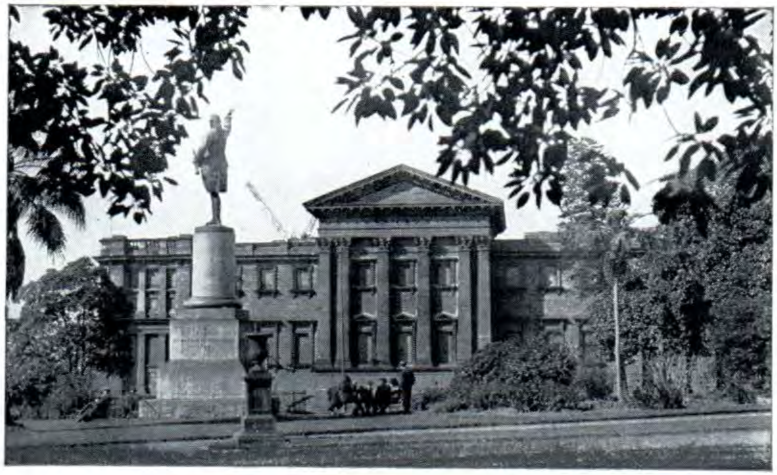
AUSTRALIAN NATURAL HISTORY

PUBLISHED BY
THE AUSTRALIAN MUSEUM
SYDNEY

DECEMBER 15, 1965
VOL. 15, No. 4
PRICE, 3/-, 30c

Registered at the General Post Office, Sydney, for transmission by post as a periodical



This special issue is devoted to the natural history of the deserts and other arid areas of Australia's interior. It contains eight extra pages.

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● **FRONT COVER:** The Rabbit-eared Bandicoot (*Thylacomys lagotis*), a typical member of the mammal fauna of Australian deserts. It excavates deep burrows with the powerful claws on its forefeet. The photo is by Howard Hughes. An article on mammals in the arid regions of Australia appears on page 119.

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Published Quarterly by the Australian Museum - - - College Street, Sydney

Editor: J. W. Evans, Sc.D. Annual Subscription, Posted, 14/-, $1.40

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The Natural History of Australia's Arid Interior

THIS issue of *Australian Natural History* is devoted to the arid interior of Australia. This is an area of increasing accessibility and tourist interest, but the numerous photographs and paintings which adorn postcards, calendars and travel posters tend, not unnaturally, to stress its more imposing but less typical features.

True deserts are rare in Australia, but arid and semi-arid areas occupy about 70 per cent of the continent. By virtue of its size alone this region is important to Australia and Australians, but it is important also for many other reasons, in particular for the scientific interest of its fauna, flora and geology.

Many of our desert and semi-desert areas receive an average annual rainfall of more than 10 inches—enough by most standards to support not only a rich fauna and flora but also moderate agricultural and grazing activities. The rainfall, however, is unreliable, and many areas may lack appreciable rainfall for periods of several years.

Nevertheless, the arid interior of Australia is relatively richly endowed with animals and plants, and many of these have evolved complex physiological and behavioural adaptations to life in arid regions. Many others have been enabled to survive not by becoming adapted to these conditions, but by actually avoiding them, for example by occupying habitats such as rock crevices, waterholes or burrows, or by their nocturnal habits.

Because of its vast area and apparent uselessness, little thought has been given to the need to conserve large samples of this interesting environment. In an area of such climatic extremes, where prolonged droughts are of relatively frequent occurrence, the need for careful and studied use of available resources should be clearly apparent. The ravages of land misuse—including overgrazing and overstocking—may be long in manifesting themselves, but they are all too evident in many areas today, and hence before very long the "Dead Heart" of Australia may come to live up to its name.

The Desert Areas of Australia

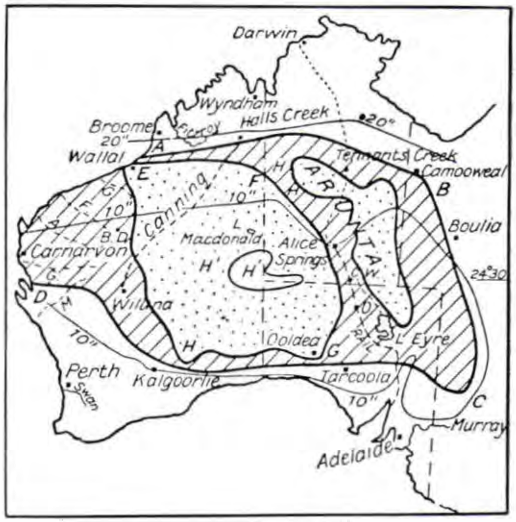
By H. O. FLETCHER

AN eminent climatologist, after a detailed study of the desert areas of the world, came to the conclusion that Australia has the second largest area of extremely arid land in any continent. It was estimated at 1,100,000 square miles in comparison with the Sahara region which has the greatest area with approximately 2,600,000 square miles of desert country. This figure for Australia very closely agrees to that which the late Professor Griffith Taylor had adopted as the combined area of what he termed "desert" and "sparseland", the former being practically useless land and the latter inferior pastoral land.

The geographical methods of defining desert and near-desert areas use vegetation, amount of average rainfall and the ratio of precipitation to evaporation. Many definitions, however, have been put forward to limit the features of what might be considered a true desert but these vary to such an extent that areas classed as deserts in one part of the world would not necessarily be the case in other parts. Very few of these would possibly not be very near to the popular idea of a desert which is formed in the mind of the average layman.

One author states that "a desert has become by definition not naked rock or sand, but a place of small rainfall with a sparse and specialized animal life". Another is that "a desert is a country with an arid climate and such a scanty water supply that agriculture is impracticable and occupation is found possible only for a sparse population of pastoralists". One school of thought accepts average rainfall as a means of determination as this involves the main factors, such as growth of vegetation and occupation. This is probably a very good test, as average rainfall as a criterion overcomes changes brought about by erratic rainfall.

Deserts and near-desert areas are somewhat of variable types in different parts of the world and in different latitudes. This is the reason why there appears to be no complete agreement among scientists as to what actually constitutes these areas. Griffith Taylor did not agree that merely rainfall determined a desert, as in parts of Australia large areas with a rainfall of about 5 inches have long been occupied by pastoralists while other regions with a rainfall ranging from 5 to 15 inches are unoccupied and are likely to remain unoccupied. The northern half of the Great Sandy Desert in Western Australia has a rainfall of 8 to 20 inches while the southern half, although it receives far less rain, has much less evaporation and there is little to distinguish between the features of the two areas.



This map shows the limits of Australian deserts. Sparselands, surrounding the true desert areas, are ruled. [From *Australia*, by Griffith Taylor.]

Very little of the Australian desert country has a rainfall less than 5 inches a year. It frequently happens, however, that over a period of successive years the rainfall may not exceed an inch, or even less, and then be followed by heavy rains of up to 10 or more inches for several seasons. On these occasions the desert areas are transformed into ones of striking beauty as the ephemeral shrubs and wildflowers quickly, almost miraculously, appear and cover the country with a carpet of colour. The transformation is, however, a very temporary one as the country soon reverts back to its arid condition of parched and barren plains.

The author, in 1939, as a member of the Simpson Desert Expedition, crossed that area by camel during a time when the country had never looked better in its known history. During the latter part of the crossing the expedition experienced almost 3 inches of rain within six days. On the other hand, about eight months ago, he passed through country lying between Ayers Rock and the Western Australian border which had had only a few points of rain during the past ten years. It was a country of dead and dying spinifex and mulga with a very marked absence of any animal life.

The late Professor Griffith Taylor, in an attempt to define a desert which would cover conditions in Australia, combined both climatic and economic factors. His definition was that "A desert is a region of small rainfall (sometimes, however, amounting to 15 inches in hot regions) with a sparse and specialized plant and animal life. It is not found capable of utilization by stationary pastoralists, even after the borders have been occupied by this class for fifty years".

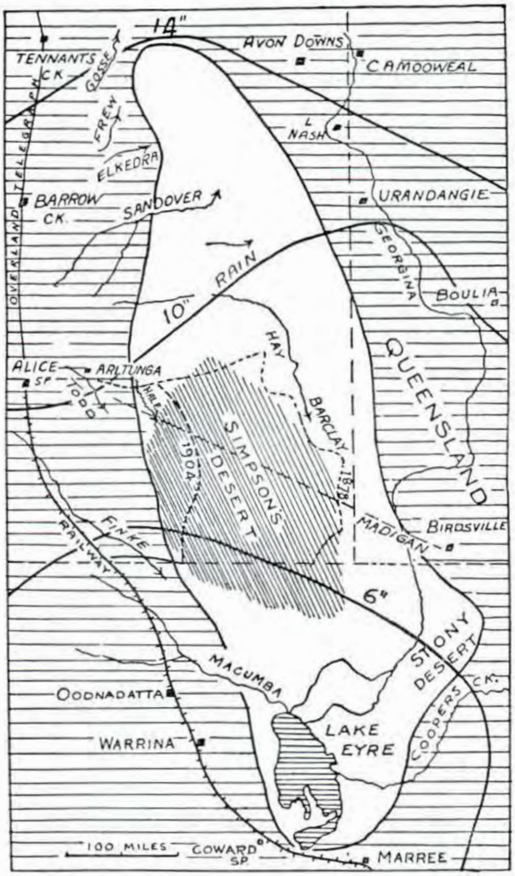
Australian Deserts

If the criteria in the above definition of a desert are adopted then obviously many large areas of country in Australia must fall into that category. The limits of the Australian deserts, including the sparselands, are shown in an accompanying illustration. They cover the greater parts of Western Australia, the Northern Territory, and South Australia and extend into the western fringes of Queensland and New South Wales.

The arid lands of Australia have very much in common with the Sahara Desert and there is little to choose between them and certain parts of it. The eastern half of the great Sahara Desert, now generally known as the Libyan Desert, consists mainly of large, flat expanses of sand or stone and areas of varying sizes where sand-ridges occur. The largest area of these dunes or sand-ridges is the Great Libyan *Erg*, which is also known as the Great Sand Sea. It lies against the western border of Egypt, forming an area about 300 miles long by 100 miles wide and has been said to be "probably the most imposing mass of dunes on the whole surface of the earth". The Great Sand Sea is quite uninhabited, is scarcely visited and the very high and long parallel sand-ridges are bare of vegetation. About one-seventh of the Sahara Desert is covered with *Ergs* or living dunes.

In Australia, the Simpson Desert and perhaps the Great Sandy Desert are the only regions which can be compared to the *Ergs* or worst sandy wastes of Africa. Most of the other Australian deserts, descriptions of which follow, also have many features of the Sahara and other great deserts of the world. The sparselands will not be dealt with as they consist of areas of arid or semi-arid land with a scattered pasture, a very limited population of pastoralists,

The Simpson Desert Expedition, 1939, descending a sand-ridge near the Queensland border. [Photo: Simpson Desert Expedition, 1939.]



The Arunta Desert, showing its elongated area of uninhabited country. [From *Australia*, by Griffith Taylor.]

but with a possibility of future development. The sparselands comprise about 700,000 square miles and they lie immediately outside the limits of the uninhabited true desert areas. These cover about 600,000 square miles and consist of two main regions, which are shown on the accompanying map illustrating the limits of Australian deserts.

The Arunta Desert

The smaller of these two regions, but an extremely arid one, is the Arunta Desert, which is situated approximately east of a line drawn between Tennant Creek in the Northern Territory and Marree in South Australia. To the east it extends into Queensland almost to Birdsville. The name Arunta was given to the desert by the late Professor Griffith Taylor, being derived from a well-known tribe of Aborigines who previously had lived in the area.

The original extent of the Arunta Desert was 700 miles long by 200 miles wide, but in 1929 the central part, comprising an area of about 56,000 square miles, was named the Simpson Desert. The south-eastern part of the Arunta Desert is known as Sturt's Stony Desert and this area, which is thinly covered with rock debris or "gibbers", has been compared with the *Serir* country of the Sahara. The Tirari Desert, lying to the east of Lake Eyre, is composed of low and firmly fixed sand-ridges with a sparse vegetation and has been said to be very like the northern part of the Sahara.

The northern part of the Arunta Desert, that is the country north of the Simpson Desert, consists of flat sandy wastes and rocky country and in this respect closely approaches the *Hamada* areas of the Sahara. The Arunta Desert, including the Simpson Desert, forms one of the driest parts of the Australian continent as it receives less than 5 inches average annual rainfall. Evaporation is also very high.

The Simpson Desert

The Simpson Desert is a large and distinct physiographical unit, its main feature consisting of long parallel sand-ridges which vary in height from 25 to 120 feet and extend unbroken for distances up to 200 miles. It lies approximately between latitudes 23° and 27° south and longitudes 135° and 139° east, extending some 300 miles north of Lake Eyre, and at its greatest width is about 250 miles. The desert was named in honour of the late Mr A. A. Simpson, C.M.G., of Adelaide. It is recognized as one of the great sand-ridge deserts of the world and its features are in close approximation to the worst desert areas of Africa.

The Simpson Desert is uninhabited, although a few pastoralists occupy its borders and the only recorded crossing of its centre, from west to east, is that by the Simpson Desert Expedition in 1939 under the leadership of the late Dr C. T. Madigan. During that expedition many chipped flints and other artifacts were collected and from this it is evident that in the past Aborigines penetrated into the centre of the desert. These occasions were possibly during periods of good rainfall when they followed the rivers down from the north.

The directional trend of the sand-ridges in the Simpson Desert is north-west to south-east, which is parallel to the direction of the prevailing winds. The average spacing of the sand-ridges is four to each mile and during the crossing of the desert 626 sand-ridges were traversed over a distance of 204 miles. The western slope of each sand-ridge is much gentler than the eastern slope which at times is very steep. The upper slopes of the ridges consist of fine, red sand, which form a fairly sharp, steep crest.

The Simpson Desert in comparison with other important deserts of the world is fairly well covered with vegetation and a number of plant species, many of them ephemeral, have been recorded. The most conspicuous and consistent are the tussocks of Cane-grass (*Spinifex paradoxus*), an excellent sand binder and one which serves to a great extent to keep the ridges compact and fixed in position. Spinifex or Porcupine Grass (*Triodia basedowii*) also grows in profusion as dense tussocks on the lower sand-ridge slopes and inter-ridge areas and also serves a similar purpose. Both of these plants are drought-resistant.

A recent writer, following a comparison of the features of the Simpson Desert, particularly in regard to the vegetation, placed it fifth in order of aridity out of eight of the great sand-ridge deserts of the world. The deserts in order of greater aridity are the Libyan Desert (North Africa), Takla Makan (Central Asia), Rub' al Khali (Southern Arabia) and the Western Sahara (North Africa).

The Western Desert

An enormous area of desert country, generally referred to as the Western Desert, is almost continuous over the major part of inland Western Australia, between the Kimberleys and the Nullabor Plain, and extends eastwards to the borders, and beyond, of the Northern Territory and South Australia. It is composed mainly of sandhills, sand-plains and a central part of stony desert. The famous Canning Stock Route, extending between Wiluna and Hall's Creek, now almost entirely unused, traverses most of the desert area. Over the whole of this area rivers are virtually absent or flow only after periods of heavy rainfall for short periods of time.

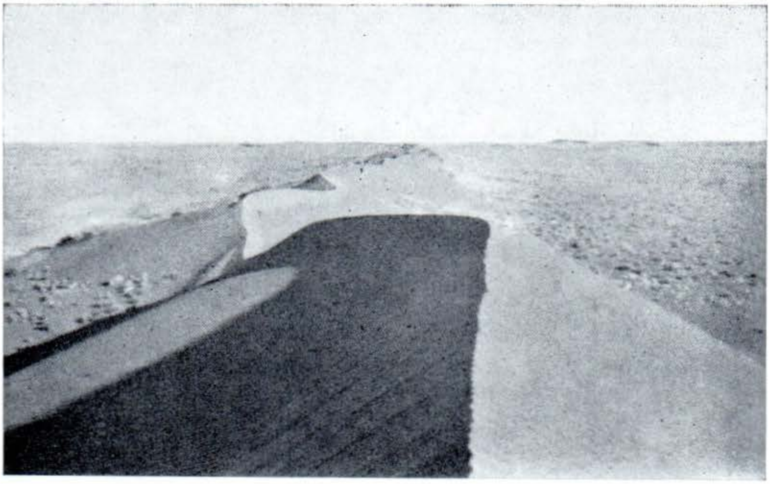
The Western Desert consists of three main regions and of these the northernmost one has been named the Great Sandy Desert; the central area is known as the Gibson Desert and south of it, extending to the Nullabor Plain, is a vast area of desert originally named the Great Victoria Desert. These three regions to a great extent lack unity, the limits are not well defined and the names are very seldom used. A brief description of these three deserts is as follows:—

The Great Victoria Desert

The Great Victoria Desert is a large, practically waterless area of sandy waste and fixed sand-ridge country which extends from Lake Barlee in Western Australia well

A high unstable sand-ridge in the Simpson Desert. Vegetation in the inter-ridge area consists mainly of gidgee (*Acacia cambagei*) and spinifex or porcupine grass (*Triodia basedowii*). [Photo: Simpson Desert Expedition, 1939.]

A big sand-ridge near the western edge of the Simpson Desert. [Photo: Simpson Desert Expedition, 1939.]



into South Australia to the east. Its southern limit is the Nullabor Plain and its northern limit the Gibson Desert, but this border has never been accurately defined. The desert was first crossed by Ernest Giles in 1875, who, after travelling more than 300 miles without finding any trace of water, found a spring which he named the Great Victoria Spring. He named the desert the Great Victoria Desert.

In 1896, the Hon. David W. Carnegie was the leader of an expedition which crossed the Western Desert from Coolgardie to Hall's Creek, a journey of 1,413 miles counting all deviations. Following the information gained during this expedition in regard to waterholes and springs the Canning Stock Route came into existence. Many hazardous cattle drives were made in the past along this route.

Carnegie's expedition entered the Great Victoria Desert at its north-western corner, east of Lake Darlot, and immediately found flat sandy country with fixed sand-ridges and covered almost entirely with spinifex. Most of the desert consists of belts of sand-ridges from 30 to 50 feet in height and 8 to 10 miles in width. The sand-ridges, more or less parallel to one another, vary in their general direction and in some cases are heaped up without any regularity. In between the belts of sand-ridges are broad sandy plains covered with spinifex, alternating with thickets of mulga and desert gums, the usual type of vegetation found over the whole of the Western Desert.

The Gibson Desert

The Gibson Desert is a large area of sandy waste and stony country, with many ranges of low hills, which stretches across the interior of Western Australia south of the Tropic of Capricorn. It adjoins the Great Sandy Desert to the north and in the south its limit is the Great Victoria Desert. Its east and west borders may be considered as the Northern Territory and the limit of settlement in Western Australia. The desert was first penetrated by Ernest Giles in 1876 and was named after Alfred Gibson, a young South Australian member of the party who disappeared when searching for water near the Alfred and Marie Range.

Carnegie referred to the Gibson Desert as "a great undulating desert of gravel", a very apt description as it consists largely of rocky or gravelly plains with only occasional sand-ridges. Practically the whole of the country extending between latitude 26° and 22° south is a vast sandy waste almost completely covered with pebbles and stone. Many ranges occur in the Gibson Desert and these, although they look imposing ranges from a distance, become dwarfed into series of low-lying, flat-topped hills, composed mainly of sandstone, as they are approached. Many are weathered into a variety of fantastic shapes.

Giles in his journal mentioned the excessive changes of temperature during night and day in the desert. This is the experience of all visitors to the desert areas of Australia during winter months. Temperatures of 32° to 36°F, and even lower, are not unusual at night while during the day temperatures soar to 90° to 100°F.

The Great Sandy Desert

The Great Sandy Desert is the northernmost region of the Western Desert. It is a large area of fixed, parallel sand-ridges, and extends approximately from latitude 19° south to about the Tropic of Capricorn, latitude 23½° south, or slightly to the north of it.

In this desert the sand-ridges run parallel to one another with great regularity and with a general trend of east by north and west by south. They are practically continuous to the border of the Northern Territory, a distance of 400 miles to the east, and maintain their regularity for at least 200 miles to the south. The average height of the sand-ridges is from 50 to 60 feet, while some reach a height of considerably more than 100 feet. They are usually about a quarter of a mile apart but at times they become closer together and quickly succeed one another with only slight troughs between them. The desert is largely devoid of vegetation with the exception of spinifex, which serves to bind the sand and keep the ridges compact and fixed in position. Scattered thickets of mulga are also found and towards the northern border of the desert occasional desert oaks.

An interesting feature of the Australian desert areas is the almost uniform type of vegetation and the fact that there are no living sand-ridges which can be compared with the *Ergs* of the Sahara. Geographers, however, agree that there is a great similarity between the northern Sahara and the Australian deserts in that to some extent both possess a fairly good covering of vegetation and can support a sparse population.

Australian Museum Publications

The following Australian Museum publications are available at the Museum:—

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LEAFLETS on natural-history and Aboriginal topics: Free of charge.

Central Australian Mountains

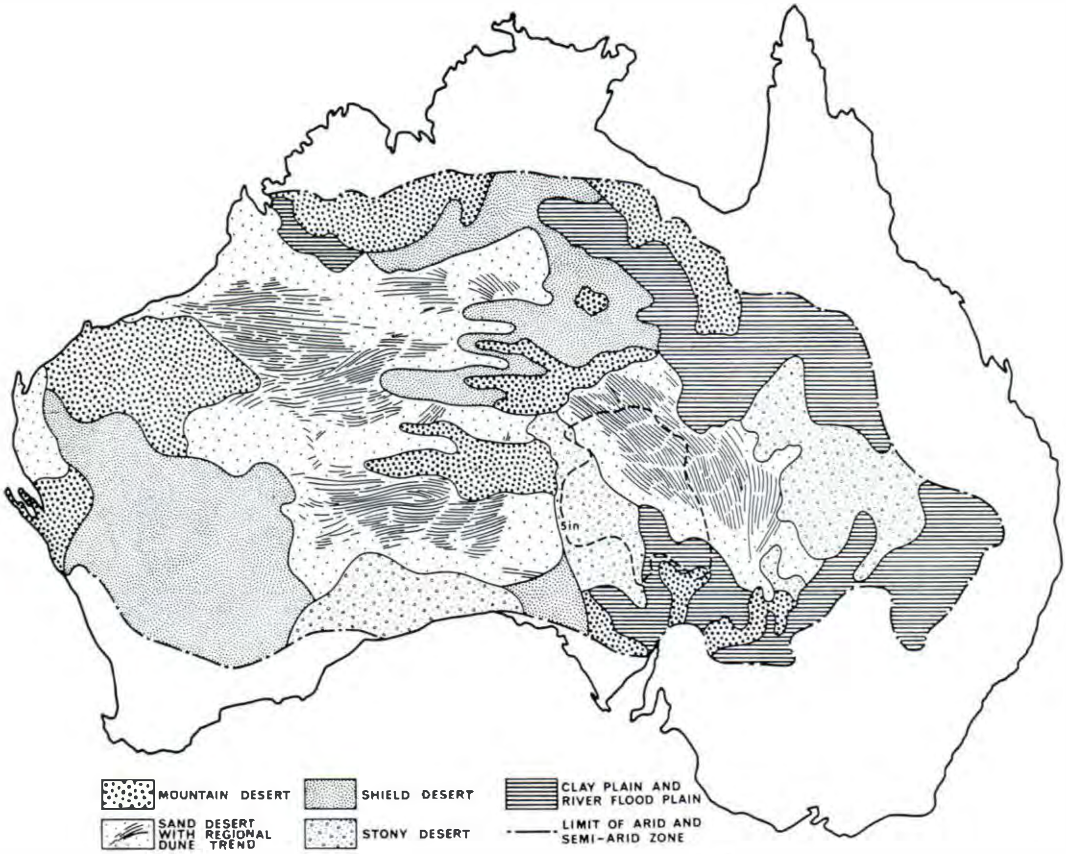
Above: Mt Olga, one of the strangest looking mountains in the world, seen from the east. It covers an area of about 15 square miles and its highest points are 1,500 feet above the surrounding plain. It was originally a single mass, but water erosion later carved out deep clefts and chasms, separating it into a series of gigantic blocks or monoliths with domed tops. In the foreground is the road running east to Ayers Rock, 20 miles away. Below: Mt Conner, 60 miles east of Ayers Rock, is a flat-topped mesa, 3 miles long, about a mile wide and reaching a height of 1,000 feet. [Photos: Howard Hughes]

Mountain desert scenery. All details of rock structure are etched out by arid weathering and left exposed in the detail of relief. The Amphitheatre, Palm Valley, James Range, central Australia. [Photo: M. Lazarides.]

LANDSCAPES OF ARID AND SEMI-ARID AUSTRALIA

By J. A. MABBUTT
Division of Land Research, C.S.I.R.O., Canberra

NO single rainfall figure serves to designate dryness, and most climatic classifications define an arid or semi-arid area as one in which evaporation exceeds precipitation. Some 70 per cent of Australia, about 2.2 million square miles, falls into this category. The Australian semi-arid and arid zone as shown in the accompanying map includes the core of the continent but also reaches the coast in the west; it extends to the 10-inch rainfall line in the south, the 15-inch isohyet in the south-east, and into areas with between 20 and 25 inches annual rainfall in the north. It coincides with the subtropical high pressure belt separating the tropical zone of summer rains from the temperate zone of winter rainfall and to this effect of latitude is added that of isolation from oceanic rain-bringing winds. Most of it is "moderate desert", with sand dunes mainly fixed by vegetation and with even larger areas in which the chief land-shaping agent is running water, as in the humid zones. Only



The Australian arid and semi-arid zone, showing the main types of desert and the regional trends of sand-ridges. Clay plain and river flood-plains are also distinguished. [Map by the author.]

a small area near Lake Eyre, with less than 5 inches of rain a year, can be claimed as very arid.

With low rainfall go other characteristics which are important for the fashioning of the land surface, namely thin loose soils, deficient in organic matter, and sparse desert vegetation which cannot protect or hold together the soil surface.

Some older and still popular ideas about the development of desert land forms have not withstood closer investigation. One was that rocks break down rapidly through strong daily heating and cooling under clear desert skies. This is no longer regarded as generally effective, and rock weathering is now seen to be controlled by available moisture; hence it is slow, and hot deserts are now regarded as land-form museums rather than scenes of rapid destruction. Another view, that wind is everywhere an important sculpting agent, has also had to be modified, for sand blast acts only near the ground, and on hard rocks its effects are confined to the pitting and polishing of surfaces.

However, although it is now seen that desert processes have much in common with those of humid areas, there is a recognized "desert system" of land-form evolution. This is dominated by scarcity of water, with drainage largely ephemeral and disorganized, occupying interior basins rather than leading to the sea. Wind has fuller play on unprotected surfaces, and may erode severely on loose, light soils, whilst wind action dominates in areas of loose sand supply, as near salt lakes and dry river beds.

Although the main systems of land-forming processes tend to be climate-controlled, we find no simple correlation between rainfall and land form across the Australian arid zone. This is because the broader landscape traits—including those inherited from past climatic periods as well as those formed in the present desert setting—are controlled by geology. Hence, we may conveniently distinguish between the mountainous deserts, the desert plains of the ancient Precambrian shield, the stony deserts of the younger sedimentary basins, and the sand deserts. These classes are shown in the accompanying map, and their description will serve to illustrate some general characteristics of the Australian desert landscapes.

Mountain Deserts

Under this head are included plateaux and ranges of resistant sandstone beds, such as the Hammersley Ranges and the MacDonnells, less regular uplands of more ancient rocks such as the Isa Highlands, and large granite hill complexes such as the Musgrave Ranges. None of them is very high, Mount Zeil (4,955 feet) in the western MacDonnells being the highest summit in the arid zone. This means that the mountains cause no significant local increase in rainfall, and also that arid Australia lacks snow-fed perennial streams for irrigation.

Nevertheless the stark beauty of many of the mountain deserts makes them an important tourist resource. Rock formations show through remarkably clearly, for there is little depth of rock waste, and smoothing processes are ineffective on desert hill slopes. Resistance to erosion is a matter of physical strength rather than of chemical stability, a factor which emphasizes lithological contrasts and which causes them to be etched faithfully in the details of relief.

Rainfall on steep rocky slopes produces rapid run-off unchecked by soil or vegetation, but flow tends to cease with the rain. Only heavy falls, say 1 or 2 inches, fill the larger channels and cause them to flow beyond the hills; the Todd River at Alice Springs, for instance, flows about three times a year, each flow being generally of 24-48 hours duration. For the remaining time this typical ephemeral river is a dry sandy trench lined with gum trees.

River floods dwindle rapidly across the plains, as there are few tributaries to replenish the water as it sinks into the river beds. Desert plains yield few streams, for slow run-off on gentle slopes tends to be lost by evaporation before finding its way into a channel. Hence each mountain area tends to be a centre of dispersal of drainage, but these fail to link into general systems.

Smaller stream channels, on reaching the plains, tend to spread their load as alluvial fans at the mountain front. In other places, particularly on granite, smooth erosional surfaces called pediments abut directly against the hill, and water entering them from the hill slopes may spread out as sheet flow, a form of run-off particularly associated with desert plains, where hard rock and shallow loose soil do not favour the excavation of channels. The juxtaposition of such smooth plains of low gradient and straight steep hill slopes is a feature of many desert landscapes.

The Shield Deserts

The shield deserts form extensive plain lands. These stable, ancient land surfaces are in many areas still being stripped of mantles of weathered rock formed in wetter climates of the past, and the ironstone-capped breakaways of the interior of Western Australia have formed in this way. Younger plains of fresh rock are laid bare as the escarpments retreat. There is little relief in these areas—mainly groups of small granite hills, and drainage lines are wide shallow valleys separated by broad featureless divides.

Under the stress of increasing aridity these ancient valleys were partly filled with alluvium, and drainage was further disrupted by wind-scouring and dune movement. Hence disconnected drainage systems arose, each draining into a salt lake. Ancient valley systems on the Western Australian shield may be reconstructed from the linear arrangement of "river lakes", and flooding may still occur along these lines at rare intervals. The bare lake floors are the scenes of strong wind erosion, which forms sand and silt into dunes on lee shores. Prominent among these wind-formed features are lunettes, crescentic silt barriers trapping shallow circular lakes.

Disorganization of drainage through wind action is characteristic of dry areas, and accounts for the apparent anomaly of the large number of "lakes" on the map of arid Australia.

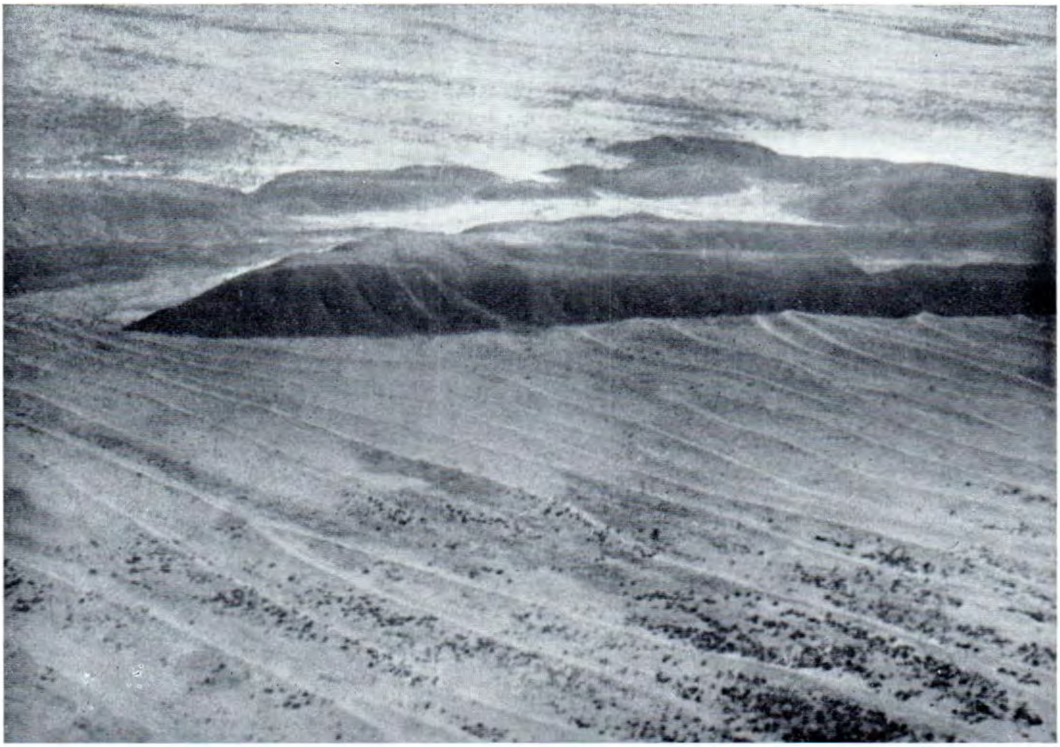
Stony Deserts

These landscapes typify much of the Great Artesian Basin. In this geologically youthful setting, owing to successive earth movements, the soft rocks have been planed off at various levels along the margins of the basin, giving rise to stony tablelands. The main source of the "gibbers" which mantle the tablelands is an ancient siliceous weathering crust known as "billy", still found capping the oldest levels in the landscape. Chemically very resistant, it breaks down into cobbles which are washed over adjacent slopes where they become concentrated as a surface pavement through a removal of finer material by wind and water, and so form an armour, protecting the soft rock beneath from further erosion. The gibbers are wind-smoothed and have a brown coating of desert varnish from the deposition of iron oxides from capillary rise of salt-bearing solutions under strong evaporation. The land surfaces of the stony deserts everywhere show lack of leaching, with the formation of surface crusts of limestone or gypsum, soluble salts which are removed from the landscape in more humid environments. Unlike the shield deserts, drainage here is remarkably integrated, an expression of centripetal slopes maintained in response to the basin disposition of the underlying rocks. The foci of the drainage systems are large salt lakes such as Lake Eyre and Lake Torrens. These larger lakes owe their general emplacement to tectonic events, and an ancestral Lake Eyre existed millions of years ago; however, the present lake basin was excavated in older lacustrine beds by wind erosion, apparently 20,000 to 40,000 years ago. The river systems rarely breach the dune barriers to reach Lake Eyre, but the basin was completely filled in the great flooding of 1949-50.

Clay Plains

The monotonous grasslands or "downs" of the Barkly Tableland and western

Stony desert near Lilla Creek, in the south of the Northern Territory, showing the gibber pavement on the tableland surface in the foreground. [Photo: R. A. Perry.]



Sand desert. Sand-ridges abut on the south side of outlying ranges in the north-west of the Simpson Desert. [Photo: C. T. Madigan.]

Queensland have characteristic black or dark-grey clay soils which are in part derived from underlying limestones and associated fine-grained rocks and in part deposited from flooding rivers of low gradient. Their great extent indicates that the countless anastomosing river channels and billabongs which characterize riverine tracts of the Channel Country, and which flood enormous areas, were even more widespread in Pleistocene times. Features of these clay plains are the surface pits and mounds known as gilgais, which result from alternate wetting and swelling and drying and cracking of the clays.

Sand Deserts

Aeolian sands cover about 40 per cent of the arid zone, mainly where rivers laid down sandy deposits in earlier times or where deep sandy soils formerly existed. They are riverless areas, and since, under normal conditions, they are protected by vegetation, they are among the most stable desert surfaces. The two most characteristic forms are sand-ridge deserts and sand plains.

Sand-ridge deserts are found nowhere else in the world on such a scale as in Australia, where they cover more than half a million square miles. They consist of parallel ridges about a quarter of a mile apart and generally not more than 50 feet high, continuous over scores of miles though locally converging as Y-forms. Dune trends and elongation follow prevalent winds in a great anticlockwise swirl around the continental anticyclone, and there is a consistent asymmetry, with the steeper dune flank toward the outer margin of the swirl. Now the dunes are mainly fixed by vegetation and only the loose crests are subject to blowing, but dunes are still being formed where loose sand is supplied, as on lee sides of salt lakes and river channels.

Sand plain is characteristic of the shield areas, and may be flat or broadly undulating with rises following the regional dune trend. It is typical of areas where sand has resisted deep aeolian re-working by virtue of its higher content of binding clay, as in sands derived from granitic rocks or in areas more recently subject to river action.

Appointment of Dr. F. H. Talbot as Director of the Museum

Dr Frank Hamilton Talbot has been appointed Director of the Australian Museum to succeed Dr J. W. Evans, who retires on 16th January, 1966.

After graduating from the University of the Witwatersrand, Johannesburg, in 1948, Dr Talbot obtained his Master's degree at the University of Cape Town, where he studied marine ecology under Professor J. H. Day. Later he was granted the degree of Ph.D. by the University of Cape Town.

During 1952 and 1953, he worked in the Zoology Department of King's College, University of Durham, first as Demonstrator in Zoology, and later on a Colonial Office grant. Subsequently, after five years as a scientific officer in the East African Marine Fisheries Research Organization in Zanzibar, where he did research on coral reef ecology and tropical fishes, he held the post of Marine Biologist at the South African Museum, Cape Town.

In 1960 he was appointed Assistant Director of that institution, and he left South Africa to join the staff of the Australian Museum as Curator of Fishes in 1964.

During 1962 to 1963, as a recipient of South African C.S.I.R. and Carnegie Corporation grants, Dr Talbot travelled in North America and England, studying Museum administration and education, and in connection with his work on the systematics and ecology of tuna fishes he attended United Nations Food and Agricultural Organization meetings in North Africa and the United States.

Dr F. H. Talbot. [Photo: Howard Hughes.]

He has published some twenty-five papers on fish ecology and systematics, and on museum administration, and has been actively involved in various scientific bodies, having served on the South Africa National Co-Ordinating Committee for Oceanography and on the Councils of the South African Assocation for the Advancement of Science, the Zoological Society of Southern Africa, the South African Wild Life Protection Society, and the Royal Zoological Society of New South Wales.

THE NATURE AND ORIGIN OF MODERN DESERTS

By REG. SPRIGG
Geosurveys of Australia, Ltd

MODERN deserts occupy narrow belts which straddle the Tropics of Cancer and Capricorn. They lie particularly in the lee of mountain ranges, or deep in the interior of continents. Prevailing winds are very dry, usually having precipitated moisture before they reach these parched areas.

Deserts tend to be stretches of desolate sand dunes, sprinkled with dry lakes and stunted vegetation. Mesa "flat tops", tent hills, and resistent inselbergs usually inhabit these places like lone sentinels.

Despite forbidding appearances, these large desert areas (some 8 million square miles in all) represent the world's largest land banks. One day this potential will be turned green by irrigation as exploding human populations force man to purify sea and saline waters for this purpose.

A characteristic of most deserts is high summer day heat. The deserts of southern Patagonia, however, are more the result of high winds and low rainfall. By comparison, in typical tropical belt deserts low humidity and clear skies let the sun's rays penetrate the atmosphere more efficiently. Daytime air temperature may range above 130°F, and surface ground temperatures may be considerably more. At night, heat dissipates quickly and temperatures may drop 50° or more. Winter temperatures may be freezing.

Desert soils are usually impregnated with sodium and potassium salts and other soluble minerals that cannot be efficiently leached out by infrequent rain. Plants tend to be specialized, and are mostly hard and thorny. Animals tend to burrow by day.

Australian Deserts

Australian deserts tend to be alluvial types. That is, they have been formed primarily as a result of prevailing high-windiness which erodes and works the dry soil of the great plains. Dust is deflated, and residual sand is concentrated into dune ridges and wind-rows. Most dunes are elongated in the direction of the dominating winds, but some may be boomerang-shaped across wind. Some Australian deserts, however, are stony, formed of gibbers and other varieties of "lag" gravels. Sturt's Stony Desert about north-eastern South Australia is a particularly good example of this.

Australia's enormous deserts are now fixed, or in a delicate balance. Sand tends to "move" predominantly along the "live" dune crests. It is now believed that these dune systems are largely sub-fossil. They are relics of the Pleistocene Ice Age. At that time Australia was much windier, due to more intense cyclonic winds then impinging on the continent. These gave an overall subcircular dune pattern about central Australia, one that is actually "anticyclonic" in circulatory direction. Prevailing winds blowing in excess of 15 to 20 miles per hour for long periods were largely responsible. Westerly wind influence dominated across South Australia (from Perth to Tasmania), becoming south-westerlies then southerlies swinging to south-easterlies in central New South Wales, and easterlies back across central-northern Australia.

Recent studies have shown that this wind system was much more intense than modern winds, and that modern dominating winds are at variance, particularly in the south, where cross winds are actually destroying the earlier impressed patterns.

That drought is not an essential feature of longitudinal sand dune formation is readily appreciable in northern Tasmania and on Cape York Peninsula, Queensland. Here enormous dunes are extending away from the coast in wet climates, and forcibly enough to overwhelm even dense "jungle".

Another feature of Australia is the predominant red colour away from the washing action of our few internal "rivers". Iron oxide accumulates as microscopic layers around each quartz grain. This is the same basic ingredient as in rouge.

Lunettes, the peculiar subcircular lakes spread widely across Australia, are also a fossil desert phenomena. They are characterized by lunar shape and lunar-shaped sediment mounds on one side—and this lies on the downwind direction of the deserts even though these directions may not coincide with modern prevailing winds. It seems that lakes in the Ice Age may have dried out periodically even despite the higher rainfall than today, and gypseus and clayey dusts blown from the dry lake beds were entrapped downwind by vegetation.

As further evidence of the erosive power of the "subfossil" glacial phase winds, prolonged dust storms were the order of the day. Where these dusts settled out, layers of loess-like (extremely fine-grained) "parna" accumulated. Successive new fossil soils became interleaved between alluvial soils of the less windy intervals as the plains were built up.

Semi-deserts surround the central cores of Australian deserts, and, in these, concentric patterns of lag gravels reveal local soil instability. Usually these patterns develop on very low slopes and the secondary subcircular and concentric low ridges become separated by swampy depressions and crab holes left as the stony soil creeps by gravity.

Although deserts are usually conspicuously sandy, ridges of crystal seed gypsum, and particularly of flour gypsum, may also appear prominently. These are mostly associated with ephemeral dry "lakes" of terminal internal drainage systems. The lighter saline residuals (salt and potash minerals) are mostly deflated (blown away) by persistent windiness, concentrating the coarser gypsum into mounds and eventually spilling over into downwind dunes. It is not an unfamiliar sight even now to experience "white-outs" during windy days due to salt dust deflation from dry lake surfaces. Most of this salt eventually gets blown out to sea via north-eastern Australia. This is why central Australia, despite its almost complete internal drainage of saline surface waters, is not the repository of great salt lakes. Lake Eyre alone is notable for salt deposits but its accumulations rarely exceed about 1 foot in thickness and then only in the southern limits. Salt lakes to the south owe their accumulation more to persistent supply from coastal surf and windborne dust, or to the cutting-off of arms of the sea.

The Simpson is probably the most formidable of the Australian deserts. Individual dunes may persist practically unbroken for hundreds of miles. These may be 50 to 100 feet high and generally they are asymmetrical in cross section. Gentle slopes occur on the west, whereas the east slopes are generally live-sand avalanche faces. In consequence of this, desert operators find westward travel far more difficult than easterly.

Minor sand structures include beautiful sand rippling and coarsely avalanched cross-bedding. Sand surfaces are usually crossed with mazes of animal tracks left during quiescent wind periods. Lizards choose to burrow into the soil on the downwind side of vegetation clumps where their holes are more protected from drift.

The sands of the dunes are remarkably even grained, and grain size averages about three-fifths of a millimetre in diameter. Sands in the interdune or corridor "flats", however, are mixed in nature. Frequently, two dominating sand grain sizes intermingle, the grain size of the coarser sand approximating ten times that of the finer. This results in a grain locking that tends to stabilize the interdune floors.

Desert Oddities

It was by coincidence that a great shower of meteoric black glass fell during the latest desert phase. This material from outer space constituted australites, which have characteristic dumb-bell, tear-drop, pudding-stone and flanged-button type shapes developed in their fiery passage through the upper atmosphere. Erosion of alluvial soils down to their clay-subsoil horizons produced the familiar clay-pan scalds on which these australites became concentrated in considerable numbers. Aborigines frequently aided the process of concentration by collecting them and leaving them in favourite spots where they camped or patiently chipped their spearheads.

An oddity of desert prevailing wind action are the angular pebbles called "driekanter" pebbles. These triangular or other polygonally facetted stones are believed to have been eroded by sand blast as they rolled over, enabling new faces to be presented to wind erosion.

Still another feature of deserts is the phenomenon of desert polish. Silica or oxidized iron and manganese impregnate surfaces of rocks and present a thin skin of high polish. This is so-called desert varnish.

Desert Riches

The hot arid areas of the world mostly lie at low elevation in relation to sea-level. For this reason they are the land areas most likely to be invaded by the sea down through geological history. Inland seas in turn are favourable places for oil and gas generation and eventual accumulation if enough sediments are deposited. Much of the world's petroleum, in consequence, is found in these areas.

High summer evaporation and low annual rainfall also bring their own harvest. Salt, potash, gypsum, borax and lithia are particularly valuable "evaporite" deposits, and most of the world's commercial resources of these minerals are locked up in deserts or their fossil deposits.

Sunshine is, of course, the greatest of all desert resources. Travellers may curse it, and the old prospector frequently died by it. But sunshine is the basic element of all life as we know it—along with water and air. Plant growth can only occur in sunlight, and given the other favourable conditions it is true that the more sunlight the more plant growth. This, then, raises the earlier quoted truism that deserts harbour the greatest world land bank now remaining to be tapped—almost 8 million square miles of it. Certainly, the problems that go with them are formidable, but the challenge for man remains. Science and engineering will increasingly work miracles in these vastnesses.

Irrigation will continue to divert tropical run-off waters into these parched areas. Artesian water basins will be used more efficiently, but it is to the purification of seawater and other saline water sources that man looks with greatest hope. Energy requirements will come eventually mostly from atomic sources, but solar energy will play its part—and there is plenty of sun energy about deserts.

Australia, for its part, is particularly fortunate in that most of its deserts cover widespread artesian basins. These include the Great Artesian Basin, the Canning Basin, the Gibson and Victoria Desert Basins, and, "marginally", also the Murravian and Georgina "semi-desert" Basins.

Even at this time salt, gypsum and anhydrite in sedimentary deposits from past eras are being cut by oil drilling rigs in desert places. These are being found as far away as the Canning Desert. Geologists have great hopes that potash and sulphur will also be found. Truly, deserts will yet be found to harbour some of Australia's greatest resources.

NOTES AND NEWS

INTERTIDAL FAUNA

The Curator of the Department of Worms and Echinoderms at the Australian Museum, Miss Elizabeth Pope, spent three weeks in the field in the Darwin area of the Northern Territory last October. She made general collections of intertidal animals on reefs near Darwin and at Cape Don on the Coburg Peninsula. In spite of the presence of much silt on the shores, the intertidal fauna is extremely rich and interesting. Brain corals, leathery Alcyonarians and oysters dominate the intertidal scene, while starfish, sea urchins and molluscs are notably rare in the area. They occur subtidally, however, and dredging should yield rich hauls in these groups. Ophiuroid brittle stars flourished and several species were notable because of their unusually long arms—several feet in length at least—although their bodies were of normal size.

VISIT BY EDUCATION OFFICER

Mr R. L. Jensz, Education Officer at the National Museum of Victoria, recently spent a week at the Australian Museum examining the educational facilities available to schools.

Ayers Rock

Above: Ayers Rock, one of Australia's greatest natural monuments, seen silhouetted against the skyline from the slopes of Mt Olga, 20 miles to the west. Ayers Rock is a single rock mass with steeply sloping to almost vertical sides. It is 2 miles long and about 1¼ miles wide, and reaches a height of 1,143 feet. The distance around its base is more than 5 miles. Below: The summit of Ayers Rock, showing deep grooves formed by active water erosion. Grooves and gullies of this kind cut across the whole top of the rock. The road at left runs to Mt Olga. [Photos: Howard Hughes]

A stand of the rarely seen Grass Tree (*Xanthorrhoea thorntonii*) near Gosse's Bluff, about 100 miles west of Alice Springs, in desert sand-plain.

Desert Plants and Their Use

By GEORGE M. CHIPPENDALE
Botanist, Animal Industry Branch, Northern Territory Administration, Alice Springs

VAST areas of inland Australia are loosely termed "deserts", but are more correctly known as "semi-arid areas". Approximately one-third of the continent has an average of less than 10 inches of rain per annum, whilst about another one-third has an average of between 10 inches and 20 inches. The natural vegetation of this huge area has evolved over thousands of years, and is well adapted to the extremely unreliable rainfall.

As an example of this type of country, central Australia has slightly less than 1,200 native plant species, but of these less than 200 are useful to the pastoral industry. Far less than 100 species are of great importance as pastures.

As establishment of introduced species appears to be extremely difficult and possibly uneconomic, the pastoral industry will be relying on native species for some considerable time. With this premise, most botanical work in central Australia has been aimed at gaining a better knowledge of the native plants and their usage. Collection of specimens took place, and continues, over wide areas, and an herbarium was established. Notes were made of the effects of grazing on the vegetation, and on particular plant species, and examinations were made of several hundred stomach samples of cattle to ascertain the species grazed.

Grasses And Topfeed

Drought-resistant grasses such as the various species of spinifex (*Triodia* spp. and *Plectrachne* spp.) are of moderate use to grazing animals, and at least provide country for relief in dry periods. Drought-evading perennial grasses such as Mitchell Grass (*Astrebla pectinata*), Woollybutt (*Eragrostis eriopoda*), Neverfail (*Eragrostis setifolia*) and Windmill Grass (*Chloris acicularis*) are the basis of the grazing industry, and even as a standing dry feed in drought times these appear to sustain animals. Species of annual grasses and herbage such as Button Grass (*Dactyloctenium radulans*), Small Burr Grass (*Tragus australianus*), Pigweed or Munyeroo (*Portulaca oleracea*), and Tah Vine (*Boerhavia diffusa*) add to the diet, and together with a number of *Bassia* species and Saltbushes (*Atriplex* spp.) are capable of producing fat cattle.

In addition, one great advantage of our arid zone pastures is the presence of a range of edible trees and shrubs, known as topfeed. The most popular of these are the drought-resistant species, Mulga (*Acacia aneura*), Ironwood (*Acacia estrophiolata*), Witchety Bush (*Acacia kempeana*) and Whitewood (*Atalaya hemiglauca*).

There is an indication that even in dry times, 75 per cent or more of the plants eaten are grasses, but in times of good rains this can be almost 100 per cent. Herbage other than grasses is important, but rarely comprises more than 15 per cent of the diet, and is more usually less than 10 per cent. Topfeed mostly comprises less than 10 per cent of the diet, but can rise to 20 per cent or more, as a dry period stretches into a drought. The relatively small amounts of herbage and topfeed, nevertheless, are extremely valuable, for these quite likely provide nutrient deficiencies which may occur in the grasses.

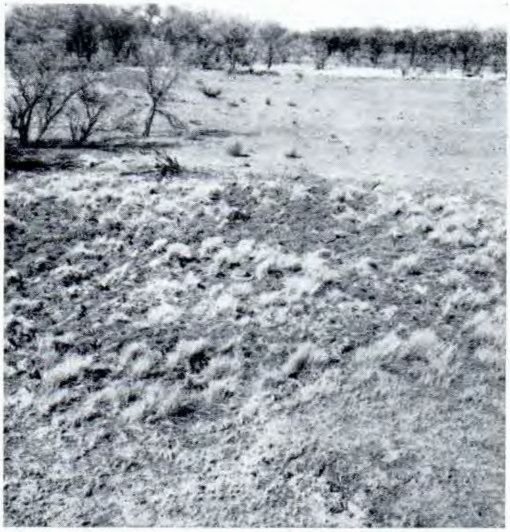
Relic Species

In another way, the arid zone plants are providing the basis for another thriving industry—the tourist influx. The tourist areas of central Australia are mostly in places where plant species of a more or less relic nature provide great interest. As has been mentioned in a previous issue of this journal, unique plants such as the rare palm *Livistona mariae* and the robust cycad *Macrozamia macdonnellii* are striking features in Palm Valley. The cycad is also seen at King's Canyon, Simpson's Gap, Serpentine, and some other places.

Other plants more or less restricted to these relic areas in the MacDonnell Ranges include *Eriostemon argyreus* on Mt. Sonder, *Hakea multilineata* var. *grammatophylla* at higher altitudes in places like Standley Chasm, and a Flannel Flower (*Actinotus schwarzii*) at Standley Chasm. Other attractive species in the various gorges and ranges are *Rulingia magniflora*, *Hibbertia glaberrima*, *Baeckea polystemonea*, *Dodonaea viscosa* var. *spathulatum*, and the wattle *Acacia strongylophylla*. Ferns other than the Rock Ferns (*Cheilanthes* spp.) are rarities in central Australia, but at a number of rock holes in the George Gill Ranges there are still surviving some Giant Maiden Hair Fern (*Adiantum hispidulum*) and *Cyclosorus gongylodes*.

Importance Of Rainfall

A reasonable rainfall during the winter initiates the growth of many annual grasses and other plants. By August or early September, there can be areas of great colour, provided by masses of yellow with *Senecio gregorii*, *Senecio magnificus*, *Helipterum stipitatum*, and *Helichrysum ayersii*, purple by various species of *Swainsona*, pink by *Helichrysum cassinianum* and *Helichrysum roseum* var. *davenportii*, and white by *Helipterum floribundum*.



Portion of a gilgai containing the Neverfail Grass (*Eragrostis setifolia*) which is grazed by the Red Kangaroo (*Megaleia rufa*).

The erratic rainfall can cause a great diminution in the seed supply of arid zone plants. For instance, during the drought up to the time of writing there have been a number of small falls of up to half an inch of rain. Such falls have caused germination and a minimum of growth. With no further follow-up rain, these plants may flower and seed at a height of 2 inches or 3 inches, or may perish before flowering, but with this process repeated over a number of years, the seed supply is gradually reduced. Undoubtedly, too, some seed desiccates, and insects destroy much seed. With grazing effects imposed in a drought period, even though with greatly reduced cattle numbers, the minimum of seed produced has been less effective. Consequently, good rains of at least 1 inch with follow-up rains within 3 or 4 weeks would be needed over a period of 3 to 5 years to aid recovery. The capacity for rapid growth by arid zone plants, given the right conditions, often leads to undue optimism about their ability to recover from droughts.

The relationship of the Red Kangaroo (*Megaleia rufa*) to the arid zone flora is being investigated by a number of people in several parts of Australia. Stomach samples of these animals so far examined in central Australia have shown an overwhelming preference for the Neverfail Grass (*Eragrostis setifolia*), with minor amounts of herbaceous plant species which occur in and around gilgais. The moisture content of both grazed and ungrazed samples of this grass have been determined, and at most times the grazed samples contained more moisture than the ungrazed samples. This may have some significance in the kangaroo's ability to survive in the arid environment, but will only be properly evaluated when other physiological aspects are considered.

Unpopulated Areas

In the unpopulated desert areas, such as the Simpson Desert, Gibson's Desert, and the Great Sandy Desert, there is fringe use of the vegetation by the pastoral industry. Again, a feature of these areas, particularly the latter two, is the presence of trees and large shrubs. Species of *Acacia*, as well as Bloodwood (*Eucalyptus terminalis*) and Coolabah (*Eucalyptus microtheca*), are scattered throughout the Simpson Desert,

A stand of Marble Gum (*Eucalyptus gongylocarpa*) in desert sand-plain about 60 miles north of Lake Amadeus.

Desert Oak (*Casuarina decaisneana*) in Desert Spinifex (*Triodia pungens*) sand-plain 21 miles south of Alice Springs.

and near the cattle station of Andado on the fringe of the desert is one of the two occurrences of the rare Waddy Wood trees (*Acacia peuce*). The other occurrence of this species is north of Birdsville on the western fringe of the Simpson Desert, on similar gravelly downs near dune fields.

In sand plains and sand dunes of the western desert areas are more species of *Acacia*, and the same species of *Eucalyptus* plus several more. Marble Gum (*Eucalyptus gongylocarpa*) is a notable addition, outstanding for its light-brown bark shedding in small sections and revealing a grey smooth trunk beneath. The Desert Oak (*Casuarina decaisneana*) is a tall graceful tree which dominates large areas of this desert. More uncommon are the Grass Trees (*Xanthorrhoea thorntonii*), and these have not been seen by many people. The Desert Kurrajong (*Brachychiton gregorii*) is a smaller tree scattered throughout western sandy deserts, but also extending onto sandy areas in the eastern part of central Australia.

Plants Around Salt Lakes

Another group of desert plants in the western areas are those around the various salt lakes, and it is interesting to see the colonizing plants such as the samphire (*Pachycornia tenuis*) on the edge of the lake surface, leading back to plants of *Bassia luehmannii* and *B. birchii* with Perennial Saltbush (*Atriplex vesicaria*) on the shore of the lake in gypscous sands. Further back again, at the edge of these sands, is usually a ring of the Tea Tree (*Melaleuca glomerata*). Sand-ridges approach to less than 50 yards from the lake surface.

It is perhaps surprising to tourists to find so many trees in our desert areas, and this has also caused remarks by overseas visitors. In recent years we have had visits from foresters from Sudan, India, and Pakistan, each of whom has admired our desert species. Their problem is to provide timber for fuel in their more densely populated arid zones, and Australian desert trees have been of great interest in this matter. As numbers of Australian species such as *Acacia* and *Atriplex* are being introduced in overseas arid zones, surely this must impress on us that we should learn more about our own desert vegetation and its uses.

[*Photos in this article are by the author.*]

NOTES AND NEWS

ARCHAEOLOGICAL SURVEY

The Australian Museum's Curator of Anthropology, Mr D. R. Moore, is surveying the upper Hunter and Goulburn River valleys for Aboriginal occupation sites suitable for excavation. He would welcome information from residents of that area, or other persons with local knowledge. The types of sites likely to be of archaeological interest are caves and rock shelters with deep occupation deposits or old Aboriginal camping areas with middens (i.e., low hummocks of food waste, shells, etc.) along the river valleys or permanent creeks.

VISITOR TO MUSEUM

Mr Lai Nhung, Librarian of the Institut Oceanographique, Nhatrang, South Viet-Nam, who is studying libraries in Australia, visited the Museum Library on 16th July.

DONATION TO LIBRARY

Encyclopaedia Britannica Inc., through the kind offices of Mr J. J. Salmon Jr, Managing Director, has presented the Museum with a set of the current edition of Encyclopaedia Britannica.

The Fat-tailed Marsupial Mouse (*Antechinus macdonnellensis*) lives in rocky areas in arid regions of the Northern Territory and Western Australia. Like many other desert mammals, it has a tail swollen with fat, the true significance of which is not fully understood. [Photo: Howard Hughes.]

MAMMALS IN ARID REGIONS OF AUSTRALIA

By B. J. MARLOW

SINCE it is extremely difficult to give a completely adequate definition of a desert, the term "arid region" has been selected for the title of this article. A general account of the deserts of Australia has been given elsewhere in this issue, and their distribution has been discussed at the same time. Although a large proportion of the continent is arid, relatively few species of mammals are specifically adapted for life in this rigorous inland environment, and in comparison with the more temperate coastal regions, the numbers of both species and individual animals are considerably smaller. Among those mammals which are confined to the arid regions, however, there exist some remarkable adaptations in structure, physiology and behaviour which are similar to those of mammals in other arid areas in the world.

The Problems Of Life In An Arid Environment

Two major factors are involved in the life of mammals in desert conditions. These are the ability to withstand extremely high temperatures during the day and the necessity to conserve water which is in extremely short supply.

The problem of temperature control is solved in two very different ways in desert mammals, depending upon the size of the animal.

Since the surface area of a large mammal is fairly small in relation to its volume, the larger mammals can use the evaporation of water from the surface of the skin in the form of sweat or saliva as a cooling mechanism. Small mammals, on the other hand, have a very large surface area in comparison with their volume, and in consequence they are unable to endure the severe water loss that would result from a cooling mechanism of this type. Their solution of the problem of temperature control is behavioural rather than physiological, since they are nocturnal and spend the hottest part of the day in burrows where the temperature is considerably lower and the humidity higher. They thus avoid the heat stress which larger mammals experience.

The problems of water conservation are solved in a similar manner in both groups. Water may be gained by drinking or be contained in food. At the same time it may also be produced in the body by the oxidation of certain foods such as fat, and this so-called "metabolic water" is of considerable importance to many desert mammals.

Water is lost from respiratory surfaces, in urine and faeces, in milk and as sweat, and the majority of desert mammals have highly efficient kidneys which can produce an extremely concentrated urine, while much water is resorbed from the faeces in the rectum. A certain amount of unavoidable water loss occurs in all mammals from the respiratory surfaces and this may be reduced considerably during the aestivation or summer sleep of certain small desert mammals.

It has been suggested that the production of concentrated milk of high fat content in certain mammals, such as whales, is a mechanism for water conservation rather than for the manufacture of highly nutritious milk. The composition of milk in desert mammals has unfortunately not been studied in great detail and this subject would be a most profitable line of research.

A delicate balance between water loss and water gain must be maintained at all times by mammals in arid regions, and the mechanism whereby this is achieved by Australian mammals will now be considered.

Monotremes

The Spiny Ant-eater (*Tachyglossus aculeatus*) is widely distributed throughout the continent and occupies both desert and temperate regions. In contrast, the platypus (*Ornithorhynchus anatinus*) is confined to the eastern part of Australia and does not enter desert areas. Monotremes are characterized by their variable body temperature which fluctuates with that of the environment, and this may confer a considerable advantage to the animal in high temperatures. In the early morning, when it is cool, the temperature of the Spiny Ant-eater would be considerably depressed and this would increase the range through which its temperature would have to rise before it experienced heat stress. Although Spiny Ant-eaters are well adapted for digging, they do not occupy burrows, but retire into crevices in rock outcrops during the day, where the humidity is higher and where they are protected from intense solar radiation. Their food, which consists of true ants and termites, contains reasonable quantities of water.

Marsupials

Marsupials are well represented in the Australian desert fauna; this is particularly true of the flesh-eating dasyurids and kangaroo-like macropods which contain several genera that are confined to arid regions. The arboreal phalangers or possums on the other hand are virtually absent because of the lack of trees, although the common Brush-tailed Possum (*Trichosurus vulpecula*) occurs along the tree-lined dry watercourses of inland Australia.

Among the wombats, one genus, *Lasiorhinus*, which contains the hairy-nosed species, is distributed in the arid centre of Queensland and on the Nullarbor Plain. These animals spend the day in deep burrows and emerge at night to feed on succulent vegetation in the form of roots and grasses.

Bandicoots are generally adapted to the forested areas of Australia, but three forms are found in arid regions. These are the

Desert Bandicoot (*Perameles eremiana*), the rare Pig-footed Bandicoot (*Chaeropus ecaudatus*) and the Rabbit-eared Bandicoots or bilbies (*Thylacomys* spp.). The latter are the only truly fossorial bandicoots, which live in complex burrows in the spinifex grassland plains. They are nocturnal in their habits and feed both on insects and the succulent tubers of plants.

The flesh-eating dasyurids of the desert are all of small size, the larger native cats being normally absent from the arid regions. The Narrow-footed Marsupial Mice (*Sminthopsis* spp.) are well represented in deserts and are smaller in size and have longer ears and tails than their counterparts in the more temperate regions. These features are probably adaptations for the dissipation of excess heat. The larger desert dasyurids are represented by Byrne's Marsupial Mouse (*Dasyuroides byrnei*) of the gibber plains of south-west Queensland and by the mulgara or Crest-tailed Marsupial Mouse (*Dasycercus cristicauda*) of the spinifex grassland of South Australia and the Northern Territory. The latter species has been studied extensively by the American physiologist Knut Schmidt-Nielsen, who showed that this small burrowing carnivorous marsupial could get all the water that it required from its diet of insects and small rodents, provided that it did not have to expend water in cooling its body. It produces a very concentrated urine which is able to expel the considerable amounts of urea, produced by its diet of high protein content, with a minimum of water loss.

Many small desert dasyurids accumulate large deposits of fat in their tails. This is particularly true in the case of several species of *Sminthopsis*, the mulgara and *Antechinus macdonnellensis* of the ranges around Alice Springs. It has been suggested that this fat is of significance in the production of metabolic water and would thus assist the animal in maintaining a positive water balance. Schmidt-Nielsen has denied that this is likely, and has postulated that any gain in water would be offset by evaporation from respiratory surfaces, during the inspiration of the large amounts of oxygen which are required to oxidize this fat.

The most highly specialized desert-living marsupial in Australia is the Marsupial Mole (*Notoryctes typhlops*), whose biology is, unfortunately, virtually unknown.

The kangaroo-like animals or macropods of the arid regions of Australia include several genera of small animals such as the rat-kangaroos *Bettongia* and *Caloprymnus*, together with other small wallabies such as Hare Wallabies (*Lagorchestes* spp.), Nail-tailed Wallabies (*Onychogalea* spp.) and Rock Wallabies (*Petrogale* spp.). Only two species are of a large size, the euro or Hill Kangaroo (*Macropus robustus*) and the Red Kangaroo (*Macropus rufus*). Of the smaller forms only the bettong (*Bettongia lesueur*) is fossorial, while the other species

The entrance to a burrow of a Rabbit-eared Bandicoot in spinifex grassland. The majority of small desert mammals avoid adverse conditions of heat and lack of water by living in burrows during the day. [Photo: Author.]

The Crest-tailed Marsupial (*Dasycercus cristicauda*) is able to live without drinking, provided it does not have to use water to cool itself. All the water it needs is supplied by the insects, reptiles and small mammals on which it feeds. [Photo: Howard Hughes.] It avoids heat stress and water loss by living in burrows at the bases of dwarf paperbark shrubs (*Melaleuca* spp.) in spinifex grassland, as seen below. [Photo: Author.]

rest in the shade of shrubs or in rock shelters during the hottest part of the day.

The water metabolism and heat regulation of desert macropods have not been fully investigated but some contributions to these problems have been made by Ealey and Newsome, who have studied the euro and Red Kangaroo respectively. Both these animals use water to cool themselves by licking the fur of their forelimbs and chest rather than by sweating. This is a relatively inefficient method of cooling, since, to be effective, the water should evaporate from the surface of the skin and not from the fur. Both species require water to drink, although this may be consumed at infrequent intervals, and both conserve water to a certain extent by resting in the shade during the heat of the day. The kidney of the Red Kangaroo is significantly more efficient than that of the euro and can excrete highly concentrated urine.

Placental Mammals

In addition to monotremes and marsupials, the mammal fauna of Australia includes two groups of placental mammals, bats and rodents.

Relatively few species of bats are to be found in arid regions of Australia and there are no species which are confined to this type of habitat. The more important species of desert-living bats include the False Vampire Bat (*Macroderma gigas*), Sheath-tailed Bats (*Taphozous* spp.) and the Small Brown Bat (*Eptesicus pumilus*),

The Australian hopping rodent (*Notomys cervinus*) shows a striking convergence towards other desert-living rodents in other parts of the world. The jerboas (*Jaculus*), of North Africa, and kangaroo rats (*Dipodomys*), of North America, show a similar elongation of the hind foot and tail which is correlated with a hopping gait. [Photo: Howard Hughes.]

all of which live in caves by day where they are protected from excessive heat. Insectivorous bats presumably obtain water from their food, but they will also drink by dipping over water when it is available. Under heat stress, the blood vessels in the wings of bats become dilated, which allows for a rapid dissipation of heat. It is probable that a considerable volume of water might be lost from the surface of the wings. It is interesting to note that the majority of desert bats roost in caves; the notable exception is the Long-eared Bat (*Nyctophilus* spp.), which normally spends the day in hollow trees or under loose bark.

With one or two notable exceptions, few genera of Australian rodents are confined to desert regions, and in consequence small native mice such as *Leggadina* spp. and *Pseudomys* spp., together with Stick-nest Rats (*Leporillus* spp.), are found in a variety of habitats. The Thick-tailed Rat (*Zyzomys* spp.) is confined to the arid areas of the Northern Territory and Western Australia but virtually nothing is known about the biology of this genus.

The delicate hopping mice (*Notomys* spp.) are the classical example of Australian rodents which are adapted to desert conditions. These animals show a remarkable convergence towards desert-living rodents in other parts of the world, such as the jerboas of North Africa and the kangaroo-rats of America. These hopping rodents have elongated hind limbs and long tufted tails. In common with many desert mammals, they have a greatly inflated auditory bulla in the skull. The significance of this feature is at present unknown. During the day, these hopping rodents live in burrows and they emerge at night to feed on seeds and other dry plant material. Unfortunately, little work has been carried out on the physiology of *Notomys* in Australia, but extensive research has been undertaken on the kangaroo rats (*Dipodomys*) in America. These rodents rarely drink, and obtain all the water they require from the metabolism of the dry seeds on which they feed. They have highly efficient kidneys which can excrete salts in twice the concentration of sea-water. They do not use water for cooling since they have no sweat glands and only leave their burrows at night. The metabolic water that they produce is just sufficient to counterbalance that lost in transpiration and in the urine. When fed on a high protein diet, such as soya beans, these animals then require water to eliminate the additional urea and under these circumstances can drink sea-water with impunity. Mammals, such as man, who lack such highly efficient kidneys, cannot drink sea-water when they are dehydrated, since additional water is excreted in an attempt to get rid of the extra salt that has been ingested.

Studies of the water balance in *Notomys* would be of very great interest, so that a comparison could be made between this typical Australian desert rodent and the highly efficient *Dipodomys*.

Mammals in the arid regions of Australia show many interesting physiological and behavioural adaptations to their environment. Intensive investigation of the hitherto neglected fields of water metabolism and thermoregulation in this highly endemic fauna would offer fascinating and stimulating subjects for research.

Typical gibber desert, where the Gibber Bird or Desert Chat is found. [Photo: Howard Hughes.]

DESERT BIRDS

By H. J. de S. DISNEY

THE Australian deserts or arid areas consisting of spinifex steppe and gibber cover about 14 per cent of the country, with an average rainfall of 5 to 8 inches. Of the 531 breeding birds in Australia only 17, or 3 per cent, are found in arid areas.

Keeping Cool

Birds that live in desert and hot arid areas have no special methods for controlling their body temperature. The body temperature of both desert and other birds ranges from about 104°F to 107°F, with the lethal temperature about 116°F. Birds do not have "sweat" glands, but must also cool themselves by evaporation of water. This is done by "panting" and passing air over the moist respiratory tracts. This takes place when the body temperature reaches about 109°F. Under very hot conditions the birds seek a cooler microclimate, either in the form of shade or, like some large birds, by soaring at high altitudes, as the temperature would decrease by 3°F for every 1,000 feet rise in altitude.

Drinking

The water lost by evaporation must be replenished; a few birds appear to be able to do this without drinking, by getting sufficient water from their food. In all cases these are either insect eaters or birds of prey feeding on flesh. There are no cases of purely seed-eating birds or birds with a dry diet which do not require to drink at least once a day and frequently more often. In this way you get the large flocks of budgerigar (*Melopsittacus undulatus*) coming to waterholes to drink, although experimentally they are apparently able to survive at least 38 days at 86°F, and apparently at 68°F some can survive indefinitely without water. However, this can only be done under relatively inactive conditions and in the wild this would not be so and it is very doubtful if a budgerigar could exist without water.

As birds must drink water the question arises, can they drink saline water? Marine birds can, as they have special nasal or salt glands. Most terrestial birds have a low salt tolerance; however, the Zebra Finch (*Taeniopygia castanotis*) can tolerate a salt solution slightly stronger than sea water. The budgerigar has apparently no special salt tolerance. Another bird in which the salt tolerance has been studied is the American Savannah Sparrow (*Passerculus sandwichensis*). Here there seemed to be differences between subspecies, and *P. s. beldingi* inhabiting the salt marshes could maintain its body weight at similar salt concentrations as the Zebra Finch. This is apparently carried out by very powerful kidney action.

Gibber Desert

Certain species are very characteristic of the different main habitats of these arid areas. The Gibber Bird or Desert Chat (*Ashbya lovensis*) is characteristic of gibber or stony desert and is found in western Queensland, the far north-west of New South Wales and northern South Australia as far south as Oodnadatta. On a field trip in 1963 this was observed near Bedourie in western Queensland out on the open gibber plain, and it was again seen near Birdsville in open stony country with a few small bushes. At Birdsville there were also Crimson Chats (*Epthianura tricolor*) and Orange Chats (*Epthianura aurifrons*) moving through on migration. At a distance it was difficult to distinguish the Desert and Orange Chats, when feeding on the ground, as they were both yellow. However, when they were disturbed it was found that the Orange Chats settled on top of a low bush, but the Desert Chats didn't; they always settled again on the ground. Another bird of dry stony country is the Cinnamon Quail Thrush (*Cinclosoma cinnamomeum*). This was also met with at Bedourie and Birdsville. It is fond of stony ridges with a few bushes for cover. It is, however, easily missed, as when disturbed it flies very swiftly and low to cover and is difficult to find again, being a great runner.

Zebra Finches (seed-eaters) coming to drink from water in drums. [Photo: Howard Hughes.]

Only by careful watch was it seen in the dry stony ridge country east of Alice Springs.

During the day few birds are seen on the open desert, but at night the Australian or Inland Dotterel (*Peltohyas australis*) can be frequently picked up in car headlights, also nightjars and even frogmouths are seen. Grey Teal move around at night and, perhaps upset by moon reflections, have flown into boundary fences and killed themselves.

When travelling through desert areas, if birds start to become common it means that water must be present somewhere, either a natural waterhole or water from an open bore, which may form a small stream. At Sandringham Station near Bedourie there was a creek with water from a bore forming pools; the surrounding country was sand. Here, at the end of October, 1963, were seen water birds, such as Spoonbills, Straw-necked Ibis, and, in the small patches of bulrushes in the pools, a Rail and several Reed Warblers. In bushes nearby were Zebra Finches and Diamond Doves, and roosting at night in some bare dead trees were Little Corella. At a small waterhole about 12 miles away there were ten Grey Teal, four Blacktailed Native Hens, several Blackfronted Dotterel, Pipits, Zebra Finches, Crested Pigeons, several Peewees, Black-faced Wood-swallows, Whitebacked Swallows and Bee-eaters.

Desert Grassland

This is very similar to open desert as there are very few birds, except near waterholes, unless it rains. In April, 1965, a visit was made to the edge of the sand dunes in the northern end of the Simpson Desert, due east of Alice Springs. Here, amongst the broken-down spinifex (*Triodia*) and scattered flowering Bloodwood trees, the Willy Wagtail (*Rhipidura leucophrys*) collected Bush Flies within a few inches of our feet. At sunrise the Yellow-throated Miners (*Myzantha flavigula*), Spiny-cheeked Honeyeaters (*Acanthagenys rufogularis*) and Singing Honeyeaters (*Meliphaga virescens*) came to feed on the flowering trees, returning to their roosting places in the evening. The miners were also feeding on the ground in the early morning and evening on termites, and getting their underparts heavily stained with the red sand. The only other birds seen in this area were two Masked Wood-swallows and two crows. The nearest water was at bore holes 8 to 10 miles away. In an area where the ground was bare except for low *Acacia* bushes, forty galahs suddenly appeared. It is uncertain what they were feeding on, but scattered over the whole area was plenty of pisolitic grit. This grit when rubbed was found to be a layer of very fine grit round a nucleus of a flat *Acacia* seed. The galahs may have been feeding on these.

A tree growing from a hidden waterhole which is protected from evaporation by large rocks. [Photo: Author.]

Breeding

The birds of the arid regions of Australia are opportunist breeders, which breed after rain. This was noted by the early naturalists, and Serventy and Marshall (*Emu*: 57.99-125) examined the out-of-season breeding in southern Western Australia in 1953 and 1955. They found that thirty-nine species bred out of season after heavy rain in the area, and the lower the

A migrating Sharptailed Sandpiper at a claypan on its return journey to north-eastern Siberia to breed. [Photo: Author.]

average rainfall of the area the quicker the response of the birds to the stimulus of rain.

In early March, 1965, the Tanami Desert Sanctuary in Northern Territory received 7 inches of rain. Four weeks later the following insect-eating birds were found nesting, but no seed-eating birds: One Crimson Chat with young; Pipit and Brown Songlark with eggs, the latter well incubated; two bustards with eggs, one clutch of which was about ten days incubated; quail with small young, and also a Ground-nesting Pigeon. Insect life was abundant, particularly Bush Flies and also a whitish Noctuid caterpillar feeding on the spinifex and which was being fed by the Crimson Chats to their young.

Migration

Most of the older indigenous birds do not appear to perform true migrations, but are only nomads within their own suitable habitats, as none of the Australian deserts or arid regions are barriers to true migrating birds. True migrating birds lay down a layer of fat as reserve energy for their journey. From examination of the heavy fat deposits of New Holland Honeyeaters (*Meliornis novaehollandiae*) in eastern Australia in July, it is considered that there would be no great difficulty for these birds to migrate across 1,000 miles of arid country to join their relatives in south Western Australia. They are not known to do this, although in the Northern Hemisphere similar small birds twice a year cross the same distance over the much more severe Sahara Desert.

As soon as any rain falls in the arid areas insects become abundant, so that small insect-eating birds would have no difficulty crossing these areas and in fact, in 1939, when the Simpson Desert Expedition crossed from west to east and there was rain, small birds were recorded all the way across. Rain also fills the claypans and at once duck and Marsh Terns and other water birds appear. The Northern Hemisphere migrants such as Sharptailed Sandpipers and Little Whimbrel also stop on the journey north at the claypans, although at this time their bodies are covered with a quarter-inch layer of fat and they could quite easily continue their journey. One of the great attractions for these birds is the abundant food supply which quickly develops in these claypans, particularly Shield Shrimps (*Triops australiensis*) (see the article on Crustacea), which the terns and others readily eat.

The Water-holding Frog (*Cyclorana platycephalus*) is found in many parts of the arid inland of Australia. It has a number of physiological and behavioural adaptations to life in arid regions. [Photo: Howard Hughes.]

REPTILES AND FROGS OF AUSTRALIA'S ARID REGIONS

By H. G. COGGER

AS already described in this issue the arid interior of Australia contains a diversity of environments and landscapes. The major features common to all of these environments are lack of water—or rather, its unreliability from year to year—and high summer temperatures, both of which make life in this region especially hazardous.

The reptiles of Australia's deserts and "semi-deserts" are rich in numbers and variety, but very few are encountered by the visitor. Most are nocturnal and secretive, avoiding the harsh conditions which prevail during daylight hours. Nevertheless, a few species of lizards, especially some of the dragons (Family *Agamidae*), can be seen at high noon even on the hottest summer day perched on rocks, stumps, termitaria or mounds of sand, within easy reach of their home burrows or clumps of Porcupine Grass.

As pointed out in a previous article (*Australian Natural History*, Vol. 14, No. 2) the reptiles of central Australia can be divided roughly into four major groups, on the basis of their preferred habitat or way of life. These are:—

1. Species which live in the Porcupine Grass (*Triodia*).
2. Burrowing species.
3. Rock-dwelling species.
4. Arboreal species.

This is, of course, something of an over-simplification, for many species do not have such clear-cut preferences. Some dragons, for example, make extensive burrows but spend much of their time in the *Triodia.* Some reptiles, such as the Western Blue-tongue Lizard (*Tiliqua occipitalis*) and the Sand Goanna (*Varanus gouldii*) move freely about the countryside to forage, and for this reason do not conveniently fit into any of these four "habitat" categories. Nevertheless, this simple classification will indicate the basic ecological niches in which reptiles are found in Australia's arid interior.

Inhabitants Of The Porcupine Grass

Those forms that inhabit the Porcupine Grass or spinifex (*Triodia*) make up one of the largest groups of desert reptiles. Various species of Porcupine Grass constitute the dominant vegetation over vast areas of central Australia, from the desert sandhills to the very tops of the mountain ranges. In many areas it is the only permanent ground cover, and as each clump consists of a relatively dense thicket of interlacing, outwardly-projecting spines, it provides shelter and protection for a host of smaller reptiles, especially lizards. Indeed, all five families of lizards which occur in Australia have representatives in this group. Some common species are the Beaded Gecko (*Diplodactylus elderi*), a legless lizard (*Delma frazeri*), the Ocellated Skink (*Sphenomorphus ocelliferum*) and the Military Dragon (*Amphibolurus isolepis*).

Burrowing Species

Burrowing species are also plentiful, although into this category are also placed those reptiles, such as some of the larger venomous snakes, which do not make their own burrows but inhabit those made by other reptiles or by mammals. Burrows offer a number of advantages. On hot days the temperature only a few inches below ground is much lower than that on the surface, and numerous nocturnal species spend the daylight hours underground. Some sun-loving dragons also construct burrows to which they retreat when danger threatens or when conditions above ground become excessively hot. In winter, reverse conditions apply, for night surface temperatures may become so low (up to 20F° or more below freezing) that only by remaining in their burrows can the reptiles avoid freezing to death.

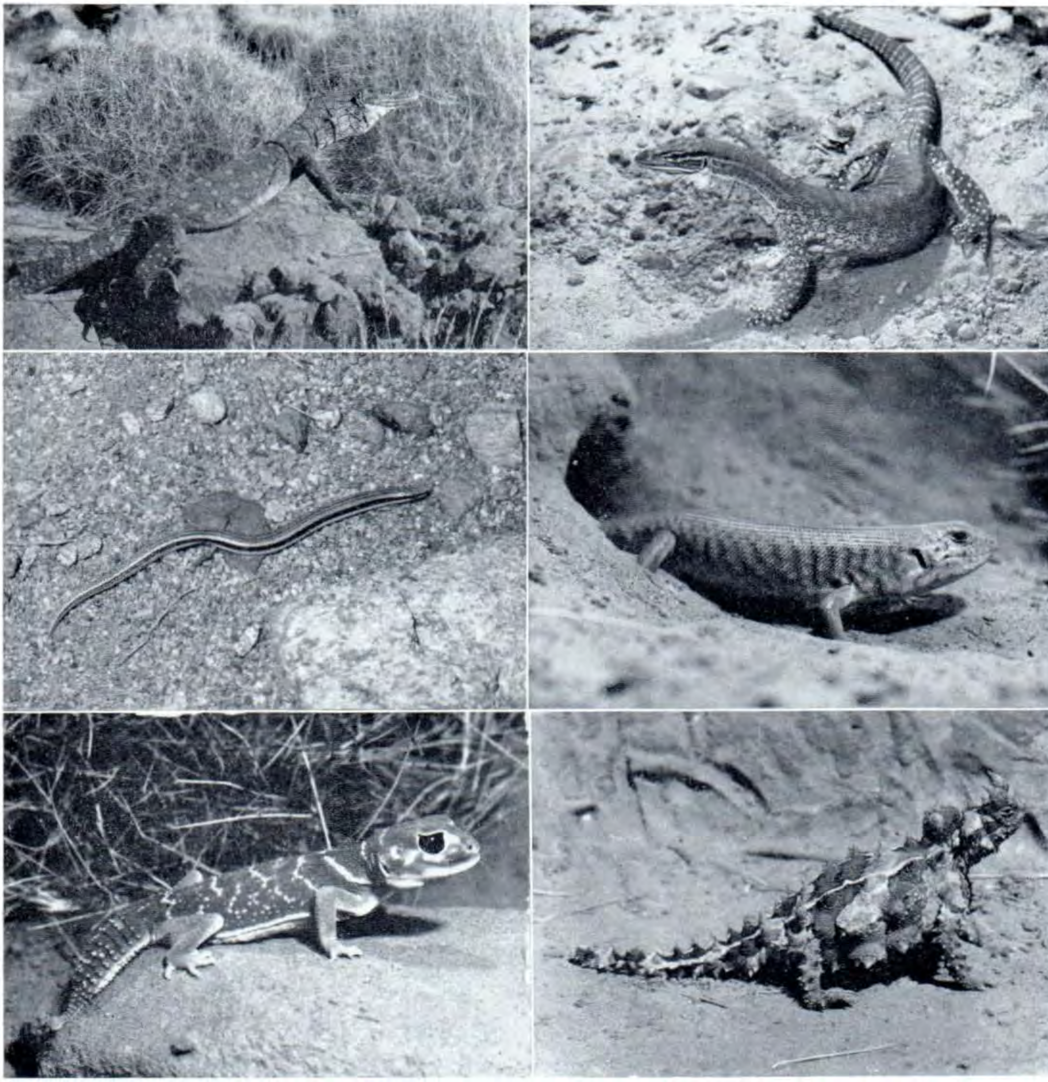
Some large lizards, such as the skink *Egernia kintorei*, have been found by zoologists in the Northern Territory to construct "family" burrow systems up to 6 feet deep and more than 20 feet long, with multiple entrances. Many species make their burrows at the bases of trees or shrubs, the roots of which may give structural support to the burrows, and where the water content of the soil is often high.

Rock-inhabiting Reptiles

Scattered throughout inland Australia are numerous mountain ranges, each separated from its neighbours by tracts of desert of varying extents. It is in these ranges that rock-inhabiting reptiles are found, living either under slabs of rock or deep in rocky crevices. It is here, too, that the only permanent water is found, for only the combination of impermeable rock base and sheltering ravines will allow surface water to be retained for any period of time. Spring points, though uncommon, also occur in the ranges and together with rock holes provide a few places in this typically waterless region where frogs can survive. The centralian "tree" frog *Hyla gilleni*, the ubiquitous little tree frog *Hyla rubella* and the ground frog *Limnodynastes ornatus* are commonly encountered at such places as Simpson's Gap, and Palm Valley in the MacDonnell Ranges. Rock-inhabiting reptiles which are found only in the mountain ranges are the Ring-tailed Dragon (*Amphibolurus caudicinctus*), the Rusty Dragon (*Amphibolurus rufescens*), White's Skink (*Egernia whitii*), a spiny-tailed skink (*Egernia stokesii*) and various geckos. The Perentie (*Varanus giganteus*), Australia's largest goanna, is usually found close to the ranges or large rocky outcrops, but will move out into the surrounding country to forage.

Arboreal Reptiles

Arboreal reptiles are relatively few; some common centralian species are the Pigmy Tree Goanna (*Varanus gilleni*), the Little Tree Skink (*Cryptoblepharus boutonii*)



Some common lizards of central Australia. *Top* (left to right): The Perentie (*Varanus giganteus*), which grows to more than 8 feet and is Australia's largest lizard. The Common Sand Goanna (*Varanus gouldii*). *Centre*: A burrowing skink, *Rhodona bipes*, only a few inches in length. Kintore's Skink (*Egernia kintorei*). *Below*: The Knob-tailed Gecko (*Nephrurus laevis*). The Thorny or Mountain Devil (*Moloch horridus*). [Photos: Howard Hughes.]

and the Tree Gecko or Dtella (*Gehyra variegata*).

It can be seen from the above discussion that the majority of reptiles (and frogs) living in the arid interior of Australia are able to survive there not so much by adapting to the rigorous conditions which exist there, but by finding niches—burrows in moist sand away from the heat, shady rock crevices, protective grassy thickets—which enable them to avoid unfavourable conditions. Those species which survive even under conditions of extreme heat and dryness are often able to do so by virtue of complex behavioural adaptations. By carefully changing their body position in relation to the sun and the hot sand, many lizards are able to maintain their body temperature up to 30F° below the temperature of their surroundings. Total water needs are often provided by the numerous insects upon which they feed.

Overseas studies have shown that many desert reptiles have complex physiological adaptations, such as increased re-absorption of water from waste products in the kidney and urodaeum, which help them to survive under arid conditions. The extent to which Australian desert reptiles have evolved such physiological mechanisms is little known, for few investigations have been carried out in this country. Indeed, it is within the field of physiological adaptation to the Australian environment that we can expect some of the most exciting work and results in the study of Australian reptiles and frogs within the next few years.

The evolution of Australia's numerous desert reptiles is a problem which is also commanding increasing scientific interest. We know little about the history of climatic and other changes which have contributed to the landscape, flora and fauna which today characterize the arid interior of this vast island-continent.

BOOK REVIEW

"THE MOSQUITOES OF VICTORIA", N. V. Dobrotworsky; Melbourne University Press; i-v, 237 pp., 86 figs., pls. I-III; 1965; price, £4 13s. 0d.

This book consists of a systematically arranged account of Victorian mosquitoes. After an introduction consisting mainly of a brief historical review of work on Australian mosquitoes there are four sections devoted to general subjects. The first of these deals with the external anatomy of adult mosquitoes, their periodicity of activity, mating, feeding and oviposition. The second deals with the immature stages. The subjects of eggs and hatching are followed by description of the external anatomy of the larvae, their biology and larval habitats. A brief description of the mosquito pupa is included but unfortunately no details are given of some essential pupal characters, such as chaetotaxy, which are used in pupal identification. The third section deals with general aspects of distribution and seasonal abundance of Victorian species. The fourth section, consisting of only two pages, deals with mosquitos as disease vectors in that State. This section concludes the First Part of the book.

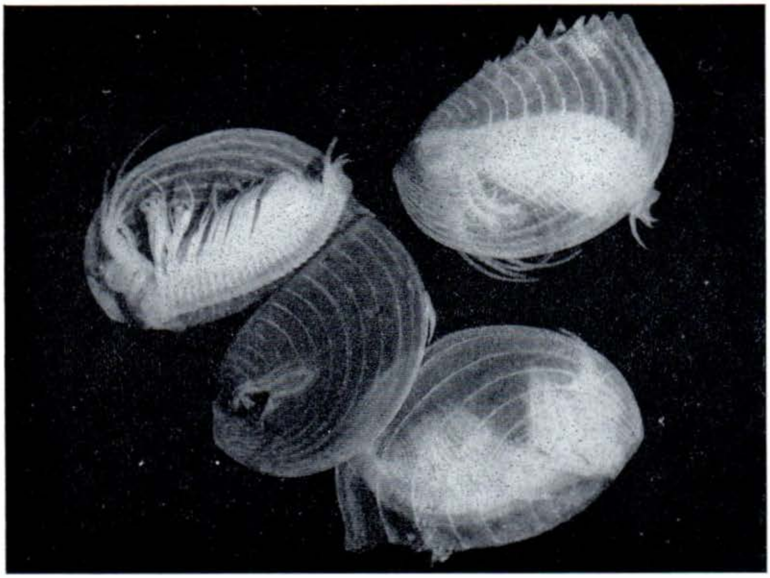
The bulk of the book, the Second Part, consists of a systematic treatment of the species and subspecies found in Victoria. Keys, descriptive text and essential figures are given for the identification of adults and larvae. Under distinct headings adult characters (male and female), larval characters, biology and distribution are dealt with for each species. Pupae are virtually ignored.

The book ends with an appendix on collecting and preserving specimens for study, a list of references, a systematic list of mosquito species in Victoria and an index. The insides of the front and back covers are used to provide a map of Victoria.

The type is clear and headings are well used so that it is quite easy for the reader to find his way about the book. The illustrations are large. Paper quality and binding are adequate. The price is high.

Entomologists engaged on work on mosquitoes in Victoria will find this book indispensable; workers in other areas, moreover, will find it very useful. In addition, it will be of considerable use to those engaged in public health and other work where identification of mosquitoes is required, with special reference to Victoria.

For a considerable time now the description of Australian insect species has been going on apace. In most groups there has been comparatively little published in the way of synopses, revisionary work or monographs with an Australia-wide coverage or even on a regional basis. The time spent by taxonomists in making identifications for others is usually time taken from their research; more publications like that of Dr Dobrotworsky would enable workers in non-taxonomic fields to make their own identifications. This they should do, of course, whenever possible leaving the taxonomist to produce more work in the same vein. This book is a good example of the kind of thing much needed for Australia at present. It is to be hoped that many more volumes will appear with similar content and coverage for other insect groups and areas.—*C. N. Smithers.*



Clam or Shelled Fairy Shrimps (*Limnadopsis birchii*). The specimen at upper-right shows prominent "teeth", typical of this species, along the dorsal hinge of the nearly transparent pair of shells. The specimen upside-down at the left has one of its shells turned back to reveal its body and limbs. Length, up to 1 inch; colour, olive-green. [Photo: Howard Hughes.]

Crustacea of the Arid Inland

By JOHN C. YALDWYN

ON the whole there is nothing unusual about the inland Crustacea of Australia when compared with those of other continental land masses in the world. One could paraphrase the words of a famous English carcinologist who wrote about the smaller freshwater crustaceans of Britain, and say that in a gathering of water-fleas, copepods and shelled ostracods from central Africa or inland Australia, we find that most of the genera, and even some of the species, are identical with those found in similar situations in his country. This does not mean that all freshwater species are so universally distributed, for there are many, especially among the larger forms, which have a restricted range, but this does not render less striking the general uniformity of this fauna over wide areas of the world.

Although we discuss here the Crustacea of the arid and semi-arid inland of Australia, it should be made quite clear that with the single exception of the terrestrial isopods or wood-lice as a group, all these animals are aquatic. In other words they live in, or depend directly upon, the presence of water, either fresh, saline, or even, in two cases at least, hot artesian bore water. All the small forms belong to the group called Entomostraca, or lower Crustacea. These are mostly inhabitants of temporary pools and bodies of water which dry up completely so that "resting eggs", of a special type which can withstand unusual heat, cold and prolonged dessication, constitute the sole means of tiding the species over from one season to the next. Such sexually-produced, resting eggs, as distinct from normal, "favourable-season" eggs (often parthenogenetic or unfertilized), are effective dispersal mechanisms for these forms. These minute dried eggs may be blown over great distances in dust or possibly transported by birds and insects. It is thus not surprising that these species are often widely distributed. Resting eggs of a few species will hatch without drying, but in most cases drying is a prerequisite for hatching.

Green Shield Shrimps

In favourable conditions development takes place very rapidly, as observed by Baldwin Spencer, Professor of Biology at the University of Melbourne, during the Horn Expedition to central Australia in 1894. During his investigations, the large green Shield Shrimp (*Triops australiensis*) (see photographs) was found in hundreds in small claypans and pools in the creek beds—in fact anywhere where there was water clouded with mud particles. *Triops* has been the characteristic crustacean seen by travellers in central Australia ever since, and its fanciful resemblance to the completely unrelated and extinct fossil trilobites, as it flounders in the mud of a drying claypan, has been remarked upon by many observers. Spencer went on to record that the rate of growth of *Triops* and Shelled Fairy Shrimps must be very rapid. Certainly not more than 2 weeks, and probably only a few days, after the fall of rain, "numberless" specimens of *Triops*, measuring in all about 2½ to 3 inches in length, were swimming in the pools. As not a single one had been found prior to the rain these must have developed in that short time from resting eggs.

In these areas too, so subject to rapid drying up of temporary water bodies, a species may locally die off as rapidly as its numbers originally built up, and at a different rate in closely allied species as physical conditions in the shrinking water body change. Thus Spencer found at Conlon's Lagoon, for example, not far from Alice Springs, that one part of the low land around the shrunken lagoon was studded with innumerable dried-up carapace shells of *Limnadopsis birchii* (see photograph), but not a single one was to be found in the muddy waters of the lagoon itself, where the closely related Shelled Fairy Shrimp (*Estheria packardi*) was swimming abundantly. For extreme examples of rapid development in Crustacea, however, we must turn to the microscopic cladoceran water-fleas. There a single brood of parthenogenetic, normal eggs will number from about thirty to sixty in *Daphnia* and its relatives. As the broods may succeed each other at intervals of 2 to 3 days it will be seen that multiplication of a species in favourable circumstances may be exceedingly fast. It has been calculated that in 60 days the progeny of a single female daphniid can, theoretically, amount to about 13,000 million individuals.

The edge of a water-filled temporary claypan a few miles east of Mt Ptilotus, Tanami Desert Sanctuary, Northern Territory in April, 1965. This is a typical habitat of the Shield Shrimp *Triops* and the Shelled Fairy Shrimp *Limnadopsis*. Louis Wright, of Santa Teresa Mission, is digging for the burrowing frogs *Cyclorana* and *Neobatrachus*. [Photo: H. G. Cogger.]

As only a few of the smaller crustaceans have common names, and as many of the groups represented in inland Australia will be unfamiliar to the general reader, a list of those groups recorded from the arid inland is given below, together with some typical generic or specific representatives from this area. This list of examples must not be taken as even partially complete at the generic level, though the list of major groups is probably definitive with the possible exception of aquatic isopods, which, other than the atypical suborder Phreatoicidea, appear to be unrepresented.

Class CRUSTACEA

ENTOMOSTRACA (literally meaning "shelled insects"), the lower Crustacea

BRANCHIOPODA (the gill-footed crustaceans)

- Fairy Shrimps or Anostraca—*Branchinella, Branchinecta* and *Artemia salina* (the cosmopolitan "Brine Shrimp" of aquarists).
- Shelled Fairy Shrimps, Clam Shrimps or Conchostraca (with a transparent bivalved shell) —*Limnadopsis, Eulimnadia, Estheria, Limnetis.*
- Shield Shrimps or Notostraca—*Triops* (formerly known as *Apus*) *australiensis.*
- Water-fleas or Cladocera—*Daphnia, Ceriodaphnia, Simocephalus, Moina, Alona* and others.

OSTRACODA (Crustacea with a solid bivalved shell)—*Cypris, Cypridopsis* and allies.

COPEPODA (the oar-footed crustaceans)—*Boeckella, Calamoecia, Leptocyclops* and others.

MALACOSTRACA (literally meaning "soft-shelled animals", the Greek equivalent of the Latin word Crustacea), the higher Crustacea

ISOPODA (slaters, wood-lice and their aquatic allies)—*Hemiporcellio* and *Cubarius* are terrestrial forms. The phreatoicid *Phreatomerus* is an aquatic amphipod-like form.

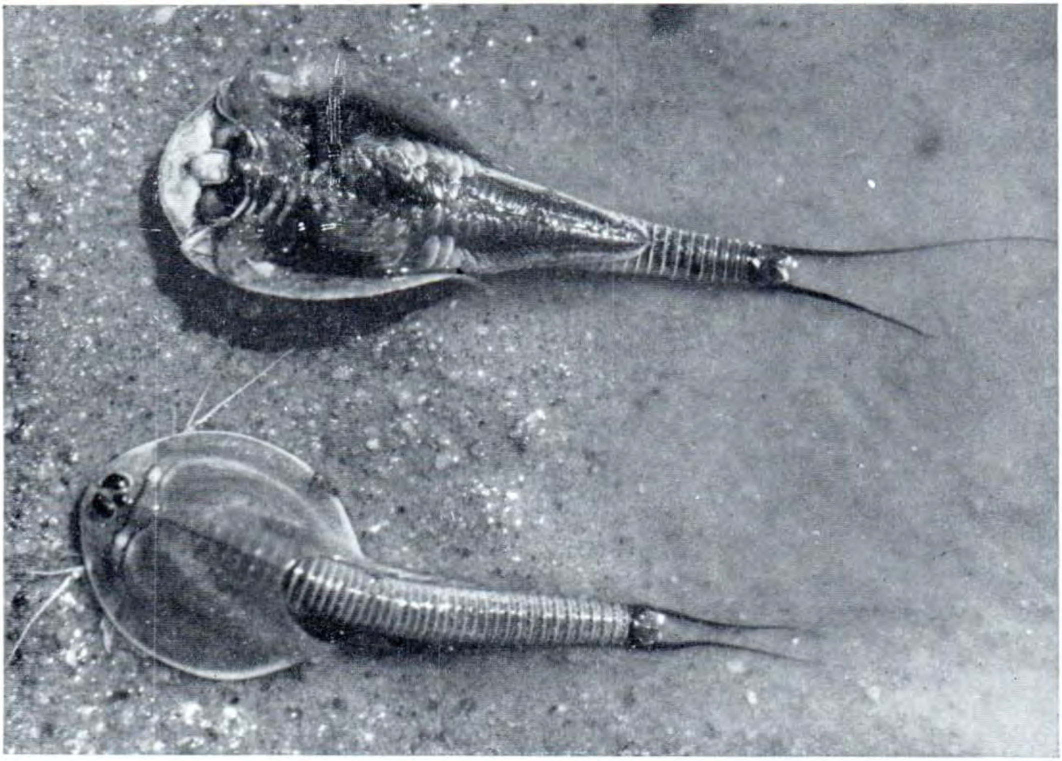
DECAPODA (shrimps, crayfish and crabs)—True "ten-legged" shrimps are represented by *Macrobrachium* in perennial waters over much of the inland, by *Caridina thermophila* from hot artesian bore water near Longreach, western Queensland, and by *Parisia* from subterranean water near Katherine, Northern Territory. At least two freshwater crayfish of the genus *Cherax* occur, as well as the single freshwater crab *Parathelphusa transversa.*

The Fairy Shrimps, with the Clam and Shield Shrimps, are exclusively freshwater forms, and though many thrive in saline waters none are found in the sea. An example is the Brine Shrimp (*Artemia salina*), which can tolerate water high in salt content, such as the Great Salt Lake of Utah, and in addition is found throughout the world from Greenland to Australia and from the West Indies to central Asia. When present in large numbers these small crustaceans give the water a reddish colour due to the presence within their bodies of the pigment haemoglobin, better known as the respiratory pigment characteristic of vertebrate blood. The Shield Shrimp (*Triops*) also has haemoglobin in the blood. Other anostracans, such as *Branchinella,* attain a length of an inch or more, are almost transparent or white in colour, with an elongate body and a bunch of leaf-like legs concentrated behind the head. They do not have a shelled carapace, but possess prominent black eyes and the unusual habit, shared with the Clam Shrimps and Shield Shrimps, of swimming upside down, that is, back downwards.

Shelled Fairy Shrimps

The Shelled Fairy Shrimps or Clam Shrimps have a similar body shape to the above forms, but possess a carapace of two transparent shells hinged dorsally, which completely encloses the body and limbs, thus closely resembling a small bivalved mollusc. The largest of these, *Limnadopsis birchii,* here illustrated, grows to a length of at least 1 inch and is olive green in life. Shield Shrimps are represented by the one species of *Triops,* described above as typical of the arid inland. On rare occasions some of these large crustaceans have been recorded hatching in eastern coastal areas after strong westerly dust storms. Under these conditions *Triops* overlaps in distribution with the closely related *Lepidurus,* found widely in temperate coastal areas

The Shield Shrimp (*Triops australiensis*) moving through drying mud at the edge of a shallow waterhole 30 miles north of Coober Pedy, South Australia, in April, 1963. Length, up to 3 inches; colour, olive-green. [Photo: A. Holmes.]



Dorsal and ventral views of the Shield Shrimp (*Triops australiensis*) at the Tanami Desert claypan. Note the long multi-segmented abdomen, with many small limbs visible on the under surface, and the two slender terminal projections from each side of the tail segment. [Photo: H. G. Cogger.]

and in Tasmania. Dr W. D. Williams, of Monash University, Melbourne, is at present doing a study of the detailed distribution of these two forms and any records of either would be of interest to him.

The water-fleas, ostracods and copepods are mostly microscopic, and consequently seldom collected and poorly known from inland Australia. One ostracod is, however, pea-sized and its opaque and rounded bivalved shell occurs in many samples brought to the Museum from this area. The copepod *Boeckella triarticulata* was originally recorded from standing water near Alice Springs and in the MacDonnell Ranges, but has recently been taken at several localities in northern Australia. Our knowledge of the distribution of this genus comes from recent work by I. A. E. Bayly, of Monash University.

Wood-lice

Terrestrial wood-lice are rare in collections from the inland area, but are possibly common in suitable habitats. The two examples quoted above were taken by an expedition to the Strzelecki and Cooper Creeks in 1916. The phreatoicids are unusual isopods with almost the appearance of an amphipod, since the body is more or less flattened from side to side, instead of from above downwards. Their distribution is of great zoogeographic interest as they are restricted to southern Africa, India, Australia and New Zealand, with their greatest development in the cooler fresh waters of the southern part of our continent. One species, *Phreatomerus latipes*, is found in the arid inland in the hot waters of an artesian bore near Lake Eyre, South Australia. It is unusual among the phreatoicids, by being able to conglobate, or roll into a ball, like many terrestrial isopods.

Apart from Entomostraca and their dessication-resistant resting eggs, few Australian freshwater Crustacea show special adaptation for survival under arid conditions. Among freshwater crayfish, *Cherax destructor*, a widespread inland form also found in central Australia, and *Cherax albidus*, of more southern and eastern regions, have developed the burrowing habit to a marked degree. These species can seal the mud chimney above their burrows under dry conditions and survive in the artificial waterhole at the base of the burrow till the next rain. The single freshwater crab, *Parathelphusa transversa*, has an extensive range from inland north-western Australia, across the Northern Territory to the Lake Eyre basin, the Darling River drainage system in western New South Wales and into inland and coastal Queensland. Like the crayfish, this crab also seals the entrance to its burrow with mud when the waterholes dry out and survives in these burrows till the next wet season.

The distribution and habits of *Parathelphusa* have been extensively studied recently by J. A. Bishop, of the University of Sydney, who found that their burrows may penetrate 2 to 3 feet into the clay soil of creek banks, ground tanks and waterholes. The crabs close the burrow mouth with a moulded plug of clay, which dries and becomes very hard. It is difficult to find burrows in habitats which have been dry for any length of time, as weathering of the soil surface destroys the surface earthworks of the burrows. This species can survive long periods of drought in these burrows, and many observers in north-western New South Wales have noticed active, adult "sidewalkers" in large numbers soon after the breaking of long droughts.

The interesting cycles of abundance and replacement of the entomostracan forms that must go on in temporary or semi-permanent claypans or waterholes are a study in themselves. To demonstrate the viability of dormant eggs, dried mud samples from suitable areas can be obtained and placed in aquariums under controlled conditions where the sequence of hatching of the various species present can be observed. This was the classical method used by the famous nineteenth century Norwegian, Professor G. O. Sars, to study these little freshwater crustaceans from all over the world. Dried mud samples from collectors and naturalists in many countries, including Australia, were sent to Dr Sars in Christiania, Norway, where they were "brought to life" in his laboratory aquariums. Often all we know today of a species, or of the small freshwater Crustacea of an area, is recorded in the beautifully drawn and coloured plates and meticulous descriptions left by this one man.

Important Studies

Miss Marguerite Henry, of Sydney, followed this lead in the early 1920's and was able to breed Fairy Shrimps, water-fleas, ostracods and copepods from dried mud samples obtained all over Australia, including many from the arid inland of the continent. From her studies she was able to produce a basic account of the Entomostraca of the Australian region. She also recorded in detail the natural fluctuations of many of her samples when placed in small, well lit aquariums, supplied with a little uncontaminated water plant for aeration and left for at least a year. Studies of this type could be done by any interested observer with the minimum of home equipment, and these should provide varied and worthwhile faunal records from any area.

THE AUSTRALIAN MUSEUM

HYDE PARK, SYDNEY

The Australian Museum

The Museum is open free, daily, at the following times: Tuesday to Saturday, and public holidays, 10 a.m. to 5 p.m.; Mondays, 12 noon to 5 p.m. (during school holidays 10 a.m. to 5 p.m.); Sundays, 2 to 5 p.m. It is closed on Good Friday and Christmas Day.

To teachers and pupils of schools and other educational organizations special facilities for study will be afforded if the Director is previously advised of intended visits. A trained teacher is available for advice and assistance.

Gifts of even the commonest specimens of natural history (if in good condition) and specimens of minerals, fossils and native handiwork are always welcome.

The office is open from 9.30 a.m. to 1 p.m. and 2 to 4.30 p.m. (Monday to Friday), and visitors applying for information there will receive every attention from Museum officials.

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