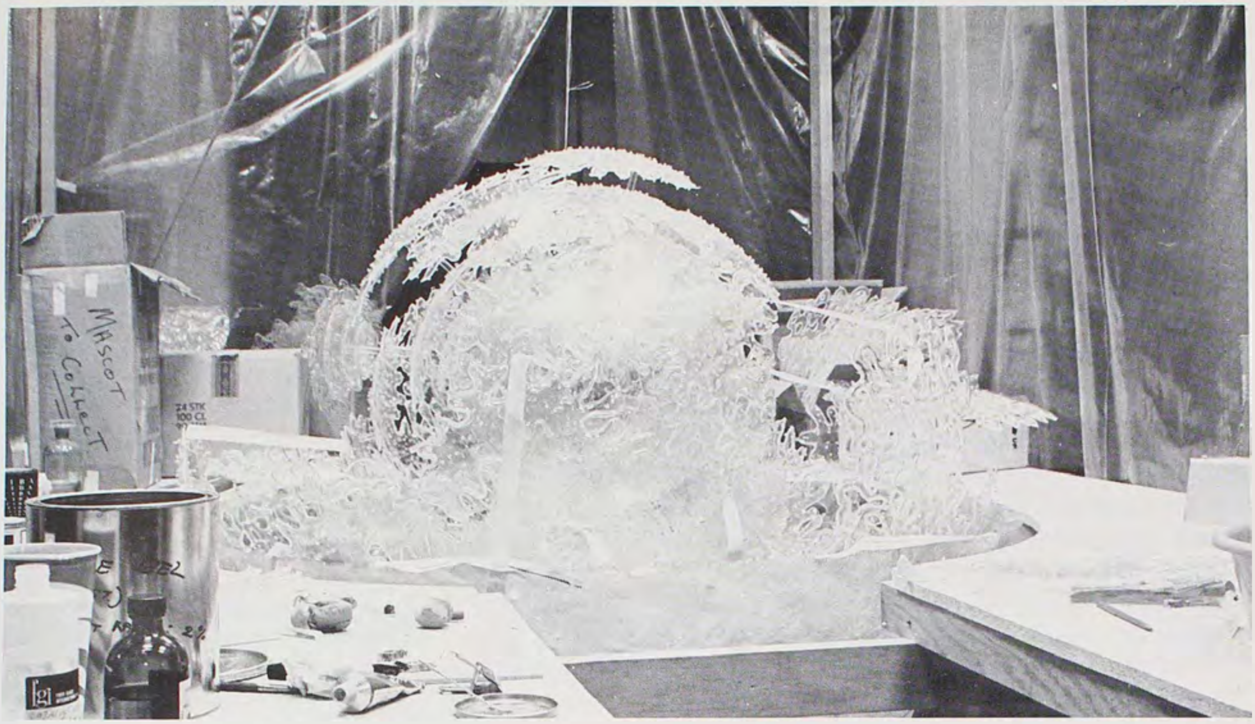
The most conspicuous feature of plant and animal cells is the nucleus, which contains the cell's genetic material. The only cells which do not have nuclei are those of the Monera (bacteria and blue-green algae) whose genetic material is not limited by a membrane.

The internal contents of the nucleus are separated from the cytoplasm by two tri-laminar membranes known as the nuclear envelope. The envelope is pierced with numerous disc-shaped nuclear pores. Its outer membrane is studded with ribosomes. Chromatin, which consists of deoxyribosenucleic acid (DNA) and protein, occurs within the nucleoplasm of the non-dividing cell and consolidates into a number of thread-like bodies, or chromosomes, during cell-division (mitosis). A second type of material occurring within the nucleus is the nucleolus, which consists of abundant amounts of ribosenucleic acid (RNA). Nucleoli play an important role in nucleic acid metabolism and in protein synthesis. They vary in size from one cell-type to another, being larger and more diffuse in cells carrying out active protein synthesis and smaller and denser in those which are metabolically inactive.

An example of how data from living material are translated into reasonably accurate, larger-than-life models was demonstrated by the making

Gregory Millen/Australian Museum

Setting the plasma membrane of the cell model onto its turntable base. The nucleus and some of the endoplasmic reticulum are suspended above the membrane before being attached.



Gregory Millen/Australian Museum

The cell model, partially constructed, in its plastic tent. Strips of adhesive tape hold organelles in position prior to final assembly.

of the nucleolus and nuclear envelope. The nucleolus can be visualised as a roundish, translucent, jellylike mass, granular in texture, riddled throughout with a maze-like network of tunnels, and perforated over its entire surface by the tunnel entrances. The translucent, granular effect was achieved by combining epoxy resin with thousands of glass beads of various sizes. Because of weight considerations, the model had to be hollow. Two separate hemispheres, about fifteen millimetres in diameter, made of the resin-coated beads, were formed over hemispheres of acrylic pierced with holes. When the resin had set, the acrylic was removed. To give an appearance of tunnelling, each hole had a thimble-shaped piece of the same material bonded over it from the inside. The hemispheres were then joined together and more beads added to conceal the equator.

The nuclear envelope that encloses the contents of the nucleus was simulated by blow-forming two acrylic domes and joining them to form a complete sphere about four-hundred millimetres in diameter. To reproduce the characteristic surface-appearance of living membrane, holes of varying sizes were burnt into the sphere. Small, irregular lumps of cured polyester resin were then attached, followed by several coats of blue-tinted liquid resin. Yellow glass beads glued to the envelope's outer surface represent ribosomes.

Ribosomes are tiny particles which catalyze the construction of proteins. They consist of protein and the nucleic acid RNA and may be found as rosettes, clusters or beads on threads (polyribosomes), scattered randomly throughout the cytoplasm, or attached to membranes in the cytoplasm. Ribosomes are most numerous in cells that actively synthesize protein.

Before the proteins can be secreted from the cell, they are usually modified—or 'packaged for export'—by structures known as Golgi bodies or the Golgi apparatus, which consists of a stack of saucer-like double membranes with bulges along the edges. Surrounding the Golgi apparatus are Golgi vesicles—little membranous spheres pinched off from the saccules containing the secreted material—which move to and fuse with the cell membrane, allowing the contents of the vesicles to be discharged to the cell's exterior. This process occurs in the secretion of enzymes, mucus and other substances in animal cells and in the secretion of plant cell walls.

The Golgi apparatus is also intimately associated with the formation of structures called lysosomes. These contain material or enzymes which dissolve various components of the cell. They are most abundant in cells that specialise as scavengers or assist the breakdown of other cells—as in the absorption of a tadpole's tail-structure during its development into a frog. Lysosomes act as 'disposal units' for debris that has been incorporated into the cell's cytoplasm and help to destroy disease-carrying material such as bacteria.

All cells need energy. By ingesting complex, energy-bearing molecules such as sugars and breaking them down into simple molecules such as carbon dioxide and water, they liberate enough

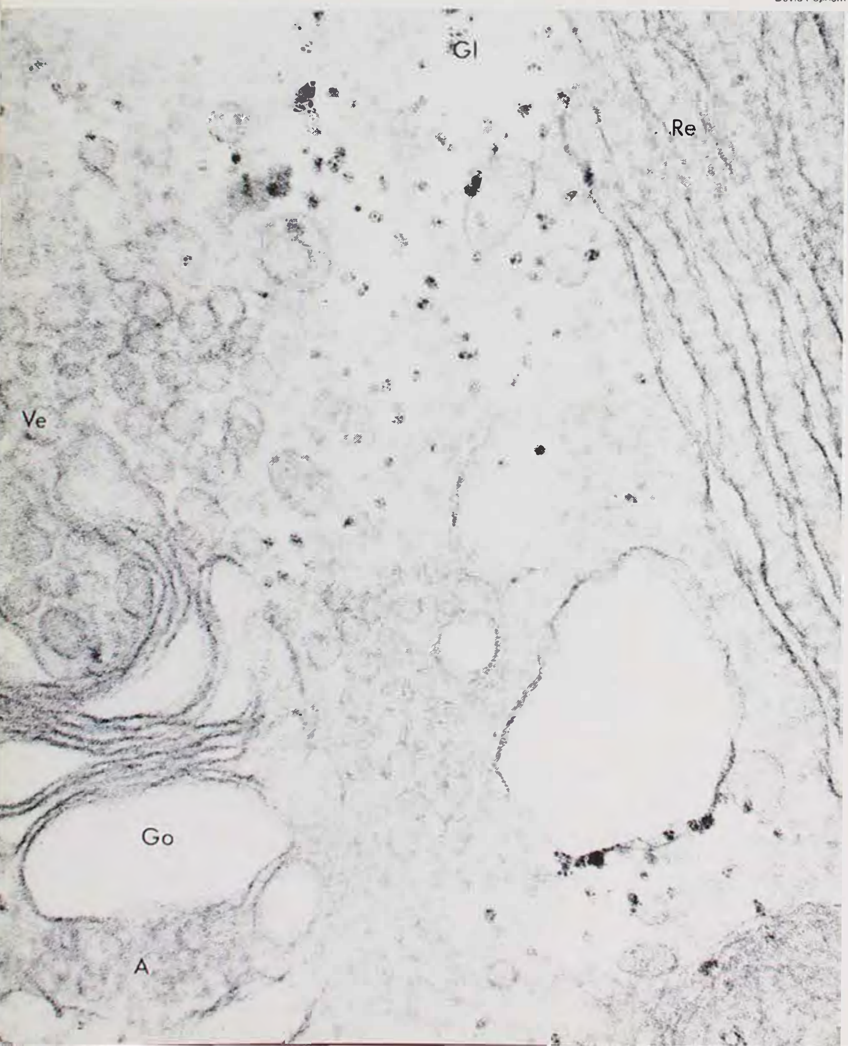
Close-up view of the centriole pair used in the model. Glass beads strung on nylon loops represent polyribosomes distributed through the cytoplasm. Layers of rough endoplasmic reticulum are connected by clear acrylic rods.

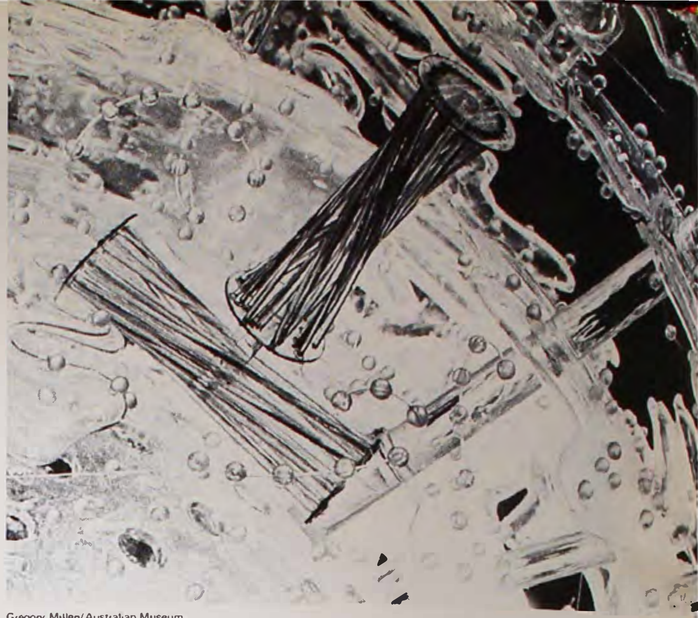
energy to carry out all other cell functions. Mitochondria, the organelles responsible for these energy-generating activities, are found in all living cells except those of the Monera. Ranging in shape from elongated rods to spheres and, in number, from one to several hundred thousand—depending on the type and function of the cell—they remain in constant motion, clustering in regions where cellular activity is most intense. Mitochondria contain some of their own genetic material—enough to synthesize some proteins but insufficient to remain independent of the cell's DNA. Unlike other organelles, mitochondria possess two membrane layers. The outer of these is quite smooth; the inner, which is granular, convolutes into folds extending into the organelle's matrix. Enzymes located on these folds, or cristae, control the formation of adenosine triphosphate (ATP), a molecule from which the phosphate groups can be readily detached to yield energy for chemical reactions.

Egg cell of the shipworm, *Teredo navalis*, magnified 8370 times. Material is taken from A into the Golgi apparatus (Go). Golgi vesicles can be seen at Ve. Gl=glycogen particles, Re=rough endoplasmic reticulum.

Mitochrondria, often referred to as the 'powerhouses of the cell', provided the Museum preparators with one of their most interesting—and probably most difficult—modelling and moulding experiences. For their manufacture, a mould was produced from a very complex wax model featuring the convolutions of the inner membranes. The inside of this mould was then coated with resin in which thousands of one millimetre diameter glass

David Popham





Gregory Millen/Australian Museum

beads were embedded. Several different sizes were produced by cutting out middle sections from some models and inserting them into others. The outer membranes were free-blown in matched halves from thin, transparent acrylic sheeting, the inner membranes inserted into them, and the halves cemented together.

Endoplasmic reticulum (ER) consists of membranes that are structurally similar to the cell membrane and the membranes of the nuclear envelope. There are two types of ER—rough and smooth. Rough ER consists of membranes doubled into flattened sacs, or cisternae, studded with ribosomes. Cisternae are occasionally continuous with the outer membrane of the nuclear envelope, which is also studded with ribosomes. Abundant amounts of rough ER in a cell is accepted as indicating that the cell is synthesizing proteins for 'export' to its exterior, via the Golgi apparatus. Conversely, small amounts of rough ER, in the presence of large numbers of cytoplasmic ribosomes (polyribosomes), could indicate that the cell is synthesizing proteins for its internal use.

Smooth ER lacks both cisternae and ribosomes. It generally resembles tubules arranged in a net-like configuration and is associated with glycogen and steroid synthesis, ion transport and lipid (fat) metabolism. It is also specialised in many muscle cells, where it functions in the calcium metabolism associated with muscle contraction.

For the cell model, components of several different sizes were made to reproduce rough and smooth ER. These comprise the bulk of the model's inclusions and represent about one hundred and forty square metres of acrylic sheeting—vacuum-formed on equipment designed and constructed by the Preparations Section at the Museum.

Units of rough ER, made from plate-shaped pieces with an amoeboid appearance created by the fingerlike processes extending from their edges, had to be formed in two halves and cemented together. Thousands of yellow-tinted glass beads, simulating ribosomes, were painstakingly attached by hand to the external surfaces of these units. In its completed form, the model's rough ER is arranged concentrically around the nucleus in a series of irregularly spaced laminations extending from the nuclear envelope to the cell membrane. The units of smooth ER are basically extensions of those of rough ER. Their process of manufacture was identical, with the exception of the glass beads. The vacuum-forming moulds, however, were somewhat more complex because of the net-like configuration and tubular structure of smooth ER.

The tedious and time-consuming task of making endoplasmic reticulum required more patience and involved more man-hours than did the manufacture of any other component of the cell model. Literally hundreds of sheets of clear acrylic had to be formed, glued together, trimmed, polished and 'beaded'—all by hand.

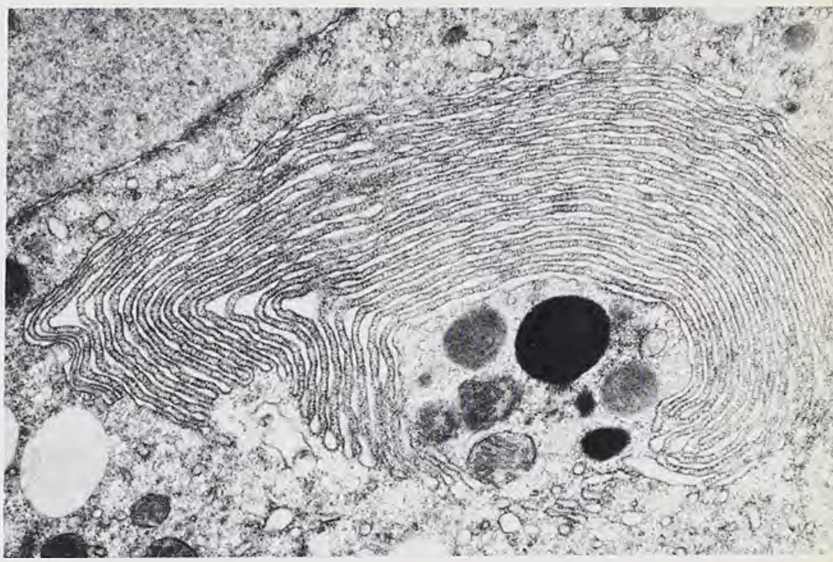
All nucleated cells, except those of the higher plants, contain one or more pairs of centrioles. Each centriole is a cylinder consisting of nine sets of three microtubular structures running the length of the centriole in a gentle spiral. The two centrioles of a pair are commonly positioned at right angles to each other. The size and structure of centrioles remains remarkably constant throughout the range of cells in which they occur. Centrioles are self-replicating and duplication normally precedes division of the chromosomes during cell-division, in which they play an important role. They also give rise to cilia and flagella—locomotory or movement-generating filaments that are found in some unicellular organisms (protozoa) and in sperm.

A single pair of centrioles is featured in the cell model. Unfortunately, because of the great difficulty involved in setting them up in a realistic fashion, their method of construction—small-diameter polythene tubes set around acrylic supports—is obvious and, as a result, they appear less convincing than most of the model's other inclusions.

Vacuoles are membranes enclosing cell products. They are active in cell processes, their sizes and functions varying according to cell type. In fresh-water protozoans such as *Amoeba* and *Paramecium*, contractile vacuoles regulate water concentration in the organism's cytoplasm. Contractile vacuoles, and vacuoles used by protozoans in general to store and digest food, are, in effect, 'pockets' of external environment contained within the cytoplasm. Other vacuoles are used by protozoans to collect, transport and discharge waste products to the exterior. Vacuoles in plant cells are large and may make up as much as ninety percent of their volume. These vacuoles are normally filled with fluid (cell-sap) under pressure which maintains the shape of each cell and gives rigidity to the plant structure.

To reproduce both vacuoles and lysosomes for the cell model, polyester resin spheres were cast. The spheres are hollow and their organic appearance is in part due to the natural colour of the resin and in part to the method of casting. Small amounts of liquid resin were introduced into the moulds which were then 'tumbled' by hand until the resin cured. The tumbling action coated the surface of the mould with a film whose uneven thickness contributed to the 'natural' appearance of the finished cast. Vacuole spheres, when cured, were left intact. Lysosome spheres, however, were opened and a number of smaller spheres attached inside them, using the resin as a glue, after which the openings were sealed off.

Glycogen granules appear in the model as small



David Popham

Egg cell of the shipworm, *Bankia australis*, magnified 1636 times. This superb photomicrograph gives a very clear picture of the arrangement of rough ER within a cell. Ribosomes can be clearly seen on the surfaces of the ER cisternae which appear in the photo as parallel bands.

clusters of uncoloured, five millimetre diameter glass beads. In living cells, glycogen—sometimes called 'animal starch'—is important as a carbohydrate reservoir. It is a soluble polysaccharide, built up from numerous glucose molecules and it occurs in the liver and muscle of animals.

The largest single component of the model is the cell membrane which, when it is first seen, has a tremendous visual impact upon visitors. There is more to it than meets the eye, however, for this seemingly delicate, translucent hemisphere also serves as a mechanical base for the model, supporting about one hundred kilogrammes of plastic inclusions, membranes and organelles. In assess-

Gregory Millen/Australian Museum

Close-up of a model mitochondrion reveals the granular inner membrane, folded into cristae, and the smooth outer membrane. Some elements of rough endoplasmic reticulum lie to the right; the glass beads represent ribosomes.

ing both physical and aesthetic aspects of the cell membrane's construction, the preparators found a source of many headaches. They strongly felt, for example, that the normal practice of introducing fibreglass reinforcing materials into the casting resin would tend to detract from the fidelity of reproduction. But, without such reinforcing, the membrane might well be too fragile to support the inclusions. They resolved the problem by cheating! Along its exposed edge the hemisphere is relatively thin—about five millimetres—and true to scale but its thickness increases to almost twenty five millimetres near the bottom. Fundamentally incorrect, of course, but it is not seen and the problem of fragility was overcome.

In living cells the cell membrane, properly termed the plasma membrane, is about seven millionths of a millimetre thick and consists of lipids and proteins. Under the electron microscope it appears as two dense layers separated by a less dense intermediate layer. The plasma membrane is a semi-permeable limiting structure that maintains constancy within the cell by separating its contents from the external environment, simultaneously regulating the two-way passage of materials involved in the cell's metabolism. Water and gas molecules diffuse freely from regions of high concentration through the membrane to where their concentration is lower. For other substances such as potassium and sodium ions the cell expends energy to overcome pressure barriers when they flow towards regions of high concentration. Hence potassium concentration is normally higher inside a cell than outside whereas sodium concentration is higher on the outside. This characteristic is exploited by nerve cells to carry messages along their membranes. When the nerve-cell membrane is stimulated, potassium flows out of the cell and sodium flows in. This exchange is not instantaneous but occurs as a wave, travelling from one end of the cell to the other, through the membrane.

The intake of relatively large particles of material used in a cell's metabolism is effected by endocytosis. This involves infolding of sections of the plasma membrane to form small vesicles enclosing substances from the cell's exterior. The vesicles are 'pinched-off' by the membrane, from which they detach and move into the cytoplasm.

The plasma membrane for the model was made from a translucent epoxy resin in which were incorporated several thousand glass beads ranging in diameter from three to twelve millimetres. A plaster mould of the membrane was taken from a smoothly modelled, heat-polished plasticene original. This relatively simple first stage was followed by the more difficult process of casting. To achieve an even gradient of thickness in the finished cast, it was necessary to tilt the axis of the extremely heavy mould to an angle of about twenty-five degrees while rotating it at a uniform speed of six revolutions per minute. As it rotated, some forty-five litres of liquid resin were poured into the mould, the glass beads being evenly distributed throughout this viscous material. After the resin had set hard, the membrane-hemisphere was removed from its mould and trimmed. The edge was given a jagged finish to suggest that the membrane had been broken like an egg-shell and its top removed to expose the cell's contents.

Lipid globules have been left till last because, although they are less spectacular than most other inclusions in the model, their method of manufacture was novel. Lipids, or fats, are important fuels whose metabolic oxidation supplies cells with a large proportion of their energy. To make these globes of fat, a foaming polyurethane resin was chosen. This material is supplied by its makers in two parts which, when mixed, produce a gas that causes the resin to foam and expand prior to its setting. Casting is very simple. Recipe: take correct proportions of each of parts A and B and mix thoroughly in a suitable vessel. Pour mixture into rubber balloon. Seal neck of balloon and shake well. When set, remove balloon. Depending on the maximum dimensions of the balloons, and the quantities of resin used, opaque, ultralightweight spheres of virtually any diameter could be produced. The surfaces of these spheres, in which a keen observer may detect millions of tiny, rigid bubbles, are perfectly smooth and of a uniform golden brown colour.

The cell model was assembled on its own

turntable adjacent to its ultimate display site in the Hall of Life. A dust-excluding plastic tent enclosed the work-area as, once the model was complete, its interior would be inaccessible for cleaning.

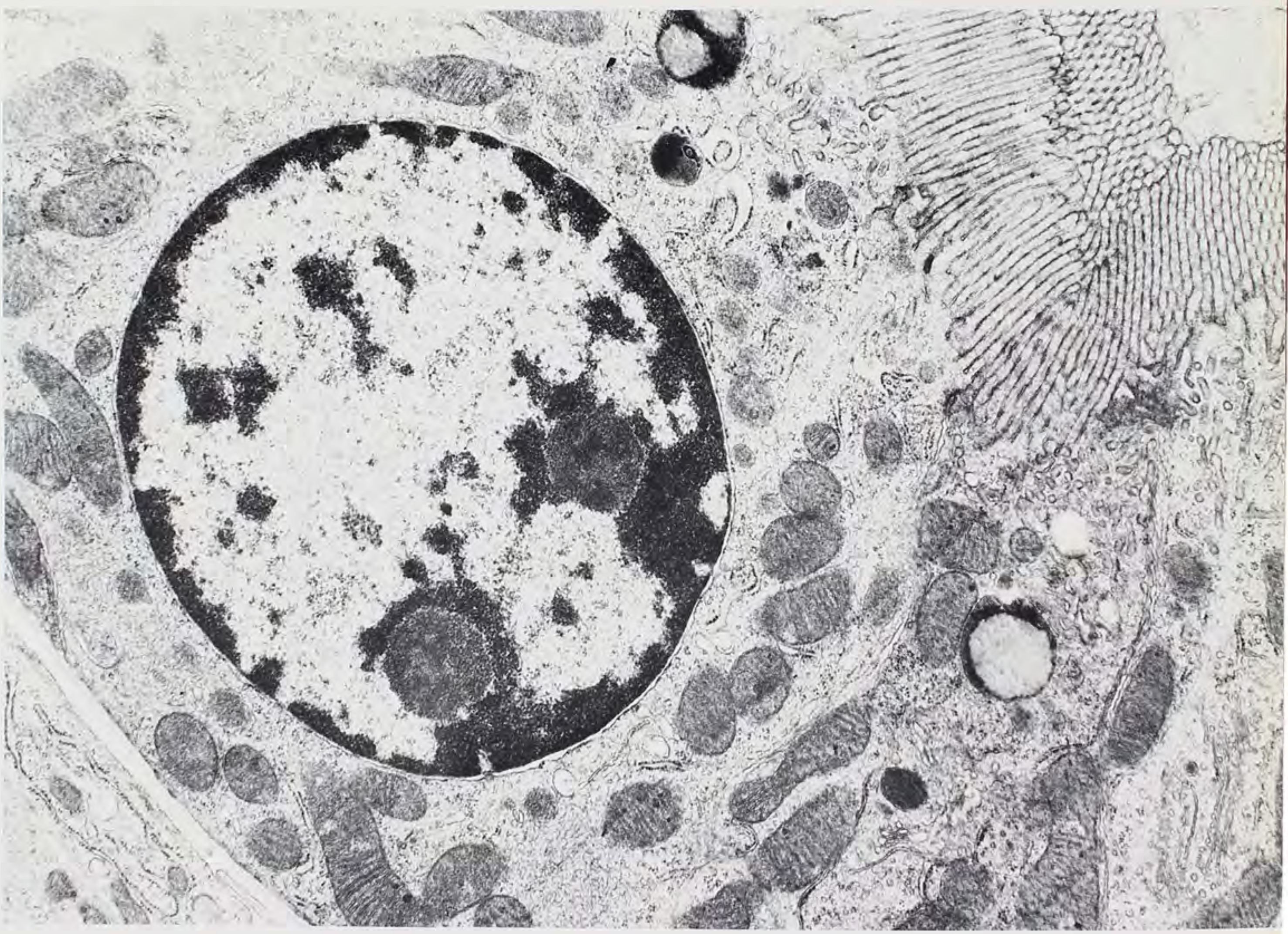
Assembling components was rather like fitting together a jig-saw puzzle—to which the handicap of a third dimension has been added. Furthermore, it was necessary to compromise between the desirability of recreating the general internal arrangements of a living cell and that of permitting an unobscured view of the model's innermost components. The optimum site for each part could only be found by trial and error. Several pieces were first temporarily positioned using all kinds of props—sticks, clamps, string, sticky tape and swearwords—individually and in combination. If the position was found to be satisfactory, the props were removed and the pieces glued permanently in place before siting the next group of units. Authenticity of support mechanisms had to be disregarded altogether. Inclusions in a living cell move constantly through the jelly-like ground substance of the cytoplasm. The model's inclusions are supported in static positions with glue, short lengths of transparent acrylic rod and fine, barely visible nylon threads.

Conventional lighting from an external source was found to be ineffective because of the model's many reflective surfaces. This problem was overcome by directing light upwards through the turntable base and diffusing it by means of a four hundred and sixty millimetre diameter, liquid-filled plano-concave lens—custom made by the preparation team. The effect achieved is dramatic and the components of the model can be clearly seen, with minimal interference from superficial reflections.

The three years taken to complete the cell were well-spent and the manifold challenges presented to its makers were more than successfully met. Watching the finished model revolving slowly behind the curved plate-glass of its elegant showcase, the Chief Preparator was heard to mutter, "A headache probably affects thousands of human cells, but this particular cell has effected thousands of human headaches. If it should divide . . .!"

A mouse kidney cell magnified 2153 times showing the nucleus with nucleoli. The nuclear membrane can be clearly seen. Upper right, endoplasmic reticulum. The prominent roundish object to the right of the nucleus is a lysosome. The dark oblong shapes are mitochondr

David Popham



DOWN UNDER AUSTRALIA

BY LIN SUTHERLAND

Photo: Howard Hughes, Australian Museum

Volcanoes, nature's active advertisement that the Earth is a dynamic heat engine, are products of slow, but relentless geological forces. They floor oceans (mid-oceanic ridge volcanoes that continuously form sea-floor in the world's major oceans), build islands to heights higher

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than Everest (oceanic island volcanoes that rise from the sea-floor), form major cones and island arc systems that fringe the earth's unstable zones (the 'Pacific Rim of Fire' and earthquake belts) and spill out flood lavas in rift valleys and continental interiors. They may be continuously active, intermittently active in regular or spasmodic bursts, long dormant, or dead and stripped. Old, altered volcanic rocks may be transformed into objects of beauty as mineralised waters deposit crystal charms. The largest eruptions can be catastrophic, with world-wide impact (at-

Mt. Schank, a group of young volcanic craters in South Australia.

This composite photograph gives a panoramic view of Tower Hill Volcano in western Victoria, and shows the nest of young cones that grew within the main crater.

mospheric dust from Krakatoa and the legend of Atlantis). The volcanic liquids may be tapped from deep in the Earth's mantle and can bring up treasures like diamonds. Volcanoes have marched across the face of the Earth through thousands of millions of years of geological time.

Australia, now a quiet and stable place, has seen recent volcanic activity. Past volcanoes and lavas extend down the east coast from Torres Strait to Tasmania. Aborigines witnessed the last eruptions a few thousand years ago. Are there more to come? Nothing now erupts, but there are volcanic fields so fresh that they raise this fascinating question.

The youngest lava fields are in southern Australia and Queensland. Radioactive isotope dating of lavas and buried vegetable remains suggests intermittent but consistent volcanism over the last five million years. In western Victoria, volcanic ash showered from the Tower Hill Volcano near Warrnambool a mere seven thousand years ago. Recent geophysical heat and electrical measurements suggest that there is still partially-molten material deep under this lava field. Nearby, in South Australia, the last ash from Mt. Gambier Volcano is only a few thousand years old and earth tremors near suspected submarine volcanoes off Robe and Beechport shook the coast as recently as 1948. Studies of pollens that settled in crater lakes on the Atherton Tableland hint that some Queensland craters are little more than ten thousand years old. Aboriginal legends describe eruptions from these areas and Tower Hill ash buries an Aboriginal midden—further witness of the recent volcanic past.

Heavy pumice drifts from external eruptions sometimes wash up on Australian coasts. In 1964, pumice from a submarine eruption in 1962 near the South Sandwich Islands was strewn along the southern Australian coast after having travelled over half the Southern Ocean. More recently, heavy drifts have washed in from eruptions near Tonga. Girdling eastern Australia, as part of the 'Pacific Rim of Fire', are the active volcanoes of Indonesia, Melanesia, New Zealand and Antarctica. Born through spreading and interaction of crustal plates, these volcanoes, except for the Antarctic vents, are commonly andesitic cones, differing in their molten chemistry from the typical basaltic volcanoes of Australia.

One would suspect that the next Australian eruptions will come in the young lava fields, but an alternative possibility arises from dating studies, mostly by Australian National University

Tasmanian Hydroelectric Commission

Fragmented pillow lava showing the typical form taken when lava flows plunge into water. From lavas which were erupted into Great Lake, Tasmania some twenty-two million years ago.

Howard Hughes/Australian Museum

scientists. They show that lavas richer in silica than the basalts punctuated the normal eruptions and became progressively younger southwards. These trachyte and rhyolite lavas date from thirty-three million years in northern Queensland (Cape Hillsborough and Mt. Jukes), twenty-four to twenty-eight million years in central Queensland (Minerva Hills), twenty-two to twenty-four million years in south-eastern Queensland (Glasshouses and the Tweed Shield), thirteen to sixteen million years in northern New South Wales (Warrumbungles) and seven million years in Victoria near Macedon. This stately progression may reflect the northward migration of Australia as sea-floor spreading in the Southern Ocean pushed the continent over a hot spot, triggering discharges of trachytes and rhyolites inside every six million years and leaving a disconnected trail down the east coast. Though it requires more study, this theory, if correct, implies that Tasmania, with no record of such rocks or of any young volcanism, would lie near the next overdue outburst of trachyte or rhyolite lava.

The evidence suggests that Australia is probably only dormant. Whether the next eruption comes in a few, hundreds, thousands, or even millions of years cannot be predicted confidently at present. Australians in areas of potential eruption should not worry; the risk is negligible when compared with parts of Indonesia, Melanesia and New Zealand. All one can say is that if the next eruption is basalt, a young field in South Australia, Victoria or Queensland should be the scene, but if it is trachyte or rhyolite, Tasmania may take the honours.

Basaltic lavas are usually fluid and may travel more than eighty kilometres, but trachytes and rhyolites are more viscous and can plug vents until they burst under pressure, sweeping out catastrophic 'glowing cloud' eruptions. Whether a long lava flow or a violent concentrated blast would create the greater havoc depends on the topography and habitation around the site.

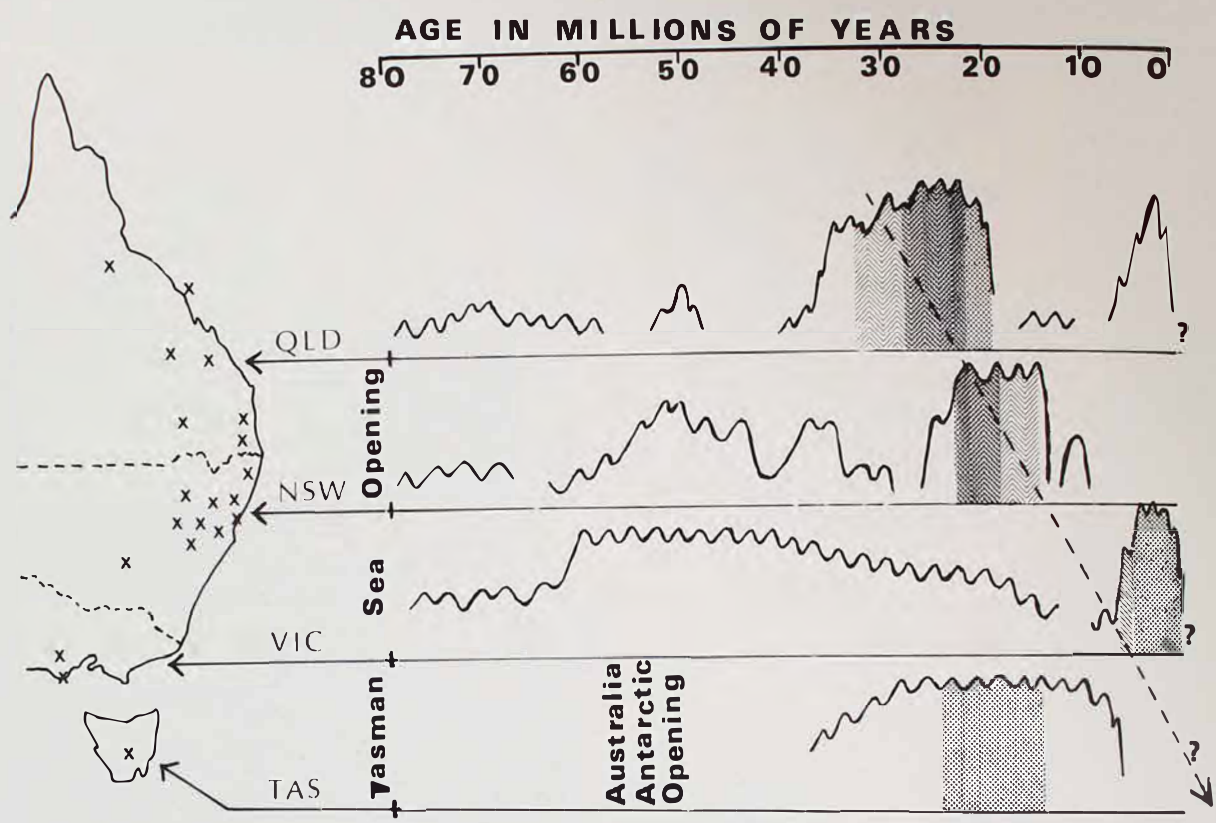
The last cycle of basaltic volcanism dates back to Australia's break away from the old supercontinent, Gondwanaland. Rifting, then sea-floor spreading, separated the New Zealand strip, forming the Tasman Sea between eighty and sixty million years ago. The separation of Antarctica, beginning fifty-five million years ago, followed and probably still opens the Southern Ocean by several centimetres a year. Most of the volcanism built up well after the initial splits and its intensity and location was varied. The general pattern

Howard Hughes/Australian Museum

Aerial view of Mt. Gambier Volcano South Australia—probably the last volcano to erupt in Australia. This westward view shows the crater walls and lakes with the celebrated Blue Lake crater in the foreground.

of eruption over the last eighty million years, since spreading began in the Cretaceous Period shows particularly widespread activity between thirty-five and fifteen million years ago, in the Oligocene and Miocene Epochs of the Tertiary Period. In this peak, most of Australia's largest volcanoes, such as the Tweed, Nandewar and Warrumbungle Shields, were built up and volcanism even visited the Kimberly area in Western Australia, a previously non-active state. Most of the volcanoes were relatively short-lived and even the large shields lived for less than five million years.

Volcanoes erupt into two environments, air and inland lakes. Lava erupting under water chills into lobe-like tubes called pillows. When it reaches the water's surface, steam-explosions deposit beds of glassy debris. As the volcano emerges, lava erupted into the air plunges into the water to form avalanches of broken pillows admixed with glassy explosion debris, which build out like deltas. Finally, if the volcano emerges completely, the capping lavas will form typical air-cooled flows. All these features are seen in spectacular eroded flanks of old coastal volcanoes around northwest Tasmania and in old lake volcanoes around Great Lake in central Tasmania. No volcanoes seem to have coincided with the ice



Graph by Lin Sutherland

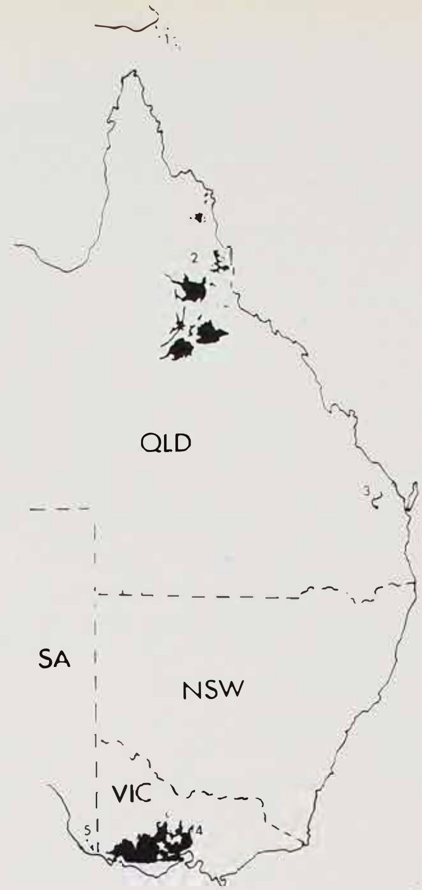
water. In land eruptions, lava exploding and issuing from pipes and fissures builds up cones and flows which, in areas of concentrated activity, coalesce to form thick lava piles, wide shields or lava plains. Maars, explosive ring volcanoes composed of fragmented lava and country rock, dot the young Victorian and Queensland fields and commonly enclose crater lakes. They may result from rising lava contacting ground-waters in water-bearing strata of permeable rock, but other explosive mechanisms are possible.

Lava-forms characteristic of eruption into water are only abundant in Tasmania where strong volcanism between twenty-five and fifteen million years ago coincided with an advance in sea-level in the Bass Strait and the existence of large caps in southern Australia during the last Ice Age, so that we see no melt-water pillow lavas of the type found in great thicknesses in Antarctica.

Ocean floors form by spreading when large quantities of basalt, erupted from the mid-oceanic ridges, form pillow lavas—often mixed with deep-sea oozes. The basalt floors of the Indian Ocean, Southern Ocean and Tasman Sea surrounding Australia formed continuously during Australia's volcanism. Sub-Antarctic Macquarie Island, officially, but not geologically, part of Tasmania is a rare example of relatively new oceanic crust which has been uplifted from the sea, allowing detailed inspection. The pillow lavas here, intersected with feeders and lava chambers, formed about twenty million years ago at oceanic depths of a few hundred metres

Volcanic islands also grew up from the ocean floors off Australia. A chain of such islands forms the Tasmantid sea-mounts under the Tasman Sea. Lord Howe and Norfolk Islands represent lava shields built above the ocean surface.

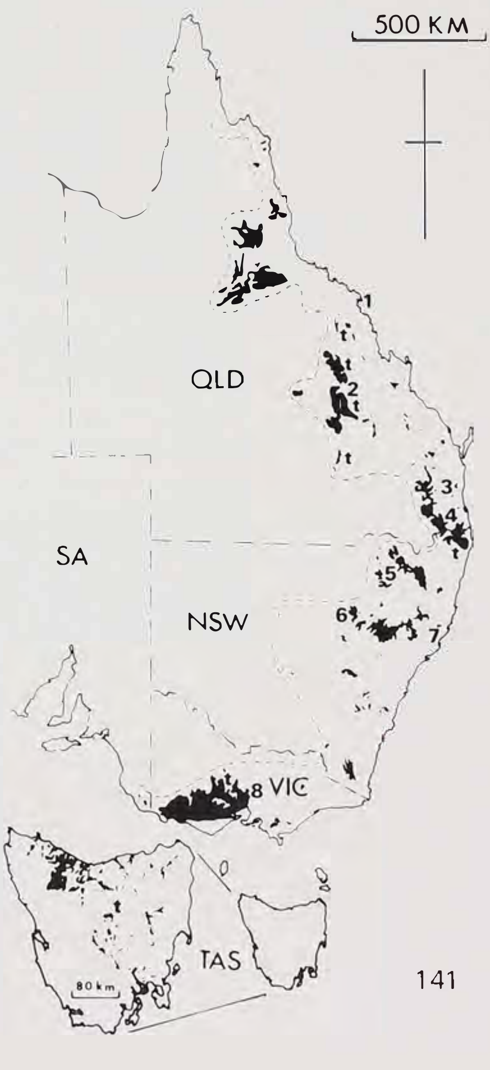
Australian volcanoes typically erupted two common basalt types, one deficient in silica, the other saturated in silica. Undersaturated types are more extensive. The saturated basalts first appeared in volume in the Oligocene-Miocene peak of volcanism, when there was substantial melting below the crust. These saturated basalts lie largely along major sedimentary basin structures and away from more massive crustal blocks, a structural setting favouring high heat flows. The even more siliceous trachyte and rhyolite lavas interrupt some basalt fields; their rather independent distribution has already been mentioned.



Above right, eastern Australia showing areas of young volcanism, less than 5 million years old. 1. Torres Strait islands, Queensland and Papua. 2. Northern Queensland. 3. South eastern Queensland. 4. Western Victoria. 5. South eastern South Australia.

The graph at left shows approximate relative intensities of the volcanism in eastern Australia in each State over the last 80 million years to the present day, based on dated volcanic rocks. The localities of volcanic fields dated by radio-isotopes are shown by crosses. Times over which significant tholeiitic basalts erupted with the prevailing alkali basalts and other alkaline lavas are shown by stippled areas under the graphs. Note that these appear in the strong peaks of volcanism in Queensland, New South Wales and Tasmania in Oligocene-Miocene times and in Victoria in Pliocene to Recent time. The youngest basalts are confined to Queensland and Victoria and may still be potentially active. Times over which significant trachytic and rhyolitic volcanism took place across the basalt fields are shown by shaded line areas under the graphs. Note that these give the general impression of decreasing in age from north to south and potentially would next be expected to appear around Tasmania (inclined arrow).

Maps by Lin Sutherland



Below right, eastern Australia showing main areas of volcanic rocks, erupted since separation started from the New Zealand and Antarctic areas over the last 80 million years. Basalt fields in which significant tholeiitic basalts accompany the prevailing alkali basalts and alkaline rocks are designated by t. Dated areas of trachytic and rhyolitic volcanics across the basalt belt are numbered 1 to 8. The dashed line enclosing the basalts represents the western limit of the volcanic activity in eastern Australia. Note that the basalt fields of Tasmania are shown in enlargement and include tholeiitic basalts.

Molten material stagnating down in the crust before eruption evolves chemically, crystallizing out early heavier minerals rich in magnesium and iron, so that the melts become enriched in lighter elements and fluids such as aluminum, silicon, potassium, sodium and water. Eruptions tapping the chambers at different levels or times produce lavas of more extreme compositions and many examples intermingle with the more primitive basalts in the Australian fields. Particularly voluminous lava, when ponded to depths of a few hundred metres in crater lakes or narrow valley-fills, can cool slowly enough to allow some internal evolution, as seen in coarse basalts in The Nut, Table Cape, and Tamar Valley in Tasmania and in Mt. Fort Cooper in Queensland.

Molten subterranean pools may also change in composition by melting and digesting surrounding crustal rocks. A sensitive method of detecting this measures proportions of stontium isotopes, as these differ from the crust to the earth's mantle. Eastern Australian lavas commonly show values for a mantle origin, but some saturated basalts and more evolved lavas show values suggesting crustal contamination during their evolution.

The composition of the source material—whether mantle or crustal—pressures, temperatures, and amount of melting, digestion and chemical evolution, all influence the final composition of the erupted lava. Because of the great interest in the structure of the earth's interior, the depths and conditions under which lava types generate are subject to many studies. Australian National University has built experimental equipment capable of reproducing the extremely high temperatures and pressures involved. Using various starting compositions, conditions under which basaltic minerals crystallize and react are determined and related back to natural rocks, elucidating their conditions of formation and evolution.

In their upward passage, lavas sweep out mineral and rock fragments, either as accidental inclusions from the surrounding rocks or as contemporaneous inclusions crystallized from the host itself at depth. Accidental inclusions illustrate the underlying structures while contemporaneous inclusions chart the upward progress and evolution of the lava. One particularly significant group, peridotites, occur in many of the Australian lavas and detailed work on some from Victoria gave them an age of over two billion years. They are interpreted as being residues of the earth's mantle which remained after the basalt was melted out during a much later period. They generally occur in the silica-deficient lavas, but have recently been found by this writer in a saturated basalt from Tasmania, the first confirmed world occurrence. Their presence immediately fingerprints a lava as having originated from deeper than the crust, which in eastern Australia typically extends down twenty-two to forty-five kilometres.

Beds of volcanic ash and cinders built up the crater wall of Tower Hill Volcano.

Some lavas are studded with particularly large minerals (megacrysts) which crystallized at considerable depth under high pressures; they usually include members of the feldspar, pyroxene, amphibole, olivine, spinel, and garnet families. Lavas with both megacrysts and peridotite inclusions indicate that they stagnated deep in the mantle. The richness of inclusions in Australian basalt fields has made them an important area for studying the origin of basalt, one of the world's most common rocks.

Older volcanic rocks weather to rich soils beloved by farmers. The fresh rocks are used as sources of road metal, aggregate, and building stone. Young scoria cones provide gravel, but their quarrying is sometimes opposed by people who prefer them to remain untouched.

Volcanism in Australia has provided interesting variations in scenery—often of tourist potential—and some national parks, such as Warrumbungle and Lamington Parks, include terrains of volcanic origin. There are other benefits as well. Sapphire, released from the basalts, can be won from the surrounding alluvials, the main Australian fields being in the New England and Anakie districts. Mineral collectors and lapidarists find rich sources of pleasure and profit in the secondary minerals, such as zeolites and agates, which fill seams and cavities in the lavas. Scientists, in studying the lavas themselves, are opening up understanding of the development of Australian landforms, the structure of the Earth's interior and the hidden continent under our feet, and the mechanisms controlling Australia's future geological movements and Plutonic moods.

Perhaps one day the long-dormant reeks and fumes of volcanism will rise once more over this island continent. Perhaps the crumbling ruins of a volcanic past will tremble under the shadows of new and thunderous cinder-capped cones of fire and vanish beneath new seas of molten rock. Perhaps.

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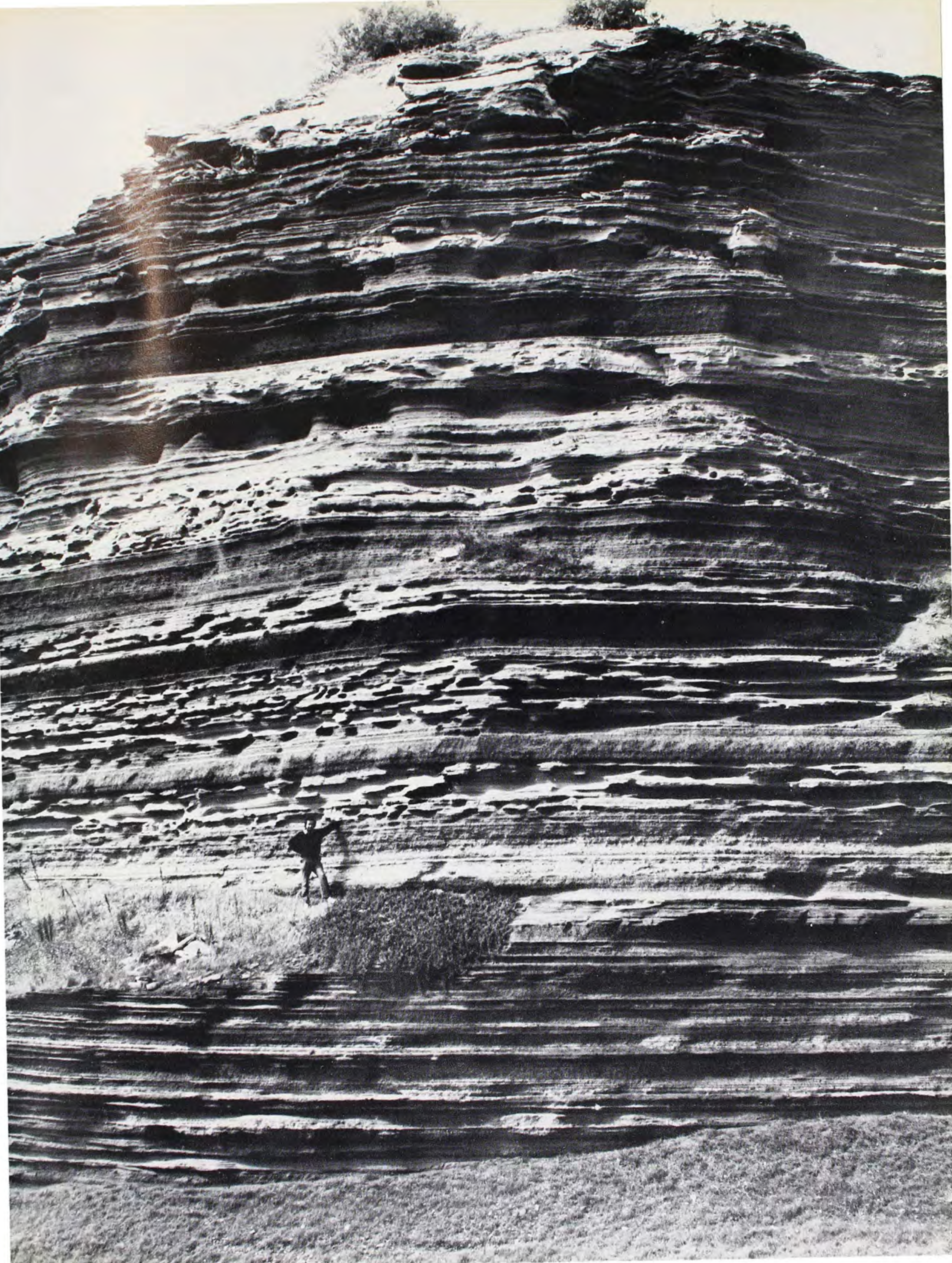


VOYAGE OF THE BANDED IGUANA

BY H. G. COGGER

The balsa raft, *Kon-Tiki*, grounded on Rarioa Reef in the Tuamotu Archipelago in 1947 after an epic voyage of 102 days from the coast of Peru. To Thor Heyerdahl and his crew, the voyage confirmed their belief that the islands of the western Pacific were colonised by people from South America. In the excitement created by *Kon-Tiki's* voyage, few people gave thought to a small green lizard which almost certainly anticipated *Kon-Tiki* by many thousands of years.

Anthropologists now generally reject the Heyerdahl hypothesis, believing that the people of Melanesia and Polynesia migrated there from the west. Similarly, except for this lizard, all the land animals of the western Pacific are clearly derived from animals that arrived from Indo-Malaysia by 'island-hopping' along the archipelagoes of New Guinea and the Solomon Islands.

The many hundreds of islands in the Fijian group have always been isolated from other land masses by vast stretches of ocean. Hence the land animals inhabiting them (except for birds and bats which can fly across oceans) are descended from those which must have arrived originally on 'rafts' of drifting logs and other flotsam. Reptiles and frogs are poorly adapted to making long sea voyages. Successful colonisation of islands by these animals is largely determined by the distance of the islands from the nearest land mass which can act as a source of colonists, and by the suitability of habitats available for exploitation. In the case of the Fijian Islands, their distance from land to the west is so great that relatively few reptiles have succeeded in making the journey; but because of the environmental diversity of these islands, their reptiles have succeeded in invading most of the available niches.

The reptiles and frogs of Fiji can be divided into two groups—those that are successful modern colonisers and are found on many of the oceanic islands, and those that have evolved in genetic isolation from their relatives over a long period and are now 'endemics'—that is, they are confined to one small geographic region. The former are usually highly adaptable species, able to survive in a wide variety of habitats; the latter tend to be highly specialised and confined to particular and often restricted habitats.

Dense forest on the island of Kadavu where the Banded Iguana still thrives.

The islands of the Fiji group are of two basic kinds—high volcanic islands with rich tropical forests, and small coral cays with poor soils and relatively simple plant communities. The endemic Fijian reptiles and frogs are virtually confined to the high volcanic islands. The smaller coral islands are inhabited by ubiquitous pan-Pacific species of geckos and skinks.

In historic times, man has changed animal distribution patterns that developed over the preceeding thousands or millions of years by transporting animals to new areas, either deliberately or accidentally. The effects of such introductions on the resident animals and plants are often profound, and rarely more so than in Fiji. Two animals in particular have had serious effects. The Indian Mongoose, *Herpestes auropunctatus*, was introduced to combat rats which were destroying sugar cane and coconuts; the Marine Toad, *Bufo marinus*, was introduced in an effort to control various insect pests of sugar cane.

As a result of these and other introductions, and of agricultural developments which have changed the face of the Fijian landscape, many of the native animals are now in very real danger of extinction. One of these is Fiji's rare green lizard or, as it is more usually known, the Banded Iguana (*Brachylophus fasciatus*).

Unlike the other reptiles of Fiji, which all belong to families that are widely distributed throughout the Australian and Indo-Malaysian regions, the Banded Iguana belongs to the lizard family Iguanidae. The members of this family are almost wholly confined to the Americas. A small divergent group is found in Madagascar, and two species (one, the Tongan Iguana, *Brachylophus brevicephalus*, first described in 1970) are known

HARROLD COGGER, Curator of Reptiles and Amphibians at The Australian Museum, has—for the first time—successfully bred the Banded Iguana in captivity, and is studying their biology and behaviour.

only from Fiji and Tonga. These latter two lizards are so closely allied to their South American relatives that a voyage by their ancestors across the Pacific appears to me to be the only tenable explanation of their origin.

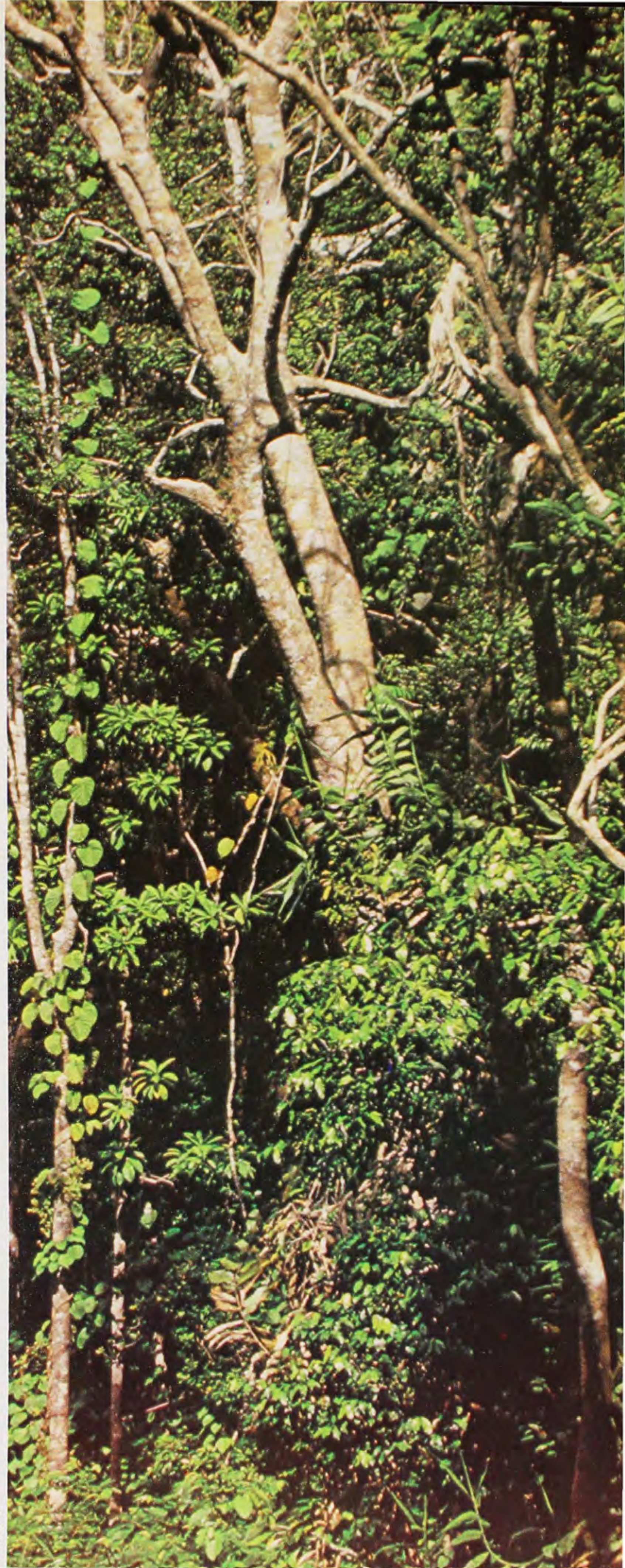
Two other origins are possible. The original iguanas could have arrived via some kind of land bridge when the continents of South America, Australia and Antarctica were in contact, but the Fijian Islands almost certainly arose from the sea floor in isolation from other land masses during the upper Eocene, about forty-five million years ago. As this occurred at the same time that the continents of Australia, Antarctica and South America were separating from one another, this origin must be dismissed.

Another possibility is that Fiji's iguanas are remnants or 'relicts' of a group of iguanas once widely distributed throughout the Indo-Pacific Region; but as no other iguanas or their remains have been found elsewhere in the region, this hypothesis also lacks support.

We can then assume that the ancestors of the Fijian and Tongan iguanas accidentally rafted from the coast of South America, to be eventually washed ashore on a Fijian or Tongan island. Subsequently, they successfully invaded many neighbouring islands, but the moderate differentiation of the Tongan populations suggests that there has long been little or no exchange of individuals between the two island groups.

The iguanas of Madagascar are believed to have arrived on that island via a land bridge before the break-up of Gondwanaland. Isolated in early Cainozoic times, they have evolved over the past fifty to seventy million years to form a distinctive sub-group of lizards only distantly related to other members of their family.

I first became interested in the Banded Iguana when studying the reptiles and frogs of Fiji in 1970. Many reports during the preceeding decade had indicated that this iguana was declining in numbers on most of the high islands. Live specimens in the Fiji Museum had laid eggs, but none had hatched. Perhaps more than any other factor, the sheer beauty of the lizards in the



H.G. Cogger

H G Cogger

Museum caught my imagination and doubtless led to deeper interest. Subsequent searches on Viti Levu and on Ovalau were unsuccessful, although good populations of the rare endemic frog, *Platymantis vitianus,* on Ovalau made the work there especially rewarding.

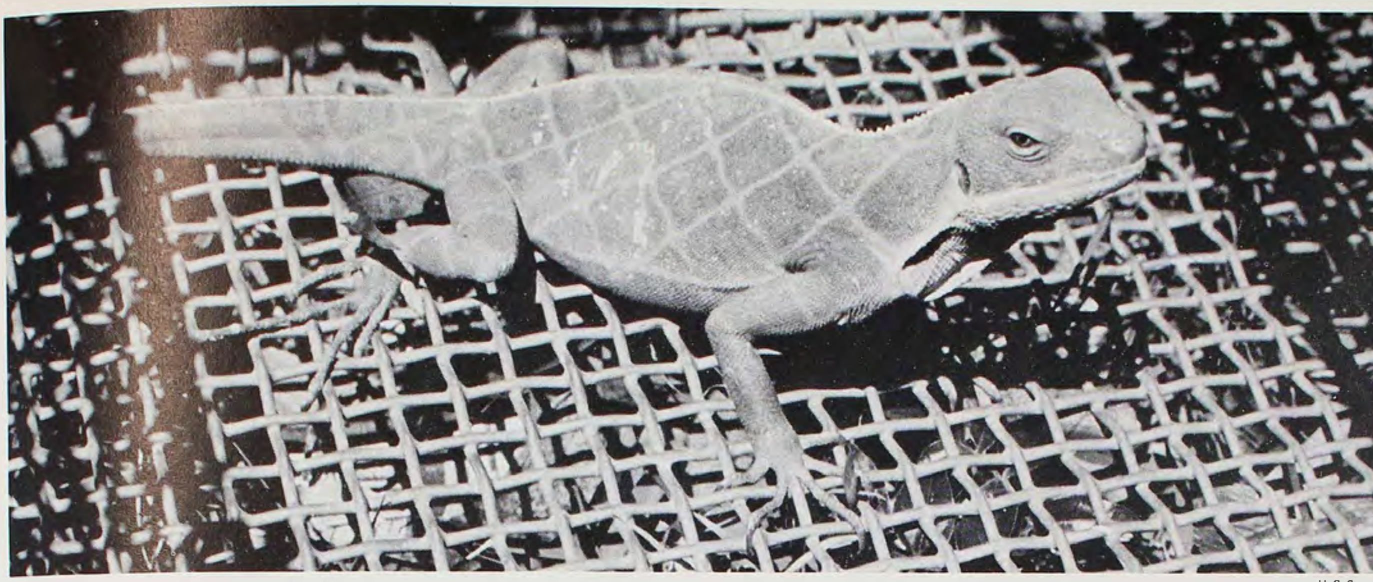
Not until I visited Kadavu, a large 'high' island some one hundred kilometres south of Suva, did I find the Banded Iguana. Kadavu has no mongooses and no marine toads. A mixture of rich tropical forests and copra plantations covers the island and, according to local advice, the iguanas are still abundant, although few were seen. They are superbly camouflaged, and I had difficulty seeing them even when they were pointed out to me. Only when some specimens were brought back to my laboratory at the Australian Museum did I begin to learn that their distinctive appearance is complemented by equally distinctive habits and behaviour.

Platymantis vitianus, one of Fiji's two native frogs, whose survival has been threatened by the introduction of the Marine Toad, *Bufo marinus.*

H G Cogger

The name Banded Iguana is somewhat inappropriate, for only the male is banded. The female is immaculate green, with no indication of banding. The skin colours vary in intensity with temperature and temperament, and can change with astonishing rapidity. The bands on the males are most intense during courtship or aggression, and may all but disappear when the lizard is at rest. The skin is extremely light-sensitive, such sensitivity being more or less independent of the eyes and brain and probably the result of light-sensitive cells in the skin itself. A shadow falling across the lizard, or an object lying against it, can leave an almost photographic image within about thirty seconds. Few vertebrate animals display such an efficient camouflage mechanism, and it is especially effective in the dappled shade of the forest trees in which it lives.

Another remarkable anatomical feature of the Banded Iguana is the presence of nasal salt glands, which are used to secrete excess salt. Such glands are well-developed in many iguanid lizards in both desert and forest species, and their function is little understood. In desert species, the need to conserve water by 'recycling' body fluids results in a concentration of salts in the body, and any mechanism which helps the body to excrete this excess salt is highly advantageous, but the advantages of salt-secreting glands to a lizard living in a wet environment are obscure. It has been suggested that the nasal salt glands of



H G Cogger

Photographs showing the light-sensitive skin of a female iguana. After a short exposure to sunlight in a wire cage (left) the shadow of the wire leaves a perfect image when the lid of the cage is opened (right). Although the pattern is of the wire, the skin is actually darkening in response to the sunny interspaces.

Brachylophus are merely the useless carry-over of an ancestral trait, but the glands are so frequently active that this seems unlikely. Salt is secreted from the nostrils by sneezing, and this occurs so often that the glass front of the iguanas' cage soon becomes clouded with fine salt crystals, which may also build up around the nostrils. The mechanism is equally well-developed in the young. Hatchlings have been observed sneezing within an hour or so of leaving the egg.

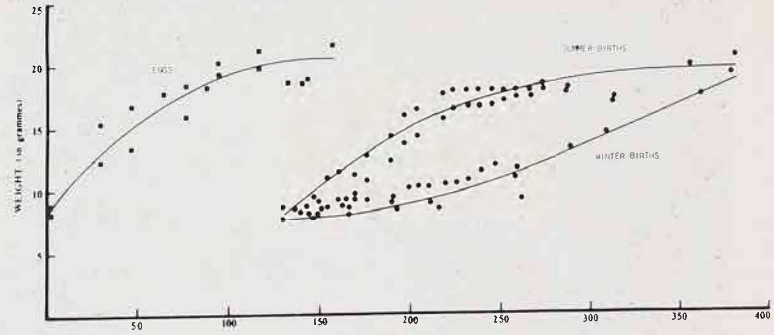
An interesting specualtion is that the nasal salt glands of *Brachylophus* or its ancestors may have pre-adapted this lizard for its long sea voyage from South America, allowing it to rid itself of any salt resulting from immersion in sea water. Only when we have sufficient specimens to risk them in experimental situations can we put this hypothesis to the test.

Because of their rarity, and because they have a number of features which make them ideal laboratory and experimental animals, we have been trying to breed these lizards at the Australian Museum, to date with limited success. Seven young have hatched from three batches of eggs, six of which are alive at present.

Males are strongly territorial, and are especially aggressive in the presence of a female. When two males make visual contact, there is an immediate increase in the intensity of body colours in both individuals, followed by a period of active 'head-bobbing' in which each male bobs his head in rapid succession. If one male continues to approach the other, the bobbing becomes more intense, the body is enlarged by inflating it with air, and the throat pouch, or fan, is lowered. Eventually, unless one male withdraws, they fight savagely and may inflict serious wounds with their sharp teeth.

In captivity, several adult males will sometimes live together in a rough kind of harmony, but invariably one male will be dominant. This domination is shown in several ways. First, he almost invariably displays the extreme aggressive/sexual colours, and occupies a central 'over-seeing' position in the cage. That colour is important in maintaining the hierarchy is shown by the subordinate males, including juveniles, each maintaining passive colouration in which the bands are so faint as to make him closely resemble a female. As courtship involves the adoption of strong colour by the male, the subordinate males generally fail to mate. Adopting the necessary preliminary colouration would result in aggression by and probable injury from the dominant male.

On one occasion I removed the dominant male (which I shall call No. 1) from a group of four males in a cage. Within minutes another male (No. 2) had assumed the dominant position in the



H G Cogger

This graph shows the growth of eggs (due to water uptake) and the initial growth of the hatchlings. Seasonal differences in hatching times results in different initial growth rates.

hierarchy, taking on full male colours, which it had not once displayed during the previous months. During its first day as dominant, it mated with all three females in the cage.

A day or two later, the original male (No. 1) was replaced in the cage with disastrous results! After a fierce fight, the new resident dominant

N. Smith

Adult male (banded) and female (unbanded) of the Fijian Banded Iguana, showing sexual differences in colour and pattern and the long, whip-like tail.

H. G. Cogger

A group of young iguanas on the hibiscus plant on which they feed. The mother (right) indicates the relative size of the young.

Gregory Millen/Australian Museum

A male iguana emerging from its egg.

(No. 2) had such an advantage and was so aggressive that No. 1 had to be removed.

Intrigued, I then removed No. 2 and within minutes one of the two remaining males (No. 3) had assumed dominant colours and position, and subsequently attempted to mate with each of the females. Next day, attempts to return Nos. 1 and 2 were unsuccessful, both losing to the *resident* dominant No. 3.

Finally, I removed No. 3, and the remaining male, as by now I anticipated, assumed full male colours and subsequently prevented the re-introduction of Nos. 1, 2 and 3.

It had become obvious that any male, once having attained dominance in the cage, had a psychological advantage over any other male. That this dominance is highly ritualized rather than a result of greater prowess is clear from the fact that within a few days the lowest individual in the 'pecking order' had reached the top position without any increase in size or prowess.

This exercise was a striking, text-book example of a male hierarchy. Presumably, due to dispersal of the population, such a situation would not normally occur in a natural habitat.

Virtually nothing is known of reproduction in the wild. Adults are seldom enough seen, but young are scarcely ever encountered. Indeed, until our first hatchling arrived, it was not known whether the banded male pattern originated in the egg or developed only as the lizard approached maturity. As can be seen in the photograph, the males are strongly banded when they emerge from the egg.

In captivity, mating is preceeded by marked display by the male, who first positions himself in front of the female, adopts his bright colours, and goes through a complex set of head-bobbing patterns, frequently nudging the flanks and foreparts of the female with his snout. As he becomes more excited, head-bobbing is so rapid that the head appears to vibrate. Eventually the male grasps the flesh of the female's neck with his jaws, and manoeuvers his vent below the female's hind limbs so that one of his two penes can be inserted into her cloaca.

It is not known how long a successful mating lasts, but it appears to be no more than a few minutes. Similarly, it is not known how long a period elapses between mating and egg-laying, but the available evidence suggests that it is about four to six weeks.

When ready to lay, the female descends to the ground and spends about half a day finding a suitable site and digging a short burrow, generally not much longer than herself, in which she lays three or four eggs. The eggs are oval, averaging 40mm in length and 30mm in diameter. The burrow is dug out by alternate use of her forefeet, the loosened soil being thrown or pushed out with the hind feet. She manipulates each egg, as it is laid, into a corner of the nesting chamber with her snout. When all are laid, usually within fifteen minutes or so, she begins the long task of filling in the nest. This is done mostly by pushing soil down the burrow with her snout, then packing it hard with a strong, jerky action of her head. The soil is packed carefully and deliberately and the sound of her snout hammering on the ground carries a considerable distance. In my laboratory, the eggs were usually removed from the nesting chamber as they were laid and placed in an incubator. The female reacted aggressively to this action, but would always complete the filling-in process even when all the eggs were removed.

At a temperature of 30°C the eggs take seventeen to twenty-three weeks to develop. The growth of the eggs (due to the uptake of water from their surroundings) is shown in the accompanying graph, together with the initial growth of the new hatchlings. The weight of the full-term lizard is only about forty percent of the total weight of the egg. The remainder is taken up by the weight of the shell, fluids, etc. Hatchlings have an average body length of 65mm, growing to about 160mm in adulthood. Males are slightly larger than females. The tail is exceptionally long and slender—nearly three times as long as the head and body.

The young grow rapidly at first, with feeding habits similar to their parents'. Some initial problems have been encountered in providing an adequate diet, but vitamin and calcium supplements appear to have overcome major problems. The Banded Iguana is omnivorous. Its staple diet appears to be plant materials—leaves, flowers and fruits—but insects are also eaten. In captivity it thrives on both the leaves and flowers of hibiscus (showing a clear preference for bright red flowers) and on a variety of fruits and insects.

It is difficult to avoid blatant anthropomorphism when studying Fiji's Banded Iguana. Its exotic origins, complex behaviour and delicate appearance and temperament make it a biologist's delight. One can only hope that it will continue to survive in those parts of the Fijian Islands where man's activities do not result in breakdown or removal of the the original forests.

FURTHER READING

Cahill, Cynthia *The Banded Iguana of Fiji*, Fiji Museum Educational Series No. 2; Fiji Museum, Suva, 1970.

IN REVIEW

IMAGES FROM AUSTRALIAN SEAS

BY GERALD R. ALLEN

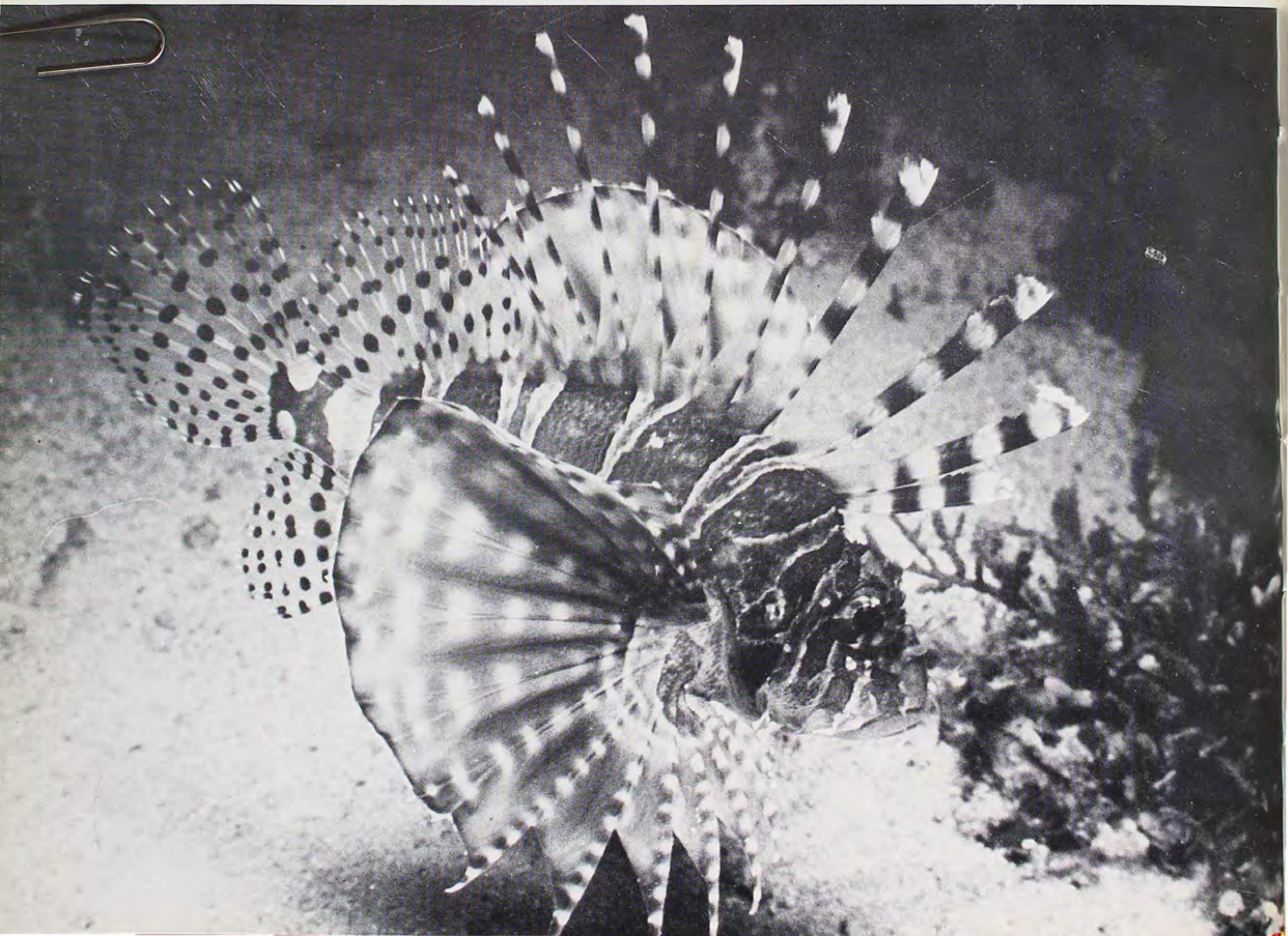
AUSTRALIAN MARINE FISHES IN COLOUR, by Neville Coleman, *A.H. and A.W. Reed, 1974; 108 pages; illus.; $4.95.*

This book includes forty-eight colour photographs of Australian shore fishes by one of the country's leading undersea photographers and amateur naturalists. A brief, but informative introduction is followed by the photographic section, which is attractively presented with each species appearing in approximate phylogenetic sequence (the primitive fishes such as sharks and rays are featured first, followed by the more specialised bony fishes). For each fish, Coleman gives the family, common, and scientific names and the author's name and year of description. Below this information, a page of text includes notes on distribution, food habits and behaviour, along with personal anecdotes which greatly enhance the full-page photograph on the opposite leaf.

Generally, the photographs are of high quality. The exceptions are those of the White-tipped Reef Shark, Manta Ray, and Shark Mackeral, which are slightly dark or poorly contrasted. The photos of the Trasselled Wobbegong, Weedy Sea-dragon, Old Wife, High-backed Boxfish, and

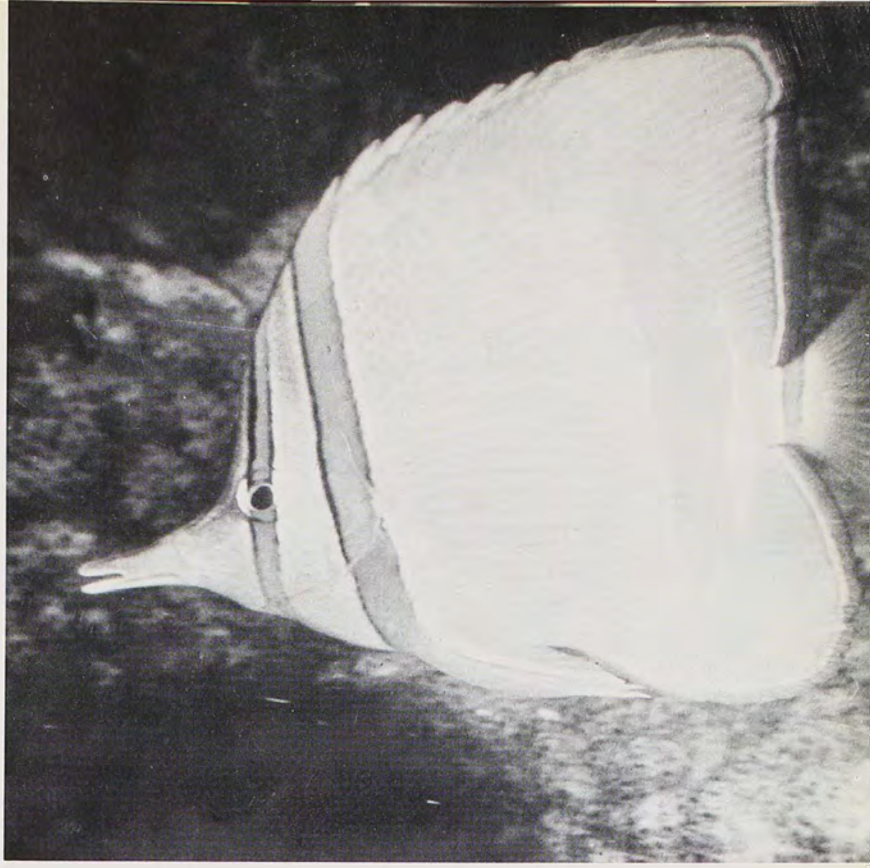
Butterfly Cod, *Brachirus zebra*

Neville Coleman



Porcupinefish are prize-winners by any standards. The author effectively exhibits the principle of camouflage colouration with excellent pictures of the Small-toothed Flounder, Peacock Sole, and Sargassum Fish. A good balance is achieved between temperate and tropical species, although the inclusion of some cryptic forms in a popular book of this type is questionable. Fishes in this category are the Sea Whip Goby and the Precious Clingfish.

The main shortcoming of this work is its brevity. Although the author had to conform to the other booklets in the Reed's Colourbook Series with regard to title selection. *Australian Marine Fishes* is an overly ambitious designation considering that such a small fraction of the over two thousand species inhabiting Australian seas are featured. —*Gerald R. Allen, Curator of Fishes, Western Australian Museum, Perth.*



Neville Coleman

Margined Coral Fish, *Chelmon marginalis*

AUSTRALIAN LANDFORMS, by C. R. Stone, *Wren Publishing Pty. Ltd., Melbourne, 1974; 80 pages; illus.; recommended price, $4.95.*

This book deals with Australian landforms in a fairly simple presentation with three sections. A short geological introduction leads into a main section of mostly coloured pictures interspersed with sporadic maps and illustrative diagrams and the book is completed with a series of diagrammatic explanations of the geological forces shaping landforms. The main topics are mountain, coastal, arid, and limestone landforms and although these cover a reasonable range, it is a pity that one or two of the more miscellaneous but interesting landforms, such as meteorite craters, were not included. The general layout of photographs and explanatory diagrams is a good idea, but more intermingling of the two, placing appropriate sections together, would have given more continuity.

The front cover, with a spectacular shot of the Macdonnell Ranges, bodes well for the pictorial side, but although many of the photographs are spectacular and interesting, some of them are quite disappointing, being too diffuse (Frenchmans Cap and Lake St. Clair on p. 17) or too dark (the Hazards and the Grampians on p. 19). Some photographs are a bit repetitive (shots of Cape Raoul cliffs and The Bay of Islands stacks). The caption under a photograph, supposedly of Ayers Rock (p. 44), states that the strata are almost vertical, but they certainly do not look it.

The biggest weakness in the book is in the geological support to the photographs and diagrams, there being a number of loose statements, errors and misconceptions. One of the main confusions lies with the nature of the dolerite cappings in Tasmania, which, in the book, are regarded as lava flows and confused with later basalt lavas. The dolerites are in fact intrusive sheets of Jurassic age (more than 100,000,000 years as stated, but more accurately 165,000,000 years old) and their 'organ pipes' jointing is due more to much later uplift than to the cooling effect claimed. The Mount Wellington dolerite cap was *not* extruded from the volcanic plug there, which is a later Tertiary feature, and dolerite did *not* block the South Esk River at the Cataract Gorge as lava flows, although Tertiary basalt lavas much further south may have caused the diversion.

Other geological statements are challengeable. Thus, gneiss is *not* always a metamorphosed granite (p. 8), but commonly derives from metamorphosed sediments; limestone is *not* necessarily associated with uplifts (p. 53), often the reverse is true; horizontal layers do *not* indicate that The Twelve Apostles are uplifted marine sediments (p. 34), it is their lithology and marine fossils that do this; the uplift of Freycinet Peninsula does *not* account for the sea not actively eroding the cliffs to cause undercutting (p. 40), it is the massive granite lithology as compared with undercutting of strata elsewhere on this coast; much of the Hamersley Ranges are sedimentary-Proterozoic and were *not* one of the first sections of the earth's crust to cool (p. 22); the Macdonnell Ranges were upfolded considerably more than the stated 15 million years ago (p. 20), and submerged areas of many Australian coastal areas are *not* fiord coasts as is the impression given on page 73.

This book is mainly useful as a pictorial tour of Australian landforms and anyone wishing for detailed, geologically-based accounts should turn to some of the texts listed in the book's bibliography, to Twidale's *Geomorphology* (N.A.P.), or the excellent volumes in *An Introduction to Systematic Geomorphology*, ANU Press, Canberra.—*F. L. Sutherland, Curator of Rocks and Minerals, The Australian Museum.*

AUSTRALIAN BANKSIAS by Douglas Baglin and Barbara Mullins; AUSTRALIAN EUCALYPTS by Douglas Baglin and Barbara Mullins; AUSTRALIA'S WILDFLOWERS by Frank Hurley and Barbara Mullins; *A. H. and A. W. Reed, Sydney, 1974; 32 pages, illus., $1.50 each.*

As a professional ecologist, it is unlikely that I would ever buy these books except as a gift, so I asked my wife for her opinion of them. As she professes little botanical expertise, I believe her opinion should be typical of most Australians who appreciate the fantastic variety of our native plants. We both agree that these books would make excellent gifts, especially for friends overseas who would like factual information coupled with glossy colour photographs.

The first, *Australian Banksias* is, I believe, the best of the three. The layout is aesthetically pleasing and the text excellent. Some twenty-six species of *Banksia* are illustrated by eighty-odd photographs ranging from close-ups of the incredible architecture of the inflorescence to well-chosen shots of the habit and habitats. Each photo is labelled with name and generally with location.

Unfortunately, the photos in *Australian Eucalypts* are not labelled and some are duplicated in part. The colour in a number of the photos does not look entirely natural but generally, the composition and layout is excellent.

The last book, *Australia's Wildflowers*, is a miscellany of sixty-odd photos by Frank Hurley with brief text notes by Barbara Mullins. Unlike the other books, a number of the photos are of artificial arrangements of different species designed to give a pleasing appearance.

Personally, I do not like this approach, but it is used sparingly and certainly would not deter me from buying or recommending the book as a gift.

Each book is the same size and is a reprint of an earlier edition. It is fairly obvious that Reeds and the Baglin/Mullins team have a successful formula and the reissue of these books before Christmas emphasises this.

I noticed one or two minor errors in names (e.g. the photo of *Grevillea banksia* is titled *G. banks* and the photo of *Anigozanthos manglesii* is titled *A. manglesh*). On the inside back cover of *Australian Eucalypts* is a recipe for an insecticide which, in the light of current environmental awareness, seems antiquated. The mixture advocated contains DDT and lead arsenate.

These criticisms are minor. I unreservedly recommend all three books, especially *Australian Banksias*, as excellent. Good photos and factual text make them ideal Christmas gifts for adults and children alike, and as 'propoganda' material for overseas, they are superb.—*John Pickard, Plant Ecologist, National Herbarium of NSW.*

Banksia menziesii

Douglass Baglin

Douglass Baglin

Pultenaea stipularis

Douglass Baglin

Spotted Gum,
Eucalyptus maculata