# INCUBATOR BIRDS

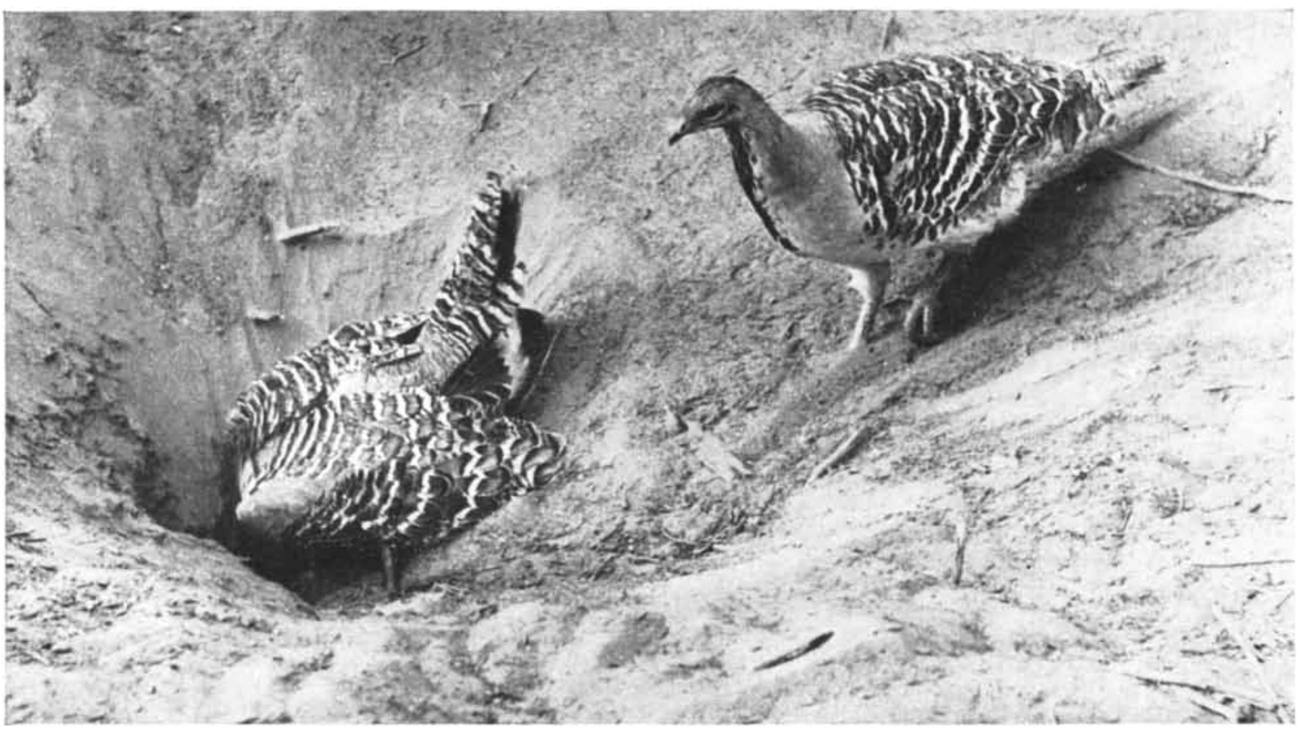
These extraordinary fowl hatch their eggs not by sitting on them but by putting them in a hot place. Some species even rake together dead leaves, the decay of which heats the eggs

by H. J. Frith

On the mainland of Australia and the islands to the north lives a family of rather dull-looking black or brown birds about the size of domestic fowl. Called Megapodiidae, after their big feet, they rarely fly, have raucous calls and are seldom seen by man. These birds are of interest because they do not brood their eggs with the heat of their bodies as other birds do but hatch out their young in incubators. Depending upon their habitat, the various megapode species have developed different ways of finding and generating heat short of sitting on the eggs themselves. They bury their eggs in sun-warmed sand, in volcanoes or in compost heaps where fermentation supplies the heat. One Australian species, the mallee fowl, constructs huge mounds of soil and vegetable matter, enlisting both the heat of the sun and of fermentation, and manages to keep the temperature within a degree or so of 92 degrees Fahrenheit throughout the incubation period despite the vagaries of an often hostile climate. The chicks never see their parents. They hatch deep beneath the soil, dig their way upward to the surface and run away into the bush, fully feathered and able to fend for themselves from the start.

The first Europeans to hear of the incubator birds were survivors of Magellan's ill-fated 1519-1522 expedition around the world. One of them, Gemelli Careri, described in his memoirs a bird about the size of a small fowl that laid eggs bigger than itself and buried them in the ground to hatch from the heat of the sun and sand. The people of Europe at that time accepted mermaids and devils as normal inhabitants of the earth, but found the idea of birds building their own incubators too fantastic to believe. Careri's tale was rejected as just another sailor's yarn.

When early settlers in Australia discovered large mounds in the inland scrub, they marveled that aboriginal mothers should build such big sand



**MALE MALLEE FOWL WATCHES FEMALE** as she prepares to lay half-pound egg in hole he has dug in incubator mound. Egg will roll down to where female here has her head. Of this male the author says: "His co-operation has immensely assisted our studies."

castles to amuse their children. Later settlers in the north of the continent found really enormous mounds. They deduced that these monuments were the tombs of dead warriors. The natives, however, denied building mounds for either children or the dead. They stoutly claimed the mounds were birds' nests. But who could believe such a fantastic story from uncultured savages? The settlers continued to doubt the bushmen until 1840, when the pioneer naturalist John Gilbert took the obvious step of digging into the mounds. Sure enough, he found birds' eggs. The aborigines chuckled.

When I first heard of these mound builders, I wondered why other birds had not adopted this habit. Why should they not deposit their eggs in an incubator and lead a life of leisure instead of exposing themselves to the cares and dangers of the common method of incubation? Now, after a decade of studying the mallee fowl, I no longer wonder. The construction and maintenance of its incubator mound call for great skill and stamina and ceaseless heavy work for most of the year. Normal incubation must be easier in every way.

The megapodes that live on small islands in Celebes and the Moluccas have adopted somewhat less arduous methods. There the climate is warm and the temperature varies little during the day or over the course of a year. The shaded soil of the jungle, where these birds live, remains somewhat too cool. But the sand on the beaches becomes uniformly warm to a relatively great depth. The birds simply go to an exposed beach, dig a small pit deep enough to find the right temperature, and lay their eggs in it. In some places old lava-flows across the beaches have weathered to black sand. Here the birds unerringly choose the black sand for egg pits; presumably the better heat-absorbing properties of black sand make it slightly warmer. The jungle fowl, however, must face one difficulty. The beach is often as much as 20 miles away. Since they lay an egg every few days for several weeks, returning to the forest in between, their life during breeding season must be a constant promenade. A few of the birds do find warm spots in the forest soil at the edges of warm springs, and lay their eggs there.

The most widely distributed of all megapodes is the jungle fowl Megapodius. It is found from the Nicobars in the west to Fiji in the east, and from the Philippines to the central Australian coast, living on small coral atolls, larger

**DIGGING MALE MALLEE FOWL** works at dawn in spring. He opens his egg-incubator mound to let out heat of fermenting matter and keep the eggs at 92 degrees Fahrenheit.

**IN MIDSUMMER** the bird adds more soil to his already high mound to increase its insulation from hot sun. Fermenting leaves under the buried eggs now give off much less heat.

**BY AUTUMN** the male must work at midday to scoop out the mound and allow the sun's heat to penetrate to the eggs. He rebuilds the mound with sand warmed by the noon sun.

islands and on the continent itself. As might be expected, it is the most adaptable of the megapodes and varies its incubation method to suit each location.

On small islands this species lives in the jungle near the beach and lays its eggs in pits dug in the beach, side by side with the turtles that heave themselves from the sea for the same purpose. On islands where there is volcanic activity, Megapodius digs egg pits in places where steam issues from the ground and, on some islands, even in the volcanic ash of active craters. On larger islands and in Australia, the fowl lives in fairly dense forests and jungles at long distances from the exposed beaches and with no volcanic heat at hand. Here Megapodius adapts the heat of rotting vegetable matter to do the work of incubation.

The hard-working birds build mounds of soil and leaf material that may reach 50 feet in diameter and 15 to 20 feet in height. In open scrub near the seashore, where the sun shines brightly, they incorporate less organic material in their incubators. Such mounds represent perhaps no more than a first improvement on the simple egg-pit, elevating the pits for drainage and for safety from the tide. In dense jungle, however, where little sun reaches the ground, the mound will be almost entirely vegetable, and much heat is generated by fermentation. Between these two extremes are many mounds of intermediate composition. I find it remarkable that a bird is able to estimate the amount of organic matter it must add to a heap of soil so that the heat generated by fermentation is just enough to bridge the gap between the soil temperature and the temperature necessary for incubation. It almost suggests that these birds understand some chemistry.

Another group of megapodes, the brush turkeys, live in the dense, steamy rain forests of Australia and New Guinea, where the sun seldom penetrates. These birds find no difficulty in generating heat by fermentation, and depend on it entirely. The brush turkeys' mounds are heaps of rotting leaves 12 to 15 feet in diameter, scratched up from the forest floor with practically no soil. The mound is built in spring and, when it is wet with the summer rains, ferments so vigorously that, as we shall see, the birds are obliged to take active steps to control the heat.

The jungle fowl on their sunny beaches near the Equator, and the brush turkeys with masses of organic matter at hand, have no great difficulty finding sufficient heat for purposes of incubation. With the mallee fowl it is quite different.

This bird inhabits inland Australia, a region of semideserts and arid scrub with an annual rainfall of as little as eight inches. The hard, dry leaves do not rot where they fall. Instead, they are eaten by termites or they wither and blow away, and there is practically no leaf litter on the ground. Even if leaves are heaped up, they do not ferment but remain dry and are eventually burned by a brush fire or swept away by the wind. Clearly a bird wanting to generate heat by fermentation here has formidable obstacles to overcome.

Nor is solar heat dependable in this landscape. The air temperature ranges from 112 degrees F. to as low as 17 degrees. The days are blazing hot and the nights may be freezing cold. The temperature of the soil near the surface fluctuates madly, and the temperature deeper in the soil is only 60 degrees.

The ingenious mallee fowl is equal to the problem. It is the male bird that takes charge, building the incubator mound, tending it constantly and seldom going more than 200 yards away. He induces the leaf litter to ferment by burying it in the ground during the winter, when it is moist. The work begins in May (the Australian "November"), when he digs a hole 15 feet in diameter and three to four feet deep. Through the winter he rakes in the leaf litter from 30 to 40 yards around, piling it in the hole. Then, in August, he covers the heap with soil up to two feet thick. The organic matter is usually moist from the few winter showers and, sealed off from the dry air and sun, soon begins to ferment, raising the temperature in the mound. If it has been a dry winter and the leaves do not ferment, the birds abandon the mound and do not breed in that year.

The female is an egg-producing machine. She lays the first egg in mid-September and the last egg in late February or early March. She weighs only 3.5 pounds, but she justifies Careri's report of her by laying a half-pound egg and valiantly laying one every four to eight days for a total of as many as 35 in a season. Since an egg needs seven weeks to hatch, many of the chicks have already hatched and taken off long before the last eggs are laid—true assembly-line production.

During the whole time that eggs are in the mound the male carefully regulates the temperature. Many birds aim at exactly 92 degrees F., though others permit fluctuation between 90 and 95 degrees. When the last egg hatches, the mound is dug out and prepared for a new charge of organic matter.

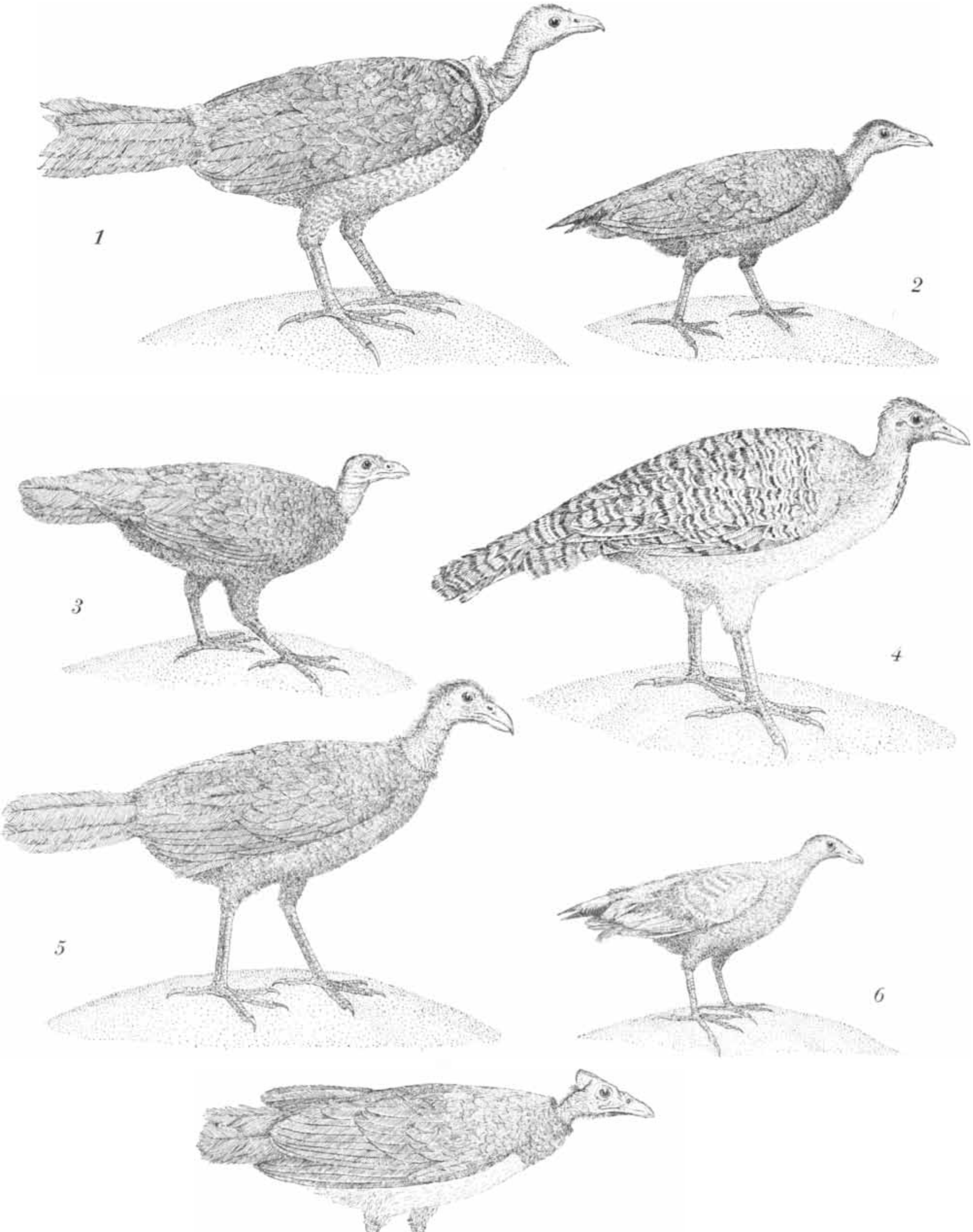
To use natural heat and to regulate it so closely, the birds must have a highly developed sense of temperature. In 1952 I set out to learn how the mallee fowl goes about it.

I found that the mound temperature will rise to 115 degrees F. in the spring if the male is kept away from it. The heat then quickly leaves as the fermentation burns itself out. I built mounds without organic matter and found that the temperature rises very slowly when heat comes only from the sun, and never reaches 92 degrees. When the internal temperature in a normal undisturbed mound rises to 92 degrees, the male goes to work and keeps it from going higher. Later in the season he must reverse his strategy and work to maintain the temperature in the mound above the declining temperature of the soil. He does so by balancing the heat from his two sources: fermentation and sun. The temperature of the eggs seldom fluctuates more than one degree during the whole season.

The male actually varies his activity from day to day according to the weather, but in general he follows three successive routines as conditions change during the breeding season. In the spring he must reduce the amount of fermentation heat reaching the eggs. He visits the mound before dawn each day and digs rapidly until he nears the egg chamber. After allowing just enough heat to escape he refills the hole with cool sand.

Later in the summer the sun gets very hot, and much heat moves by conduction from the surface of the mound to the egg chamber. Some heat still moves

**SEVEN MEGAPODE SPECIES** are depicted on the opposite page. They are: (1) *Alectura lathami* of eastern Australia; (2) *Megapodius freycinet*, spread throughout the South Pacific area; (3) *Aepypodius arfakianus*, which lives in New Guinea areas above 3,000 feet; (4) *Leipoa ocellata*, the mallee fowl of southern Australia; (5) *Tallegallus jobiensis* of New Guinea; (6) *Eulipoa wallacei* of the Moluccas, and (7) *Megacephalon maleo* of the Celebes Islands.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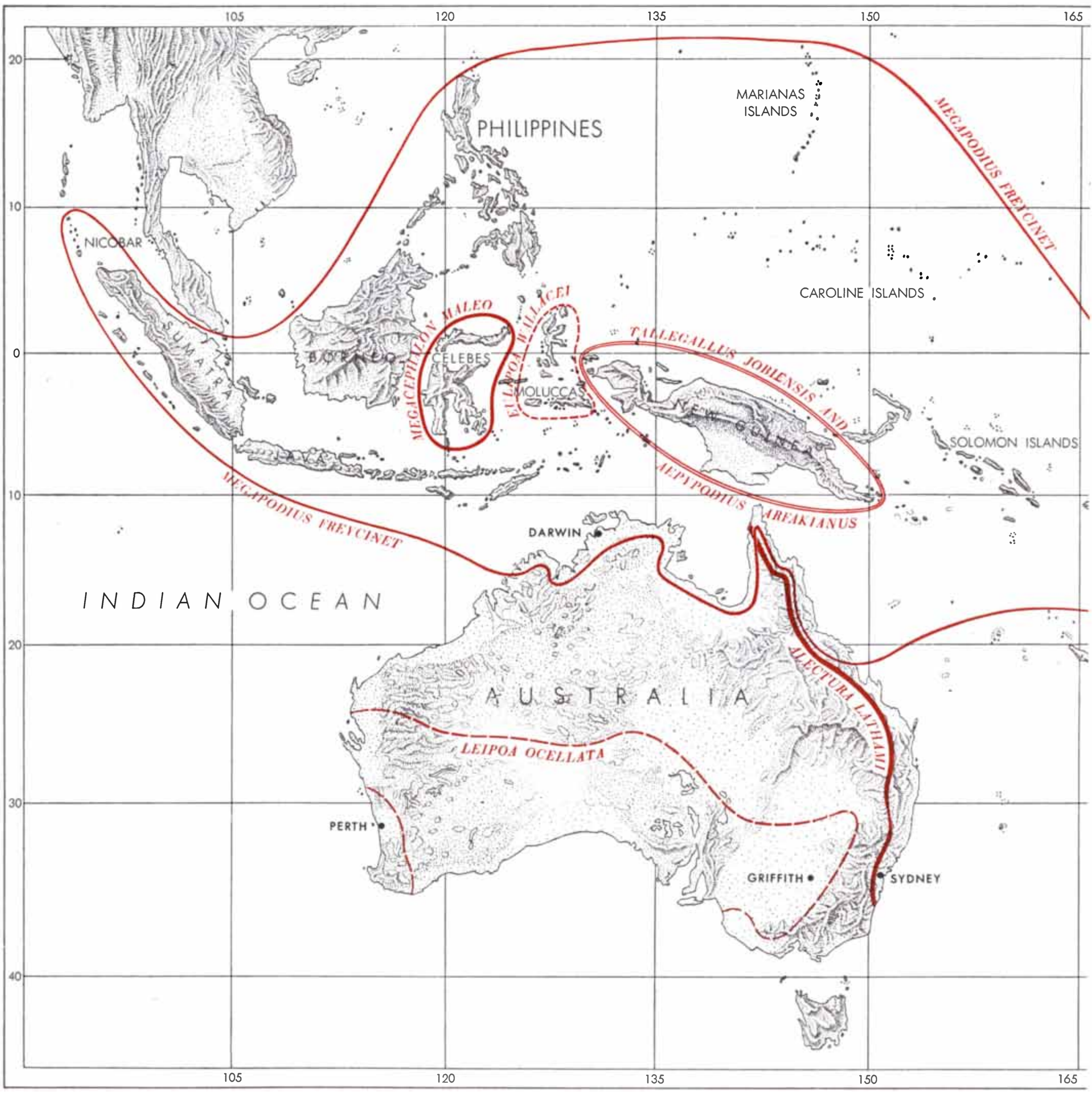
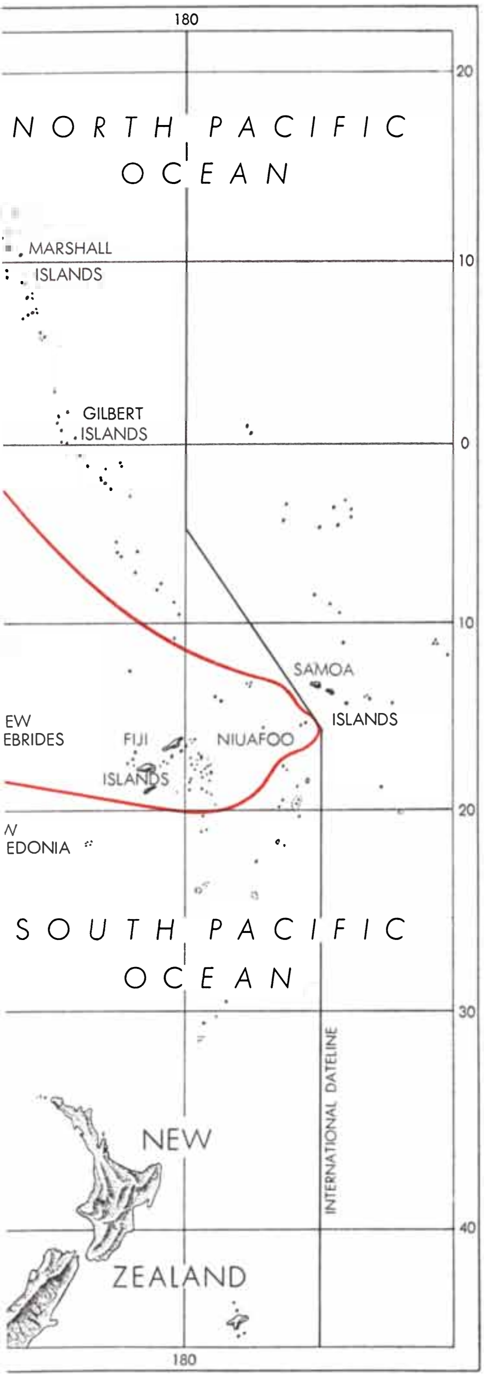
up also from the organic matter, though fermentation is slowing by this time. The eggs thus tend to overheat, and the bird must do something to reduce the temperature. There is little he can do to slow the fermentation rate, but he does lower the rate of solar conduction. Daily he adds more soil to the mound. As the mound grows higher and higher, the eggs for a while are more thoroughly insulated from the sun. After a time, apparently, the bird can build the mound no higher, and a wave of heat begins to go down toward the eggs again. Now the male bird visits the mound each week or so in the early morning, removes all the soil and scatters it in the cool morning air. When it is cool, he collects it and restores it to the mound. This is strenuous work, but effective in destroying the heat wave in the incubator. The temperature in the egg chamber remains steady at 92 degrees.

When autumn comes, the bird is faced with the opposite problem: falling temperature in the mound. The mound no longer generates fermentation heat, and the daily input of solar heat is declining. The bird now changes his activities to meet the challenge. Whereas he had scratched and scattered the sand to cool it in the early morning, often before




**MEGAPODE HABITATS** cover much of the South Pacific area, as shown on this map. *Megapodius freycinet*, the most widespread of all, varies its incubator-building habits with location. *Leipoa ocellata*, the mallee fowl of southern Australia, is the hardest work-dawn, he now comes to the mound each day at about 10 a.m., when the sun is shining on it. He digs almost all the soil away and spreads it out so that the mound resembles a large saucer, with the eggs only a few inches below the surface. This thin layer of soil, exposed to the midday sun, absorbs some heat, but not enough to maintain the temperature throughout the night. The saucer must be refilled with heated sand.




**ing, because it lives in arid country where it is very difficult to get leaves to ferment.**

Throughout the hottest part of the day the bird scratches over the sand he has removed from the mound, exposing all of it to the sun. As each layer gets hot, he returns it to the mound. He times the work so that the incubator is restored with layers of heated sand by 4 p.m., when the sun is getting low.

We thought it possible that all this temperature-control work could be merely part of a fixed behavior pattern evolved by natural selection to suit the seasons. But the birds, while changing their work with the season, make day-to-day adjustments. On an exceptionally hot spring day they do not open a mound; instead they pile more sand on top, presumably to insulate the eggs from the sun. Similarly, during a series of dull days in autumn, the birds build a mound up higher to conserve the interior heat, rather than scooping it out to spread the sand at midday. Our observations suggested that the birds know what is happening inside the mound and vary their activity deliberately. We decided to see whether the birds could detect unusual temperatures in the mound and cope with them.

In one case we sabotaged an actively fermenting mound by removing all the organic material. The internal temperature quickly fell from 92 to 60 degrees. The male bird had been visiting the mound daily to release heat. On his next visit he detected the fall in temperature. Although it was October, he immediately began his autumn type of digging and opened the mound in the heat of the day to warm it. He did this every day, but the spring sun was not strong enough. He only managed to get the mound to 80 degrees by midsummer. In December this male was slaving away warming his mound, while all the others were busy cooling theirs. Obviously he was aware that something was afoot.

In another series of experiments we installed heating elements in a mound so that we could control its temperature. By switching the heat on or off we were able to keep the male on the jump, making him change from working to warm the mound to striving to cool it. He always detected our trickery and was so efficient that our thermostats and our 240-volt generator could barely cope with his efforts. He almost won the struggle to keep the eggs at 92 degrees.

We have no doubt that the broad pattern of activity—the time of day a bird comes to the mound, whether he opens it on a given day, and so on—is determined by the weather. But our observations and experiments show that the work actually done on the mound in the course of a particular day is determined by its internal temperature. This implies that the birds can actually measure temperature. How else could they detect the variations we had caused inside the mound with our heating elements?

When a bird is working, he frequently pauses and buries his bill in the mound, withdrawing it filled with sand, which then trickles out. The work that follows is clearly influenced by the results of this probing. We have little doubt that this is the temperature-measuring action and that the bird's "thermometer" is inside the bill; it may be either the tongue or soft palate.

The temperature-taking is particularly significant during egg-laying. The male mallee fowl opens the mound, a job that takes an hour or more. The female then comes out of the scrub and probes the place in the egg chamber that he has exposed. If she is not satisfied, she goes off and sits under a bush, and the male must refill the hole and dig another one. This may happen three or four times before she is satisfied that her egg will be placed in a suitably warm spot.

The brush turkeys measure the temperature in the same manner, but their temperature-control work is neither so prolonged nor so precise. The male brush turkey is also in charge of the mound, and he savagely drives off the female except when she wishes to lay eggs. After the mound is built, in August, the male daily turns over the fermenting material while clouds of steam rise from it. He thus keeps it well aerated until the first burst of fierce heat from the rapid fermentation has passed. Then he allows the female to lay, and for the rest of the season watches over the mound. When fermentation lags he scratches small amounts of fresh material onto the mound, and when it gets too hot he digs out the center to cool it.

The jungle fowl's task is even simpler. Those that lay in warm sand simply choose a spot with exactly the right temperature. Those that build fermentation mounds do not attempt to control them, as the mallee fowl does, apart from judging the initial composition. They do, however, select the spot for the eggs. As the season advances they scrape additional material onto the mounds, starting new cycles of fermentation in successive layers. It seems probable that for each egg the jungle fowl choose the layer that is in the appropriate state of fermentation. They probe their mounds with their bills, just as the other megapodes do, no doubt to help decide where to place each egg.

All of this egg-laying, egg-burying, mound-building and temperature-control work is directed, of course, to only one end: the production of offspring. But the birds' preoccupation with eggs keeps them so busy that they have no time for their chicks. As a result young megapodes are probably more precocious than the nestlings of any other bird.

The mallee chick hatches three feet beneath the soil; we have watched them do so behind glass. The egg bursts and the chick immediately begins his struggle, moving slowly and spasmodically upward. The journey can take 15 to 20 hours. At last its head comes through; it breathes fresh air and takes stock of the situation. The outlook must be grim. Alone and defenseless, the infant is exposed to any predator that happens along; there is little food and no water.

The chick at last works free of the mound, tumbles down the side, and struggles to the nearest bush for shelter. Here it rests for a couple of hours and then moves purposefully off into the world. It is already able to run swiftly and soon can fly up to a limb to roost in safety. Throughout its early life it remains solitary and flees from anything that moves, including other mallee fowl.

The egg that yields a mallee fowl that grows up in turn to tend its own mound in the bush is one of a small minority. The incubator system is not particularly efficient, discounting the unremitting toil it involves for the bird. Many eggs fail to hatch because of mishaps to the mound, the commonest one being thunderstorms that catch the mound open and drench its interior. Foxes and other predators dig out and eat large numbers of the oversized eggs. The chicks that do hatch often suffocate before they escape. All in all, the megapodes are no more successful in breeding than other ground-nesting birds.

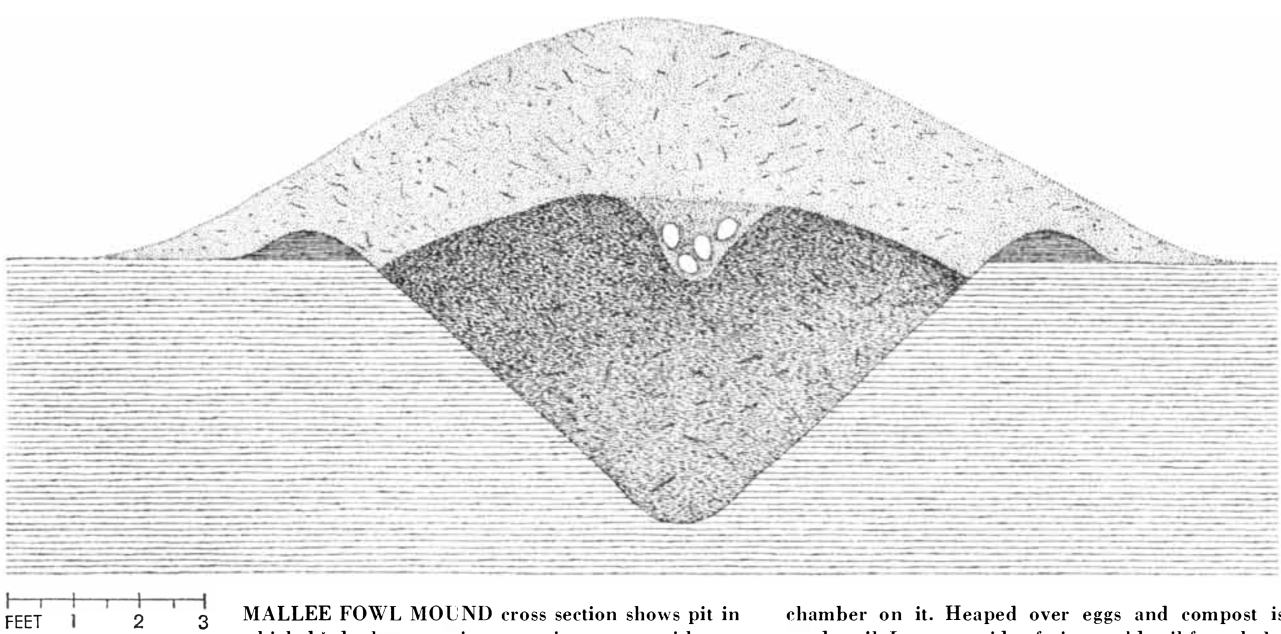
How, then, did they come to possess the mound-building habit? Some observers believe it is a survival from birds' reptilian ancestors. As the prehistoric reptiles began to develop wings and feathers, so the story goes, one group retained the habit of burying its eggs, as do turtles, crocodiles and many reptiles of today. Having watched the labors of the male mallee fowl and the less spectacular but equally precise work of the brush turkeys, however, I refuse to believe that it is a primitive characteristic. Every observation suggests that the incubation process is very highly developed and specialized.

It is more likely that the ancestors of the present-day megapodes were ground-nesting birds that developed the habit of covering their eggs with sand or leaves when leaving the nest, as a protection against predators. Several present-day birds, in fact, do this. Natural selection favored these individuals, perhaps because the covering tended to prevent severe fluctuations in the egg temperature and even, by accidental fermentation, provided some extra heat. The use of fermentation heat could have increased as the birds extended their range from the sunny beaches into the dense, shady forests.

To explain the temperature-control work of the mallee fowl we need only consider Australia's climatic history. Originally the interior of the continent was well watered and supported rain forests. It is probable that the ancestors of the mallee fowl ranged the forests building large leafy mounds like those of the present-day brush turkeys. In the Pleistocene epoch an arid cycle began, and deserts and scrub gradually replaced the forests. The birds then adopted the habit of covering the mound with sand to conserve its moisture and absorb the heat of the sun.

While the course of evolution that selected the mound-building habit may have helped the megapodes to survive, it certainly did not give them an easy way of life. It is strange to see a mallee fowl panting heavily, out in a clearing under the blazing desert sun, grimly digging in a huge pile of sand. When everything else in the bush is still and resting, the mallee fowl works. One early observer wrote: "Its actions are suggestive of melancholy, for it has none of the liveliness that characterizes almost all other birds, but stalks along in a solemn manner as if the dreary nature of its surroundings and its solitary life weighed heavily on its spirits."

Although I have a deep personal interest in these birds, I must admit that is a fair comment. They do seem to have little to live for.




**MALLEE FOWL MOUND** cross section shows pit in which bird places rotting organic matter, with egg chamber on it. Heaped over eggs and compost is sandy soil. Lumps at side of pit are old soil from hole.

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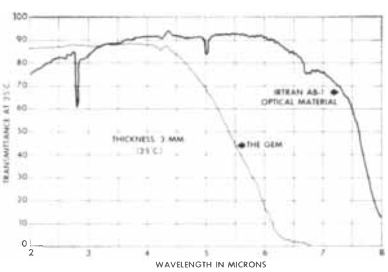


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