

REFERENCE

# AUSTRALIAN NATURAL HISTORY



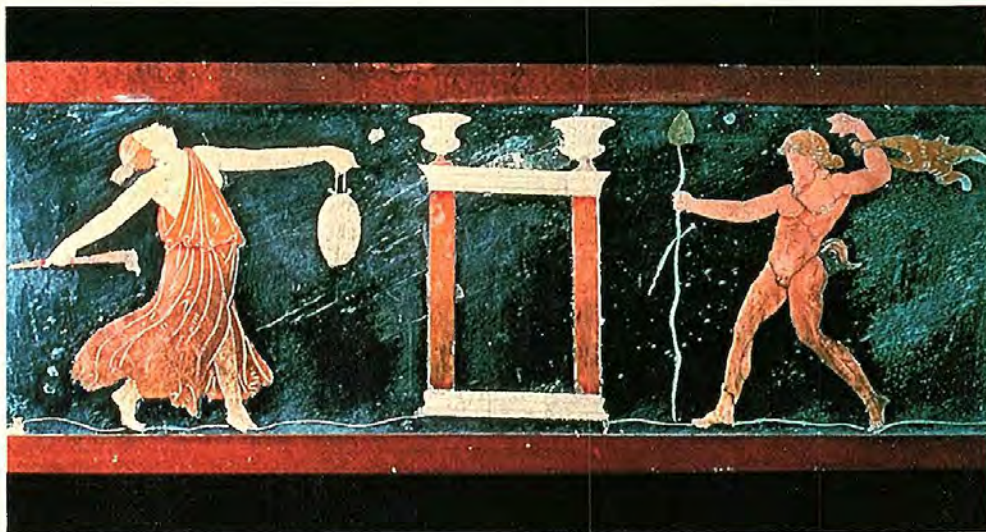
Vol. 20 No. 4  
1980 \$2.20

# AUSTRALIAN NATURAL HISTORY

PUBLISHED QUARTERLY BY THE AUSTRALIAN MUSEUM, 6-8 COLLEGE STREET, SYDNEY TRUST PRESIDENT, JOE BAKER MUSEUM DIRECTOR, DESMOND GRIFFIN VOLUME 20 NUMBER 4 1980



The Christmas bell, *Blandfordia grandiflora*, is but one of the many colourful plant species found in Australian heathlands. Photo by Tony Rodd.



Formally decorating the *tablinum* in the House of the Coloured Capitals, Pompeii, was the above intarsia panel showing a dancing maenad and satyr on either side of a small shrine. Photo by J.-P. Descoedres/Sydney University.

EDITOR  
Barbara Purse

ASSISTANT EDITOR/ART DIRECTOR  
G. Dennis Campbell

CIRCULATION  
Bruce Colbey  
Jack van der Kooi

Annual Subscription: Australia, \$A8.00; New Zealand, \$NZ11.50; other countries, \$A9.50. Single copies: Australia, \$A2.20, \$A2.65 posted; New Zealand, \$NZ3.00; other countries, \$A3.40.

New Zealand subscribers should make cheque or money order payable to the New Zealand Government Printer, Private Bag, Wellington.

Subscribers from other countries please note that moneys must be paid in Australian currency.

Opinions expressed by the authors are their own and do not necessarily represent the policies or views of The Australian Museum.

## CONTENTS

FROM THE INSIDE	109
Editorial	
NATURE'S FLOWER GARDENS	111
by Harry F. Recher, Marilyn D. Fox and Helen Tranter	
A POMPEIAN HOUSE REVISITED	117
by Jean-Paul Descoedres	
KOALA, <i>Phascolarctos cinereus</i>	123
Centrefold	
BUTTERFLIES AND EVOLUTION	127
by R. L. Kitching	
FOSSIL SQUIDS AND PAST GEOGRAPHY	131
by Graeme Stevens	
IN REVIEW	137
HIGHER FUNGI IN FOCUS	139



# FROM THE INSIDE



The tendency for the wanderer, *Danaus plexippus*, to form over-wintering aggregations presents some interesting evolutionary problems for its predators. Photo by C. V. Turner/The Australian Museum.

*Gymnopilus* (above right) is a wood-destroying mushroom genus commonly found in temperate areas of Australia. Mushrooms and other members of the plant group known as the 'higher fungi' often make interesting photographic studies. Photo by G. Dennis Campbell The Australian Museum.



I am a keen gardener and a sucker for native plants, and however many times my green fingers are superseded by my black thumbs I persist in strong endeavour to go native in my bit of dirt on the lower North Shore of Sydney. For conservation and related reasons many of our readers will therefore share my enthusiasm for the article 'Nature's Flower Gardens' and, like me, perhaps assuage horticultural frustration in reading, then visiting, an Australian heathland.

We are happy to publish another article on Pompeii and its treasures and hope many of our readers will be able to see the exhibition currently touring the country . . . it is magnificent in concept and presentation, it is of inestimable value to our own anthropologists, and our scientists in the field and to archaeology and conservation, and the work at present proceeding on the site of the House of the Coloured Capitals is led by an Australian team making a vital contribution to world science.

Women-libbers may be surprised to learn that the symbol of mediaeval women's status—the chastity belt—did not originate in ancient times, neither did it entirely go out of fashion with a more enlightened age. In fact, the chastity belt is still much in vogue among, of all creatures, the butterflies. If readers' curiosity is whetted by my bit of anthropomorphism, turn to the article by Robert Kitching on 'Butterflies and Evolution'.

A function of The Australian Museum is to enhance our understanding of the world about us. This magazine serves that function and hopefully enhances the rich store of recorded observations by men and women practically engaged in learning from the book of nature. Graeme Stevens has provided a fascinating study of a group of fossil squids called belemnites. He draws some thought-provoking conclusions about these ancient squid-like creatures—an article which will influence the mind of anyone who next has an 'eye-ball to eye-ball' confrontation with present day squids.

A new photographic feature appears for the first time in this issue. Called 'In Focus', we hope to make this a regular series.

Which reminds me—many readers are expressing bewilderment at the sporadic nature of *Australian Natural History* production. To clear up the most frequently expressed query—a subscription covers four issues, renewals are due on receipt of the fourth issue and are not related to dates. As this issue goes to press the year 1981 is upon us—a peaceful and properous year to all on the outside from all on the inside. It is our major resolution for 1981 to catch up the backlog and get the magazine out on a regular schedule.

Barbara Purse  
Editor



# NATURE'S FLOWER GARDENS

by Harry F. Recher,  
Marilyn D. Fox and Helen Tranter



The flowers of this heath plant, *Epacris impressa* (above), make a colourful addition to the heathlands of Australia. Photo by National Herbarium of NSW.

A colourful carpet of flowers appears soon after fire (left). Scattered between the burnt remains of the heath-leaved banksia, *Banksia ericifolia*, are yellow goodenia flowers, *Goodenia heterophylla*, and white flannel flowers, *Actinotus helianthi*. Photo by Tony Rodd.

Heaths are plant communities primarily dominated by low shrubs, the colours of which in certain times of the year would rival any well-kept suburban garden. These natural flower gardens are closely interrelated with soil conditions, fire and the resident animal life. Harry Recher, Curator of Vertebrate Ecology, and Helen Tranter, Research Assistant, of The Australian Museum, and Marilyn Fox, Botanist, of the National Herbarium of New South Wales at the Royal Botanic Gardens have teamed up to document this interesting, and vulnerable, ecosystem so familiar to hard-core and weekend nature enthusiasts.

A flower garden. There may be no better image of an Australian heath than that simple description. Australia's heaths are among the richest and most diverse plant communities in the world. Each winter and spring these superficially monotonous shrublands put on a floral display which transforms them into one of the most spectacular and colourful plant communities found in Australia. It is from the heathlands that the majority of native plants propagated in Australian and foreign gardens are derived. The native honeysuckles, *Banksia* spp.; bottlebrushes, *Callistemon*; and spider flowers, *Grevillea*, which have become the mainstay of landscape architects from Perth to Los Angeles, are shrubs of the heathlands.

Heaths are shrublands; plant communities dominated by evergreen, sclerophyllous (hard-leaved) shrubs which are mostly less than two metres high. In this sense the chaparral of California, the púna of the Andes, the South African fynbos, and the wallum of Queensland are all heaths. They differ, of course, in the kinds of plants which form the community. Originally heath meant 'waste land' and referred to the low shrublands of north-western Europe dominated by heather, *Calluna vulgaris*, and other plants in the family Ericaceae. These plants do not occur naturally in Australia, but the similar looking and closely related family Epacridaceae is widespread in Australian heathlands. It was, therefore, natural that the early settlers in Australia would call the low shrublands of their new home 'heaths'.

In Australia, heath occurs around the coast from Cape York to Tasmania and through Victoria and South Australia to Geraldton in Western Australia. Although restricted to humid and subhumid regions, climate is not a major factor in the development of heathlands. Heaths are found in the tropical north and the cool south, at the edge of the sea and in the mountains, but nowhere are they really extensive.

The distribution of heathlands in Australia is determined by edaphic (soil) conditions. Australian heaths are largely confined to acid, sandy soils which are podzolised. Such soils are nutrient-poor and, as is the case with the unimproved heaths of Europe, unsuited for crop farming. Nitrogen and phosphorus levels are especially low. The phosphorous content of the soil may be only 0.002 per cent, a low value even for Australia with its notoriously

poor soils. Heath vegetation is highly flammable, and the low nutrient levels of the soil may result in part from losses during fire.

Heath soils are often waterlogged for part of the year and affected by drought for the remainder. Heaths can be classified as 'wet' or 'dry' with the level of the water table reflected roughly in the height of the vegetation. Wet heaths occur on soils in which a relatively shallow layer of sandy soil overlies a more or less impermeable layer of sandy clay or bedrock. Such soils can verge on being swamps during the wet season. The soils of dry heaths are deeper and well drained. Wet heath is usually dominated by low shrubs and includes a large component of sedges. Dry heath tends to be dominated by tall shrubs. Sedges and grasses are less abundant. In cooler climates or on upland sites, sedges and grasses may be the dominant vegetation in wet heaths.

Except in its low stature, a heath is not a uniform expanse of vegetation. The diversity of its plant species is repeated a thousand times over in the pattern of the heath itself. Each change in elevation, aspect, depth of soil and drainage leads to the development of a unique association of species. Imposed on this pattern of topography are the events of history; fire, storm and animals create new environments to be reflected in the pattern and process of the plant community. Vegetation patterns are often subtle and may be a response to changes in elevation of a few centimetres or to fires which occurred in previous decades. The effect of environmental changes on heath vegetation has been studied in detail at the Myall Lakes National Park on the north coast of New South Wales by botanists from Sydney University.

The heaths, or moors as they are known locally, at Myall Lakes form a flat expanse of vegetation between the high ocean dunes and the lakes. A casual inspection of the moors creates the impression of an unvarying heathland, but careful examination reveals a well-defined pattern of alternating vegetation types. This is especially easy to see in spring when the different plants are in bloom and each line of vegetation has its own set of colours.

The heathland at Myall Lakes has developed on parallel sand dunes formed about 30,000 years ago and which have been eroded to the point where the difference in



A view of a typical dry heath community near Sublime Point, NSW (top left). Short shrubs, forbs and grasses in the foreground lead into a much taller eucalypt woodland. Photo by Howard Hughes/The Australian Museum.

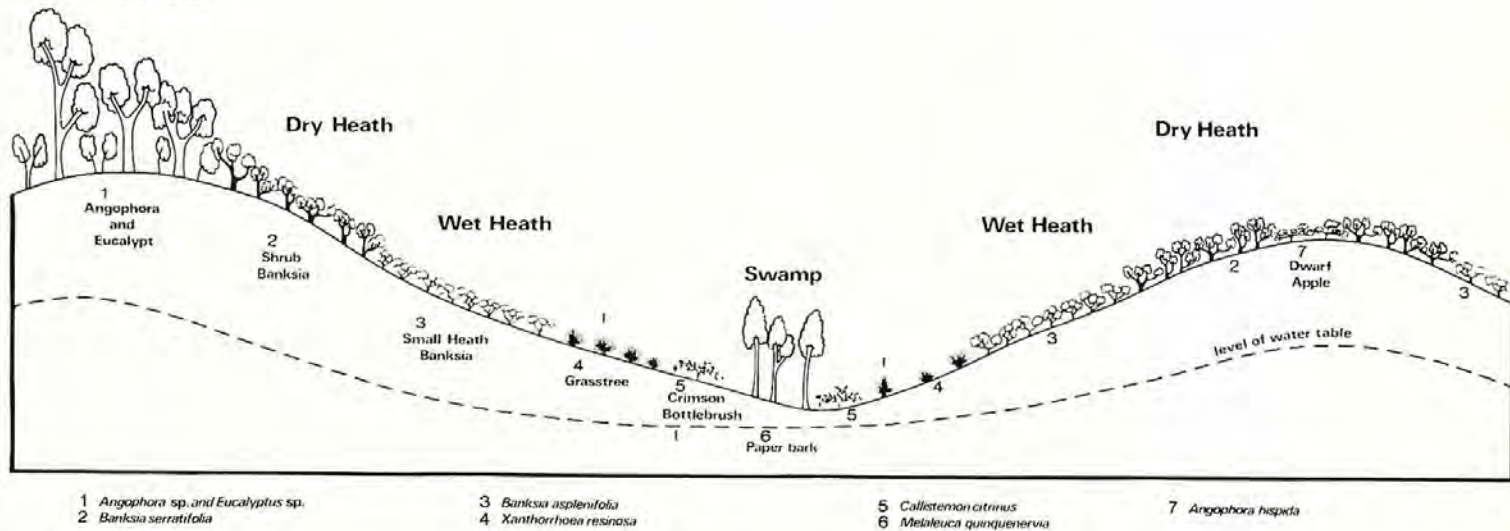
Fire is not an uncommon sight in Australian heathlands (above). Many heath plants are specifically adapted to the varied effects of fire. Photo by Harry Recher/The Australian Museum.



The ground parrot, *Pezoporus wallicus*, and the tawny-crowned honeyeater, *Phylidonyris melanops*, are two Australian birds totally restricted to heaths. Rarely seen because of its preference for low thick vegetation, the ground parrot (centre left) is found in coastal heaths. Photo by G. Chapman. The tawny-crowned honeyeater (bottom left) is an elusive bird which nests in shrubs close to the ground. This species feeds on both nectar and insects. Photo by M. McNaughton.



**Eucalypt Woodland**  
on dry ridges



elevation between the crest of the dune and the swale is a matter of centimetres. This difference in elevation is sufficient to affect soil drainage and leads to different plant communities. Moreover, a hard pan has developed in many of the swales which impedes drainage. As a result, a wet heath community develops, alternating with a dry heath on the dune crests.

The distribution of individual plant species illustrates the pattern of dry and wet heaths at Myall Lakes. Such plants as old man banksia, *Banksia serratifolia*, and the native pea, *Dillwynia pedunculata*, grow only on well-drained sites. The fern-leaved banksia, *Banksia asplenifolia*, and *Dillwynia glaberrima* grow on both well-drained and waterlogged sites, but another pea, *Dillwynia floribunda*, and the swamp banksia, *Banksia robur*, are restricted to the swales where the soil is waterlogged for much of the year. Workers from CSIRO have found comparable patterns on the heaths of the Nadgee Nature Reserve in southwestern New South Wales, but there the effects of frequent fires set by graziers may have affected the distribution of plants.

Fire is a frequent event on Australia's heathlands. The vegetation is flammable, and it is likely that Aborigines regularly burnt the heaths to drive game or to attract kangaroos to the new growth following the fire. After Europeans settled Australia, graziers commonly burnt the coastal heaths to encourage the growth of grass for their cattle.

Frequent burning can change the composition of the heath vegetation. Shrubs and other long-lived plants are discouraged and replaced by grasses, sedges and quick growing forbs. If fires are frequent enough, the effects may be permanent. During fires nitrogen and phosphorous are lost and, although heath plants are adapted to growing in nutrient-poor soils and to surviving fires, there are limits to their ability to regenerate.

To withstand fire many heath plants such as old man banksia have a heat-resistant bark. Some species regenerate by vegetative

means after burning. Shoots develop either from a swelling or lignotuber at the base of the stem or from epicormic buds buried beneath the bark. The fern-leaved banksia is one plant which develops from a lignotuber while the heart-leaf apple, *Angophora cordifolia*, sprouts from epicormic buds. In other species the adult plant is killed by fire, and the species regenerates from seed; for example, the heath-leaved banksia, *B. ericifolia*. Many heath plants require fire to release their seed which is protected from the heat in hard, woody capsules. Good examples of these are the many species of hakea and banksia. Others like the wattles, *Acacia* spp., and the native heathers (Epacridaceae) develop from seed which is stored in the soil. The seeds of these plants may not sprout unless they are heated.

Some plants which are killed by fire and grow from seed may need a long period between fires to allow them to mature and flower. The heath-leaved banksia which is an important species in the coastal heathlands in New South Wales does not bloom until it is at least five years old and does not accumulate large amounts of seed until it has flowered several times. If the heaths burn or are burnt deliberately more often than once in every ten years or so, this species and others like it may be reduced in abundance, substantially changing the character of the heath. Changes in the abundance of the heath-leaved banksia may have pronounced effects on the animals of the heath.

Unlike plants, animals lack special adaptations to survive fire. At best they avoid burning by seeking shelter from the heat or by running from the flames. Despite this simple response, surprisingly large numbers of animals survive even the hottest fires. Inspection of a heath during a slow-moving fire will show birds and large mammals like kangaroos moving calmly in front of the flames. Birds can be seen moving through still smoking vegetation feeding on insects killed or stunned by the heat and smoke. Small lizards, frogs and insects survive under rocks or in burrows which remain cool and moist.

Profile through a typical sand heath. Notice the zonal response of the plant species to the elevation of the land and the level of the water table. Diagram modified from R. C. Carolin (1971, *Proc. Ecol. Soc. Aust.* 5:123-129).



Immediately after fire has moved through heath very little foliage remains, resulting in either the death or displacement of most of the heath animals. However, within a week after a fire at Lucas Heights, NSW (top left) heath-leaved banksia, *Banksia ericifolia*, and grasstrees, *Xanthorrhoea resinosa*, are beginning to show signs of regeneration, and grazing mammals will quickly respond to this regrowth. Photo by Marilyn Fox/National Herbarium.

Detail of *Banksia* cones immediately after fire is shown (top right). A natural and necessary process in the life history of many heath plants, fire results in the release of the seeds from the woody capsules comprising the cone. Photo by Howard Hughes/The Australian Museum.

Even after the above-ground plant is completely burnt away, *Banksia serrata* will regenerate, with shoots being produced from a lignotuber—a swelling below the ground at the base of the plant. The photograph (above left) shows such a lignotuber exposed by erosion. Photo by Tony Rodd.

Another post-fire vegetative regeneration process exhibited by some heath plants is the formation of epicormic shoots. Young shoots of a banksia (above right) have sprouted from buds beneath the heat-resistant bark. Photo by Howard Hughes/The Australian Museum.

Some animals are killed during fires, but the most important effect of fire for animals is the change in vegetation. Fire destroys the complex vegetation of the heath. After burning, a heath is devoid of foliage and there is no cover and little food. Mortality during this immediate post-fire period may be high, but as the heath sprouts and grows, it is rapidly re-populated.

Some animals of the heath find the early stages of regeneration particularly favourable. Kangaroos and wallabies respond to the flush of new growth, and mobs may congregate on newly burnt areas. There they feed on the new vegetation which is especially rich in nutrients. The nutrients released from the old vegetation and litter by the fire are quickly taken up by the new growth.

Populations of the introduced house mouse, *Mus musculus*, can increase dramatically on heaths in the first years after a hot fire. In the Myall Lakes National Park the New Holland mouse, *Pseudomys novaehollandiae*, is slower to respond and reaches peak abundance in the third year after fire in dry heath habitats, while in the wet heaths the eastern chestnut mouse, *Pseudomys gracilicaudatus*, also reaches maximum abundance in the third year. The common dunnart, *Sminthopsis murina*, appears to be most abundant on heaths four years after fire. Another native

mouse, the heath rat, *Pseudomys shortridgei*, is only found on heathlands from 8 to 12 years after fire in Victoria. An abundance of food, cover and perhaps the absence of other small mammals enables these species to increase in numbers. As the vegetation matures, they become less abundant and may be rare on older heaths.

Birds show a similar response to fire. In the 1972 wildfire on the Nadgee Nature Reserve, the heaths burnt to mineral soil, and few birds were present on the bare expanse of seared stems and drifting ash. Nonetheless, many species returned to nest in the first spring after the fire and, although numbers were low, the morning songs of birds could be heard. Within four years, bird populations on the heaths were back to normal, and some birds had increased in numbers over the pre-fire environment. These were birds like the ground parrot, *Pezoporus wallicus*, which need low vegetation. The ground parrot prefers dry heaths with sparse vegetation. This is the situation which develops during the period of 3 to 7 years after fire. Heaths which are protected from fire become overgrown by tall shrubs and are unsuitable for the bird. One could conclude from this that the conservation of the ground parrot and other heath animals is a matter of managing, rather than merely preserving, areas of heathland.



Although most birds and mammals are sufficiently mobile to stay ahead of the flames, some individuals, such as this ring-tail possum (top right), will ultimately succumb to the heat or smoke of a heath fire. Photo by Harry Recher/The Australian Museum.

Like a number of other small mammals found in heaths population numbers of the New Holland mouse, *Pseudomys novaehollandiae* (bottom right), fluctuate following fire in response to changes in factors such as availability of food and cover and the presence of competitors and predators. Photo by A. C. Robinson.

Insects are important pollinators of the many nectar-rich flowers found in heathlands. One frequently finds scattered upon and among the beautiful blossoms of the dwarf apple, *Angophora hispida* (below), a number of small insects busily going about their daily feeding routine, which concurrently results in the transport of pollen from one flower to another. Photo by Howard Hughes/The Australian Museum.



A heath should be managed through the use of fire to retain all of its diverse plants and animals. Fire should be used to ensure that all stages of post-fire vegetation are available. In this way each kind of animal can find the habitat which provides its specific needs. But it may not be necessary deliberately to burn heathlands. Rather, the role of management may be to manipulate the many naturally occurring fires to ensure that the heath burns, but not too often.

Australian heaths are rich in animal life, and the birds, mammals, reptiles, frogs and invertebrates of the heaths form a distinctive community. Some species, such as the dibbler, *Antechinus apicalis*, in Western Australia and the ground parrot in the east, are among the continent's rarer animals and depend upon heathlands for their survival. Most animals, however, occur in a wider range of habitats and may be more abundant in forests where there is a layer of sclerophyllous shrubs similar to that in heaths. This is well illustrated by birds where no fewer than 414 species—more than half of the Australian avifauna—have been recorded as occurring in heaths, shrublands and scrubby heaths. No more than 20 of these are restricted to heath or shrub habitats, and the vast majority of birds seen on the heathlands are transients or visitors. In New South Wales about 30 species of birds are typical of coastal heaths. These are the birds

you would expect to see when bird watching, but of these only four are more common in heathlands than in other habitats. Two of these, the ground parrot and the tawny-crowned honeyeater, *Phylidonyris melanops*, are confined to heath environments.

Despite the wide distribution of heath animals, they have evolved a close relationship with the heath vegetation; a relationship which is all the more impressive when one recalls the poor soils and difficult conditions under which heaths develop and grow. One of the most striking features of Australian heathlands is the abundance of nectar-rich flowers which are pollinated by birds and mammals. Outside the breeding season, winter or summer, nectar-feeding birds—honeyeaters, lorikeets and silvereyes—move along the east coast and aggregate wherever there is an abundance of nectar. The concentrations of birds are mostly associated with the species of banksia, but blooms of eucalypts and epacrids also attract birds. This phenomenon is particularly spectacular on the heaths near Sydney where each winter tens of thousands of honeyeaters congregate on the flowers of the heath-leaved banksia.

Nectar-feeding birds depend on nectar for energy, and many plants have adapted to pollination by birds. Flowers pollinated by birds tend to be red or tawny in colour, secrete

nectar during the day when birds are active and have their pollen placed so that it is transferred to the bird. The bird then carries the pollen to another flower where it fertilises the developing seed.

Not all heath plants are pollinated by birds. Most are probably pollinated by insects, and a few are pollinated by mammals. Some, like the eucalypts, are visited by bats, and others like the heath-leaved banksia are pollinated by rats and small marsupials. The heath-leaved banksia is visited by birds during the day and birds carry banksia pollen, but this banksia produces exceptionally heavy amounts of nectar (it forms icicles of honey during dry weather) and secretes the nectar during the night. These features and its strong odour are what one would expect from a plant pollinated by mammals which locate the flower by its aroma and are attracted by the large amount of nectar. Bush rats, *Rattus fuscipes*, and brown antechinus, *Antechinus stuartii*, trapped in heaths where the heath-leaved banksia is blooming have large amounts of its pollen on their fur showing that they visit the flowers and act as pollinators. In Western Australia, the honey possum, *Tarsipes spenserae*, is specially adapted to feeding on nectar and is probably an important pollinator of many heathland plants.

Heathland conservation has been a battle against mining, timber, grazing and real estate

Coastal heathland in Bouddi National Park, NSW (right). Photo by Doug Benson/Royal Botanic Gardens.

Boneseed, *Chrysanthemoides monilifer* (bottom right), is an introduced weed that has replaced many of the native heath plants of northern NSW. Photo by Doug Benson/Royal Botanic Gardens.

The heath vegetation of Australia is found on soils very low in plant nutrients and which are often waterlogged. Conditions that suit the development of heath can occur on coastal sand deposits, on sandstone or at high altitudes. The map (below) indicates those parks and reserves in NSW where heaths occur. Diagram modified from Carolin Pettigrew/NPWS.



interests. In northern New South Wales and southern Queensland, heaths have been degraded by mineral sand mining and in Western Australia by mining for bauxite. Queensland is converting large areas of its wallum country to plantations of exotic pines. The growth of the tourist industry and the proliferation of holiday and retirement complexes along the coast threaten heathlands from Cape York to Geraldton. Grazing, too frequent fires, roads and military manoeuvres have been additional problems. Despite these difficulties, in New South Wales, Victoria, Tasmania and South Australia large areas of heathland are already reserved in national parks or nature reserves, and the major problem with heaths in these states is one of management: how to maintain a heathland with all its diverse plants and animals in an environment visited by countless people each year. In the other states, there is still a need to set aside heathlands as reserves and reference areas.

The fact that heaths develop only on nutrient-poor soils poses special management problems. Any addition of nutrients will change the heath by allowing plants which require high levels of nutrients to colonise. Seedlings of many heath plants are poisoned by higher than normal levels of phosphate. Even the small amount of nutrients contained in orange peelings is sufficient to raise the nutrient levels of heathland soils and lead to changes in the

heath vegetation. Obviously the run-off from roads, fertilisers used by mining companies to accelerate the growth of plants after mining, and the drift of fertilisers from agricultural lands and pine plantations pose a more serious threat to heathlands than orange peelings. Nonetheless, the litter which seems to accompany visitors to national parks in unlimited quantities is a management problem in heathlands.

The corollary of this is that plants that have evolved on other continents in similar low-nutrient environments can invade the Australian heaths, and in the absence of their normal predators and diseases, grow unchecked. Ultimately these weeds can out-compete and replace native plants. The major weed of heaths in northern New South Wales is such a plant. It is commonly known as boneseed, *Chrysanthemoides monilifer*, and comes originally from Africa. As with some other introduced weeds, it was purposefully introduced to bind sand when the native vegetation was disturbed or removed. Now it is smothering native shrubs and converting rich heath and shrublands to monotonous, albeit colourful, swards of boneseed.

Infrequent hot fires are a normal part of the heath environment. Most of these fires will be started by people, and the challenge is to ensure that fires are hot enough to stimulate the growth of vegetation but not so frequent as to

prevent the longer-lived plants from developing seeds. Management also needs to consider the requirements of animals for different stages of growth following fire. The deliberate burning of heaths to control fire hazards, therefore, creates problems. Other problems arise from changes in the water table or enrichment of the soil following mining or from road building, from grazing by domestic animals and from the use of heaths for recreation.

The management of heathlands must, therefore, take into account the immediate impact of human activities and the longer term consequences of each change to the heath environment. The manager needs to integrate each of these effects and evaluate the impact on a complex ecosystem. It is not an easy task, but it is a challenge we must accept if we are to continue to enjoy the beauty of our rich heathlands.

#### FURTHER READING

- Fairley, A. T. 1976. *A Field Guide to the Sydney Bushland*. Rigby Ltd., Adelaide.
- Recher, H., D. Lunney and I. Dunn. 1979. *A Natural Legacy: Ecology in Australia*. Pergamon Press, Australia.
- Rotherham, E. R., B. G. Briggs, D. F. Blaxell and R. C. Carolin. 1975. *Flowers and Plants of New South Wales and Southern Queensland*. A. H. & A. W. Reed, Sydney.

# A POMPEIAN HOUSE REVISITED

The House of the Coloured Capitals, freshly redecorated following the devastating earthquake in 62 A.D., was to be buried 17 years later together with all the other buildings in the ancient city of Pompeii under 4 metres of volcanic ash in the eruption of Mt Vesuvius on 24 August, A.D. 79. Although this house was one of the first buildings to be excavated in the early 19th century, the consequences of the initial haphazard work have carried over to this time. Preserved beneath the ash for nearly 2000 years, wall-paintings when they were unearthed were particularly susceptible to deterioration—natural and manmade—and more than half of them have been lost. As part of an international group, the Australian Expedition to Pompeii has been engaged since 1978 in researching the House of Coloured Capitals. Jean-Paul Descoedres, a Senior Lecturer in Sydney University's Department of Archaeology and Director of the Expedition, describes for us some of the artistic and architectural treasures that have been discovered during the recording, restoration and maintenance of this historical building.

by Jean-Paul Descoedres



The House of the Coloured Capitals holds a wealth of Pompeian wall-decorations. The wall-painting illustrated was made between 62 and 79 A.D. and is representative of the so-called Fourth Pompeian Style. The central panel depicts the goddess Aphrodite (Venus) riding a sea-centaur; the enthroned figure in the upper zone is the goddess Fortuna holding a cornucopia, the symbol of abundance. Photo by P. Grunwald.

Following an invitation by the Italian authorities, a team of Australian archaeologists in 1978 joined an international program aimed at recording Pompeian houses in detail and at analysing them from an urbanistic, architectural and artistic point of view. The present Director of Antiquities of the region encompassing Pompeii, Professor Fausto Zevi, first entrusted the team with the study of the 'House of the Coloured Capitals'. A short report on this first campaign was published in a previous issue of *Australian Natural History* (Vol. 19, Number 8, 1978). Thanks to the continuous support of the Australian Research Grants Committee, the expedition has been able to work in Pompeii each May since 1978 and has now almost completed the study of its first house.

The House of the Coloured Capitals lies in the northern part of *regio VII* of Pompeii in an area which was one of the most favoured residential quarters of the upper class, judging from the very high proportion of large mansions there. In fact, the House of the Coloured Capitals is one of the largest of these palace-like structures, containing more than 50 rooms and 2 peristyles and covering a floor-area of about 1850 m<sup>2</sup>. In comparison, the approximate floor-area of some of the better known houses are: House of the Faun, 2950 m<sup>2</sup>; House of Pansa, 2300 m<sup>2</sup>; House of the Labyrinth, House of the Menander, House of Obellius Firmus, 1800 m<sup>2</sup>; House of the Dioscouri, 1450 m<sup>2</sup>; House of the Vettii, 1100 m<sup>2</sup>. Extending across the entire *insula 4*, the House of the Coloured Capitals has its main entrance on the south end, opening on to the 'Via degli Augustali', at a distance of less than 100 m from the Forum. On the opposite side, the house faces the 'Strada della Fortuna', one of the city's most important business streets.

Since the return of the Bourbons in 1815 and Carlo Bonucci's appointment as Director, excavations in Pompeii had first concentrated on the area around the Forum and had then proceeded along the main streets leading eastwards. In the so-called 'Street of the Temple of Augustus', the first crossroad was reached early in November 1832, and excavation started in a building subsequently named the 'House of the Coloured Capitals' after the

well-preserved painted capitals found in its peristyle. Work in the house was carried out intermittently throughout 1833. By the beginning of 1834 most parts were cleared, with the exception of some rooms in the eastern part and in particular the large exedra 31. However, even in the seemingly excavated rooms, important discoveries could still be made as late as 1846. It was quite usual at that time for excavators to move rather frequently from one area to another, guided mainly by their hope of finding important buildings, precious objects and beautiful paintings.

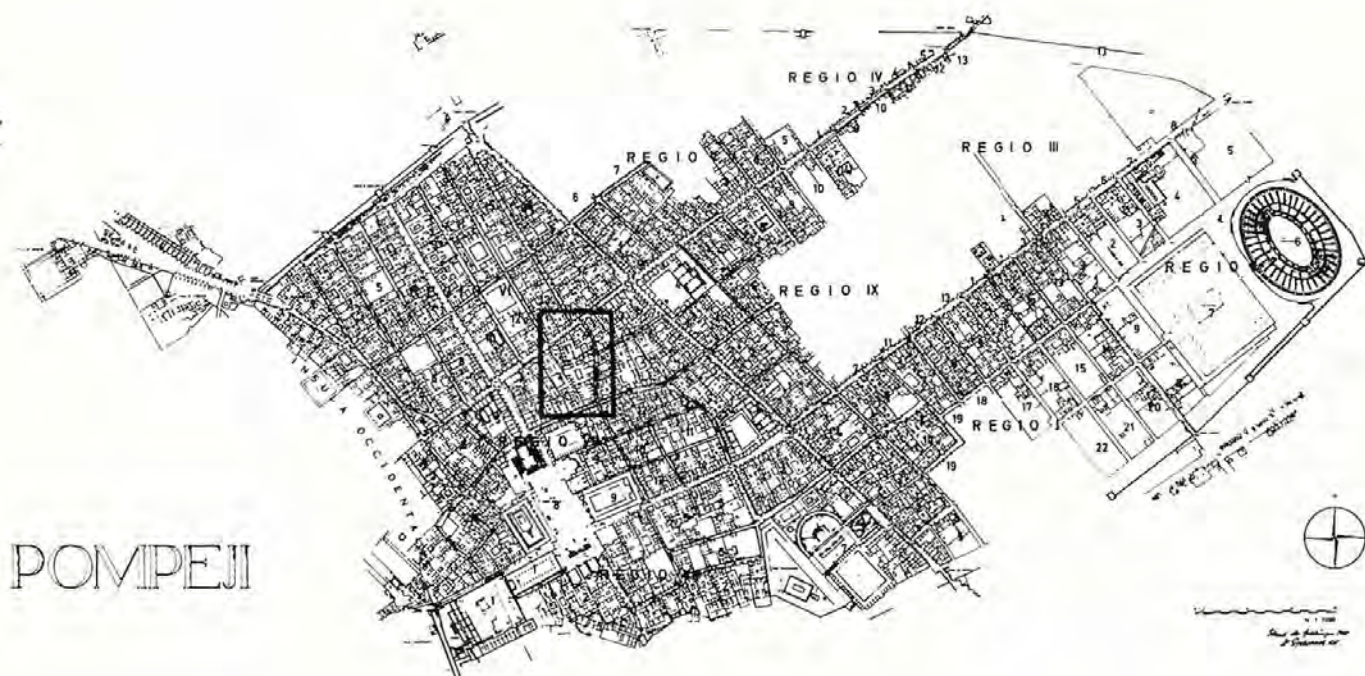
More rational and systematic excavations had to wait until Giuseppe Fiorelli was appointed Director in 1860; he was the first to proceed house by house, quarter by quarter. At the same time, Fiorelli started to publish excavation reports on a regular basis. Our main source of information for the period before Fiorelli consists of the official diary kept by the various directors since the dig began by order of Charles of Bourbon in 1748. This diary is now deposited in the National Archaeological Museum, Naples, but substantial extracts of it were published by Fiorelli in his *Pompeianarum Antiquitatum Historia* which appeared in three volumes from 1860 to 1864. A look at one of the entries, chosen at random, immediately reveals the two main problems this early excavation diary presents:

"21-28 July (1833): Work proceeds in two points, one in the middle of the Street of Fortune, the other passes from the peristyle of the fifth house to a house which remains on the left hand side of the Lane of the Temple of Augustus. During the excavation in the house of the Lane of Augustus the following objects were found. Bronze: a very small coin, a fitting with a ring. Glass: 20 flasks of various shapes, almost all broken at the neck."

The first problem of this diary is the difficulty—or in more than a few cases, the impossibility—of identifying the buildings mentioned in the text. In describing the relative position of two or more buildings to each other, terms such as "left" or "right" and "in front of" or "behind" are used instead of referring to the cardinal points, and an overall identification system did not, of course, yet exist.



# POMPEII



Plan of the excavated portion of the ancient city of Pompeii (top). The rectangle encompasses the House of the Coloured Capitals. Diagram after H. Eschebach, *Die städtebauliche Entwicklung des antiken Pompeji*, 1970.

Plan of the House of the Coloured Capitals (above) indicating entrance and room numbers. Diagram by R. Apperly/University of NSW.

This, too, was to be created by Fiorelli who subdivided the entire city area into nine regions, each comprising a varying number of *insulae* (blocks). Within each *insula* every entrance was given a successive number so that any Pompeian building was henceforth identified by three numbers—for example, VII (regio), 4 (*insula* within the regio), 31 (entrance number; in this case, also 33 and 51 since the House of the Coloured Capitals has three entrances). Needless to say, the absence of a consistent identification system before Fiorelli's time soon became, and still is, an inexhaustible source of confusion, misunderstandings and errors.

The second main shortcoming obviously lies in the brief nature of the descriptions, particularly with regard to objects. With a very few exceptions, not even approximate indications of size are given. Combined with the absence of any reliable and consistent inventory system, this means that the chance of subsequently identifying any find made during these early excavations and then brought to Naples is rather slim.

On the basis of this admittedly rather poor source material, the history of excavation in the House of the Coloured Capitals can be reconstructed in very broad lines as follows. Starting from the south, the excavators proceeded to clear the house at an astonishingly rapid pace, especially when one considers that only 13 workmen were employed at a time. By mid-January 1833, only ten weeks after work had started, they had reached the *tablinum* (13). In February, the west aisle of the peristyle (18) was uncovered, in March the north wing, and by April the first restoration work could be carried out, including the re-erection of several columns. At the same time, in the week 21-26 April, the north entrance was found when digging was resumed in the Street of Fortune after an interruption of more than two years. From then on, the excavation progressed, intermittently as usual, from both

sides; from the south in the House of the Coloured Capitals, from the north in the "Fifth house on the right hand side of the Street of Fortune". It was not until mid-August that the two dwellings were finally recognized as being one and the same.

At the time our house was excavated, stratigraphical observations were not yet known. Neither had the early excavators realized that it was possible to recuperate, by plaster casts, bodies and objects made of organic material which, before decaying, had left their imprints in the Vesuvian ash and mud. When finds were listed in the diary, the only indication given concerns the room in which they were discovered—but, more often than not, even this was omitted. The greatest puzzle for the modern archaeologist, however, is that these pre-Fiorellian excavations seem to have proceeded haphazardly, without the slightest trace of a clear system. For example, the *tablinum* (13) was roughly cleared as early as mid-January 1833. Its floor, however, remained in the ground until mid-June when part of a mosaic was discovered with a black rosette at its centre. However, the room was still not completely excavated, for as late as 1846 a dig conducted in the presence of the members of the Accademia Ercolanese led to the discovery of two panels in marble intarsia with the representation of dancing maenads and satyrs, one of which has been on show in the 'Pompeii A.D. 79' exhibition.

In fact, this last episode is rather characteristic of the Bourbon excavation 'method', *sit venia verbo*, and reveals there was indeed a ruling principle in what looks at first as being sheer haphazardness and disorder. This principle could, perhaps, be called 'the principle of greatest possible theatrical effect'. During the first stage, the excavation of a house does not go as far as uncovering the floor or completely clearing the painted walls. The last layer of Vesuvian mud and lapilli, the stratum which contains whatever ash covered on 24 August,

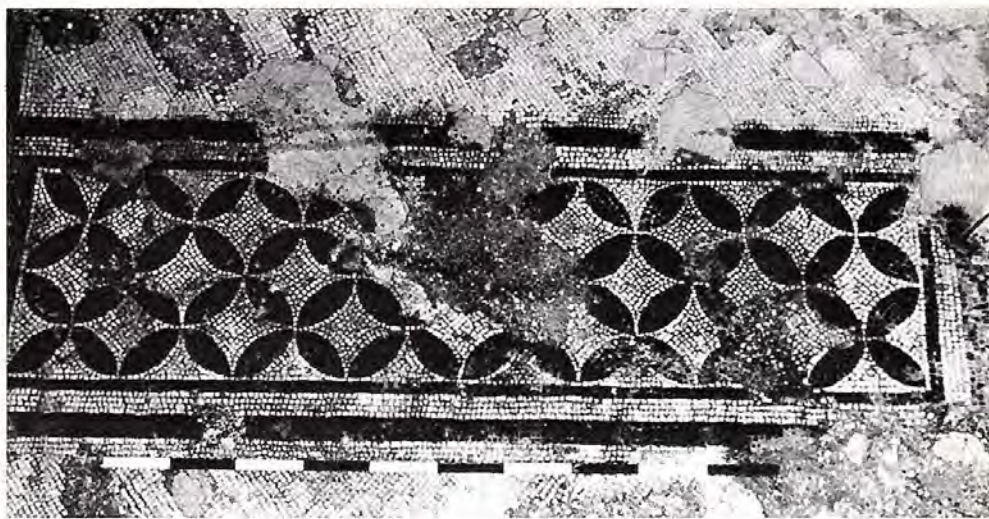
79, is left untouched and some earth remains on the walls to cover the paintings. The final and most romantic and exciting clearing takes place on appropriate, well-chosen occasions, preferably when members of the Royal Family or other high guests visit the site.

Thus, the floors of both wings in the House of the Coloured Capitals (7 and 8), the west part of the peristyle (18) and the left *fauces* (14) were cleared in February, 1833 in the presence of His Excellency, the Minister for the Interior, for whom the north wall in room 22 was also uncovered on the same day. On 1 June, Leopold II, Grand Duke of Tuscany, and his suite were offered the following spectacle: uncovering the mosaic floor in room 24 first, then clearing the wall-paintings in the same room before moving to the shops on either side of the north entrance (49 and 51). In 49, two skeletons came to light, also one gold ring with a sardonyx showing a little cupid riding on a dolphin, several bronze vessels, a bronze lamp and a surgical instrument and, furthermore, some wall-paintings. The harvest in 51 is not less impressive: various harness fragments, five glass vessels, nine clay vases and several small objects made of bone.

The subsequent history of the House of the Coloured Capitals can be summarized rather briefly. Until the end of the 19th century, it was one of the houses not to be missed by any visitor to Pompeii. Among the watercolourists who set up their easels in it were: G. Mancinelli, 1834; Giuseppe Abbate, 1836; H. Roux and W. Zahn, both around 1840; Anton Theodor Eggers, 1844; Antonio Ala, 1856; Sydney Vacher, 1879; A. Brangi, 1884; V. Loria, around 1885; and Pierre Gusman, shortly before 1900. The earliest photographic reproductions of two painted panels were made by J. H. Parker in the late 1870s.

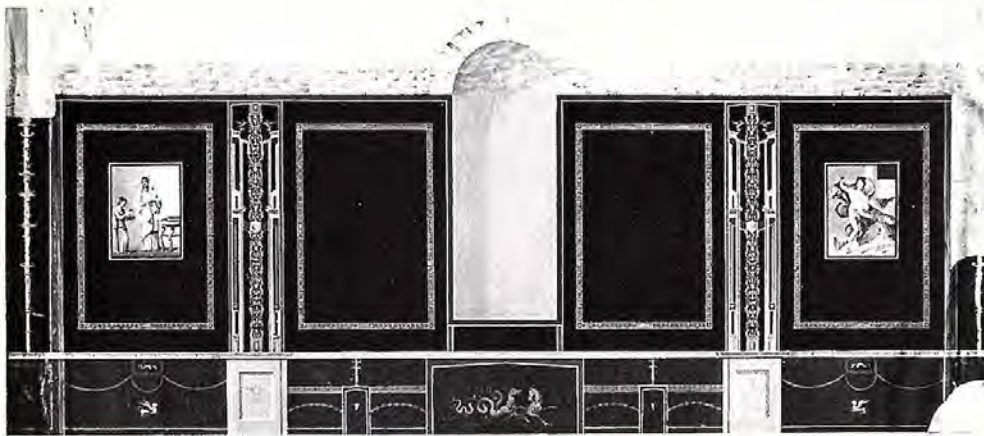
The first description of the house, by Guglielmo Bechi, was published in the *Real Museo Borbonico* in 1833 and 1834. It included a plan and a longitudinal section, as well as illustrations of most of the well-preserved mythological panels in etchings, either by N. La Volpe or V. Murano. In 1860, Fausto and Felice Niccolini included the house in their large-scale publication *Le case ed i monumenti di Pompei disegnati e descritti* which appeared in four volumes from 1854 to 1896. The description, which followed Bechi's rather closely, was supplemented by a list of objects allegedly found in the house. It was compiled from the official excavation diary and contained numerous errors due to the latter's lack of clarity.

E. Pernice in 1938 was the first to deal with our house in more than a purely descriptive way. In his *Pavimente und figürliche Mosaiken*, an analysis of its floors and mosaics led him to conclude that the house had been extensively restored shortly before 79 A.D. Twenty years later, K. Schefold published his topographical catalogue of all painted motifs on Pompeian walls, putting the paintings in our house for the first time into an overall context and also giving an approximate date. According to Schefold all the preserved paintings can be attributed to the so-called Fourth Pompeian Style, but while rooms 7, 17 and 27 were



This black and white design found in room 24 (top) is one of the few portions of the mosaic floor of the House of the Coloured Capitals still preserved. Photo by J.-P. Descoedres/Sydney University.

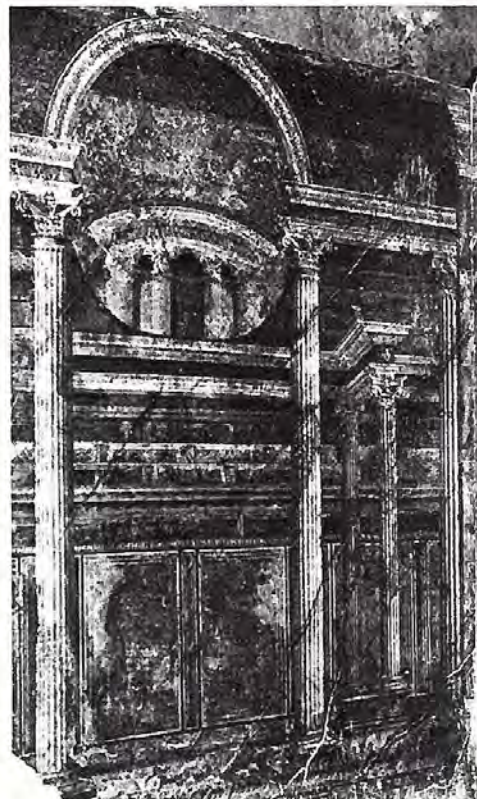
The little cupid in this watercolour (above) by P. Gusman (ca. 1900) suggests that the couple are lovers. Gusman copied a wall-painting discovered in room 17 of the House of the Coloured Capitals. The original wall-painting is currently in a very poor state of preservation (left). Photos by J.-P. Descoedres/Sydney University.



The watercolour (top) by A. Ala (1856) illustrates the east wall of the large exedra 31 in the House of the Coloured Capitals. The wall is decorated in so-called Fourth Pompeian Style and can be dated to the period between 62 and 79 A.D. Photo by P. Grunwald.

The large panel (above) from the west wall in room 24, House of the Coloured Capitals, shows Dionysus discovering Ariadne on the island of Naxos. The panel is now at the National Museum, Naples. The photo (above right) shows the present state of preservation of the wall and the place from which the panel was removed. Photos by P. Grunwald.

The wall (right) in the Villa of the Mysteries, Pompeii, was decorated in the so-called Second Pompeian Style during the mid first century B.C. Photo by J.-P. Descoeudres/Sydney University.



decorated under Nero's reign (ca. 65 A.D.) the large exedra 31 is to be dated around 70 A.D. and the paintings in room 22 belong to the years immediately before the final destruction in 79 A.D. Thus, Schefold keeps basically to the classification system that goes back to Mau even though his attempt to distinguish between Neronian and Vespasianic Fourth Style is new.

By 1873, August Mau had given a preliminary sketch of the history of Pompeian wall-painting in a paper published in the *Giornale degli Scavi di Pompei*, and in 1882 his *Geschichte der decorativen Wandmalerei in Pompeji* appeared. Mau's merit is that he approached Pompeian wall-decoration from an art-historical point of view and thus created the first—and up to this day, only—coherent classification system of a monument that comprises several thousand paintings. For more than a century, interest in these paintings had focused on the main panels with mythological representations. Considered to be copies or at least reflections of lost Greek paintings of the Classical age, these panels were highly esteemed and therefore often cut out of the walls to be brought to the Royal Museum in Naples, forever torn from their context. The remainder of a wall was left unprotected and so decayed. Naturally, this practice was not immediately abandoned—but Mau's study none the less marked a turning point and for the first time made it clear that Pompeian walls had to be considered as integral entities.

The First Style consists of stucco decorations representing in plaster a wall built of marble with huge orthostates below and regular ashlar above, an arrangement typical of Classical Greek temple architecture. Mau dated the first examples of these stucco decorations to ca. 200 B.C., while the end of the First Style, around 80 B.C., coincides with the beginning of the Second Style, called by Mau the 'Architectural Style'.

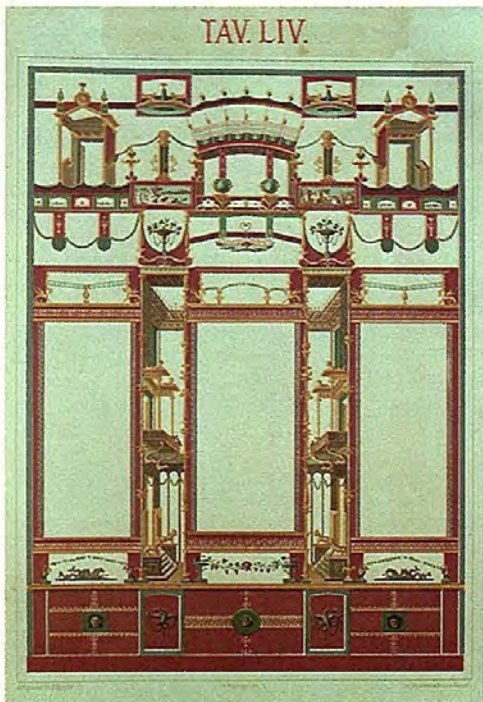
In the Architectural Style the walls are now decorated in true fresco technique, with representations of entire architectural views that give the beholder the impression of standing before a Greek sanctuary. In the first phase, the illusion thus created is that of a limited enlargement of the room in which we stand with its boundaries being pushed back, not eliminated. In a second phase, however, the wall opens and we are able to perceive through large apertures temples and other sacred buildings surrounded by porticos. In the late Second Style, the architectural features start losing their realistic appearance—the columns are too slender, the entablature too light to be real. At the same time the central opening is transformed into a small shrine containing the imitation of a precious Greek panel painting. Both these aspects herald a concept which finds its expression in the Third Style. Mau had no clues at his disposal to date the creation of this new decorative system with any precision. He assumed that the change from the 'Architectural' to the 'Ornamental' Style took place around the beginning of the Christian era, a chronology which, in the meantime, has proven slightly low. A *terminus ante quem* is provided by the pyramid of Cestius in Rome dated on epigraphical evidence before 12



As illustrated in the first peristyle (above), the well-preserved colours on the capitals give the House of the Coloured Capitals its name. Photo by J.-P. Descoeudres/Sydney University.

The Room of Ixion (right) in the House of the Vettii was decorated in Fourth Pompeian Style (ca. 70 A.D.). Photo by J.-P. Descoeudres/Sydney University.

The west wall of the *tablinum* (27) in the House of the Coloured Capitals, decorated in late Fourth Pompeian Style shortly before 24 August, 79 A.D., was illustrated in watercolour by A. Magliano (below). Photo by J.-P. Descoeudres/Sydney University.





This room in the Villa Imperiale was decorated in so-called Third Pompeian Style probably about 20 A.D. Photo by J.-P. Descoedres/Sydney University.

the foot of Vesuvius in 62 A.D. We know of no example of true Third Style painted after this disaster.

The Fourth Pompeian Style is by far the most commonly exhibited in Pompeii's houses, precisely because of the earthquake which destroyed almost all earlier wall-decorations. It amalgamates the two previous styles into a new, grandiose unity. On the one hand, the wall continues to be subdivided according to a tripartite scheme with a mythological panel at its centre. The unrealistic, dreamlike character of the architectural elements is another Third Style feature preserved by the Fourth. On the other hand, the illusionary opening of the wall is clearly reminiscent of the Second Style. However, the buildings one perceives through the various apertures no longer look real—they seem to belong to a world of fantasy and add to the theatrical, baroque atmosphere which is so typical of this Fourth Pompeian Style. Mau thought little of this last decoration system. According to him, Roman wall-painting had reached its peak with the Third Style, and consequently he devoted only a summary analysis to the Fourth which he considered to be the beginning of decay.

In the field of Classical Archaeology, few books have stood the test of time as brilliantly as Mau's history of Pompeian wall-painting. His distinction of four main decoration systems is still generally accepted, and a recent monograph on the Third Style has again fully confirmed his analysis. But there remains one problem about which the debate has not come to rest since it was opened by A. Ippel in 1910. In his thesis on the Third Pompeian Style, Ippel argued that the Third and the Fourth Styles were, in fact, contemporary. Soon, this view gained wide acceptance, and although Henk Beyen and Karl Schefold later proved it to be wrong, the basic problem remained unsolved: What is the relationship between the Third and Fourth Style, both in terms of style and chronology?

Beyen placed the beginning of the Fourth Style around 35 A.D., and this chronology has been supported most vigorously by Bastet, while for Schefold there is no Fourth Style before Nero, say about 60 A.D. If, as some seem to think, this minor difference in dating represented the actual bone of contention, it would be hardly worth mentioning. But behind this seemingly chronological debate hides a fundamental difference of concept of the Pompeian styles. For Beyen and his pupils there is a continuous evolution leading from one style to the next; the Fourth Style in particular emerges gradually from the Third. ("What the one defines as early Fourth Style is considered late Third Style by the other."—Bastet.) Schefold takes the contrary view considering every style as representing a coherent, well-rounded entity, created by an individual artist. According to him the Fourth Style was invented by Famulus, the painter responsible for the decoration of Nero's palace in Rome.

There is no doubt that several walls in Pompeii combine Third and Fourth Style elements. But while for Beyen these walls are proof and illustration of a gradual transformation of the Third into the Fourth Style, for Schefold they belong to the end of the Fourth Style with their heterogeneous character being due to a deliberate revival of Augustan features under Vespasian. One of these controversial walls brings us back to our starting point—it is the west wall of the second *tablinum* (27) as recorded by A. Magliano (see photo on previous page). The wall is treated as a compact, clearly defined surface, decorated with various kinds of grotesque-like ornaments that subdivide it horizontally into three zones, vertically into three fields. Were it not for the two openings on either side of the central panel, one would hardly hesitate to attribute the wall to the Third Style. But these side-apertures through which one perceives fantastic, dreamlike buildings are, of course, characteristic of Fourth Style. So, is this amalgam illustrating the transition from Third to Fourth Style as Beyen claimed, or is it typical of the Augustan renaissance under Vespasian, as Schefold replied?

The work carried out by the Australian Expedition in the House of the Coloured Capitals is manifold. Among the various tasks is the analysis, by the conservator, of all the plasters used throughout the house. Here, the analysis has proven Schefold to be right—both the underlying plaster and the final coating on the west wall of *tablinum* 27 are identical with those applied on the walls of rooms 19, 20 and 23-26 which are all decorated in typical and undisputed late Fourth Style.

In itself, the solution of this particular problem is of little importance. However, it shows the necessity of the recording program in which the Australian team participates. It is only on the basis of a great number of such painstakingly gathered detailed observations that we might at some stage be able to complete the work started by Mau 100 years ago—to write the history of the Fourth Pompeian Style.

B.C. On the walls of its grave-chamber, Third Style appears already fully developed. There is no trace left of the spatial illusionism so characteristic of the previous system. The wall is treated as a firm plane, clearly delimiting the room it surrounds. In the horizontal sense, the wall is subdivided into three distinct zones; the socle, the middle and the upper zone, and this tallies with the tripartite arrangement that prevails in the vertical sense. Two, or two pairs of, narrower panels frame a central field which is usually occupied by a large mythological painting. In its combination of a rigid framework with a dreamlike, mysterious atmosphere, the Third Style is typical of the Augustan age.

After Augustus' death in 14 A.D. the sobriety characteristic of early Third Style gradually disappears and a more enthusiastic mood prevails with the classical, graphic style yielding to more impressionistic means and a more variegated palette replacing the cool, subdued colours of the earlier phase. However, the system as such remains unchanged until its end which Mau placed around the middle of the first century A.D., mainly because of the *terminus ante quem* provided by the earthquake that devastated the cities at



# CENTREFOLD NO. 7

## Koala, *Phascolarctos cinereus*

by Ronald Strahan



Eucalypt leaves constitute the exclusive diet of koalas, and each animal will put away more than a kilogram of gum leaves a day; its liquid needs are apparently not great. Further research is needed on its dietary habits although much is already known and recorded. Far less is known about the diseases which affect koalas such as cryptococcosis, a fungal disease which is fatal to this animal and can be passed on to humans. Photo by H. Millen.

There is no such animal as a 'koala bear'. Bears are flesh-eating animals which reproduce young about the size of puppies, and rear them in a den. Koalas, *Phascolarctos cinereus*, are leaf-eating animals which produce young the size of peanuts and rear them in a pouch on the mother's belly.

Koalas are marsupials, members of the same group of mammals as the American opossum and the Australian possums, kangaroos, wombats, bandicoots and carnivorous marsupials all of which produce tiny naked young with undeveloped hind legs. Little more than an embryo, the newborn marsupial crawls to one of its mother's teats and firmly sucks onto this for months while it continues its development. Most female marsupials have a pouch surrounding the teats and providing protection for the young 'pouch embryo' while it is suckling, but the young of some marsupials dangle below the mother's belly.

The pouch of the kangaroo opens forwards and upwards while that of a koala opens downwards and backwards—which is difficult for a tree-climbing animal that spends most of its life in an upright position. This inefficiency suggests that the koala was originally a ground-living animal like its nearest relative, the burrowing wombat, which also has a backwardly opening pouch. After a young koala is old enough to leave the pouch it is carried on its mother's back for many months.

Koalas are slow-moving specialised leaf-eaters with a way of life similar to that of the South American giant sloth. Whereas the sloth eats the leaves of the *Cecropia* tree, the koala depends upon the leaves of certain species of *Eucalyptus* trees.

The word 'koala' comes from an Aboriginal word meaning "seldom drinks". Generally, koalas receive all the water they need from the leaves they eat, but they are known sometimes to drink from rivers or pools.

Like some possums, the koala has a 'two-thumbed' hand—the paw being divided in such a way that the thumb and first finger are on one side and the remaining three fingers on the other. This feature, together with strong sharp claws, makes for a very secure grip when the koala is moving among the branches of a tree. As in the possums, kangaroos and bandicoots, the second and third toes of the hindfoot of the koala are joined together to form a digit with two claws—these are used as a comb to groom the fur.

Although koalas may congregate around suitable food trees, they are not social animals. The male is polygamous but the females disperse while they are rearing their young. Adult males advertise their presence by loud grunting noises similar to the braying of a donkey and may fight when they encounter each other.

Female koalas reach sexual maturity at two years or more, while the age of sexual maturity of males is not known. A single young is born at periods of from 12 months to 2 years. The gestation period is 35 days and the pouch life 7 to 8 months. Weaning commences at 6 months and is usually completed at 12 months. Birth-weight is from 0.36 g, and adults reach an average weight of 10 k (females), 13 k (males). The maximum age in captivity is about 20 years, but the average length of life in the wild is unknown.

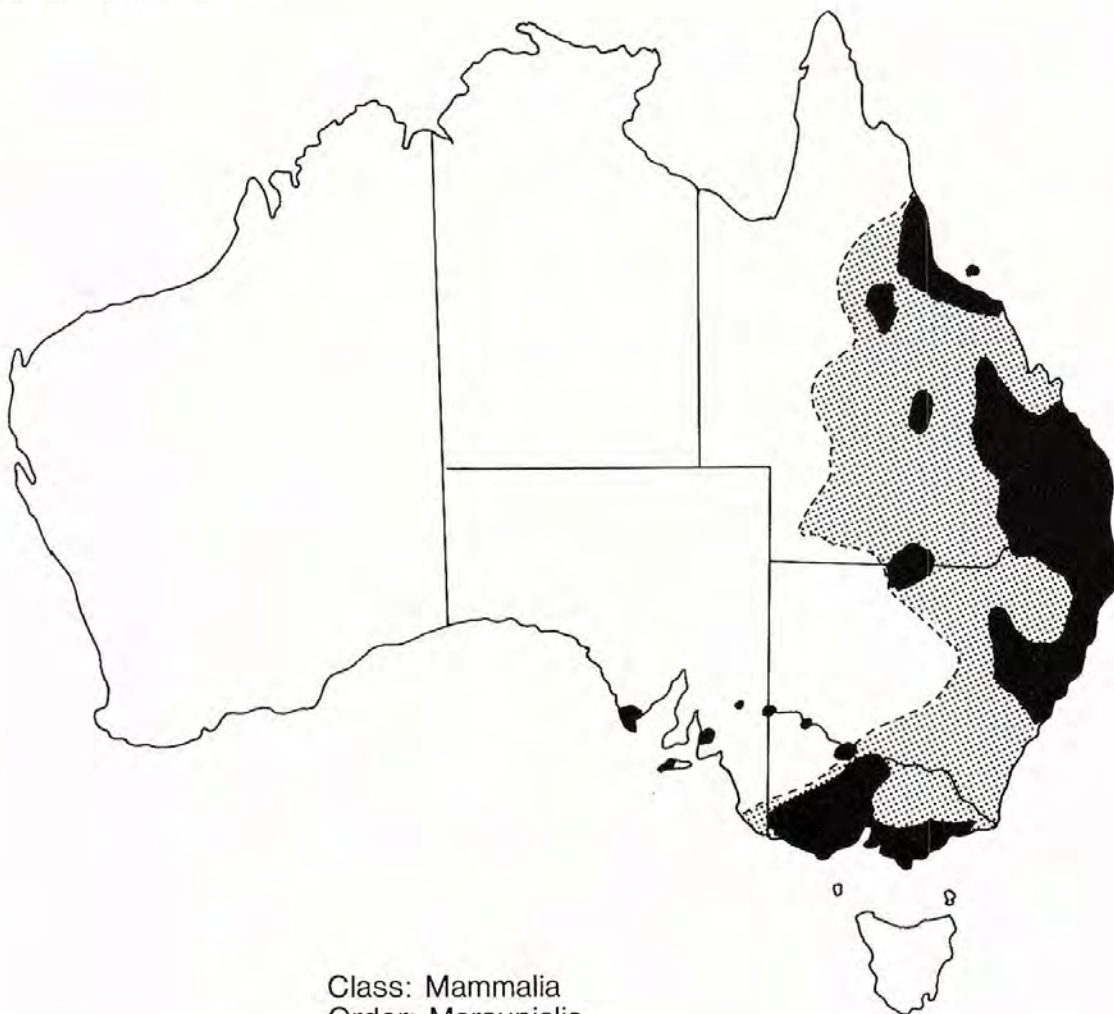
The koala is a harmless, essentially helpless, and not very bright creature. Clearing of eucalypt forests has severely reduced its range and numbers, but it still survives well under strict protection in many natural areas, in reserves and sanctuaries, and in a few zoos. A symposium held in Sydney in 1976, and attended by over forty people having first-hand knowledge of some aspect of koala biology, declared that "... the koala is not rare nor endangered ... but its ... vulnerability emphasised the need for active management practices."





The sight of a female koala nursing its young as pictured here generally evokes rapturous public support for its conservation, equalled only by emotional urges to 'cuddle' this popular marsupial. Pouch life for the young lasts about seven months, and they are carried about on the mother's back for some months more. Photo by V. Serventy.

The current view expressed by experts on the biology of the koala is that this marsupial is neither rare nor endangered; however, the need for active management practices has been emphasised. The koala at the present time is common in suitable habitat along the east coast and as far as Victoria and South Australia, but 'suitable habitat' is limited, and perpetuation of the species may well depend on provision and management of such habitat. In reference to the distribution map, the light shading represents the original range according to Burnett (Sutton, 1934. *The Koala's food trees. Vict. Nat.* 51: 78-80), and the dark shading the present distribution according to Bergin (1978. *The Koala: Proceedings of the Taronga Symposium on koala biology, management and medicine.* John Sands Pty, Sydney). Diagram after R. W. Martin.



Class: Mammalia  
Order: Marsupialia  
Family: Phalangeridae  
Genus: *Phascolarctos*  
Species: *Phascolarctos cinereus*  
Common Name: Koala

# BUTTERFLIES AND EVOLUTION

by R. L. Kitching



The wanderer butterfly, *Danaus plexippus*, is a native of North America and arrived in Australia late last century. The bright orange and black colouration makes it quite conspicuous while fluttering from flower to flower. Photo by Howard Hughes/The Australian Museum.

The study of insects has revealed many fascinating details of their adaptations to a minute world. Roger Kitching, a Senior Lecturer of ecology in the School of Environmental Studies at Griffith University, Brisbane, studies the population dynamics of insects, particularly butterflies. His article on the use of evolutionary principles in explaining a number of butterfly life-cycle strategies is based on a talk given on the ABC 'Science Show' and available on cassette from the ABC, Sydney.

In the late 17th century, the will of a Lady Glanville was challenged in the court in England on the grounds of her insanity. The observation presented as evidence was that she was a collector and student of butterflies! The suit was dismissed after various worthies including some Ministers of State were produced, who were also active butterfly collectors. The general impression of the lepidopterist as an eccentric amateur still persists today. The theory of evolution proposed by Darwin and Wallace in 1858 shook the biologists' world, and most biological effort since has operated within its framework; first, in the often heated pro and con debates and, later, in the systematic investigation of the organic changes which the theory encompasses. From an early stage butterflies and moths featured prominently in evolutionary biology. H. W. Bates, in his classic "A Naturalist on the River Amazon", was moved to write on butterflies, particularly of their wing patterns. "On these expanded membranes nature writes as on a tablet, the story of the modification of the species so truly as all changes of the organisation register thereon . . ."

That butterflies do provide admirable subjects for the study of the processes of evolution has been amply demonstrated. Recent work on mimicry and other forms of protective resemblance, population genetics, mutation, mate-finding and interactions with other organisms present the truth of Bates' statement.

In Australia the biology of our 300 plus species of butterflies, although accessible now through some first-rate handbooks, has remained until recently largely unstudied. Research on the ecology and behaviour of selected species is in progress at James Cook and Griffith Universities, and I shall describe some of this work, together with as yet unstudied aspects of our fascinating butterfly fauna.

Firstly we must review the mechanics of the evolutionary process as we currently understand them. All organisms have the potential to produce an excess of young; that is, more than can survive to maturity. Organisms show individual variety, and much of this is transmitted genetically from one generation to the next. The number of offspring surviving to the next generation reflects the success or otherwise of the parent's in-

dividual attempts to cope with the many and varied environmental pressures it encounters. This differential reproductive success, together with the heritability of individual characteristics, leads to a process of organic change. This is seen either at one location or through differences in adjacent groups of organisms reflecting spatial differences in environment. Given enough space and time this mechanism is sufficient to account for all the levels of biological diversity in the living world.

This process of adaptation to environmental variation acts at the level of the individual. Some recent writers have drawn special attention to its genetic base through the 'selfish gene' metaphor. Here, evolutionary change is seen as a 'striving' by particular genes for representation in the next generation. Of course, neither genes nor individuals strive for anything in evolutionary terms. But the anthropomorphism is useful to interpret and explain so long as we convert back into the more biologically acceptable terms of random genetic change interacting with largely unpredictable environmental forces afterwards.

Returning to the butterflies, I would like to look at the life-style of three examples and try to develop an evolutionary explanation for the strategies each displays.

The wanderer, or monarch butterfly, *Danaus plexippus*, is a relative newcomer to Australia having first been noted here shortly before the turn of the century. With the spread of its food-plant, the introduced milkweeds or cottonbushes, the butterfly has spread. These food-plants contain heart poisons, the cardiac glycosides, and the butterflies extract and store these substances while the larvae are feeding on them. A proportion of the adults also contain these poisons and are, accordingly, distasteful to potential vertebrate predators, notably birds. It is argued that the strikingly contrasting orange and black colouring of the butterfly has developed as an advertisement to predators of this distastefulness. A predator, after having tasted and rejected these insects, theoretically will learn to avoid similarly coloured organisms. The more memorable the colour pattern the more quickly the predator will learn and the greater the advantage to potential prey, the butterflies in this instance. Of course, once the distinctive colour pattern has evolved there are disadvantages to the butterfly to appear other than as



Newly emerged adult female wanderer butterfly (top). The wings are in the process of expanding and hardening following emergence from the pupa on the remains of which the butterfly is hanging. Photo by D. Nott.

Two larvae or caterpillars of the wanderer butterfly on a seed-pod of their host plant—a milkweed of the genus *Asclepias* (top left). The butterfly is very selective in its choice of food-plant, laying eggs only on this or closely related genera of plants all of which may contain cardiac glycosides. The brilliant black, yellow and white banding makes the caterpillar conspicuous, at least at close range, and may advertise its poisonous nature to would-be vertebrate predators. Photo by D. Nott.



A young pupa of the wanderer butterfly suspended from a twig (left). The mature larva of this species usually leaves its milkweed food-plant to pupate on nearby twigs, tall grass stems or other prominences. Photo by C. V. Turner/ The Australian Museum.

much like its fellows as possible. Populations of wanderers in fact vary little compared with more palatable species. What we see here is an example of coevolution, where the plant may have developed its poisonous nature as protection against and in response to its predators (vertebrate grazers). In turn, the butterfly exploits the now poisonous plant thus gaining protection against its predators. In North America, where the butterfly congregates seasonally in vast over-wintering aggregations, a further step in the coevolutionary chain may be seen. Certain birds, species of oriole and warbler, have learnt to exploit the ready supply of food represented by masses of butterflies and have evolved special techniques of tasting to pick out the palatable butterflies. Once such techniques are available it presumably becomes disadvantageous to the butterfly to appear and behave like the norm for the species—a selective force in a sense opposing those which produce the striking colouration of the species.

We may now make a point often overlooked in elementary treatments of evolution. What we see when examining a species is the *resultant* of the many and varied selective forces that have acted over its recent evolutionary history. What we can suppose is that the structure and behaviour of the animal usually presents an optimal solution to its environmental problems. We should not necessarily expect any single morphological or behavioural characteristic to have taken precedence over all others, and in similar fashion, we cannot assume the primacy of any single selective influence. Selection acts on whole organisms. It is multidimensional just as they are, and to assume unidimensionality for such complex phenomena will not work.

Turning to another species, I shall consider the big greasy, *Cressida cressida*, a common 'swallow-tail' butterfly in northern Australia, which exploits another poisonous plant, a vine of the genus *Aristolochia*. However, it is not the food-plant relationship I wish to consider here, but the equally important competition between the sexes! Returning to the 'selfish gene' metaphor and quoting its originator, Richard Dawkins: "If one parent can get away with investing less in each child . . . he will be better off, since he will have more to spend on other children by other sexual partners, and so propagate more of his genes . . ."

The situation is complicated in butterflies as sperm is transferred in a package, the spermatophore, into the female on copulation. There, it is stored until the developing eggs are ready for fertilisation. A female may collect several spermatophores from different males through her repeated mating. The evolutionary problem is that the male has no guarantee that sperm from his spermatophore will be involved in a particular fertilisation event. The commonest solution is male promiscuity—spreading spermatophores and investing little in pre-mating rituals. However, a small group of butterflies, which includes the big greasy, has adopted a different strategy. The logic is that if, after mating, the male prevents further mating then his spermatophore is bound to be the sperm source for fertilisation. This 'sole ownership' strategy is achieved by the



The sphragis or 'chastity belt' on the underside of an adult female big greasy butterfly, *Cressida cressida*. The sphragis is the large waxy-looking structure almost as large as the abdomen itself. Photo by C. Horton.

secretion of a complex waxy structure over the genital opening of the female after mating, thus preventing further penetration. This 'chastity belt' or sphragis as it is known technically, is a large structure and, as far as we know, lasts the life of the female. Whether this process means that males invest more time in pre-mating ritual than in other species, awaits study. It is indeed hard to see any advantage to the female in this process, and the species seems an excellent example supporting Dawkins' 'battle of the sexes' theme.

My third example is the group of butterflies that has developed special relationships with ants—usually voracious predators of other insects. A wide range of blue or lycaenid butterflies are the species in point, but the biology of the imperial blue, *Jalmenus evagoras*, is an excellent introduction.

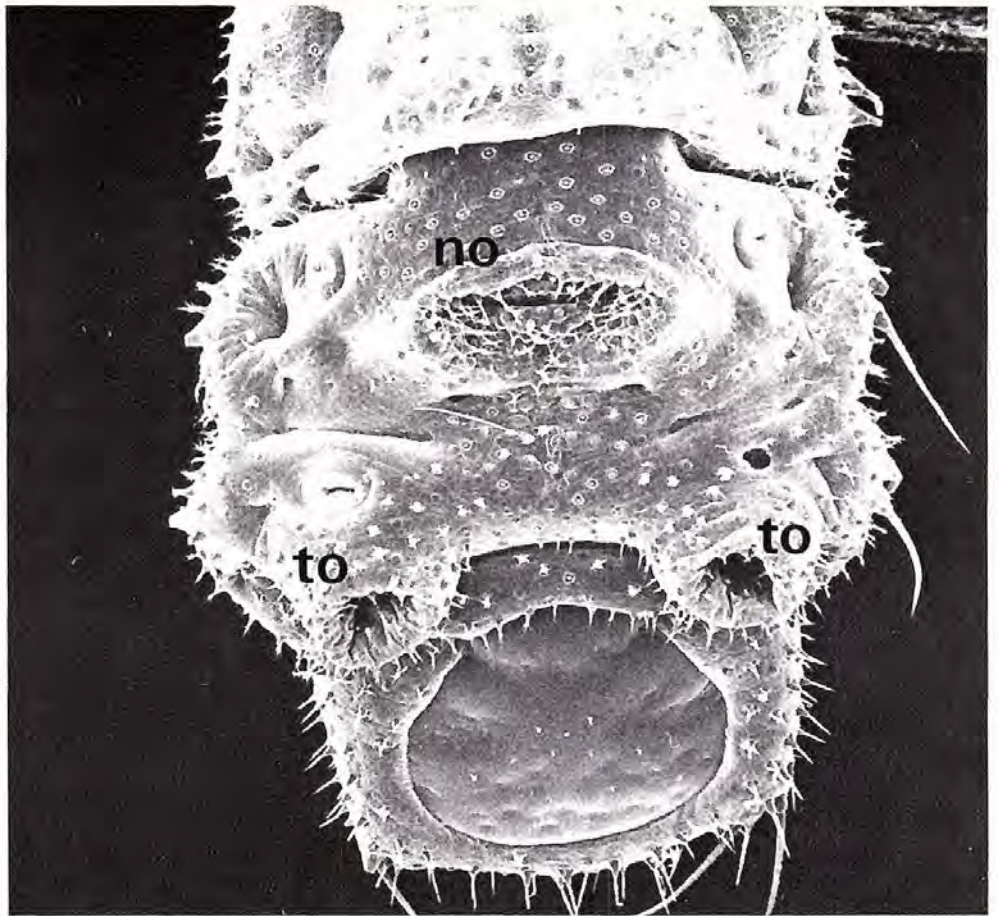
In this species, the larvae and pupae are invariably attended by hordes of small black *Iridomyrmex* ants. The ants groom the larvae and pupae and receive droplets of sugar solution secreted from a special gland—Newcomer's organ—on the larvae. In return for this largesse, the ants defend the butterflies from predators, notably insects such as assassin bugs and the nymphs of lacewings. In other species we find further developments in the relationship—the ants may corral the larvae at the base of the food-plant during non-feeding periods, and they may even carry them into the ant nest either periodically and/or just before pupation. This may well have led to the larvae taking advantage of the ants themselves, developing predatory habits and feeding on the ant brood. This habit occurs in the Australian moth butterfly, *Liphya brassolis*, and the various species of so-called ant-blues of the genus *Acrodipsas*. On the other hand, the association of some species with ants is so casual as to be frequently overlooked. The first obstacle to be overcome in this chain of evolutionary development would have been the ants' tendency to eat everything in their path. The exceptionally thick, relatively bite-resistant cuticles of the lycaenid larvae may represent a pre-adaptation to ant attendance. Also, the habit of ants to attend and milk other insects of more ancient lineage than the lycaenids may have predisposed the ants. This theory may seem

An adult imperial blue butterfly, *Jalmenus evagoras*, sunning. Fresh specimens such as this one have long black and white 'tails' on their hind-wings. Photo by D. Nott.



Mature pupa of the imperial blue butterfly with attendant ants of the genus *Iridomyrmex* (below). This individual is unusual in being solitary. Most larvae occur in groups of five to twenty during the day, the whole group being covered in a mass of ants. Photo by D. Nott.

Scanning electron microscope shot of the upperside of the abdomen of a larva of the imperial blue butterfly (left). The honey gland or Newcomer's organ (no) is clearly shown and is the structure from which ants 'milk' sugar solutions from the caterpillar. Also labelled are two tentacular organs (to). Photo by R. Kitching.



simply to postpone the necessity for an explanation by turning the question around into: How did ant attendance on more ancient insects begin? But the other insects involved are mostly plant-sucking bugs which tap directly into the relatively inexhaustible food flowing in plant tissues. They act like a spigot and may even exude droplets of sugar-rich sap. Thus the primitive marauding ant may well have encountered the palliative sugar droplet of the primitive plant-sucking bug, in this way initiating a more mutualistic relationship.

Origins apart, the ant-lycaenid relationship is remarkable, associated with many, as yet, unanswered questions. The most fascinating for me can be classified into three inter-related groups: morphological, chemical and behavioural. At the morphological level we know caterpillars have special organs associated with ant attendance—the Newcomer's organs already mentioned, eversible tentacular organs on either side of the Newcomer's organ and various dome or peg-shaped receptors scattered over the body. Not only is their specific role largely unknown, but the range of their occurrence across species has not been examined systematically for thirty years. Tantalising snatches of information, such as the fact that these organs appear to have been lost in an Hawaiian species which is not ant-attended, what one's appetite and is one of our ongoing studies on ants and lycaenids. At the chemical level, we adduce from one analysis of the exudate from a European species of lycaenid that Newcomer's organ secretes sugar droplets. For the majority of species we know nothing of

what sugars are involved in what concentrations. More significant, perhaps, we do not know if other compounds such as amino acids are present. We must tackle these questions to know what 'payoff' the ants get from the relationship. Non-food substances, notably volatile external hormones (pheromones), have been postulated as involved in the maintenance of the relationship. It could be that the rapid eversions of the tentacular organs are dispersing some such substance. This remains, however, speculative, and prickly questions of collection and analysis must be resolved before we can hope for light in this area. Behaviourally, there are endless questions, some of which we have begun to tackle in our studies of the imperial blue. How do the ants apportion their time around different parts of a caterpillar? Why is it that very small caterpillars tend actively to seek and nestle against larger ones? How do ants find particular larvae, and how do they transmit this information to their fellows? How do adult butterflies deposit their eggs to ensure ant attendance on their larvae? What is the role of the type and quality of the food-plant in maintaining or modifying the relationship? The list could be extended indefinitely.

Space precludes further examples, but equally interesting instances abound among the Australian butterflies. Some mimic the distasteful species 'cashing in' on their distastefulness; others tend to differentiate into forms or sub-species over relatively short distances; whereas others exploit specialised food-plants such as mistletoes. I could continue, but conclude on the general point that

the studies of organisms that I have described not only tell us about the ecology and behaviour of a particularly fascinating group of animals, but also shed light on the universal process of organic evolution.

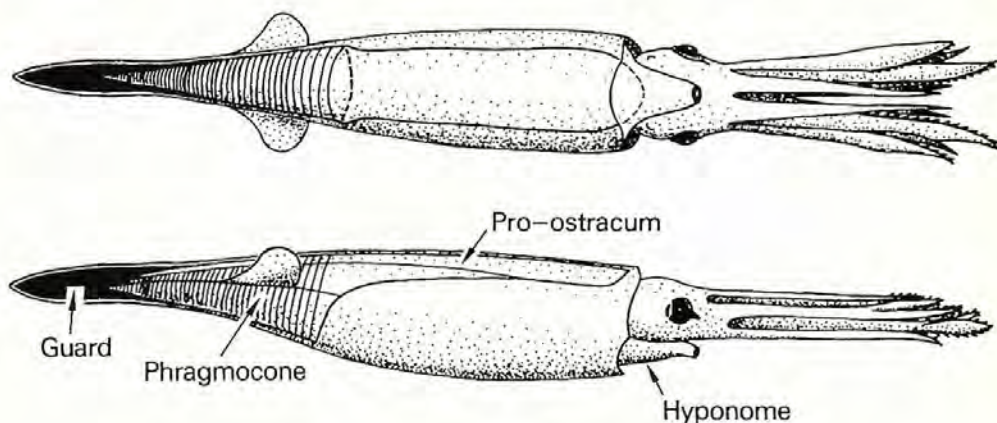
To complete the quotation from Bates: "... As the laws of nature must be the same for all beings, the conclusions furnished by this group of insects must be applicable to the whole organic world; therefore, the study of butterflies—creatures selected as the types of airiness and frivolity—instead of being despised, will some day be valued as one of the most important branches of biological science." I submit: The day has come!

#### FURTHER READING

- Brower, L. P. and J. V. Z. Brower. 1964. Birds, butterflies and plant poisons: a study of ecological chemistry. *Zoologica* (N.Y.) 49: 137-159.
- Calvert, W. H., L. E. Hedrick and L. P. Brower. 1979. Mortality of the monarch butterfly (*Danaus plexippus* L.): avian predation at five overwintering sites in Mexico. *Science* (N.Y.) 204: 847-851.
- Common, I. F. B. and D. F. Waterhouse. 1972. *Butterflies of Australia*. Angus and Robertson, Sydney.
- Dawkins, R. 1976. *The Selfish Gene*. Oxford University Press, Oxford.
- McCubbin, C. 1971. *Australian Butterflies*. Nelson, Melbourne.
- Patterson, C. 1978. *Evolution*. Queensland University Press, Brisbane.



# FOSSIL SQUIDS AND PAST GEOGRAPHY



by Graeme Stevens

Belemnites had a squid-like body, but with a hard shelly internal skeleton, divided into three parts. The diagrams above right depict underside (top diagram) and side (bottom diagram) views of a belemnite. The main body part of the belemnite is depicted as though transparent to show the three elements of the internal skeleton: guard, phragmocone and pro-ostracum. A funnel—hyponome—projects from the gill chamber, and belemnites were able to make quick dashes by squirting water out of the funnel, like modern squids. After death the guard often separated from the remainder of the body and is frequently found on its own. Diagrams by Graeme Stevens/N.Z. Geological Survey.

Although now extinct, squid-like marine animals called belemnites were once common in ancient seas. Their fossilised remains tell us much about the Earth's geography many millions of years ago. Graeme Stevens, a macropalaeontologist at the New Zealand Geological Survey, DSIR, has research interests in the Jurassic and Cretaceous cephalopods, which includes belemnites, and the Mesozoic palaeobiogeography of the Southwest Pacific.

Australasia's ancient seas were populated by many bizarre creatures. For example, in the Jurassic and Cretaceous periods 190 to 65 million years ago numerous ammonites and belemnites lived in the sea. In some areas squid-like belemnites and ammonites, resembling large coiled snails, were more common than the various types of shellfish then living.

Belemnites and ammonites belong to the class Cephalopoda, a combination of words meaning 'head' and 'foot'. The molluscan 'foot', the plough-like fleshy projection used by bivalves to crawl or burrow on the sea floor, is united with the head in these animals and forms a ring of tentacles, often called arms, around the mouth. Another part of the foot forms a funnel, through which the animal can squirt out a jet of water, sometimes mixed with ink, and thus propel itself rapidly backward to escape danger.

The earliest cephalopods, in the Palaeozoic era 570 to 230 million years ago, had a straight, long, narrow conical shell, divided internally into a series of chambers. At the open end of the cone in a large chamber, from which head and tentacles emerged, the animal itself was accommodated. The other chambers were filled with gas and fluids, and by varying their relative proportions the animal, like a submarine, could adjust its level and position in the ocean.

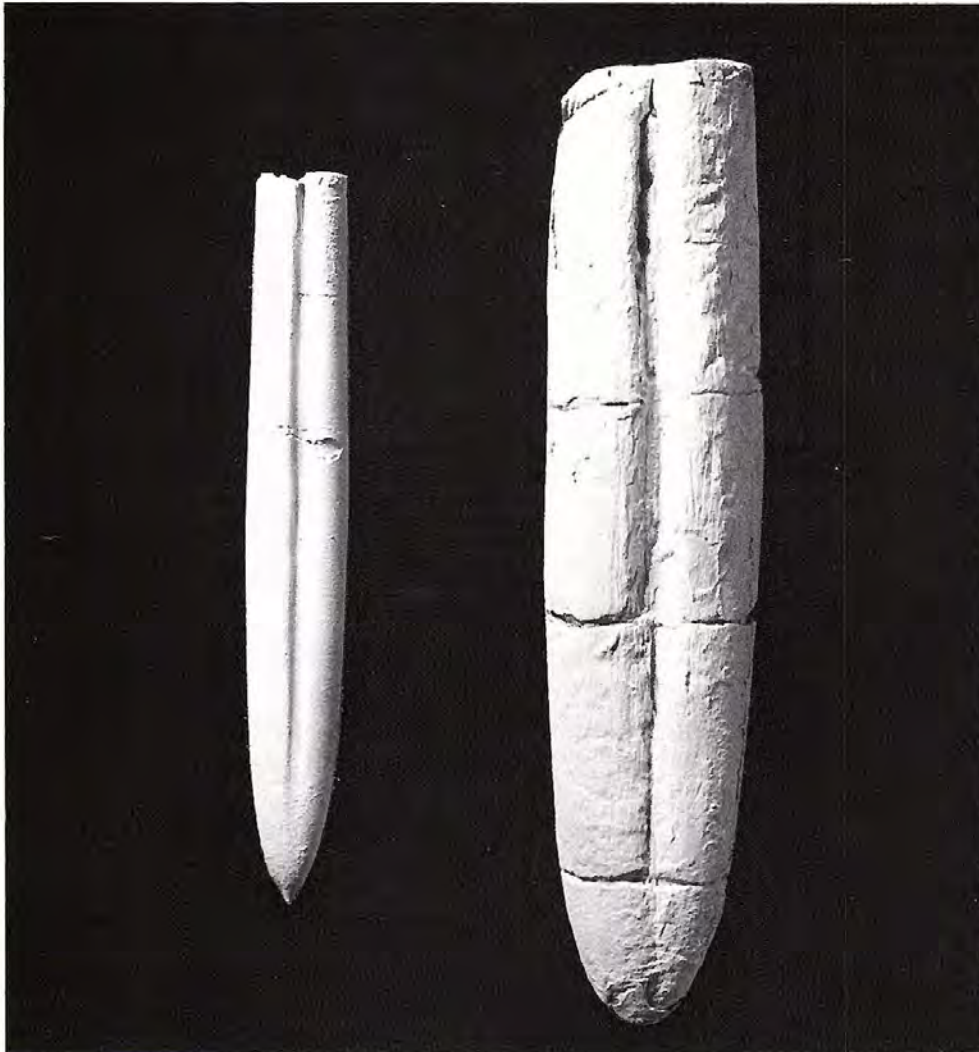
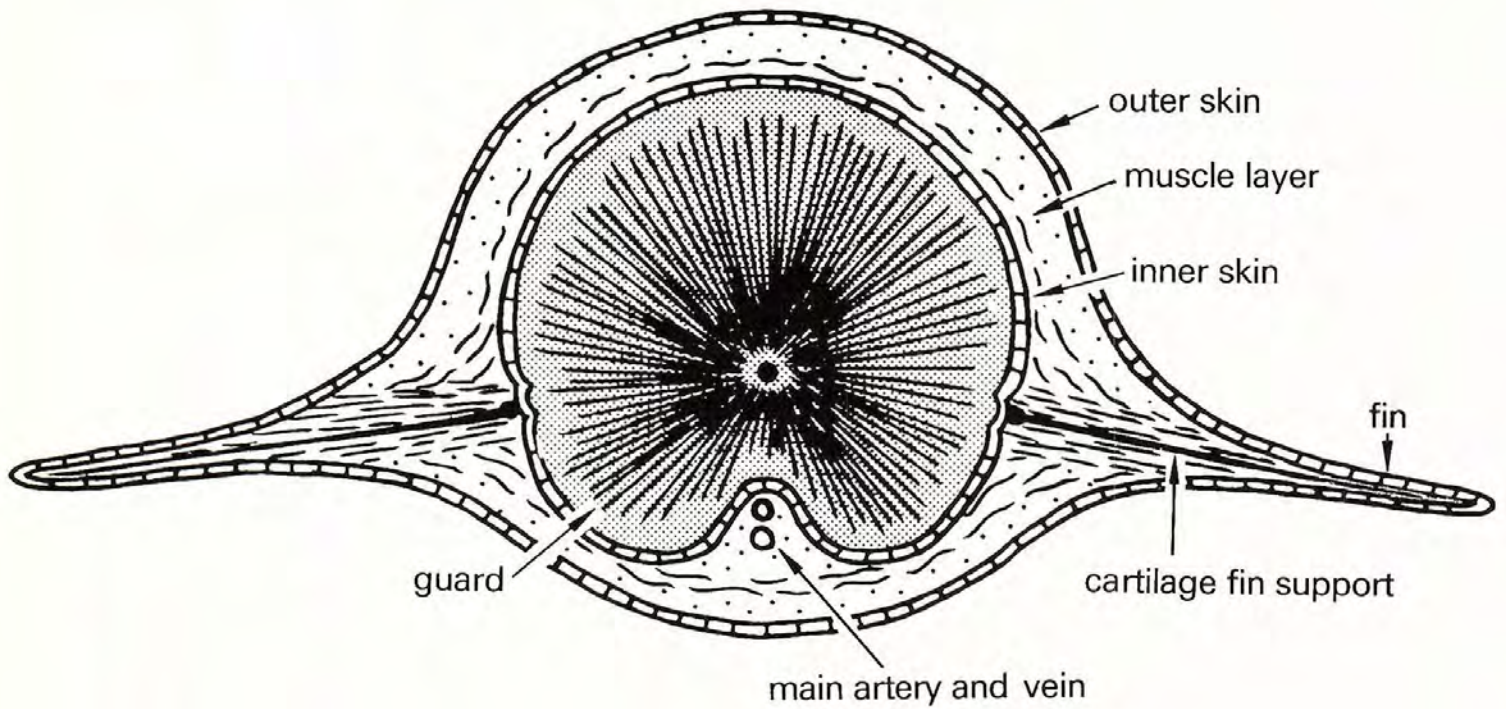
As geological time passed the conical chambered shell of the cephalopods evolved into a spiral and gave rise to the ammonites, which became extinct at the end of the Cretaceous, 65 million years ago, and to the nautiloids, which survive as the beautiful pearly

nautilus in tropical seas around New Caledonia, Fiji, Solomon Islands, New Guinea, the Philippines and SE Asia.

An early branch of cephalopods retained the straight, long, narrow chambered shell as an internal support, modified in various ways. One modification was the expansion of the dorsal part of the shell and its extension forwards as a flattened structure, the pro-ostracum, to support the soft parts. Another was the posterior development of a solid shelly rod, the guard, to counterbalance the heavy head and tentacles. From this developed the Coleoidea which include the modern squids, cuttlefish and the extinct belemnites.

Belemnites appeared in the Jurassic period, 190 million years ago, although earlier ancestral forms are known. Belemnites had a squid-like body but differed from today's squids in having a hard shelly internal skeleton divided into three parts. One part, towards the front, consisted of a thin shohorn-like shell, the pro-ostracum. The second was a chambered cone, the phragmocone, extending backwards from the pro-ostracum, which fitted into a deep conical pit in the front end of the third part of the skeleton. This third portion, the guard, was a solid calcareous bullet- or cigar-shaped structure which extended into the belemnite's tail. It was often the largest and most commonly preserved skeletal part.

Belemnite guards occur in abundance in certain areas of England and Europe and were well known to ancient peoples. The word 'belemnite' is very old, and its first written appearance was in the treatise *De natura fossilium*, published in 1546 by the 'Father of



Cross-section through a belemnite guard and the surrounding soft tissues (above). Large blood vessels run along the underside of the squid-like body, sending out branches to the fins. Often the blood vessels lie along a groove in the ventral surface of the guard. Diagram by Graeme Stevens/N.Z. Geological Survey.

Belemnite guards (left) from New Zealand (left, 114 mm in length) and Papua New Guinea (right, 160 mm in length). Both came from late Jurassic rocks, laid down in the sea about 140 million years ago. It is estimated that the New Zealand guard came from a belemnite squid about 1.2 m long, and that the Papua New Guinean one from a squid about 1.6 m long. Photo by N.Z. Geological Survey.

Mineralogy', Georgius Agricola. The word came from the Greek *belemnion*, a dart. Around the shores of Kawhia Harbour, New Zealand, Maori children played with belemnites which they called *rokekanae*, mullet excrement. They thought this fish leapt out of the water leaving belemnites on the shore. In mediaeval times belemnites were believed to be either underground stalactites or thunderbolts fallen from the sky. In the seventeenth century Sicilian naturalist and painter Agostino Scilla concluded that belemnites were the shell of some unknown mollusc. He was correct. At the beginning of the nineteenth century French naturalists Cuvier and Lamarck proved that they were the remains of extinct molluscs related to squids and cuttlefish. In the late nineteenth and early twentieth centuries, specimens were found in England and Ger-

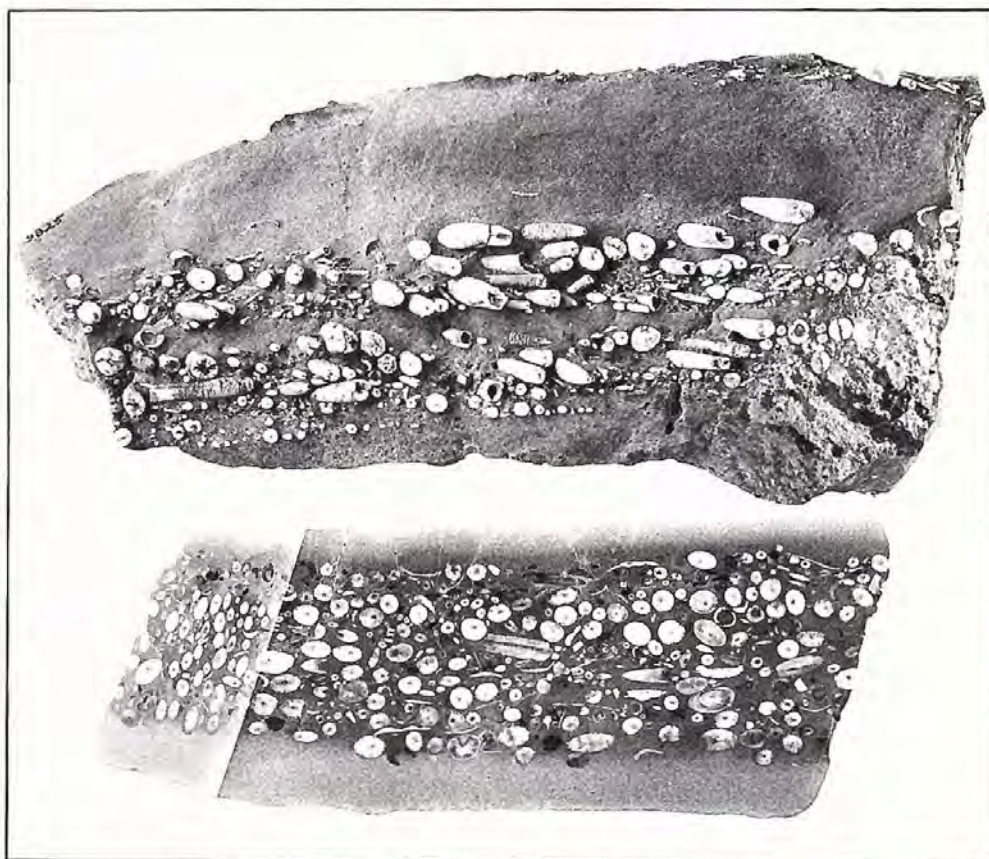
many with guard, phragmocone and pro-ostracum intact and impressions of the soft parts, including the arms with rows of hooklets and ink sac, outlined in the surrounding rock.

Study of fossils with impressions of the soft parts indicate that belemnites looked and acted like the modern squids. The torpedo-shaped body was surrounded by a fleshy mantle spreading into two lateral fins. These kept the body right side up and guided it up or down. Behind the head was a constricted neck, and the eyes, like those of the squid, were extremely efficient. Ten tentacles surrounded the mouth and were set with rows of strongly curved, sharp hooks for grasping and holding soft-bodied prey. Like most cephalopods belemnites probably swam by taking water into the mantle cavity and forcing it out as a jet through the funnel. When the funnel pointed forward, the belemnite moved backward. When it pointed to the rear, the belemnite moved forward. If alarmed the animal could release through the funnel a thick dark liquid from an ink sac that opened into the cavity. The ink spread to confuse the predator and help the belemnite to escape. An ink sac, like that of modern squids, is sometimes discovered in well-preserved fossils.

The pro-ostracum was seldom preserved and probably served as an internal support for the forward portion of the body and an attachment for muscles. The chambered phragmocone, sometimes found still attached to the guard but usually as isolated pieces, probably functioned as a buoyancy apparatus which helped to suspend the body weight in water without undue muscular effort. The guard served as a counterweight and balanced the main part of the body, including head and arms. It probably also protected the delicate phragmocone tip, and was composed of fibres of calcium carbonate (calcite) oriented at right angles to the surface. As the belemnite grew, layers were added to the guard so that a concentric layered structure developed, resembling the growth rings of a tree trunk.

Like present-day squids, belemnites probably preyed upon small fish and crustacea and were in turn preyed upon by larger fish. Cuts, scratches and punctures on belemnite guard surfaces have been attributed to predators. Their principal enemies could have been fish, particularly sharks, and extinct marine reptiles such as ichthyosaurs and mosasaurs. Over 250 guards were found in the stomach of a large fossil shark—which perhaps died from indigestion!

When belemnites died and sank to the sea bottom, their flesh decayed, and the hard guards were usually all that survived to become fossils. The total body length of the original animal, from tail to the tip of the tentacles, was probably nine or ten times that of the guard. The largest known guard, from Indonesia, is 457 mm long, indicating an animal about 4.6 m long. The largest from Papua New Guinea measures 160 mm long. Specimens from Australia, New Zealand and New Caledonia measure about 113 mm in length representing animals some 1.2 m long, but most guards found are around 40 mm, representing animals about 0.4 m in length.



Belemnites occurring in rock (above). The specimens illustrated—naturally weathered (top) and polished (bottom)—come from a belemnite bed of late Cretaceous age (70 million years) outcropping on the coast of the South Island, New Zealand. The top slab measures 440 mm in length and the bottom slab 310 mm in length. Photos by N.Z. Geological Survey.



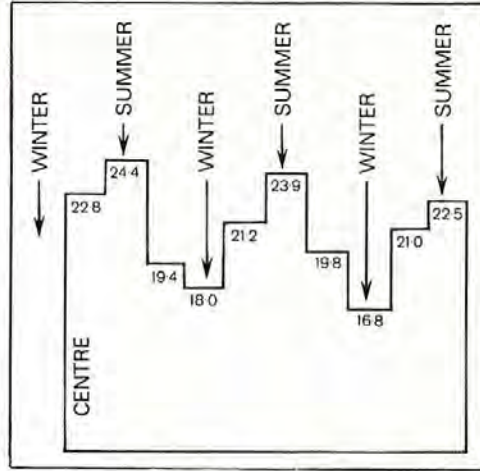
A hooklet from the arm of a belemnite (length = 22 mm) of late Jurassic, New Zealand. Photo by N.Z. Geological Survey.

Phragmocones from belemnites of late Jurassic, New Zealand (bottom right). Lengths are 50 mm (left) and 43 mm (right). Note the walls separating individual chambers. Photo by N.Z. Geological Survey.



Belemnites were comparable to the small or medium-sized squids of our coastal seas. Giant squids from deep waters, some of which have been washed up on New Zealand beaches near Cook Strait, reach lengths of 18 m and are the largest known invertebrates.

As with the ammonites, dinosaurs and many other creatures of land and sea, belemnites died out at the close of the Cretaceous period, 65 million years ago. Related cephalopods have survived as squids and cuttlefish. In the squids, the belemnite's hard internal skeleton has been lost and all that remains is a modification of the pro-ostracum, a horny gladius or pen providing some degree of dorsal stiffening. The cuttlebone or sepion of cuttlefish represents an expansion of the phragmocone along the underside of the pro-



Section cut across a belemnite guard 12.7 mm wide, from the late Jurassic of New Zealand (far left). The minor growth rings, barely visible in the photo, may represent monthly variations in growth, whereas the prominent major rings are probably annual. If this is correct, the guard is three years old. Photo by N.Z. Geological Survey.

Record of sea water temperatures (left) obtained from the guard illustrated. The figures are averaged temperatures in degrees Celsius and have been obtained from samples extending from the centre of the guard to the outside. They show that 140 million years ago (late Jurassic) sub-tropical seas surrounded New Zealand. The fluctuations show that the belemnite lived through three winters and died in the third summer. Diagram by Graeme Stevens/N.Z. Geological Survey.

ostracum. In addition to bodily support, this light, spongy structure also serves as a buoyancy mechanism. The animal can pump water and gas in and out of the cuttlebone to adjust its density.

Belemnite guards from Papua New Guinea, New Caledonia and New Zealand identify related rock strata in these widely separated areas, and provide information about past geography. In the Jurassic, 190 to 136 million years ago, we can recognise certain belemnites as having lived close to the then North Pole. Such groups are known only from areas like Siberia, Greenland, Spitzbergen, northern Europe and northern Canada and have been called 'Boreal', signifying their northern distribution. Others lived in the shallow seas (collectively called 'Tethys') that then covered parts of central and southern Europe and at times, South America, India, Africa, SE Asia, Indonesia, Australia and New Zealand. These belemnites, living essentially in the Tethys and interconnected seas, have been named 'Tethyan'.

As a globe will show, we should, in the Southern Hemisphere, expect to have an equivalent of the Northern Hemisphere Boreal life in seas peripheral to the South Pole. For years, despite exploration, no equivalent fossils were found. When expeditions to west Antarctica in 1964 discovered Jurassic belemnites similar to those of New Zealand, New Caledonia, Australia and Papua New Guinea, it became evident that in Jurassic times Tethyan animals could penetrate as far south as 75° S Latitude, in terms of modern geography.

Studies of Tethyan belemnites in the Mediterranean region indicated that they were associated with coral reefs and other tropical animals. Boreal belemnites had no such associations. Therefore they were considered as inhabitants of cool to cold water and Tethyan of warm to tropical water. At this point chemistry helped.

Belemnites and other sea creatures lived in and 'breathed' sea water containing dissolved oxygen of two main varieties, oxygen 16 and oxygen 18, which occur in proportions related to the water temperature. In any one area the proportions change with the seasons, or over longer periods if there were prolonged cooling or warming trends.

Lime (calcium carbonate) containing the oxygen isotopes was extracted from the sea water by marine life such as shellfish and belemnites to build their shells. Most shellfish built thin shells which after death did not withstand the stresses and strains of burial in sands and mud, and the original structure became altered in various ways. The bullet-like belemnite guards were more robust and their outer layers protected the inner growth rings from harmful chemicals. The oxygen isotope content of each limey growth ring depended on sea water temperatures at the time. If the guard was well preserved, each layer recorded temperature changes of the ancient seas. Sometimes fluctuations of as little as half a degree were detected and measured.

Detailed temperature analyses of individual belemnite guards give the summer and winter temperatures of the seas in which the belemnite lived. Climatic fluctuations revealed whether the belemnites lived in tropical seas, subtropical and so on. Also, the belemnite's age can be obtained from the number of seasons recorded. New Zealand belemnites seemed to have lived for three to four years, roughly comparable with the age span of squids living in our coastal waters.

Oxygen analyses of Boreal belemnites showed that they inhabited cool, but not frigid, waters. Fossils suggest that no polar ice caps mantled the Poles in the Jurassic, and oxygen analyses confirm this.

Oxygen analyses of Tethyan belemnites showed that those from the Mediterranean and southern Europe, found in association with coral reefs, lived in temperatures equivalent to the modern tropics. Other Tethyan belemnites, including those from the southwest Pacific and Antarctica, lived in subtropical or temperate seas similar to those now between New Zealand and New Caledonia.

Thus in Jurassic times countries like Scandinavia, Greenland, northern Europe, USSR and northern Canada were close to the North Pole, and seas were cool (geographers would term it cool-temperate) and similar to the waters now surrounding New Zealand's sub-Antarctic islands, e.g. Campbell and Auckland Islands.

Remaining land masses were either in tropical or subtropical waters. By tracing the

occurrences of Jurassic coral reefs and other tropical animals we can delineate a belt corresponding to the Jurassic tropics, and find it is slightly north of and at an angle to the present equator. Either side of the tropical belt we see in both Hemispheres areas corresponding to today's subtropical-warm temperate zones. In the Southern Hemisphere subtropical to warm temperate Tethyan fossils were evidently able to live in the southwest Pacific and spread to Antarctica and Patagonia. This distribution does not accord with our modern globe unless subtropical and warm temperate waters extended to the South Pole. We know from the Northern Hemisphere that cool water Boreal animals lived then in seas around the North Pole, hence we should find equivalent animals in the Southern Hemisphere. Despite diligent searching only warm water Tethyan animals have been discovered, even in Antarctica.

Palaeomagnetism shows that areas such as Greenland, Scandinavia, northern Europe, USSR and northern Canada formed part of a Northern Hemisphere super-continent called Laurasia, and in Jurassic times were grouped around the North Pole. Marine animals living at that time in the Laurasia seas would predictably have preferred cool water. Palaeomagnetism also shows that India, Africa, Papua New Guinea, Australia, New Caledonia, New Zealand, South America and Antarctica were then grouped together as a Southern Hemisphere super-continent, Gondwanaland. Some of the latitudinal 'fixes' are vague and have placed Gondwanaland close to the South Pole, to match Laurasia in the north. Our readings of rock records in the southwest Pacific and elsewhere in the Southern Hemisphere disagree. Clearly, from fossils and other evidence, Australia, New Zealand, New Caledonia, plus much of Gondwanaland, was close to the South Pole in the Permian. New Zealand and New Caledonia were then under the sea, but much of Australia was land scoured by continental ice sheets. But in the Triassic and Jurassic, seas covering the southwest Pacific appear to be subtropical or warm temperate. Temperate forests preserved as fossils grew in New Zealand, Antarctica and Patagonia leaving coal beds and layers containing plentiful leaves, seeds and pollen.

The conclusion is that New Zealand, Australia, Antarctica, South America

The belemnite world in the late Jurassic, about 162-136 million years ago (right). Clustering of the Northern Hemisphere landmasses around the North Pole, to form the super-continent Laurasia, led to development of distinctive cool-temperate Boreal belemnites. The Southern Hemisphere landmasses, grouped together as the super-continent Gondwanaland, were largely equatorial or mid-latitude in position. Many of the Gondwana countries were covered by an extensive sea, the Tethys, populated by tropical, subtropical and warm-temperate (Tethyan) belemnites. Diagram by Graeme Stevens/N.Z. Geological Survey.

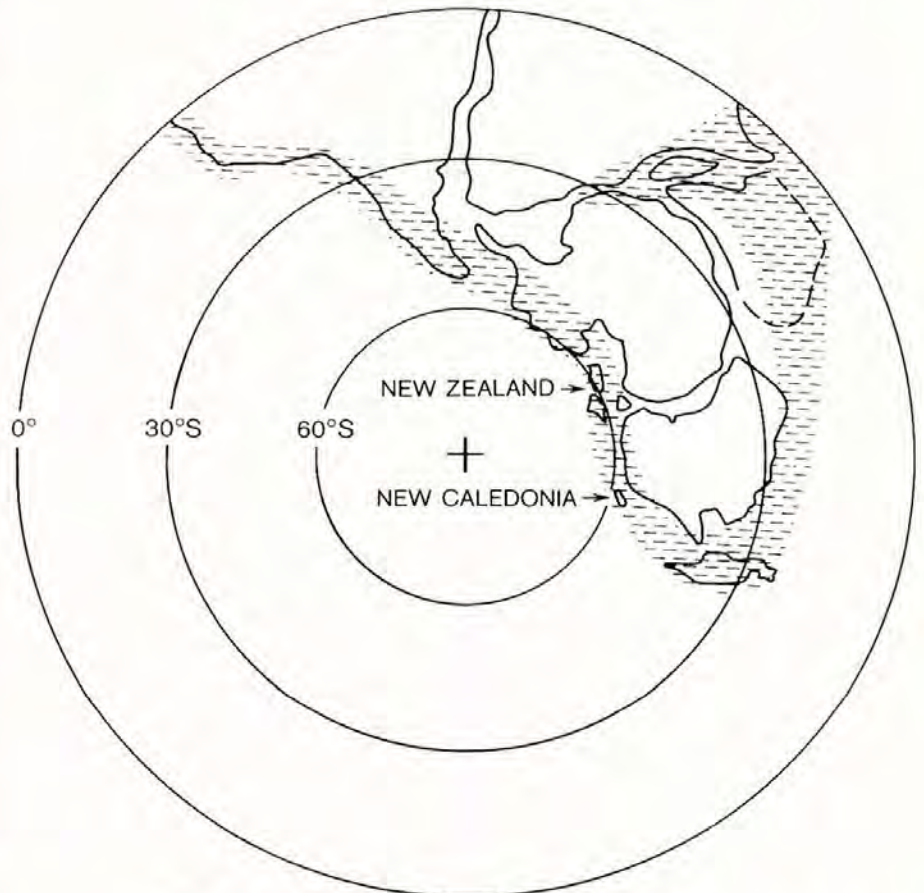
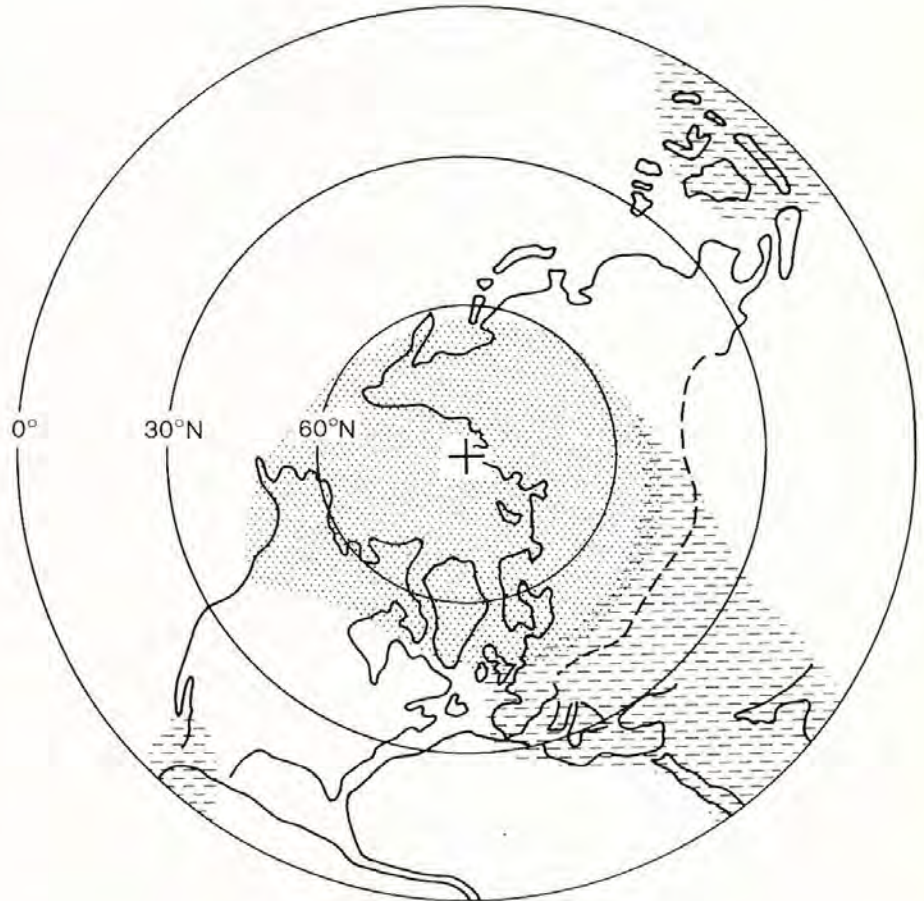
and probably the remainder of Gondwanaland were some distance from the South Pole for most of Triassic and Jurassic time. The Jurassic South Pole was probably a mere spot in the midst of a large southern ocean.

After the Jurassic there is a break in the fossil story preserved in rocks. Throughout much of the southwest Pacific no marine rocks were laid down for some 20 million years, covering much of the early Cretaceous. This could mean that land occupied most of what is now Australia, New Zealand, New Caledonia and Papua New Guinea.

When some of this land became submerged and the fossil story recommences in the early Cretaceous, some 115 million years ago, animals of the southwest Pacific seas were not the subtropical Tethyan types of earlier seas. They were cool water types and oxygen analyses of belemnites show that the seas corresponded in temperature to those now found south of New Zealand, between Stewart Island and Auckland and Campbell Islands. Similar faunas, called "Austral", also lived then in seas covering Antarctica and Patagonia. For the first time since Permian times, sea animals equivalent to the cool water Boreal forms of the Northern Hemisphere lived in Gondwanaland. Other factors such as changing world climate or oceanic currents may have influenced this marked swing from Tethyan to Austral animals in the fossil records, but a favoured interpretation is that the change is related to continental drift.

Much happened to Gondwanaland at this time. Splits started to appear, the Tasman and Atlantic seas were opening and land masses were moving and rotating. Palaeomagnetic measurements show that Australia, New Zealand, Antarctica and South America were gradually swung southwards during this breaking-up. As they moved closer to the South Pole, their shores were deserted by the warm currents of the Jurassic and Triassic, and cool currents were introduced. Thus the warm water Tethyan animals moved away from New Zealand and Australia and are found, for example, in India and SE Asia. Perhaps indicating a transitional zone between warm and cool waters, Austral and Tethyan forms mingle in Papua New Guinea.

Cool water Austral animals moved into areas vacated by Tethyan animals, and in the



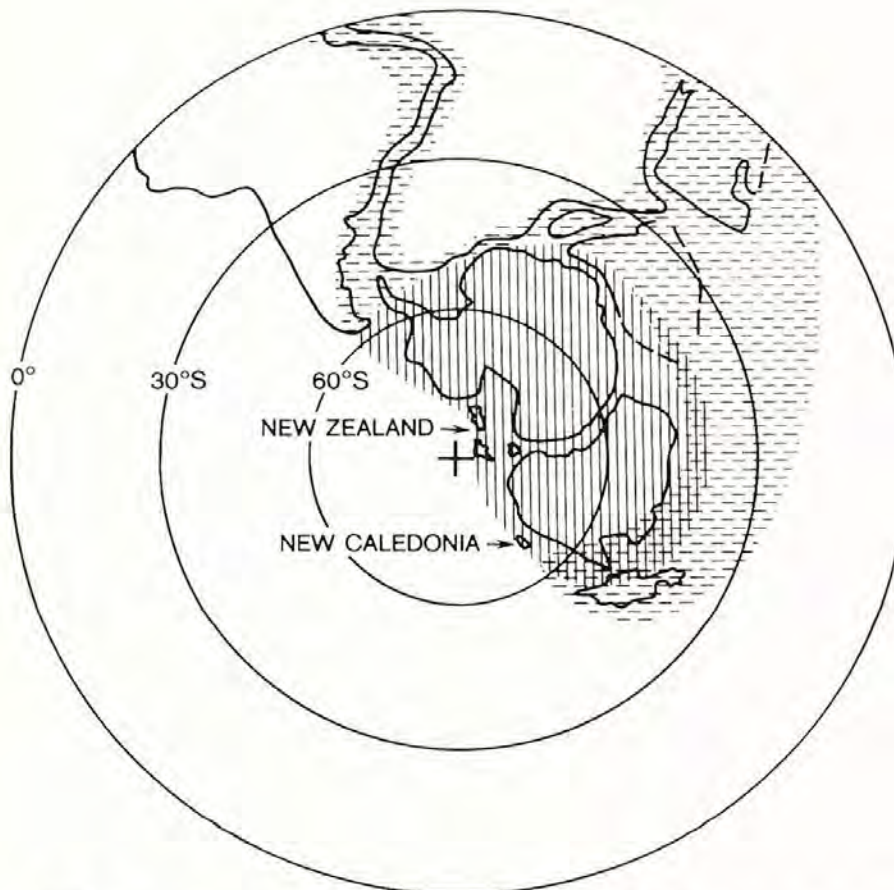
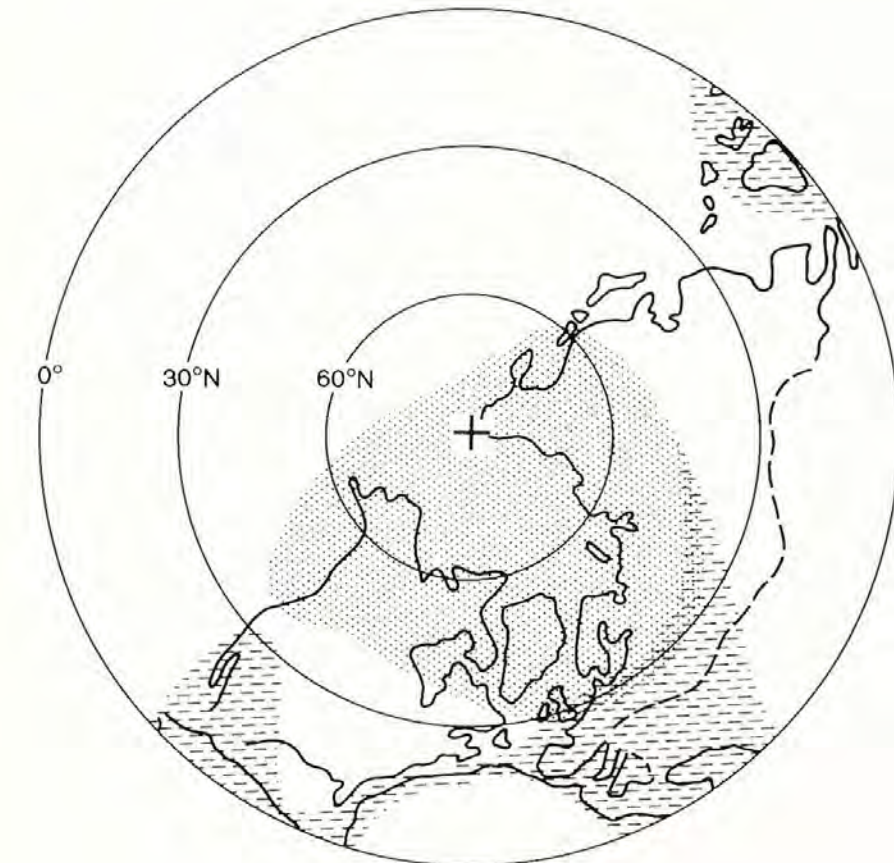
Boreal Realm



Tethyan Realm

Major changes in world geography occurred at the end of the Jurassic and extended into the early Cretaceous, as the two super-continents Laurasia and Gondwanaland started to break up.

The diagrams (left) summarise the situation in early Cretaceous times, 136-100 million years ago, when cool-temperate Boreal belemnites lived in the seas around the North Pole. At this stage the Northern Hemisphere landmasses had barely started to split apart. Fragmentation of Gondwanaland opened up a split between South America and Africa, allowing warm-water Tethyan belemnites to migrate along the shores of the infant South Atlantic Ocean. Movements of Australasia and Antarctica brought them closer to the South Pole, and the seas of these countries were populated by Austral belemnites, which, like the Boreal ones, preferred to live in cool-temperate seas. Diagram by Graeme Stevens/N.Z. Geological Survey.



Cretaceous we have a completely new set of fossils with marked southern affinities. Austral animals lived in New Zealand and Australia for the entire Cretaceous, and oxygen analyses show that cool waters washed these shores throughout. In the early Cenozoic, tropical and subtropical immigrants, signalling warmer seas, started to appear and the Austral animals gradually disappeared. This warming of the southwest Pacific seas may reflect a gradual reversal of the drift south and, with the opening of the sector of the Southern Ocean between Australia and Antarctica, starting 55 million years ago, Australia and New Zealand began to separate from Antarctica to journey northwards back into subtropical realms. Antarctica drifted south and from this time on their fossil histories, which had had so much in common, began to diverge.

#### FURTHER READING

- Stevens, G. R. 1965. The Jurassic and Cretaceous belemnites of New Zealand and a review of the Jurassic and Cretaceous belemnites of the Indo-Pacific region. *N.Z. Geological Survey Paleontological Bulletin* 36.
- 1967. Upper Jurassic fossils from Ellsworth Land, west Antarctica, and notes on Upper Jurassic biogeography of the South Pacific region. *N.Z. Journal of Geology and Geophysics* 10: 345-393.
- 1971. Relationship of isotopic temperatures and faunal realms to Jurassic and Cretaceous palaeogeography, particularly of the southwest Pacific. *Journal Royal Society N.Z.* 1: 145-158.
- 1973. Jurassic belemnites; Cretaceous belemnites. In A. Hallam (ed.) *Atlas of Palaeobiography*. Elsevier, Amsterdam, pp. 259-274, 385-401.
- 1977. Mesozoic biogeography of the southwest Pacific and its relationship to plate tectonics. In *International Symposium on Geodynamics in the Southwest Pacific*. Editions Technip, Paris, pp. 309-326.
- Stevens, G. R. and R. N. Clayton. 1971. Oxygen isotope studies on Jurassic and Cretaceous belemnites from New Zealand and their biogeographic significance. *N.Z. Journal of Geology and Geophysics* 14: 829-897.



Boreal Realm

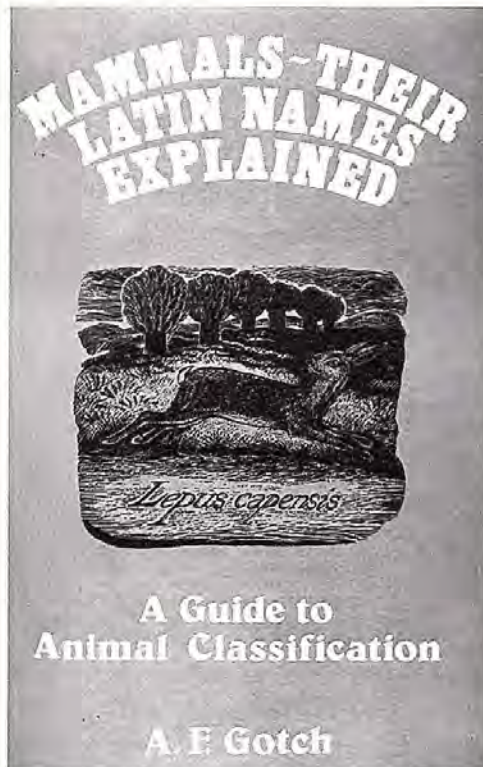


Tethyan Realm



Austral Realm

# IN REVIEW



*Mammals—Their Latin Names Explained* by A. F. Gotch, Blandford Press Ltd, Poole, UK 1979, 271 pages, \$19.50.

Animal taxonomy, the system of naming species and other fixed categories with which we attempt to impose systematic order upon a fluid and uncompliant Animal Kingdom, is almost as much an art as a science. To an outsider, the intricate arguments considered by the International Commission on Zoological Nomenclature may seem to have more in common with mediaeval theological scholasticism than with the language of scientific research. However, a great deal of infinitesimal nit-picking is required to ensure that, once a scientific name has been properly attached to an animal, it remains unchanged.

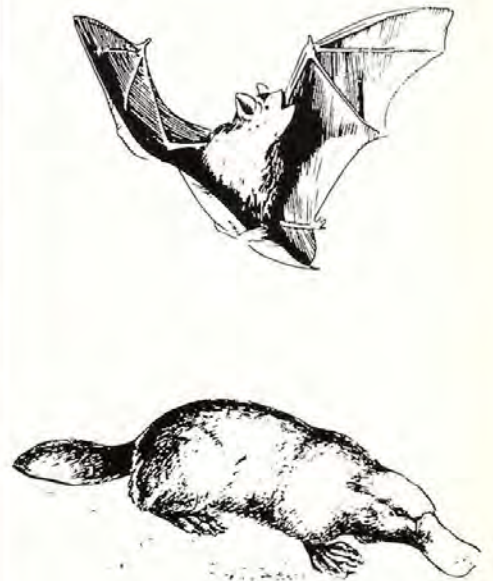
Coining the name for a new species provides a zoologist with a rare chance to make his mark, perhaps in perpetuity. A name may be stolidly descriptive of appearance as in *Pteropus poliocephalus*, 'grey-headed wing-foot' for the grey-head fruit-bat or flying-fox; it may mix description with locality, as in *Rhinoceros sondaicus*, 'Sunda Islands horn-nose' for the Javan rhinoceros; or behaviour, as in *Tachyglossus aculeatus*, 'spiny fast-tongue' for the echidna. Often a name commemorates a person, as in *Gazella granti*, Grant's gazelle, or *Dendrolagus goodfellowi*, 'Goodfellow's tree-hare' for the tree-kangaroo. Good manners demand that one does not name a species after oneself: wise tactics suggest, however, that if one bestows the name of a fellow-taxonomist on a species, he or she is likely eventually to return the compliment.

Some names are derived from languages other than Latin or Greek, as in *Potorous*, from the Aboriginal *potoroo*, a small wallaby, or *Vombatus*, from Aboriginal *wombat* or *wombach*. A few seem intended to be obscure, such as *Zyzomys*, the name of an Australian mouse, which seems to have no meaning apart from its reference to a mouse, *mys*.

Gotch's book provides the non-specialist reader with a short introduction to the principles of animal taxonomy and explores the meaning of about 1,000 mammal names, presumably chosen because of their interest, from the 4-5,000 species that have so far been described. On a photographic safari to Uganda, Gotch, a retired schoolmaster, became interested in the names of the animals he encountered, found there was no book explaining their derivation, and so set out to compile one. For an author who is neither a classical scholar nor a zoologist, it is a remarkably good work, although—almost inevitably in a first edition—it contains errors which attract the attention of those with more detailed knowledge. Without wishing to detract from the general value of the work, I feel it worthwhile to record some corrections or amendments to the names of Australian animals that are mentioned:

*Antechinus stuartii*, the brown antechinus, was named after Dr James Stuart (1802-42), Assistant Colonial Surgeon in Sydney and Norfolk Island—not after J. McDouall Stuart, the explorer.

Although Troughton did not explain the deriva-



tion of the name *Planigale* when he coined it, it almost certainly means 'flat' (*planus*) 'weasel' (*gale*); weasel having taken the secondary connotation of 'marsupial' as in its use in *Phascogale*, *Petrogale*, rock-wallaby; *Thylogale*, pademelon; and *Onychogalea*, nail-tailed wallaby. *Planigale* does not mean 'flat helmet'.

*Antechinomys spenceri*, the kultarr or jerboa marsupial-mouse, was not discovered by W. B. Spencer, but by E. C. Stirling.

*Dasyurus quoll*, the eastern quoll, is properly known as *D. viverrinus*; 'quoll' is a vernacular name.

*Dasyurinus*, the western quoll; *Satanellus*, the northern quoll; and *Dasyurops*, the tiger quoll, are currently all known by the older name, *Dasyurus*.

*Thylacomys*, bilby, is currently known as *Macrotis*.

*Isodon marcourus* is a misspelling of *macrourus*.

*Cercartetus*, pygmy-possum, is not of clear derivation. It obviously refers to a tail, Greek *kerkos*; but Gotch's derivation of the rest of the name from Greek *artao*, 'fasten to' and Latin *-etus*, 'a place', is unconvincing.

*Burrmys parvus*, the mountain pygmy-possum, has never been known as the dormouse possum. The generic name is derived from Aboriginal *burra-burra*, 'place of

many stones' and not from "Burra . . . a town in south-eastern Australia".

*Gymnobelideus leadbeateri*, Leadbeater's possum. The generic name, as Gotch points out, means 'naked dart', but since *Belideus*, 'dart', was once a name for the sugar glider and its kin, *Gymnobelideus* carries the extra connotation of 'naked glider'.

*Petaurus australis* is the name of the yellow-bellied glider, not the sugar glider, *P. breviceps*.

For *Hypsiprymnodon*, the musky rat-kangaroo, Gotch is puzzled by the apparent meaning: *hypsos*, 'high'; *prymnos*, 'romp'; *odontos*, 'tooth'. The reference is to a species having molar teeth like those of *Hypsiprymnus*, a name which was once applied to the potoroos.

*Pteropus poliocephalus* refers to the grey (*polios*)-headed fruit-bat or flying-fox, not as Gotch suggests, a 'polished or whitened head'.

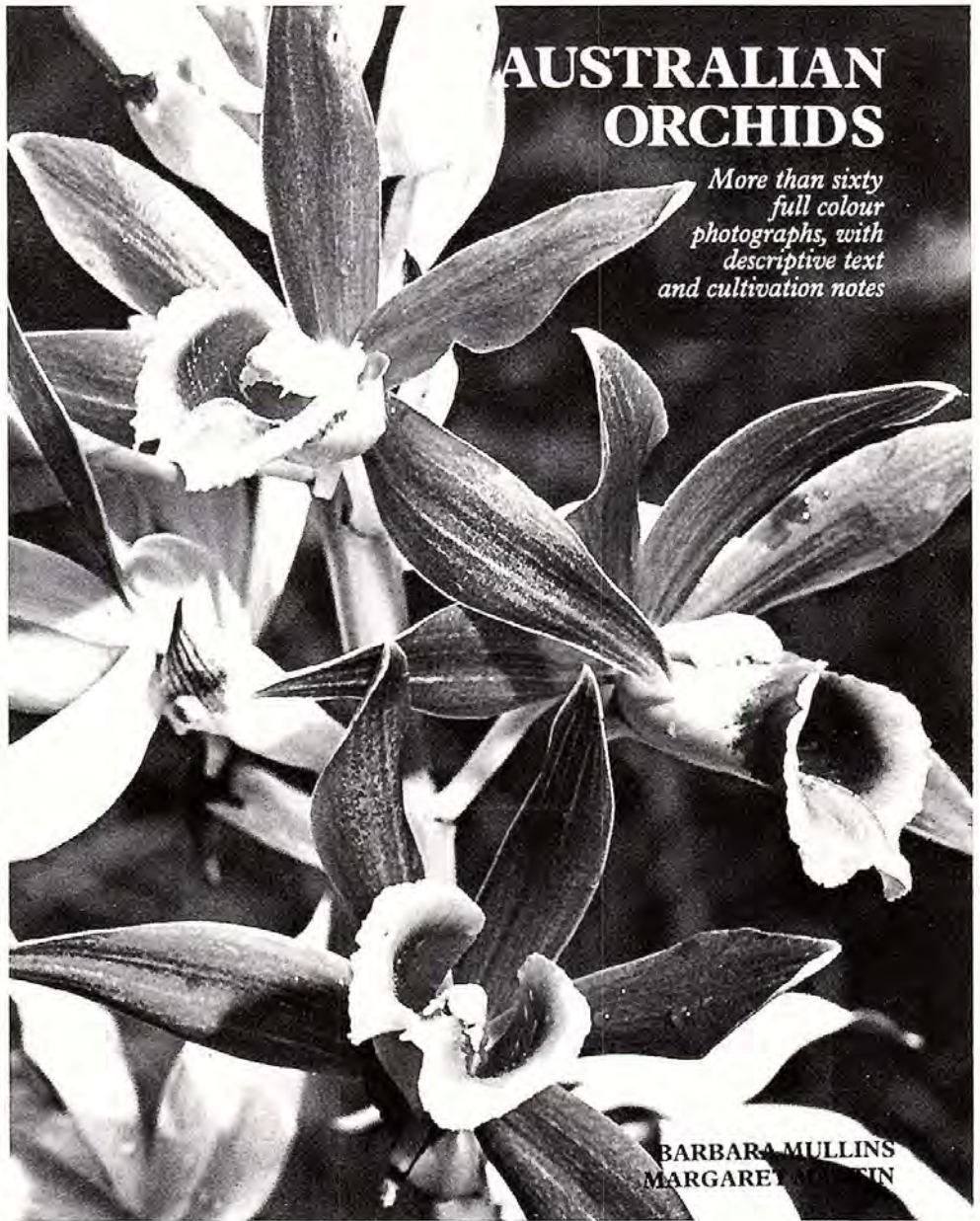
Among the 75 Australian species mentioned, these errors are not very considerable and it would be hardly worth mentioning them if I did not feel that the book is of sufficient value to deserve a second edition.—*Ronald Strahan, Research Fellow in Functional Anatomy Unit, The Australian Museum.*

**Australian Orchids** by Barbara Mullins and Margaret Martin, Angus and Robertson, Sydney 1980, 36 pages (including covers), illustrated, \$3.95.

This is a most attractive booklet, containing 60 colour photographs of Australian native orchids and text. The cover blurb states there are more than 60 photographs, but this number can only be accounted for by including those duplicated on the covers. The photographic quality is generally high with most photographs being faithful to the subject. A few are not of adequate quality for publication (e.g. those of *Diuris maculata* and *D. longifolia*), and six are upside-down. The captions accurately name the plants, except that *Acianthus exsertus* is wrongly spelled, and the orchid given on page 19 as "*Diuris* species" is undoubtedly the well-known *D. longifolia*.

In recent years numerous prettily illustrated natural history books with worthless text have appeared on the market. I believe, however, that the text of this book is not merely worthless but so misleading as to work against reasonable educational processes. The number of erroneous or misleading statements is prodigious and covers the fields of botanical science, history, and horticulture.

I mention only one example of each kind. The body of the duck in the flying duck orchid, *Caleana major*, is simulated not by "an inflated hollow sepal" (page 4) but by the broadly winged column. The rare and diminutive *Bulbophyllum minutissimum* was certainly not "first reported in Pitt Street, Sydney, in the 1840s" (page 4) as by this time that area had been built up for some years. The discovery was made according to Fitzgerald, who quotes Archdeacon King, "in 1849, at the back of the old mill in the gully, then in a state of nature,



leading down from Woollahra to Rushcutters Bay". Those who follow the advice on page 35, that "terrestrials (i.e. ground orchids) should be tucked around the base of trees and beneath shrubs in the sheltered, leaf-littered native garden" are in for many disappointments. I would advise the reader who feels he must grow these plants to grow them in pots of bush loam if he hopes to keep them for more than a season or two.

I have tried to find some plan in the sequence of the text, and, apart from placing a few introductory remarks at the beginning, there appears to be none.

The orchids are a plant family that has suffered depletion from land development and over-collection more, perhaps, than most. I therefore approached the book in the expectation of finding a conservation message. I eventually discovered at the foot of the index the inaccurate statement: "All native orchids growing in wild state are protected." Nothing

more. Elsewhere in the book there is indeed a message. It runs something like this: If you find a wild orchid dig it up or remove it from its perch, take it home and try to grow it. I can only attempt to counter this irresponsible attitude by pointing out that only a few Australian species can be cultivated successfully without a great deal of knowledge and care, and, with changes in human culture and interests, the only chance for the survival of a great number of species into future centuries is in sparing them in their natural habitats.

It must now be apparent to the reader that I am not recommending this book, though it might be suitable, because of its illustrations, to give to a short-term visitor to this country. No doubt publishers produce books of this none-too-rare ilk to make a quick dollar. I find it sad that a publishing firm which has been associated with many of Australia's best books on popular natural history should have so dropped its standards.—*David K. McAlpine, Curator of Entomology, The Australian Museum.*



# HIGHER FUNGI IN FOCUS

The very mention of mushrooms and toadstools conjures up visions of a mystical world of elves and the supernatural. The real-life world of these and other fungi is just as fascinating. Fungi do not have chlorophyll in their cells and do not rely on photosynthesis to grow and develop as do other plants. They obtain their nourishment in a similar way as animals—by breaking down the complex organic material of plants and animals (living or dead). The types of fungi range from microscopic forms that are responsible for, among other things, ringworm, athlete's foot, potato blight, penicillin and the making of beer, to the more familiar 'higher' fungi—the Basidiomycetes—such as mushrooms, puff balls, brackets, jelly and coral fungi, and the parasitic groups of rusts and smuts. Certainly the variety of shapes, colours and textures found in some of Australia's higher fungi deserves a closer look.



The above ground portion, cap and stalk, of mushrooms as seen in the lilac-coloured blewit (top) is the fruiting body which arises from a below ground mass of fungal threads. Photo by Bob Crombie.

Radiating from the centre and beneath the cap of a mushroom are the gills which hold the spores. The gills of this old decaying individual (above) have already released their spores. Photo by Greg Gowing/The Australian Museum.

Moisture and warmth encourage the production of the fruiting bodies of mushrooms; which explains the abundance of these *Galera* (right) in the rainforest vegetation. Photo by Bob Crombie.





The group known as Basidiomycetes has about 15,000 species and contains the largest and most conspicuous of the fungi. However, it is not the size or shape of these individuals that separates them from other fungi, but rather the composition and arrangement of the fungal threads, called hyphae, and the spore-forming structures. The Basidiomycetes are further divided into two main subgroups. One, the Heterobasidiomycetes, includes the jelly fungi and the closely related, but structurally dissimilar, smuts and rusts. The species in the second subgroup, the Homobasidiomycetes, have large fruiting bodies and include mushrooms, toadstools, coral fungi, brackets, puff balls, stinkhorns and earth stars.


The gelatinous texture of the open fruiting bodies of *Tremella* (top left) identifies this species as a jelly fungus. It is frequently seen growing on dead wood. Photo by Bob Crombie.

Bracket fungi (above) typically produce shelf- or plate-like fruiting bodies of a leathery or corky texture that may persist for years. These fungi attack dead and living trees, and can be a serious problem for the timber industry. Photo by Philip Green.

Coral fungi and fairy clubs (left) are close relatives of the bracket fungi. Spores are released from most of the above ground surface of the plant. Photo by Bob Crombie.

The agarics are the gill-bearing cap-and-stalk fungi we normally call mushrooms and toadstools. Even within this group of fungi variety is very much evident, with differences in the development, size, colour and texture of the fruiting bodies, form of the gills, and the colour of the spores. The delicacy of the small *Mycena* (right) illustrates but one aspect of this variation. Photo by G. Dennis Campbell/The Australian Museum.





Mushrooms are a common sight on a forest floor following rain. Although they are unable to photosynthesise, mushrooms and other fungi serve an important role in a forest ecosystem food web by recycling the nutrient substances of dead plant tissues. Clusters of the grey bonnet, *Mycena subgalericulata*, can be found in Australia's wet forests throughout the cooler months. Photo by Bob Crombie.