A NATURALIST IN HINDUSTÁN

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PREFACE

THIS volume is a record of Natural History relating to animal life. It is a collection of varied observations and experiments made during hours of occasional leisure at a station in the Indian plains. They have been gathered at intervals as opportunity offered, and have all been gleaned from one small patch of jungle in the secluded district of Fyzabad.

My first chapter describes the jungle itself; it is merely a brief and passing notice, but it will serve to introduce the reader to the scene. The next six chapters record my observations on ants. I have selected four conspicuous species and have entered with detail into the economy of their lives. In the one I have discussed the organisation of the commune, the instincts on which its work depends, and the senses which guide it in its daily toil. Two others have supplied material for a comparison in behaviour, have disclosed how the communicating instinct has originated and the line along which it has evolved. In the fourth I have dwelt mainly on the cattle-tending instinct, that most interesting habit possessed by the species of constructing an elaborate variety of shed for the protection of those insects which supply it with juice. I then pass to four chapters of observations on spiders. First I consider those natal chambers which I found constructed on the blades of grass; one chapter describes *their graceful architecture, the other discusses a series of* experiments made on the instincts of the architects themselves. I then come to the manufacture of an exquisite snare; it is in a sense a modification of the circular pattern, but is constructed of an infinitely more delicate texture and shaped in the form of a hemispherical dome. I then pass to a second of still finer workmanship, since the architect not only spreads her apron, but has also the power of twisting her filaments into innumerable spiral springs. The next three chapters deal with the dung-rolling beetles, and chiefly consist of a series of experiments made to elucidate the nature of the instincts employed in the performance of their peculiar work. Lastly I will describe the onset of the rains and the wealth of life that adorns the jungle at the burst of the south-west monsoon.

The few photographs should serve to illustrate the subjects discussed, and the sketches will make clear the appearance of those species whose habits and instincts come under review. I am glad to have this opportunity of thanking Miss Tassart, who has given me so freely of her artistic skill, and Mr Bainbrigge Fletcher, the Imperial Entomologist in India, to whose kindness in entomological matters I owe much.

I trust that my record may interest others who observe and investigate Nature's ways. I have tried to make it plain and simple, and have endeavoured to describe the living story in language intelligible to all. I have had little help from other records. I merely write what Nature shows me, and any omissions and errors are my own. The pages that follow are an earnest effort to interpret Nature's work, an attempt to penetrate her endless problems and disclose the truth which she reveals.

R. W. G. H.

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THE MANJHA

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In the United Provinces of Northern India, close to the sacred city of Oudh, is a rather tame and unattractive tract of country, the district of Fyzabad. In shape it is a quadrangular mass, some eighty miles in length and twenty miles in width, and it lies along the bank of the Gogra river, which limits it on the northern flank.

The district gains some little reputation from containing within its limits the city of Ajodhya or Oudh. For this city, as the birthplace of Rama, has a special sanctity in Hindu thought. It is a city of temples and shrines, a stronghold of Vishnu worship. The river that waters it is as sacred as the Ganges, and thousands bathe in its unsullied stream. Its streets are thronged with mendicants, its temples crowded with Hindu priests, and every year a vast concourse of pilgrims pours through its walls in an endless throng.

Many of them traverse the district of Fyzabad in their journey to this sacred spot. They stream into a city famous before the birth of Christ, and to one where a seat of Government was established under the powerful Moghul rule. They flow through a station which revolted in the Mutiny, and whence the ill-fated garrison endeavoured to escape in boats. They pass beneath the shelter of the still-existing palace where the great Warren Hastings seized the eunuchs and imprisoned the princesses of Oudh.

But I pass from historical associations to consider the natural history of this district. Throughout its whole extent it is an absolutely level plain. The débris worn from the great ranges to the north has been swept down into the substance of this land. The rocks, first ground into fragments by the torrents and the ice, then triturated in the submontane streams, at length drift down as a fine sand to be deposited in this alluvial bed. Slowly this soft silt subsides on the river floor, gradually it expands into a uniform layer, and thus through centuries it spreads itself into an even land. Coursing through it is the same river system to which it owes its origin and growth. The affluents that compose it run lengthways through its soil; for the most part they are roughly parallel, moving from west to east, but all end at last in the mighty Ganges and each adds its tribute to that river's sacred flow.

In such finely broken and well-irrigated soil wide areas of cultivation must necessarily spring up. They are spread abroad in a large expanse of well-tilled, unassuming fields. Here they support rich crops of rice, there a meadowy field of wheat, elsewhere an exuberant harvest of stately Indian corn. Scattered amongst them are the simple villages, and often a cluster of handsome trees. In one place we meet a grove of mango, with its dense inviting shade; in another we come on a luxuriant jungle; in a third we enter a thorny thicket of coarse, neglected scrub.

But it is with the natural history of just one small corner of this district, with a narrow tract of half-arid soil, where the Gogra river courses past the town of Fyzabad, that I wish here exclusively to deal.

The Gogra, though a river of no wide repute, is nevertheless a mighty stream and a powerful affluent of the Ganges. As is customary with rivers in alluvial plains, the Gogra pursues an extremely variable and erratic course. Its whole appearance alters beneath the marked contrasting influence of season. In winter it subsides into a moderate stream about one quarter of a mile in width. Shrunk into these narrow limits, it occupies but a strip of its alluvial bed, which is spread out on either side in wide tracts of moving sand. Thus it remains until the break of the monsoon. It may rise a little in early summer, when the snows and glaciers of the Himalayas melt, and the remote tributaries in the mountains expand with the dissolving ice; but not till the monsoon breaks, and the great deluge bursts over the plains, does the river swell into the full volume of its bed. It then dilates into a copious flood, measuring from bank to bank two or three miles in width. Its surface seethes in a swirling tide, its waters darken with the uprooted silt, and, as it overflows its shelving sides, it pours a deluge for miles around. At every inundation it eats deeper into its banks. Large masses of alluvium are loosened from its concave bends, and, as they fall into the eddying flood, they disappear with a voluminous roar. Thus each summer it hews and digs; it erodes into its enclosing banks, it excavates new channels in unirrigated soils. Each winter it again retracts, but it now presents a changed appearance, for it has swung into some new course. In this way it rises and again subsides. It sweeps alternately from bank to bank and transforms the general outline of the land.

The small corner of the district to which I have referred is the product of this Gogra river through its perturbations over the sandy plain. The river in its oscillating course has left bare a tract of neglected land, in winter coarse and arid, in summer exposed to transient floods, and known to the local inhabitants of this district as the Manjha. I must tell something of its general aspect, as it is the natural history of this small patch of country that I wish essentially to describe.

The manjha is a flat expanse of sand which supports a low jungle of tamarix and scrub. It is an old river bed, long since disused and given back to Nature for her work. Its surface is almost as even as the desert. Save where it is cut through by the channels which have made it, or where some moist depression has sunk into its soil, it is in its geographical features a uniform plain. In one spot, indeed, there is a low and rounded mound; it is the one figure in the landscape that breaks the smooth monotony of green. But this is the mere ruin of a temple long since enshrined in sand and with the roots of some substantial trees now knotted round its crumbling walls. It is the sole elevation on this even manjha. It may be not more than thirty feet in height, yet it stands as a landmark from all around ; and from the summit we can look out over this unbroken jungle stretching like a sea to the farthest limits of our vision, where it fades into the distant sky.

There is very little culture on this broad, precarious tract. Here and there a few fields are tilled, but the crops have to struggle hard for life. At one season they almost perish from the dearth of moisture, at another they are all but enveloped in a swamp. For the most part the manjha is an unculturable jungle, a well-covered but unvalued waste. Such inevitable neglect is an allurement to the naturalist ; for here is a land as Nature made it, first thrown down in a river bed, then exposed as a barren plain, then clothed in wild profusion almost untarnished by the hand of man. It is an attractive stretch of simple jungle for those who pry into animal life. Over large areas it is carpeted with grass, sometimes soft as a verdant lawn, more often of a large and coarser kind which sends its leaves curving above one's head. In swampy areas these grasses grow in dense profusion, where they freely intermingle with the pointed blades of the rush. In other places the manjha supports a jungle of tamarix, *T. gallica*, thick and green, but scarcely rising more than five or six feet in height. There is no forest worthy of the name, though here and there are clusters of acacia, *A. arabica*, often only a thin scattering of trees, but occasionally gathered together so as to form a substantial grove.

In the dry season the manjha presents a somewhat desiccated view. The broad sweeps of sand, uncovered by the shrunken stream, are then nothing but a powdery waste. Here and there a clump of tamarix has fixed itself in this crumbling soil, but for the most part it is utterly barren, shelving on the one side to the river and on the other rising to the jungle within. Nevertheless, in its very barrenness, it has an intrinsic beauty of its own. Its silver granules eddy in the wind; they dance and leap and sparkle in their flow, and change the fickle surface of the sand at every winter breeze. Lines of graceful ripples flow in regular array, and whenever an obstruction meets them they are swept into high, massive dunes. Then the wind strengthens into a storm and these swirling crystals are carried aloft and driven along in a low cloud of granules that moves with a blinding force.

Within these desiccated belts is the more attractive stretch of jungle. Its grass at this season is dry and brown; its higher vegetation scorched and stunted; the leaves are all coated with powdery dust and grey with the driven sand. Even the sky is bleak and dismal; it is filled with the cloud of yellowish dust which the powerful currents of shimmering heat have carried high into the air.

At length, in the end of June, comes the first burst of the monsoon. The preliminary showers cleanse the manjha; they freshen the foliage and purify it of its dusty shroud. Quickly the deluge inundates the earth and the manjha soon assumes a bright and most attractive show. It displays the most alluring landscape of these tropics, a vast expanse of green. Its brown and sandy soil, now swollen with moisture, gives forth a profusion of vegetative life. In a few days it is clothed in a verdant garb, and its semi-arid wastes support a soft carpet of grass. The acacia, in scattered clumps, now stands dark against the distant sky, and the low jungle of tamarix adorns itself in a denser green. In places, as far as the eye can reach, are the smooth, extensive, grassy tracts. They have been transfigured into a luxuriant pasture-land. There the tall elephant grass gathers itself into denser clumps, and spread out between them are the smaller grasses massed into a meadowy lawn. In one place they lie in an even green; in another they are spangled with downy tufts, spikes of the soft plumed seeds that dapple the surface like a fleece of snow.

Many a happy day have I spent wandering through this manjha, exploring its leafy nooks and crannies in my inquiries into insect life. But not alone did I see these humble forms; almost any day some of the nobler creatures might be found. Numbers of wild pig, *Sus cristatus*, used to hide themselves in the denser jungle. Shy and suspicious enough by day, when disturbed they seldom appeared in view, but broke into an excited herd that went crashing through the reeds and cane. At evening they assumed a bolder front; they emerged from their cool seclusion in the scrub, and, after first wallowing in a convenient pool, crossed over from the manjha to invade the gardens, the fruit groves, the cultivated fields, and encroach on the habitations of men. Here, too, in this jungle we meet with the nilgai, *Boselaphus tragocamelus*, a powerful antelope of ungainly build. In herds it used to congregate beneath the shade of the acacia, or, browsing in the lower tamarix, used to raise its curious head above the thicket and gaze with inquiring doubt at the intruder. Here again, usually in the densest parts, we come upon the graceful swamp deer, *Cervus duvauceli*. These handsome creatures, though thinly scattered and almost rare, used to gather into shy gregarious herds and conceal themselves in the most secluded patches, where they were least likely to be disturbed. But at times they moved into the more open jungle, where their branching antlers rose above the herbage in many clustered points.

The leopard, though seldom seen in so dense a cover, yet haunted the long grass. Its kill was sometimes met with in the mornings, or its rough growl was heard on a hot and silent night. Other smaller mammals more often came in view. The porcupines used to dig their dens into the banks; the jackals gave forth their unearthly howls, and the hares, in suitable places, used to go scampering over the fresh grass.

Birds of many kinds made their home upon this manjha. It was the haven of a crowd of skulkers that loved to hide themselves in tangled scrub. There the soothing note of the coucal used to rise from the moistened ground or the softer cooing of the Indian dove came forth from some thorny tree. On points of vantage sat the bright green bee-eaters, whence, in company with the elegant drongos, they made swift and graceful sallies into the air. Sky-larks rose from the grassy tracts, giving utterance to the full volume of their song, while in the drier parts were crested species, with their own sweet but less voluminous notes. There the babblers hung upon the branches, there the martins drilled their neat tunnels in the sand, and there the skilful weaver-birds attached their inimitable nests. Often on a peaceful evening the sweet voice of the cuckoo came floating across the stream, or the shriller cry of the francolin burst forth in a ringing note. It was no very vast assemblage, but it had a special interest of its own.

Perhaps more alluring than the jungle itself were the tributaries that enclosed it. The main Gogra was the chief attraction. It was delightful in the early morning to sit on the sandy bank of this smooth, unrippled stream. It is the dry season. A cloudless sky expands above, a warm sun just peeps above the earth, and a peaceful silence reigns everywhere around. The stream itself is dark and murky, permeated with the silt which even its gentle flow can raise from the river bed. Its crumbling banks merge upward to the plain. At one side we see them steep and broken where the river at its latest flood has eaten into the concave shore; on the other side is the more shelving bank spread out into a plain of sand. In the main course of the river are low shifting islets that raise their dark backs above the turbid stream, and serve as a haven for that host of birds that seek their prey upon the water. In the far distance we can trace the river as it winds round its sinuous bends. Currents of heated air shimmer on the brown crumbling banks; they clothe the water in a dim haze, envelop the earth in a thin translucent veil, raise a cloud of the finest dust high into the clear sky, and so obscure our distant vision in a mingled shroud of heat and sand that water, earth and sky all blend in one common scene.

Animal life in wild profusion gathers near these sandy shores. Crocodiles float like logs upon the water, or emerge on to some secluded islet to bask in the morning sun. The porpoises roll themselves in the turbid flow; the clumsy tortoise thrusts its wary head above the surface, and the fishes break it into rings of ripples everywhere they rise. Tall and stately herons stride majestically along the banks, or a cloud of snow-white egrets rise circling into the dusty sky. Ruddy sheldrakes give forth their clanging notes and flights of duck go crashing into the water. We observe the skilful pratincoles darting and turning after insects in the air, the wonderful scissor-bill shearing the water with its beak, or the graceful terns first gliding, then poising, and then plunging into the stream. All are actively engaged in the struggle for the means to live. And all around is peace and silence. Save for the cry of the water-fowl, the very silence of the ocean seems to rest upon its banks, and not alone on the river itself, but far away too into those endless plains that extend to the farthest limit of our view.

It was even more peaceful on those warm evenings that preceded the onset of the rains. The sun, then shorn of its fiercest light, hangs low on the cloudless sky, and its pale rays now gleam like silver through an atmosphere of heated dust. Before us is the smooth stream, as tranquil as the dusty sky, and broken only by those ripples where the fish ascend, or the birds curve down to lift the insects off the water. The moist and heated air rises from the river bed, and, without the faintest sign of motion, hangs like a heavy pall. Perspiring in the damp heat, we look lazily on the scene of life. We hear the faint cry of the terns as they sail slowly along the stream; we watch the flocks of hirundines as they gather up the little insects that rise into the moist air; we see the graceful bee-eaters and drongos come sailing out from the fringe of trees to take their toll of life upon the wing. We gain some impression of the vast profusion of Indian bird life as it wends its way to roost. Species of many kinds pass along the river bed on their journey to the distant trees. The shrieks of the green parrots intermingle with the chatter of the mynas as they both descend to their evening drink in company with the vultures and the kites. The weaver-birds then join them in enormous flocks, and wagtails of many kinds alight for a little while, then move off in a slow and undulating flight. As the sun sinks low in the murky sky and hides itself in the veil of dust, then the noisy birds pass quietly away to roost. We see no setting of the sun; the orb just steals into the dusty shroud and pales away from view. There is again a silence in the air, and a feeling of relief follows on the fading day. The bats come fluttering across the sky; the soft-winged nightjars glide down upon the stream; and the unearthly howling of the jackals rings out to proclaim the advent of the night.

The sun's last rays have faded out of view whilst we still maintain our vigil on the bank. Through the gloom we see the dense herd of cattle steal down to water at the river's edge. We see the wild boar come hurrying from the jungle to splash and wallow in its muddy lair, or we watch the more silent nilgai drink before moving off to feed. We hear the varied jungle sounds that break the stillness of the night. From afar comes the cry of the swamp deer, a loud and broken whine, and the rough snarl of the leopard seems to answer it. From some thick tree comes the chatter of the owlet uttering its noisy shrieks, or close by we hear the chuckle of the nightjar as it sails swiftly on the wing. At the water's edge is the host of frogs giving vent to their trembling chorus in one continuous croak. From the clumps of trees breaks the wild shriek of the brain-fever bird, or from over some swampy patch comes the "pity-to-do-it, pity-to-do-it," the bleating, plaintive cry of the lapwing disturbed by some passing game. And thus throughout the long dark hours we hear the sounds of jungle life.

Such is a very brief description of this wild, neglected manjha. It is a fitting prelude to the detailed study of its life. I now pass from its general aspect to consider those features in its natural history which I have had the opportunity to observe.

CHAPTER II

THE INDIAN BLACK ANT—GENERAL HABITS

Distribution—Types of Workers—Characters of Ant—Location of Formicary—Collection of Food—Ant-Cattle—Attention to Cattle—Attack on Cattle—Types of Cattle—Relation between Ants and Cattle—Ants appropriate Sheds—Distension with Juice—Transfer of Food—Enemies—Ejection of Poison—Treatment of Dead and Wounded—Cannibalism—Behaviour in Storm—Escape from Floods—Recreation—Sexual Forms

THE large Indian Black Ant, the *Camponotus compressus*, must be one of the most familiar insects of these plains. We observe it wherever we go: we see it on the roadsides, in the foliage, on the trunks of the trees; it even drives its tunnels into the walls of our houses, and invades the interior, attracted by the shade, or by some welcome patch of moisture on the ground. Nor is it alone conspicuous in its numbers; it is also widespread in its geographical range. It is dispersed over the whole surface of the peninsula, and has forced its way up the Himalayan ranges to a height of 7000 or 8000 feet.

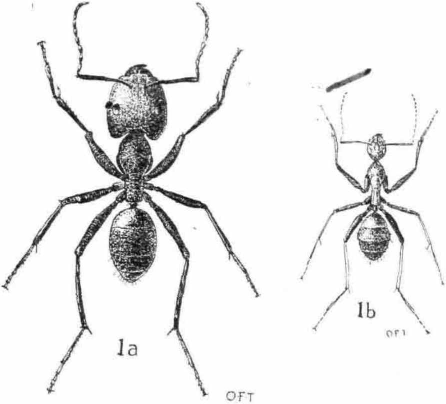
I will describe its habits in a little detail—not that they possess any feature of very striking peculiarity, but because they will provide us with a fair illustration of the customary activities of ant life.

On our first acqaintance with this community of ants we will observe that there are different types of individuals collected together in the same nest. The most conspicuous are the workers-major, the soldiers and defenders of the home. They are the huge, black, savage-looking forms that move sluggishly around the aperture of the nest. The second type are the workers-minor, which are the individuals of a moderate build. They are many times more numerous than the soldiers; they are also of a more active and industrious disposition, and we are sure to see them busily engaged in bringing provender into the nest. They vary greatly in size: some are so large as almost to approach the bulk of a soldier, others so small as almost to constitute a special miniature type. In addition to the workers the community contains its sexual forms. If fortunate, we may witness their emergence from the nest; we will then distinguish the robust females from the smaller and more slender males.

A worker-major of this species is a dense black, robust ant rather more than half-an-inch in length (see Plate II.). Its head is square and massive and armed with powerful jaws. Behind it is the thorax, which is raised above into an even arch and has its sides laterally compressed. It graduates posteriorly into a narrow waist, and to this is fixed the large abdomen clothed in a few scattered hairs. The worker-minor is distinctly smaller. In length it is only half that of the soldier, and in relative size and bulk it is even proportionately less. But it is in the shape of the head that the most apparent difference is seen. That of the soldier is exceptionally large; it is a quadrangular mass produced into a pair of lobes behind. The head of the minor is of the ordinary structure, and of an elongated oval shape. I will mention only one other point of contrast—connected, I suppose, with their character and their work: the jaws of the soldier are armed with seven teeth; those of the smaller worker with only five. The sexual forms have special peculiarities of their own. The female is conspicuous by her ponderous abdomen and her distinctly larger size; the peculiar feature about the male lies in his insignificant head. Of course, both are immediately distinguishable from the workers by the possession of transparent wings.

The most favoured site for the selection of the formicary is at the base of a large tree. There the ants dig themselves into the soil, and heap the ejected débris into a mound about the nest. At the summit of the pile is the aperture, which, if well chosen, leads into a natural fissure in the trunk. Sometimes they will excavate on the open ground a considerable distance away from a tree; but this is unusual, and, moreover, is a disadvantage to the ants, since what they require is a site whence, as soon as they emerge from the aperture, they can immediately ascend to seek out their provender amidst the leaves. Often they will establish their formicary in some part of the tree itself. They do not, like certain other ants, construct a special arboreal edifice of their own; but they will often take advantage of a natural crevice, or will appropriate a tunnel or cylindrical boring dug by some insect into the tree. Where the soil accumulates in a fork between the branches, or collects in a dark decaying hollow in the trunk, there these ants will sink their galleries and establish themselves in the crumbling mould. At times they will locate themselves in a fractured branch where the decomposing timber has mouldered to a grit, or they will dig themselves into the solid substance of the wood, and break away the compact tissue with their jaws.

They often possess the peculiar habit of constructing their formicary in a brick wall. They tunnel into the mortar that binds the masonry, and laboriously tear the fragments away. This seems a strange and profitless performance since the ants desire the vicinity of vegetation, and here they find themselves isolated on a wall. I think that the reason for the selection is this: it must be an error of instinct on the part of the original foundress of the nest. When the impregnated female first wanders about in search of a place to establish a home, I have little doubt that her instinct guides her to select some spot near a vertical mass. Such a structure will almost always be the trunk of a tree, and therefore we find the nest so placed, since it is the instinct of the female to establish it there. But away from the natural woods and jungles there happen to be other structures besides trees. In civilised surroundings there are the innumerable buildings and walls. But the female has been given natural



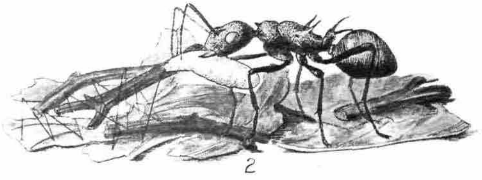


PLATE II.—(1) THE INDIAN BLACK ANT (*Camponotus compressus.*)
(*a*) Soldier. (*b*) Smaller Worker.
(2) BYRE-BUILDING ANT (*Polyrachis simplex*) SPINNING WITH LAVA.

instincts, so simple indeed that she does not concern herself with the physical nature of the mass. A vertical structure of any kind is sufficient to satisfy her instinctive needs. To her a vertical mass will give the natural impression of a tree. She will not differentiate further: she will find a crevice and deposit her eggs. It is ill fortune if she happens to strike a wall, and her progeny will suffer because her instinct errs.

One of the most interesting features in the economy of this ant is the manner in which it obtains its food. It lives mainly on the excretions of other insects, and thus belongs to that class of ant which depends on cattle to supply its needs. But, in addition to the fluid thus obtained, the *Camponotus* has other tastes. It will gather up the remains of every kind of insect and will carry the dead bodies back to the nest. I have notes of their bringing bugs, moths, diptera and spiders down the branches and trunks of the tree: I have seen them conveying caterpillars through the leaves, and dragging worms over the moist ground. A juicy grasshopper is a most acceptable morsel, and they will even fall on their injured comrades, and either cut them in pieces or convey them entire into the nest. But they do not confine their attentions to the carcass, they also capture insects and larvæ alive. I have seen them pouncing on the luscious termites, or carrying struggling flies down the bark of the tree, or shearing a wriggling caterpillar in pieces by hewing at it with their massive jaws. There is very little of the instinct of combination in their actions. They do not join in concentrated effort, and, as a single body, fall on a resisting prey. Three or four may gather round a large insect and drag it together to the nest, but there is none of the swarming legion such as pours out of the *Phidole's* gates. Nor indeed is there any necessity for it. Each *Camponotus* soldier is a giant in itself; it is only the largest insects which it could not overcome alone. If the prey is difficult of transport then a soldier may divide it into more suitable parts. It grinds and chews it with its powerful jaws; it eats first at one side, then at the other, and in this way it quickly decapitates an insect or severs a caterpillar in half. Then, supporting the morsel with its fore legs, it clenches it firmly in its mandibles and transports it piecemeal away.

But in addition to animal matter they are also eager for any vegetable fluid which opportunity happens to provide. They will themselves cut into the tender shoots or sip up the nectar from the flowers. They will assemble round a breach in the surface of the bark or will follow up the excavations of some other insect to secure the sap which oozes through the wound. Indeed, I have occasionally seen them, like leaf-cutting ants, carrying down pieces of the young, green leaves in order to store them away in their nest. Another very favoured substance is the juicy droppings of birds. They gather the pellets on the branches and add them to their varied store. Except for the excretions of their special cattle, I think that the greater part of their food must be supplied by the excretions of birds.

But it is to their care and attention to the cattle that they owe the chief portion of their food. They associate closely with different kinds, each of which supplies its special limpid juice. The most important are the scale insects, or *Coccidæ*, of which the giant *Monophlebus* is the chief. This coccid, at least in its general appearance, has scarcely a feature worthy of note. It looks like a structureless lump of matter, is white in colour, oval and flat in shape, and about half-an-inch in length. Both extremities are bluntly pointed, and its body is uniformly clothed throughout in a coating of powdery scales. On its back is a minute pore, just in front of its hinder end, and from this exudes the juice which the ants so eagerly devour. The coccid, of course, belongs to the Order of Bugs; and it is only the inert females which render up their fluid to the ants.

A group of workers (see Plate II.), often four or five in number, will congregate round one bug. The insect is fixed motionless to the plant; its suctorial beak is thrust into the stem, and it is drawing out the sap. It must imbibe a considerable amount of the fluid since, at frequent intervals, its organs distend, and it feels the desire to excrete. When that moment arrives then the juice begins to appear at the pore, where it swells into a limpid drop. The surrounding workers are waiting for this. For some minutes they have been stroking her with their hair-like antennæ, and treating her with apparent regard. Now they immediately fall on the excretion and rapidly sip it away.

The ants in one way show a sign of judgment in their attentions to this fountain of supply. They seem to appreciate the fact that only when the bug is feeding is it in a position to excrete. For often the coccids crawl lazily about, or ascend and descend the trunk of the tree; but at those times the ants will never attend them; they seem to know that the bugs have nothing to excrete, and therefore they pass them by unconcernedly.

Thus do they appear to show some judgment; but another little incident in their attentions to the bugs will indicate how limited it is. I have already said that the two ends of the coccid are much alike, and that the juice escapes from a little pore just in front of the tail. The ant knows well that it is from the pointed end of the coccid that the precious fluid flows. Watch its mode of attention to the bug. The worker strokes her pointed end; it stands with its head just over the pore waiting patiently for the drop to exude. It does not titillate her broad flanks; it appears to realise the fact that it can obtain nothing there. But though the ant watches the extremity of the bug, yet it seems unable to differentiate the ends, and confuses the head with the tail. Both in shape are much alike, but the little pore at the posterior end is evident to the naked eye. I greatly doubt if the worker ant is able to detect this pore, although it is the source of its valuable supply. I have often seen a group of them gathered round a bug with one of them eagerly stroking the head and another stroking the tail. They neglected the flanks, where they could obtain nothing, but the one at the head was as earnest in its efforts as was its more fortunate companion at the tail. Moreover, it held its mouth in the exact position, waiting in vain for the fluid to escape. This did not indicate a fine sense of discrimination ; indeed it seemed strange that these ants, which pay such continuous attention to their cattle, have not learnt to appreciate with a better judgment the exact point from where their fluid exudes.

These living fountains of valuable juice suffer, of course, no injury from the ants. Their excretions provide a continuous supply infinitely more abundant than would their bodies if they were carried in as food. Nevertheless there are certain occasions when even the cattle are attacked. The area round the nest is sacred ground ; it is under the protection of the stalwart soldiers, and any creature that happens to intrude is looked on as a dangerous foe. Even the coccid then becomes an enemy ; it is set upon by the watchful guardians of the gate and is torn in the jaws of those hosts which at other times it abundantly supplies. The spectacle provides some points of interest. It shows us not only the manner of attack, but also the means by which the coccids secure protection from their foes.

It is easy to originate a contest ; so let us see what actually occurs. I pick a coccid from the branches of the tree. It lies absolutely passive ; only for the faint rings around its body, and its tiny legs pressed closely underneath, it might be a lifeless, inorganic thing. It is an insect with a delicate integument, and the surface of its body is tense and firm, owing to the pressure of the juices within. I prick the distended skin with a needle. Through the puncture oozes forth a drop of the enclosed juice. It is a bright yellow and somewhat viscid fluid of about the consistency of cream. Its odour is aromatic and slightly pungent in character, but it has, so far as I could detect, no distinctly unpleasant taste. I repeat the perforation in different parts of the body. Everywhere the creamy juice bursts forth, and soon the whole

PLATE III.—BLACK ANT ATTENDING ON *Monophlebus* BUG.
(*Photographed from specimens.*)

surface of the insect is smeared in an ochreous slime. It has certainly become a distasteful and unattractive morsel for any insectivorous creature to devour.

I now place a coccid near the aperture of a *Camponotus* nest. A soldier comes forth, rushes at it with open jaws, and seizes it by the narrow flank. It immediately perforates the delicate skin, and out bursts the yellow juice direct into the attacker's mouth. Its effect is clearly unpleasant to the ant, yet so strong is the instinctive force of battle that the soldier refuses to relax its hold. More juice wells up through the penetrating wound; the jaws of the ant become clogged; the delicate mouth-parts get glued into the sticky mass, and the black, formidable head is soon yellow with tenacious slime. Sometimes the soldier will now withdraw and release the wounded bug. More often the force of battle moves it, and it drags its victim along the trunk of the tree. But soon the pungency seems to take effect. The ant walks with a more uncertain gait: it staggers; it moves more aimlessly; it seems to have some difficulty in keeping its foothold; it is like an ant which might have been given a dose of some narcotic drug. Nevertheless, in spite of its stupefaction and discomfort, it continues to cling tenaciously to its prey. In the end it may have to release its hold, or lodge its victim in some fissure on the bark, or it may keep a grip on the slimy morsel and carry it temporarily into the nest.

The little contest thus makes it clear that the coccid is filled with a nauseous juice. To this it owes its freedom from attack and its power to remain without any protection fully exposed to view. The ants will not assail them in their usual haunts, but only when one becomes an intruder and approaches the gate of the nest. No doubt the ants instinctively know that if they attempt to seize the coccid they will meet with an uncomfortable fate. Thus they preserve them for the better purpose of using their excretions for food. Strange it is that insects which give forth this limpid juice in a clear and intermittent stream should have their whole bodies so tightly distended with a thick and stupefying slime.

Other species of this same family also receive attention from the ants. They will gather in a crowd round those tiny scale insects which lie like coins along a blade of grass. With their antennæ they stroke the oval discs and receive the precious liquid in exchange. In the same way they attend the *Membracidæ*, another family of the bugs. They associate with the young and the full-grown forms, and receive nourishment from both. Here it is chiefly on the tamarix and the acacia that they find the richest supply, and I have sometimes seen them in so dense a mass as to blacken the whole stem.

The *Fulgoridæ* is another family which renders up its substance to the ants. I have watched them waiting on *Ricania zebra*, a species of fulgorid with dark brown wings banded with light stripes. The insect used to feed on the jungle grass, and on superficial appearance looked very like a moth. It used to thrust its head into the green blade and turn up its wings behind. Then the *Camponotus* advanced into the usual position; it pushed its head in under the shelter of the wings and waited patiently for the drop to appear.

They will attend also on the *Lecanium hesperidum*, a delicate, flattened, scale-like bug, so common on the mango-trees. They usually find it near the midrib of the leaf, where it rests merely as a passive flake and at intervals ejects its fluid to the ants. Both the black ant and the red ant seek after this bug, and in a grove I have seen the two species each appropriate its own tree. The red ant, being the fiercer and existing in greater numbers, in all probability more securely holds its own. It could easily eject a company of the blacks if they attempted to invade its tree. The red ant takes a greater care of its cattle, and more skilfully employs itself in protecting the herd; for it confines them in specially constructed chambers, while the black ant retains the primitive method of tending them on the open leaf.

On the same trees they will find the snow-white *Icerya*, an insect enveloped in a mealy coat which surrounds it in a fringe of points. This kind they likewise meet with on the leaves, though more often they come on a conspicuous herd assembled round the base of a stem.

They also receive fluid from the *Aschistocoris brevicornis*, which feeds on many kinds of leaves. It is a slender bug of a grass-green colour, belonging to the Coreid group. Its wings and antennæ are well developed, and it gives forth an obnoxious smell. The ant stands quietly near the point of its abdomen, gently strokes it on either side, and patiently waits for the nectar to appear. The bug excretes only at long intervals, but when it does so it exudes a substantial drop which repays the long delay.

In the same determined manner they will wait on the *Cercopidæ*, which is still another family of bugs. I have seen the workers in close attendance on *Clavia puncta*, a common species of this group. But the point of interest in the relationship was this. On no occasion was I able to observe that the *Clavia* yielded any secretion to the ant. The supply was obtained in this instance by a much more primitive plan. The *Clavia* was resting stationary on the tree. Its stout beak was thrust into the stem and it was sucking in the sap. The ant stood immediately behind with its head closely applied to the spot where the fluid might be thought to escape. It was very patient, very persistent; it stroked first one wing, then the other with its antennæ, but the *Clavia* showed no desire to respond. I waited for an hour, expecting every minute to see the wings open and a drop of the usual clear liquid to exude. But no fluid appeared, so I felt sure that the ant gained nothing from the bug. I then touched the *Clavia*. It advanced a little, and immediately a drop of liquid oozed up from the perforation in the stem. The ant then came forward; it pressed its jaws down into the drop and sipped up the vegetable juice.

This, so far as I know, is the true relationship between the ants and this family of bugs. They attend them only for the perforations in the plant and thus feed on the sap direct. But it seems that the ants do not realise this. I think that they regard the *Clavia* itself as the actual source of the liquid supply. They treat it with every care; they take their stand at the accustomed points; they stroke it with the same eagerness and attention which they give to the other living fountains of supply. The ants no doubt erroneously imagine that the drop received has issued from the bug, though it is only a bead of superfluous sap which has happened to lie rejected on the stem.

The *Camponotus* is known to attend on certain caterpillars which excrete an agreeable juice. In this district I only once observed the occurrence, when, strange to say, the attraction was the pupa rather than the larval form. The pupa belonged to the Lycænid group. It had fixed itself to the trunk of a large tree, where, owing to its brown and silvery coloration, it blended most closely with the bark. The workers stroked it in the usual way, first at one end, then at the other end, sometimes standing fully astride of it and titillating either head or tail. Of course the pupa could give no excretion, but the ant seemed to find fluid at its anterior extremity, which was its point of attachment to the bark. At intervals the worker brought its head to this point, where it evidently found something to satisfy its thirst. But it obviously could gain little from a dormant pupa, and thus the attention continued for only a little while, after which it abandoned the supply.

It is, therefore, from the vegetable sap of plants that these ants derive their most important food. This may at times be obtained direct, as when the ants sip the secretion from the flowers or themselves cut into the tissues of the plant. More often they need some adventitious aid in order to bring the sap within their reach. The simplest is to attend on some boring insect and secure the juice which oozes from the wound. A rather more advanced plan is to wait on a bug like the *Clavia* and watch for the drop which wells to the surface as soon as it withdraws its spear. But infinitely the largest amount of fluid is obtained by indirect means. A coccid, a fulgorid, or a membracid is discovered, and employed as an intermediate host. The sap is first taken into the substance of the host and elaborated in some special way. The bug withdraws the nourishment from it and discharges what remains as waste. And the ants wait for this fluid excretion, which is their main source of food. Thus the bugs are a kind of living fountain intermediate between the vegetable tissues and the ants.

There are other kinds of ants which tend on cattle and build for them special byres. In this way they give something in exchange; they gain the sweet excretion for themselves, and in return they supply the cattle with a shed. But the *Camponotus*, so far as I have seen, has not reached so advanced a stage, and never constructs a byre. It tends its cattle in the open, on the juicy stems and leaves. Yet occasionally I have found it in the interior of a shed, usually of the type constructed by the *Polyrhachis* on the tamarix and other shrubs. It seemed at first to be the work of the *Camponotus*, but such it could scarcely have been. The ant must have seized on another's handiwork and appropriated the chamber for itself. It had either taken over a deserted byre for which the *Polyrhachis* had no further use, or else it had engaged in battle with the architects and driven the rightful owners away.

It is the smaller workers which are the most diligent in collecting food. The soldiers will, too, attend on the cattle, but not with the same patience and care. If the number of the cattle happens to be large, then the bellies of the workers get greatly distended owing to the quantity of juice they imbibe. We watch them first emerge from the nest. They are black, uniformly coloured and their abdomens are of normal size. They immediately ascend into the foliage, wait upon their cattle and gorge themselves with the liquid food. Later we observe them returning with the store. Their bellies are now swollen; they are globular in shape, and the hard black rings are stretched apart so as to show the clear tissues between. This gives the abdomen a banded appearance ; it looks like a black and swollen mass encircled in translucent rings. Thus, when the ants have abundant supplies, we can distinguish the workers returning with fluid from those emerging for a further store. In their distended condition the abdomen becomes an unwieldy load. It tends, when the ant is descending the tree, to hang down over its back. Consequently progress may at times be more difficult ; the weight may tend to overbalance the ant, and it sometimes topples down to the ground.

It is seldom that the great soldiers get into this distended state. They are not living vessels like the smaller workers. Though they will sip up the fluid, yet they seem to imbibe it only for themselves, and they carry little back to the nest. Nevertheless I once observed a soldier with its belly so distended with juice that the intervals between the rings were clearly seen. It was standing near the aperture of the nest and was engaged in the interesting occupation of rendering to its fellows a share of the food. This was an excellent opportunity to observe the details of the act. The soldier was so sluggish and so large that the method could be clearly seen. It remained in a stationary attitude and received close attention from the other ants. They took particular notice of it, and seemed to realise the fact that its abdomen was a liquid store. A worker would proceed to its head and commence to stroke it in the usual way. It touched it gently with its antennæ as though the soldier was one of the bugs which it was trying to induce to excrete. Then, failing in this, it passed to persuasions of another kind. It grasped the soldier's head in its mandibles and rubbed the hard integument with the rough edges of its jaws. Then it would direct its attention to the antennæ and take them carefully into its mouth. The soldier appeared to enjoy the behaviour, or at least to show signs of satisfaction at the caress. It stood absolutely motionless, its legs wide apart, its head bowed, its antennæ neatly turned down so as to be out of harm's way. It looked like the attitude of an insect which derived a feeling of pleasure from the act. After a little while the blandishments had the desired effect and the soldier began to disgorge. Both ants then opened wide their jaws; they brought their mouths into apposition, so that the mandibles of one lay within the mandibles of the other. The delicate mouth-parts thus came into contact and the drop of fluid was transferred.

This is the manner in which certain ants supply with food the others in the nest. I have described the method in the case of a soldier, though it is far more usual for the smaller workers to act as carriers for the larger forms. Moreover, there are certain members of the community engaged in duties within the nest, and there are the males and females which scarcely ever appear outside. These must likewise be supplied with nourishment, and such is the way it is obtained.

Ants as a rule have not many enemies, and the *Camponotus* is not often attacked. Birds will sometimes devour them for food, but only, I think, when hunger is severe. For we would see them attacked on every side if they happened to be an acceptable prey. Crows and babblers will sometimes take them, mynas will seize them on the ground near the nest, but their most dangerous enemies are the powerful woodpeckers, which capture them as they ascend the trunks of the trees. But the sexual forms are more tasty morsels, and they often fall victims to chats and flycatchers when they issue on their nuptial flight. They also suffer destruction from spiders. The kinds that hunt on the bark of the trees will sometimes seize one by a sudden spring; and I will elsewhere tell of the mimicking forms of which these ants are the essential food.

There is another subtle and dangerous enemy which captures the workers by stealth. This is the book-scorpion, an inhabitant of the bark, and in appearance a tiny miniature of the larger and more venomous form. It lies in ambush in some suitable fissure, waiting for the opportunity to strike. Its flat body is concealed in the interior of the cleft ; the tips of the claws at the ends of its pincers are all that project outside. These are the points of its most formidable weapons, and while it rests secure from danger in the crevice the *Camponotus*, in its wanderings, walks thoughtlessly into the vice.

When we consider the immense numbers of these ants, their large size, their conspicuous appearance, and the fact that they crawl fully exposed on almost every Indian tree, we must conclude that they have some special device to protect them from insectivorous foes. Otherwise we would see their enemies snapping them off the trees or hunting the wanderers over the ground. They are, therefore, rendered immune by some special means, and the method is not difficult to find. I meet with a nest in the usual place. The soldiers are crawling about, and I take between my fingers the largest on the tree. It immediately turns down its abdomen and strikes at my finger as though it were about to sting. But it has no weapon to fulfil this purpose. It does not penetrate the skin ; it merely ejects on to the surface a drop of watery juice. This, I suppose, is formic acid. It is acutely sharp and bitter to the taste, and has a penetrating pungent smell. It gives off powerful acid fumes which immediately change the colour of litmus when held some distance away. An excretion of this kind must be an excellent protection ; there are surely few predaceous creatures which would care to take such a morsel in their mouths.

Although the *Camponotus* injects no poison, yet it is able by indirect means to thrust it into the tissues of its foe. I again take a fierce soldier from the tree. It instantly makes an attack. But not only does it shoot forth its poison, it also fights stubbornly with its jaws. It soon severs the skin, and since it curls its abdomen right under the chest, some of the poison makes its way into the wound. The acid stings and burns, and thus the ant has gained its end by a rather indirect way. I have no doubt that under natural conditions this simple combination of poison and jaws must often be of considerable value to the worker in its efforts to overcome a foe.

This excretion of acid has both a defensive and an offensive use. It renders its host immune from attack, and when necessity offers, it can be driven into a stubborn prey. It is possessed by the workers of all sizes, though the soldiers are the most venomously equipped. I could find no trace of it in the sexual forms. They certainly emitted no fluid when touched, and though a pungent smell arose from their bodies, yet this, I think, was but the natural odour of the nest. Nor indeed would the venom be of much value to them. They do not join in offensive action, and, since they live in the interior of the nest, they are not subject to an enemy's attack. The females are little more than egg-producing mechanisms; the males just flutter for a little while in order to start the wheel of life again. They have not been given any poison, since it is not needed for their special ends.

I will now mention some particular habits in which these workers may be seen engaged. There are some ants which will fall on their injured comrades; there are others which will carefully dispose of them when dead. The *Myrmecocystus*, for example, will attack its wounded; the *Messor* will carry away a corpse and drop it a long distance away. Let us observe the manner in which the *Camponotus* behaves when in the presence of its wounded and dead. I killed and injured some of the workers and placed them in the vicinity of the nest. The soldiers showed none of the anger of the *Myrmecocystus*; there was no fury, no excitement; they just calmly examined the wounded and dead. Soon they began to dispose of both. Some they took up entire and conveyed immediately into the nest; others they severed across the narrow waist, and, rejecting the hard head and thorax, they carried away the succulent abdomen for food. Thus they are cannibals. They differ from *Messor* in not having a cemetery for their dead; they differ from *Myrmecocystus* in showing no sign of anger or excitement when confronted with the wounded of their own nest.

Their natural instinct to devour their fellows will explain a certain incident in their lives. We will often notice that on a main thoroughfare the ants have spread themselves all over the road. This at first seems strange, since the habit of the ants is to search the foliage, while here they send their parties through the dust. The cause of their profusion on the thoroughfare is this. There are splendid trees at either side, and beneath them are situated the nests. To begin with, some of the workers were killed when they wandered out on the main road. They were either trampled on by human feet, or were crushed beneath the wheels of carts. Other workers soon found them out. They came themselves or dispatched their parties to gather in the dead and dying as spoil. But in so doing they entered the danger-zone and met with a similar fate. Still others advanced with the same object; a vicious circle was soon established, and the road was crowded with many workers endeavouring to retrieve the dead. Thus is cannibalism the cause of their destruction, and their efforts to secure their comrades for food may lead to the depopulation of their nests.

Another habit to which I will refer is the manner in which these ants behave when they are caught in a sudden wind. I allude to the monsoon season, when heavy squalls break over this plain. The ants have established their formicary on the ground and the workers are scattered all over the tree. The foliage is profuse and dense, yet the ants have spread themselves through all its parts; they are exploring every leaf and stem in search of the valued cattle and their juice. Suddenly comes a rough squall and a burst of blinding rain. The foliage trembles, the branches shake, and the ants no longer feel themselves secure. They desert their cattle; they leave their places on the twigs and leaves; they converge on to the larger branches, and make their way down the main trunk of the tree. We see them descend in a continuous stream; it is a rapidly increasing multitude that is pouring down into the aperture of the nest. As the wind strengthens in its force so also does the volume of the stream. It reminds one of the army of harvesting ants that at evening enter the gate of the formicary when work has ceased for the day.

At last all have disappeared. The gale continues, but the workers are safe from every danger; they are hidden away in the galleries of their nest. By their haste they have gained security; otherwise, with their distended bellies, they would surely be shaken from the tree. The gale has passed. At the very first streak of sunshine we see them again emerge from the nest. They quickly ascend in a long black line and scatter themselves widely all over the tree.

In this season of heavy rain the ground is a vast flood. All ants must then suffer great destruction, and certain kinds toil in special ways in order to keep the moisture from their broods. On the manjha the *Polyrhachis* was a common form, and, as soon as the first inundation appeared, it quickly abandoned its tunnels in the earth and constructed an arboreal nest. The *Camponotus* is not quite so advanced as this. It does not construct a special nest in the foliage, though, when occasion demands, it will leave its galleries to ascend into a temporary shelter on the trees. The move is a migration in order to escape the moisture, and the ants carry with them their goods and offspring, which they lodge in the drier quarters elsewhere. Sometimes in the evenings after heavy showers I used to chance upon migrations of this kind. I will describe one instance which is more or less typical of all. The ground was sodden with the recent flood. No doubt the moisture had invaded the formicary and the ants were compelled to leave. A stream of workers was hurrying up the tree; their ordinary duties had come to an end, and all were now engaged in evacuating the flooded home. Many of them were laden with goods or offspring. Some were carrying eggs, others larvæ; others had hold of large yellowish pupæ enclosed in loose capsules of silk. A few conveyed termites and miscellaneous insects, so it seems that they transport not only their offspring, but also their more valuable stores. The males and females had also to be carried; each was gripped round the neck by a worker and borne onward in the stream. In this way they rapidly transported their goods, and, as soon as they deposited their burdens, they returned for another load. Workers of all sizes were evident in the stream, but the soldiers appeared to carry nothing with them, and no doubt it is on the smaller workers that the whole labour of migration falls. When the *Phidole* migrates I have seen the minors carry the soldiers, but the *Camponotus* is not so degenerate as this.

Thus do these ants evacuate their nest in search of a drier abode. They find some crevice or hollow in the tree, a place, perhaps, where soil has collected, in which they can easily dig. But they use it only as a temporary retreat. On the following evening I again visited this nest. The deluge had ceased; the ground was dry, and the ants were bringing back their possessions and re-establishing themselves in the old formicary on the ground.

I have sometimes seen them collect into a cluster like a globular swarm of bees. This occurred on the open manjha, when for weeks it had been covered in a flood. There were no high trees up which the ants could escape; nothing was available but the bushes of the tamarix, mere stems and leaves where they could find no hollows in which to establish a home. As a consequence they congregated in clusters on the branches, massing themselves into balls composed of hundreds of individuals, workers and soldiers all clinging to one another in a solid motionless mass. They must have hung for a long time in this helpless state, since the surrounding ground was knee-deep in water and the ants had for weeks been isolated on the plants. Such is their resort when driven to extremities. If they are unable to secure some suitable hollow, they mass themselves into a solid ball.

At sunset, when the work of the day is over, these ants will often collect in a body and congregate round the mouth of the nest. The sexual forms will sometimes join them, and they all gather in a dense throng. It is the vivifying influence of moisture that has caused it; and when the males and females join, then it becomes an important event. The general duties of the day cease; the ants collect in an idle swarm; some stroke themselves; others just crawl quietly about; it looks as though they sought a peaceful recreation, a rest after the toil of the day.

Although the males and females emerge, yet this is not a nuptial flight. Sometimes it may be a preliminary to migration; more often it is a mere enjoyment of the air which has been freshened by the fall of rain. At this time the soldiers are very pugnacious. They know that the sexual forms are with them, and they recognise the sanctity of the charge. They will then fight with the utmost valour. Interfere in the slightest degree with the multitude and the soldiers instantly come forth to the attack. They are now a dangerous and angry swarm. They scatter widely in their search after the foe; they fall on it with unusual ferocity; so fierce is their attack that they may draw blood from the human skin, and they will often allow themselves to be torn in pieces before they will let go their hold. The smaller workers scarcely heed the battle, and the sexual forms, with still better judgment, retire for safety into the nest.

I have told elsewhere how an allied species takes special care of its sexual forms, and how the workers, on certain occasions, will carry them forcibly into the home. I have noticed a similar behaviour at the time of these evening swarms. The workers, great and small, had gathered in a throng around the gate. The males and females were with them; they seemed to be wandering aimlessly about, and some had strayed a considerable distance up the trunk of the tree. It was sunset, and almost time for the ants to retire. But, as I have before observed in the case of *Camponotus dolendus*, the sexual forms appear to be unable to find their own way back to the nest. They need the assistance of the workers, and this, of course, was immediately supplied. The workers quickly scattered themselves abroad and sought out the wandering males. Each worker seized a male by the neck and hoisted the burden high above its head. The winged ant made no resistance. It lay passive with wings folded and body thrust high into the air. It just quietly resigned itself to the purpose of the worker, and was carried in triumph back to the nest.

It is, therefore, a duty of the workers in the commune to cherish and guard their sexual forms. They feed them, they fight for them, and, when the hour of sunset arrives, they convey them for safety into the home. Moreover, they are able clearly to recognise the sexual forms of their own swarm. They will bestow their care on them alone, and will have nothing to do with any sexual forms which have been born in another nest. I gave to the workers some males and females which I had removed from a formicary near a different tree. But they made no attempt to guard or carry these strangers; though they were the valued sexual forms, yet the workers immediately set upon them and drove them headlong away.

In the manifold activities of ant life each individual commune is distinct. Each is a complex, living entity which lives and works as a single being regardless of all other communities elsewhere. It repels the individuals of other nests and keeps strictly to its own sphere. Its members are all linked by invisible bonds so as to act in one common swarm.

CHAPTER III

THE INDIAN BLACK ANT—SPECIAL HABITS

Duties of smaller and larger Workers—Mode of Excavation—Value of Soldiers—Special Senses—Faculty of Communication—Summoning of Troop—Transfer of Information—Dispatch of Parties—Leadership of Troop—Successive Troops—Recognition of Route—Sense of Direction—Guidance by Scent—All Ants differ—Contrast with *Phidole*

Now that I have discussed the general habits of this ant I will pass to consider the special duties allotted to the different castes.

The first and all-important business of the season is the gathering-in of food. This falls almost altogether on the smaller workers; it is they which seek out the provender and carry it to the interior of the nest. They are the honest and industrious labourers of the commune; it is they which scatter themselves far and wide amidst the foliage; it is they which attend so assiduously on the cattle; it is they which acutely distend their bellies and descend with their liquid burdens to the nest. I do not imply that the soldiers seek no food of themselves. I see them at times ascending the tree; I see them sipping the juice from the cattle; I even see them with fragments of insects and particles of the dung of birds. But these are only occasional efforts; they do not engage, like the smaller workers, in the untiring methodical duty of transporting nourishment into the nest. I have told of a soldier with a tense abdomen, but this is a rare event. When the smaller workers feed, it is for the general good, since they convey the liquid to others below. But the soldiers, I think, feed only for themselves. For mere personal motives they wait on the cattle, or will greedily sip the syrup which I give them on the surface of a leaf.

It is not their business to act as portable receptacles for the benefit of those on duty within the nest.

I noticed one little incident which indicates a capacity to divide their labour when engaged in the collection of food. I had cut up a grasshopper into many parts and placed these in a pile not far from the nest. Soon a worker discovered them and carried a fragment within. It then came back for another piece, and after a few more journeys became very enthusiastic and returned again and again. It must have recognised the value and profusion of the supply, for it soon cut short its circuitous journey into the subterranean galleries of the nest. It adopted another plan. As soon as it arrived at the gate of the formicary on its return journey from the store, it immediately handed over its burden to a soldier, and then hastened back for another supply. In this way it clearly diminished its labour and more rapidly retrieved the spoil. Other kinds of ants would have solved the problem by calling out companions to their aid ; but this was not the case with the *Camponotus* worker ; it shared its labour in another way.

The chief duty of the soldiers is to protect the formicary from attack. Hence they are of exceptionally powerful build. They are formidable not by reason of their numbers, but because of their individual pugnacity and strength. For this reason, too, they post themselves around the aperture. Some in all likelihood are just within, and the opening may be blocked with black heads and bristling with antennæ ; or more often we may see them in a quiet group just idly sunning themselves outside the gate.

I throw a large insect into the area under their defence. Out they rush with wide-open jaws ; two or three in the vicinity advance to the fierce attack. They throw themselves upon the enemy, fix it with their mandibles, turn in their abdomens and shoot forth their pungent fumes. The unfortunate insect endeavours to escape, but the soldiers quickly overpower it, and either dismember it or drag it bodily into the nest. But it is only the workers-major that take part in this sudden attack. The minors continue their ordinary occupations. They have been earnestly engaged in collecting provisions, and they remain thus occupied while the struggle ensues. The peaceful labourers gather in supplies while the valiant soldiers defend the nest.

Thus the *Camponotus* adopts the militant maxim that an attack is the best form of defence. There are certain ants, like *Messor*, the harvester, which defend their nest by raising a barrier so as to block the entrance with earth. There are others, like the active *Phidole*, which pour out of the gate in a teeming multitude, and by force of numbers overwhelm the foe. There are still others, like the fierce and well-armed *Sima*, which attack their enemies with venomous stings. The defence of the *Camponotus* differs from all these. Special workers have been modified for the purpose; they depend on their own individual strength and the obnoxious acid fumes.

The laborious duties involved in excavation fall completely on the workers-minor. From time to time I observe the galleries being dug at the base of a tree. I see each little worker carry out its load and throw it over the mound of earth that accumulates round the aperture of the nest. A worker-major seldom appears; at this period they remain within the formicary, and they never carry out any loads. Later in the season, when excavation is over, I block the entrance with earth. An interruption follows in the ordinary routine. Many workers accumulate outside. The abdomens of some are acutely distended, and they are eager to disgorge the contents. No doubt others have collected in the interior, equally anxious to get out. Soon they set to work; they begin to excavate and dig their way into the nest again. But the point to observe is this. It is the smaller workers alone that take any part in this toil. There are many of the soldiers crawling lazily about, but not one of them shifts a load.

But there is one occasion on which the soldiers will lend a hand in the excavation of their nest. If pebbles or other obstructions are encountered which are beyond the power of the smaller workers to move, then the soldiers will come to the rescue and lend a more vigorous aid. Such assistance is not often required here, since the soil consists of a uniform silt deposited in the river bed. But I have little doubt that in stony places the soldiers thus utilise their exceptional strength. On one occasion I placed a pebble, on another occasion a piece of wood, immediately over the aperture of the nest. These were beyond the strength of the minors to move. They struggled hard to shift them, but they were unable to pull them aside. At last a soldier came to their assistance; it took hold of the obstructing object in its jaws and dragged it clear of the nest. Thus on certain particular occasions the soldiers will help in the excavation of the soil.

In the routine method of ordinary excavation there is no division of labour employed. Each little worker digs, transports and disposes of its own load. But I observed on one particular occasion that the ants had slightly modified the sequence of their toil. The ejected earth had accumulated into a pile around the aperture; a steep slope was formed, and the loose debris was in imminent danger of rolling back again into the nest. I noticed that, under these circumstances, the ants had adopted a relay system in order to extract and accumulate the earth. Each worker was not solely responsible for its own load. Many of the workers brought their burdens to the aperture, but they went no farther; they just deposited them at the gateway and returned for fresh supplies. A second batch of workers was employed upon the mound. From time to time they shuffled back the debris; then, at intervals, they would proceed to the aperture, take up the burdens which the excavators had carried out, and drag them up the slope of the mound until they reached the summit of the pile. Thus the labour was divided into relays. Certain workers were appointed as excavators, to others was assigned the particular duty of shaping and constructing the pile. No doubt this was a more efficient system to adopt when the mound had reached a dangerous size, and the ejected fragments, if not carefully placed, might roll back again into the nest.

I will mention just one other way in which it is a definite advantage to the commune to have workers of exceptional strength. Sometimes a specially large insect is discovered; it is too massive a load for the smaller worker and cannot be carried away. But as in the removal of obstructions from the nest, so also in the transport of the spoil the soldiers may lend their aid. They can get their powerful jaws around the largest capture and heave it along to the nest. I have often fixed an insect to the bark so that the soldiers could not move it an inch. They then show an excellent discretion in their behaviour. Since they cannot shift it, they go straight to its narrowest part. They sever it, usually at the neck or slender waist, and carry it piecemeal away.

I come now to some simple observations made on the special senses of these ants. In certain ants, such as the *Messor*, the sense of smell is very acute; in others, such as the *Myrmecocystus*, it seems scarcely to exist at all. The *Camponotus* appears to be intermediate between the two. I take some pieces of camphor and with them I half close the aperture of the nest. Now a *Messor* would have withdrawn before this powerful odour, a *Myrmecocystus* would scarcely have noticed the smell. But the *Camponotus* showed signs of olfactory perception, though not in an extreme degree. Some of the ants drew back as they approached the camphor; others hesitated; but most of them, without much sign of reluctance, passed through into the nest.

That the workers possess the sense of taste is indicated in the following way. I crush the abdomen of one of the soldiers; the juice oozes out to the surface, and I give the pulpy morsel to another major near the gate. It immediately seizes the fragment with the intention of storing it as food. But it shows its distress at the very first taste.

It is agitated and discomfited; it brushes the interior of its mouth with its tarsi in the effort to rub the taste away. It clearly appreciates the distastefulness of this juice, which is very bitter, as I have myself tried.

I fired my collecting-gun at one foot distance from a number of workers assembled round the gate. They showed no indication of having heard the report. I fired it again at six inches distance. This time some of them became excited and disturbed; but this, in all likelihood, was less due to the sound than to the sudden shock and sense of disturbance caused by the forcible vibrations of the air. If these ants possess any sense of hearing, then it must be limited indeed.

The *Camponotus* displays some faculty of vision, though not in an acute degree. When foraging amidst the foliage I am sure it can detect a twig or a leaf a little distance away, for I have seen it stretch over an empty space in order to secure its foothold elsewhere. Also I have observed it snap at strange objects before appreciating their presence by touch, and the soldiers will sometimes rush out at an enemy while still an inch or more away.

But the faculty I wish to discuss in detail is that by which one ant is able to communicate information to its fellows. Like all ants they can communicate the presence of danger. This is a very ordinary feat. I touch one of the soldiers. It is immediately alarmed and begins to run excitedly about. It meets other soldiers; it imbues them with the same enthusiasm, and soon there is a spirit of flurry and commotion distributed amongst all the wardens of the gate. This is the faculty of communication in its simplest and most rudimentary form.

Let us consider its manifestation in a more advanced and interesting degree. I take a large and tough-skinned locust, and I stake it firmly to the trunk of the tree about five feet from the aperture of the nest. For some time it remains neglected, since not many ants happen to come that way. At last a wandering soldier finds it, rushes on it, fixes its jaws in it, turns in its abdomen and endeavours to stifle it with fumes. The locust, though impaled, is still alive, and it struggles beneath the fierce attack. But it is firmly fixed, and the ant is unable to drag it away. The soldier clenches it and endeavours to wrench it from its hold. It pulls at the legs, it cuts at the bases of the wings, it tries to divide it in pieces by eating through the stout waist. For ten minutes or more it exerts every effort, but it can neither dismember the locust nor tear it from its fastening to the tree. Then it apparently begins to think of help. It leaves the locust for a minute, and scurries about in the near vicinity, probably hoping to find aid. But it is loth to leave the capture, and it soon falls on the victim again. Another struggle follows, then a few more scurries, until at last it seems to realise its impotence, and it makes off hastily and with decision to the nest.

It perhaps meets a companion on the road. Their antennæ meet, and the news of the discovery is told. Both may then turn about and return to the victim on the stake. Or more probably the discoverer will continue on to the nest, while the stranger will make off with great enthusiasm, and may even come upon the locust by itself.

Let us follow the discoverer. It soon arrives at the vicinity of the nest. The great soldiers are at their post of duty near the door; some are just crawling lazily around the aperture; others have their heads projecting through the gate ready to move should occasion require. Unexpectedly the discoverer comes into their midst. Antennæ meet; they titillate one another; communication follows, and the good news of the discovery is spread. A new enthusiasm pervades the group. They plainly recognise the value of the information and, from the way they run up to meet the discoverer, it is clear that they give a special reception to the worker that has brought the news. But the discoverer does not halt; it leaves the soldiers running aimlessly about and goes straightway into the nest. It meets those in waiting just within the door; they immediately dash out and join the other soldiers in their excited scurry around the nest.

The discoverer disappears. It remains inside for a minute or more, obviously engaged in important duties within. At last it emerges, and there is a little troop of workers following in its train. It has not collected the first soldiers that it found. It has ignored the outside sentries and also those in waiting just within the door. It has gone deep down into the galleries of its nest in order to call out the rescuing troop. Such indeed is in accordance with the principles of ant life that certain workers should be detailed for this duty, and should remain in some particular part of the nest. It is no doubt their main business to wait in the formicary and hasten out to the rescue when aid is required.

The discoverer now is at the outside of the nest and is making its way back to the spoil. Immediately in its rear is the rescuing troop. They are probably about eight or ten in number, and both soldiers and smaller workers are represented in the file. Sometimes only two or three emerge; these are all the discoverer has managed to collect, yet with them it hastens on its course. The party, thus formed, gathers into a fairly compact troop. Its members follow closely one behind the other, sometimes in single file; the foremost keeps immediately in rear of the leader, and the remainder fall into position behind like a well-trained pack of hounds. It is a steady, regular and deliberate procession: the discoverer leads; the troop follows, and they all have a clear purpose in view. The discoverer is of course the all-important member of the troop. The other workers will sometimes run up to it, touch antennæ with it, and in so doing find their confidence restored. If the leader deviates to one side then the followers will deviate too; if it happens to lose itself in some tangled scrub, then the troop will follow it in all its wanderings, until it regains the original course. If the leader advances at too rapid a pace then the followers may be left behind, but they will use every effort to avoid this, and will hasten at the utmost speed in their desire to reach the discoverer again. Sometimes they may lose their leader for a moment, and as a result confusion prevails. Then they catch it up again, and order and position are restored.

At length they draw near to the quarry. A burst of enthusiasm occurs; they rush forward; they gather round it, and fall on it with their dentated jaws. They cleave and clench and macerate it, and perhaps tear off little pieces, which they carry individually to the nest. The discoverer has brought a crowd to the rescue, and they cling on to the struggling prey.

Now this is a very definite act of communication; it is a request on the part of the discovering ant for others to come to its aid. A transfer of information in some way occurs. It is not merely the excited manner of the returning ant, nor is it the presence of food in its jaws which arouses the others to action, and impels them to pour from the nest. I believe that they are definitely summoned; they do not come merely because something has been found. For I have often supplied a worker with pieces of insects and watched it return again and again until it had carried every fragment away. But it never brought any companions with it; alone it retrieved all. It is only when the worker cannot deal with the quarry that it will return to summon out the troop. In my experiment, therefore, I must fix the locust, and, even then, it is only after a fruitless struggle that the worker will return for aid. If I give the locust in fragments, then the discoverer will remove it piece by piece and will always come back alone. It is the feeling of powerlessness, the knowledge that it has met with something beyond its strength, that induces it to seek for aid. For this reason it actually summons its fellows, and calls on them to come. Indeed, I have sometimes seen it, on emerging from the nest, actually trying to persuade its companions, which for some reason seemed reluctant to follow. It repeatedly approached them, communicated with them, then advanced a little, then again returned, and behaved to all appearances as though it were endeavouring to induce them to fall in behind. How the transfer of information takes place it is quite impossible to understand. But its substance I take to be this, if I may be allowed to interpret it in words. The discovering ant informs its fellows: "I have found valuable food, come to my aid and we will secure it."

This plan of calling out a party is employed in another and perhaps more important way. After a heavy shower of rain it is a common sight to see a group of workers progressing steadily over the ground, and moving in a definite direction, under the guidance of one in front. This is not a call to overcome a victim; it is rather a method by which the species increases its geographical range. It occurs in this way. The rain has imbued the ants with vigour; the numbers in the nest have become excessive, and it is necessary for the population to spread. An emigration is essential in order to relieve the strain. A worker is dispatched from the overcrowded nest. It explores the ground all round about; it often wanders a considerable distance, and at length alights on some hole or crevice suitable for the establishment of a new home. The investigator then returns to the formicary, summons out a number of workers, and bids them follow it to the new nest. It is these parties engaged in emigration which we witness after a shower of rain. We see the leader marching steadily in advance; we see the others following in a close and well-ordered line. There are twenty or thirty of them; a few are stalwart soldiers, but most are of the smaller caste. Nothing balks their progress. We observe them advancing over a ploughed field: they turn round the sticks and tussocks of the grass; they surmount the broken clods of earth in a disciplined and even train. They sometimes meet with trouble at an awkward place. There is some confusion, the line is temporarily broken, but they soon recover and the laggards hurry on to resume their original places in the line. Thus they advance, and under the guidance of their leader they surmount their difficulties and are established in the new nest.

In this way the strength of the formicary is reduced, especially when a number of successive parties are dispatched out of a single nest. I think this very frequently occurs, and on those ocasions more than one worker must be employed in leading the excess population away. It is often a prolonged and laborious journey, since the party will sometimes travel a distance of eighty or a hundred feet. I will tell later of certain byre-building ants which enlarge their area of geographical distribution by transporting their submissive companions in their jaws. The *Camponotus* adopts a different plan. The explorer summons out its party of migrants and bids them "follow me to the new nest."

I have said that the discoverer acts as a leader, but I have yet supplied no proof of the fact. I must mark the ant with a spot of paint in order to recognise it again. This is a simple matter with the *Camponotus*: it is so large, so black, so sluggish and, at the time of the operation, is not easily disturbed, since its attention is fixed upon its prey. I place a white speck upon the thorax, and it returns to the nest. I repeat the operation on many occasions; the result is always the same. The marked ant emerges first from the nest and always leads the troop.

Its leadership is of essential value, as a simple experiment will show. After it has led its party a short distance I suddenly remove it from the group. Excitement and confusion immediately follow; the members of the troop now scurry about and search for their leader in every direction; their disciplined and methodical progress ceases: they become an aimless and a leaderless mob. In the end they fail to advance any further; they are unable to reach the treasure, and most of them soon return to the nest.

Now I have often performed this experiment, and it always leads to consternation in the troop. I then replace the leader—at least, I place it in the midst of the excited throng. The members of the company recognise it, they lick it, they titillate it; they again gather themselves behind it, and the orderly procession to treasure is restored.

The nest is not completely emptied by the emergence of this rescuing troop. I have told of another ant, the *Phidole,* which calls out successive reinforcements to its aid. But this is not the habit of the *Camponotus,* nor indeed is it required. For in this species the workers are so massive and strong that a party consisting of eight or ten is sufficient to deal with the largest prey. But I have no doubt that reinforcements could easily be obtained should any special occasion require; for I have swept away all the members of a party, and have then observed the discoverer return to the nest and call out a second troop.

Two further points now require investigation: first, how does the discoverer find its way, and, second, how does it exert its leadership over the troop?

From previous observations I was led to imagine that when the discoverer emerged from the nest, and made its way back again to the treasure, it followed out along its inward track guided by its sense of smell. But this was not so. The leader does not return on its old track; it takes an utterly different and often very erratic course. The line of its outward journey may be a foot or more distant from its inward route, and at times it may deviate to the right or left in a far more circuitous course. Hence its faculty of scent cannot serve it as a guide.

Nor does it recognise its outward path by reason of its sense of sight. I place certain objects before it in such a way as to obstruct its path. Amongst them are some leaves, two paper flags and three little pyramids of clay. These are peculiar landmarks to find upon the trunk of a tree, and if sight had been the guiding agent for the ant then they would certainly have caused confusion and informed it that it was taking the wrong road. But the ant was not in the slightest degree perplexed. It certainly took some note of the unexpected objects; it examined them, even bit at them with its angry jaws; but they did not turn it aside from its course. On the contrary, it circumvented each in turn, and in the end came upon its goal.

Smell and sight being out of the question, the leader can maintain its true course only by some directive sense. What it is or how it works is a mystery to the human mind. But in some way the ant seems able to appreciate the different directions of space ; it appears to know by some peculiar instinct of direction that it is moving in the right course. This is a feeble explanation, if indeed it is any explanation at all. But I feel sure that certain insects can appreciate direction in some manner that is quite incomprehensible to us.

I pass now to the second point. In what manner does the discoverer lead the rescuing troop? It may seem a somewhat unnecessary question, and scarcely worth investigation at all. Let us see.

With my hand I rub the bark of the tree in front of the leading ant. The leader is unaffected ; it keeps straight on. I then watch for an opportunity, and when an interval happens to occur in the line I rub the bark behind the leader—that is, between it and the following troop. Now we observe a very different result. The followers are thrown into confusoin ; they fall out of line ; they scatter ; some of them may wander far and wide and go completely astray. The rubbing of the bark has introduced a barrier ; it has checked the onward progress of the troop, though in the end many find their way across it and catch up their leader again. The only possible conclusion is this. By scent the troop follows its leader. When I draw my hand across the track I obliterate the scent. Hence confusion results, and discipline and order is lost.

The leader is guided by its sense of direction—a most powerful faculty in this species of ant. It has been out before at the treasure ; hence this mysterious sense can guide it and lead it back to the treasure again. But the troop, not having made the journey, cannot utilise their directive sense. They follow by what in this species is a less powerful influence, the delicate faculty of smell. As a consequence they always keep close behind their leader; for if they wander from the track they are lost.

I arrive at a similar conclusion when I observe a party migrating from a nest to establish itself in quarters elsewhere. On these occasions a worker often falls in rear; it may be a foot or two behind the troop, and it is hurrying forward with all its speed in order to regain its comrades in front. It does not lose its way. Its sight is certainly far too feeble to detect the main body in advance, and since it follows every undulation of the track it can only find its way by smell. I rub the track with the sole of my boot immediately in front of this ant. The laggard

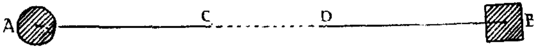


FIG I.—Experiment on Communication

now finds itself in serious difficulties. It loses its way where my boot has been, obviously because I have obliterated the scent.

I will mention a few more simple observations which bear on this faculty of smell. I have said that an ant, after making a discovery, and when on its way back to the nest, will often communicate the valuable news to another which it meets on the road. The second ant as a rule runs somewhat aimlessly about, but, if the distance be not too great, it may return along the discoverer's path, and come by itself on the treasure. I feel sure that it must effect this by means of its sense of smell, for I have seen it work its way back along a horizontal stick where in the ordinary course of its wanderings it would be most unlikely to go. Nevertheless the faculty of scent cannot in this species be exceptionally acute; for if the distance is great, then the ant, though it may search assiduously, will not be able to find the treasure. Moreover, the troop is almost completely dependent on its leader; it cannot, like certain other ants, scent back along the inward track of the discoverer should the latter happen to get lost.

Now let A (Fig. 1) be the nest, B the discovered insect, and A—B the track of the leader with a rescuing troop following in its train. At C, I raise the leader from its path and transfer it forward to the point D. The leader continues straight on and, without further interruption, reaches its goal. But the troop is thrown into confusion at C owing to the gap in the scent between C and D. Some of them go completely astray; others, after a vigorous search, find their way across the gap, again come upon the scent of their leader, and follow on its track to B.

An ant from the rescuing party will sometimes happen to get lost. It runs about excitedly; it searches everywhere for its leader in its efforts to regain the route. It meets with other ants, but they are unable to supply the information though they may belong to its own troop. It wants its leader; this is the only individual which is able to satisfy its needs. At length it comes upon the leader. Their antennæ meet; it is immediately satisfied; it falls in behind, and resumes its place in the advancing train. I have no doubt that by scent it distinguishes its leader, and by the same faculty it follows on its path. But any ant can act as a discoverer, and each can, therefore, be separately distinguished by the members of the rescuing troop. Consequently we arrive at the same conclusion—which I have elaborated and discussed elsewhere—that all the ants in a community differ, and that each is capable of individual recognition because each has a distinctive scent.

There is another ant, the active *Phidole*, which possesses this power to call others to its aid, and exerts it in a more elaborate degree. I will contrast its methods with those of the *Camponotus*; it will indicate how the same instinct has become modified in two different species, and how in each it has developed the particular characteristics best suited to the habits and structure of its host.

The most striking points of comparison are these. The *Camponotus* summons about eight or ten of its comrades; the *Phidole* calls out an army to its aid. For the *Cam-*

ponotus is a giant with individual strength: the *Phidole* is a pygmy, and can do nothing without its swarm. The *Camponotus* calls out the aid of its troop only when some special difficulty occurs; the *Phidole* requires the help of its army whenever a capture happens to be made. Both the soldiers and the minors in the *Camponotus* nest are able to bring out the rescuing troop; in the case of the *Phidole* the soldiers are helpless, it is only the minors that possess this power. The *Camponotus* summons just one troop from the nest, and this is sufficient for its needs; the *Phidole* returns for additional reinforcements until the capture is overwhelmed in the swarm. In the advance of the *Camponotus* the discoverer is the leader and the rescuing troop follows in its train; in the *Phidole* army the discoverer may be anywhere, and is usually lost in the body of the host. With the *Camponotus* the discoverer is essential as a guide; with the *Phidole* I can capture it when it issues from the nest and the army has no difficulty in finding its way. The *Camponotus* leader at the head of its troop moves out along a different road; the *Phidole* sticks to its previous line and retraces its inward path. I rub the tree before the *Camponotus* leader but it is not in the slightest disturbed; I rub the ground in front of the *Phidole* and confusion instantly occurs. For the *Camponotus* is guided by some sense of direction; the *Phidole* by the faculty of smell. Such are the essential points of contrast between these two communicating ants. The *Phidole* possesses the valuable power in an infinitely more refined degree. But what has most impressed me in my observations is this. The sense of direction is comparatively more powerful in the *Camponotus*; in the *Phidole* the sense of smell.

CHAPTER IV

THE INDIAN BLACK ANT—DIRECTIVE SENSE

Ability to find its Way—Experiments with Sticks—Sense of Smell and Sense of Direction—Observations bearing on Directive Sense—Experiments with Rotating Stick—Influence of Direction more powerful than Scent—Memory for Location—Experiments on Memory for Location—Summary of Experiments—Conclusion

I WILL now introduce a series of experiments which I made with the object of trying to determine how these ants moved so widely over the branches without becoming hopelessly lost. The experiments, I fear, are very inconclusive, but at least they will serve to indicate this: that the sense of direction, the faculty of smell and an excellent memory for location have each an influence over the worker ants in the daily routine movements of their lives.

There are certain ants which on the slightest interference seem completely to lose their way. Take for example *Messor*, the harvester, which works along a beaten road. I take a *Messor* worker from the gate and I transfer it to another spot only about six inches away. It is immediately lost; it wanders about aimlessly in every direction; it repeatedly explores every square inch of ground, and only after a long and laborious search does it happen to come fortuitously on its nest. I perform a similar experiment on a *Camponotus* worker, with the difference that I transfer it eight feet away. Of course it is at first confused, and indeed for a little time is lost. It wanders up and down the tree; it makes wider and wider sweeps and circles; then after a few minutes it seems to strike some track; it moves with a more assured and certain gait, and makes a course direct for the nest. Thus the *Camponotus* is much better equipped than the harvester, at least in the important faculty of finding its way home.

Let us proceed to investigate. I fix a stick vertically on the ground a short distance away from the nest. At the summit of the stick is a small platform on which some fragments of an insect are placed. I apply a worker ant to the food. It carries off a fragment, soon finds its way to the nest and comes backwards and forwards for more. I now rub my hand up and down the stick so as to obliterate any trace of scent, but the ant is not in the slightest confused; it goes straight up to the fragments just as if nothing had occurred. It is clear, therefore, that it does not find its way back by scent.

It is easy to confirm the fact. While the ant is absent in the nest I replace the stick by another, up which the ant had not ascended before. But, as in the previous experiment, there is no confusion: the ant climbs unhesitatingly up the new stick in search of the fragments at the top. How very different is this from the *Phidole*, which would be hopelessly lost at the base of the stick, and would assuredly never reach its goal.

I fix three sticks in a transverse row, each an inch apart. They do not in this case stand vertically on the ground; they are thrust into little sockets and project horizontally from the trunk of the tree. I place the food at the tip of the middle stick, and apply to it a worker which carries off a piece and returns for additional supplies. When it knows its way and is absent from the food I remove the central stick and interchange it with the one an inch to the right. What will the worker do now? If it were a *Phidole* ant then its manner of behaviour would be this. It would advance unhesitatingly to the base of the central stick, but there it would lose the scent; then it would hunt aimlessly about until at last it happened to find it again at the base of the stick to the right. We witness a different behaviour in the case of the worker from the *Camponotus* nest. It, too, reaches the base of the central stick, but at that point it does not go astray. Sometimes it may seem a little confused, nevertheless it climbs straight out to the tip, where it appears very surprised at finding no supply of food. Now, since no ant had previously made any use of this stick, the worker could not have been guided solely by its sense of smell.

I repeat the experiment again and again. On ten occasions I interchange the middle stick with the one on the left; on ten occasions with the one on the right, and I always take care that the new stick should be clear of any trace of smell. The result was not as conclusive as I had hoped. On thirteen journeys the worker climbed out along the middle stick, and thus made its way independently of the faculty of smell. On seven occasions it climbed along one of the lateral sticks and thus deviated from its previous course. It is not a very satisfactory nor conclusive result; nevertheless it indicates what I believe to be the truth, that both the sense of direction and the sense of smell influence the movements of the worker ants in their ordinary wanderings about the trees. If any more definite conclusion may be drawn then the only one possible is this, that the sense of direction stands to the sense of smell in the relation of 13 to 7; or, in other words, that direction is almost twice as powerful as scent in influencing the movements of the ants.

I will here mention a few trivial points. They are in themselves of little significance, but they bear evidence to the strength of the directive impulse in guiding the comings and the goings of the ants. When the worker reaches the base of a stick it may often be observed to hesitate, and this quite independently of whether its course happens to be right or wrong. I attribute this feeling of confusion to the fact that, when the ant arrives at the foot of the stick, it must suddenly change the direction of its course. It has been travelling up the vertical tree trunk and must now turn through a right angle in order to climb out along the horizontal stick. This is an unexpected and unusual movement, at least on the trunk of a tree. Hence its ordinary appreciation of direction is confused; it finds it difficult to make the turn, and it hesitates at the base of the stick.

I place the food on the top of a vertical stick some distance above the aperture of the nest. The ant as a rule soon learns the route; but if it has made only one or two journeys it may frequently lose its way On those occasions I have often noticed that the ant, when it misses the base of the stick, will almost always ascend the tree. I have no doubt that its sense of direction moves it and impels it to act like this. It is *filled* with the directive instinct to ascend in order to reach its food, and having missed the true ascent at the base of the stick, it feels that it must ascend somewhere, so it climbs up the trunk of the tree.

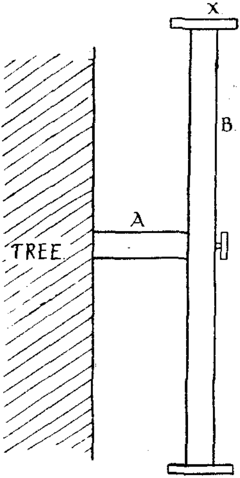


FIG. 2.—Rotatory Stick Experiment on Directive Sense

And not only this. I have also noticed from time to time that the ant seems to realise the distance to be climbed. It does not just merely continue to ascend and so lose itself in the branches and leaves. The sense of direction may be a faulty guide, but it will not permit such futility as that. For when the ant reaches a height about equal to that of the food above the nest it will turn about, commence to descend the tree, and seek another ascent elsewhere. It must be some sense of direction which guides it to turn in its course. It no doubt feels that it must ascend, and must do so for a certain distance in order to regain the food. It makes the ascent, but at the required distance it finds nothing, therefore it feels impelled to return.

I fixed two sticks to the trunk of the tree as shown in Fig. 2. A is a short horizontal rod and is firmly driven into the bark. B is a similar but much longer piece; it is pinned through its centre to the end of A and can rotate to either the right or left. I secure the insect-food to the little platform X. The rod is perpendicular; X is above, and I place a worker on the food. It seizes a fragment, and after a short exploration finds its way across the horizontal rod and down the tree to the nest. It returns, makes a few more journeys, and thus learns the correct route to X. During its absence I rotate B. I turn it through two right angles so that X is now below. The question now is, which has the most powerful influence over the ant—the sense of direction or the sense of smell? If direction, then the ant, after it crosses A, should ascend the stick, for that was its previous line. If smell, then it should descend the stick, for the scented half is now below. Let us see. The ant returns; it crosses the bridge at A; it scarcely hesitates, but immediately ascends the rod and seems rather surprised at finding nothing at the top. I repeat the experiment a number of times and on almost every occasion the result is the same. I give one worker ten consecutive journeys, and every time it ascends. The sense of direction is the main guide. No matter how the stick is turned the ant is influenced in the same way. As soon as it crosses the bridge it feels in some way that the food lies above it, and is thus impelled to ascend.

Nevertheless, again I feel that we cannot altogether abolish the influence of smell. It has some effect, though in a rudimentary degree. For though the ant was unmistakably guided by direction, nevertheless it often hesitated a little when on the unscented half of the stick, and on a few occasions it turned about before it actually arrived at the top. It behaved as though it felt it was on the right course, and yet, at the same time, there was something wrong. The cause of the confusion I take to be this. Scent and direction were opposed to one another, and it had to choose the more potent of the two.

I modified the experiment slightly, and arrived at the same conclusion, though in rather a different way. The rotating stick is placed in the vertical, and the ant, having learnt the route, is coming methodically to X. I rotate the stick through one right angle; in other words, I twist it from the vertical to the horizontal, which I can do, of course, by turning it either to the right or left. I make the experiment twenty-six times; thirteen rotations are to the right and thirteen rotations to the left. The sense of direction must seem to be eliminated, since the vertical half is now turned down. Smell is given an even chance, since, as in the previous experiment, I take good care that one half of the stick is deprived of scent. Consequently, if smell has much influence as a guide, then, since direction is eliminated, the ant should make most, if not all, of its journeys along the scented half of the stick. But it is not so. Out of twenty-six journeys it makes fourteen along the scented half and twelve along the unscented half, only a mere negligible majority in favour of the faculty of smell.

But the real point of interest to be noticed is this. The ant has a very decided preference for utilising the half to the right. Whether this half is scented or not seems to have only the slightest influence on the ant. On almost all occasions when it crosses the bridge it turns sharply to the right. In fact out of twenty-six journeys it took twenty turns to the right and only six to the left. Now, what explanation can be given for this quite unexpected result? Before the rotation of the stick the ant had learnt to turn into the vertical as soon as it crossed the bridge; why, therefore, when the stick is horizontal, should the right half have more influence than the left? The reason I believe to be this, and it indicates still more epmhatically the influence of the directive force. During the experiment the whole apparatus happened to be placed on the right side of the nest. Consequently the ant, in order to reach the food, had first to move out to the right, then cross the bridge, then ascend the vertical to X. In no part of its journey did it ever move to the left. When the stick was rotated the vertical part of the journey was cut off; but the ant had still to move out to the right in order to reach the base of the stick; hence rightness was the forcible idea in its mind, and, therefore, as soon as it crossed the bridge, its instinct was to turn to the right.

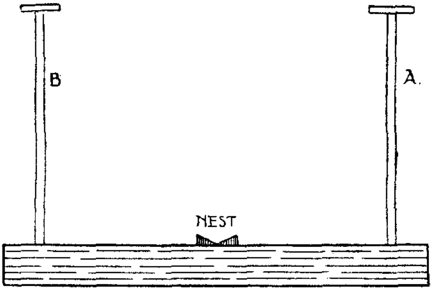


FIG. 3.—Vertical Stick Experiment on Directive Sense

The little incident was a further confirmation of the superiority of the directive sense.

Thus the ants seem to feel the direction which they take, and they must have a very good memory for location in order to follow the correct route. I taught a worker to come for food to the top of a stick at the right of its nest. During one of its visits, while it was at the food, I removed the stick and transferred it to the opposite side. I wished to see what the ant would do on its return journey with the food. Its directive instinct would guide it to the left as soon as it reached the trunk of the tree, but this direction would now lead it astray owing to the fact that the stick was transplaced. To many ants this would be an impossible problem; they would find themselves hopelessly lost. But this is not so with the *Camponotus* worker. It is certainly confused when it reaches the tree, tries for a little to find the nest by searching away to the left; but it soon realises that something is wrong, then works off in the opposite direction and comes without difficulty on its nest. It is easy to cause the ant to hesitate by confusing the directive sense, but it is difficult to so completely dislocate the instinct as to send the worker astray.

Two sticks, A and B (Fig. 3), are fixed, one on either side of the nest. The food is placed on a platform attached to the tip of A. Whenever the ant reaches the platform it is lifted across to the tip of B. It returns down B, arrives at the nest, then comes out to the foot of A and climbs to the tip again. It is thus made to follow a kind of circular course. When the route is established, and when the worker is in the nest, I remove the stick A. Of course when it emerges it searches for A in the place where that stick had been. But not finding A, it works back along its track to B and ascends that stick in the hope of finding the food there. This must have been a feat of topographical memory. It had not before worked out in the direction of B; that had always been its inward course. Indeed, it acted contrary to the established instinct of direction by reversing the circular round. I imagine that, when the directive impulse failed it and it could not find the stick, it fell back on its topographical memory and returned to the spot where it had been before.

I teach an ant to come for food at the tip of the stick A. Subsequently I remove A as soon as it knows its route. I then try to teach it the way to B, a similar stick fixed an equal distance away on the opposite side of the nest. But it takes a very long time to learn and makes many a circuitous journey in its efforts to find the base of B. Its topographical memory is clearly confused and it is always returning to its old route.

After it had learnt its lesson fairly well, and came without much confusion to B, I removed B, and at the same time I replaced A. The worker came out to search for B, but not finding it immediately went off to the opposite side of the nest, and straightway ascended its old stick A. This again showed that the ant retained a good memory for places, though in the meantime it had journeyed elsewhere.

I now removed both A and B, and the ant, finding no more food, soon retired into the nest. There is a spot of paint upon its thorax, so it is easily recognisable again. I return in the evening after an interval of twelve hours. I replace the stick A and give some fragments of insects to the soldiers in order to arouse enthusiasm in the nest. When I do so a number of the ants emerge, and amongst them the worker with the white spot. Most of them run aimlessly about, but the ant of the experiment comes out with a purpose ; it goes direct to the base of A and quickly runs up to the top. The idea of food had recalled the memory of the morning and it returned to its old place.

I came back the following evening after another interval of twenty-four hours. I saw the same worker moving about in the vicinity of the gate. I placed A in its old position and again excited the ants. The one under observation joined in the flurry ; at first it behaved without very much purpose, but after a time it found its way to the stick and climbed to the platform at the top. Thus the ants have a good topographical memory, and, moreover, one which is moderately exact after an interval of thirty-six hours.

I will very briefly summarise the results of these experiments in so far as their imperfection permits me to judge. They certainly lead to the clear conclusion that the ants can track one another by scent. By this means the workers follow their leader when a troop is called from the nest. If in any part of the journey I break the scent, then the troop is unable to advance. If I restore the scent by returning the leader, then the progress is again resumed. But in the ordinary business of their daily lives the ants possess another guide. They are influenced by some wonderful sense of direction which is quite inexplicable to us. And this is a very powerful force, many times superior to scent. For, when direction and scent are placed in opposition, then direction easily wins. In addition the ants have a memory for places—a kind of topographical sense. Although confused in the interval by innumerable deviations, yet they still retain the memory of places which they visited days before.

Would that we could form some more definite conception of the operations of that tiny brain! For I feel that the ants are guided by forces more subtle than we can ever know. All that we can do is to grope and wonder, and compare their actions with our own. But of the real workings of their minds is it possible to learn anything at all? We observe some special action and we infer some mental state. It is easy to record the actions, but how can we appreciate the mental states unless we compare them with ourselves? It is all analogy and inference, but it is the best that we can do. Our own minds are the sole standard for comparison, and the whole truth we may never learn.

CHAPTER V

THE EVOLUTION OF INSTINCT

The Ashy and Silky Camponotus—Their Habits contrasted with those of the Black Ant—Haunts—Protection of Nest—Mode of Excavation—Food—Comparison of Castes—Relation of Castes to Duties of Nest—Reason of Enormous Heads of Soldiers—Evolution of Communicating Instinct—Association of Tineid Larvæ with Ants

THE great genus, *Camponotus*, to which the Indian black ant belongs, comprises nearly fifty described species throughout India, Burma and Ceylon. They vary considerably in their anatomical structure, but nothing is known of those other variations relating to their instincts and habits of life. Taking, therefore, the black ant as a type for comparison, I will consider the operations of two other species which were common in this portion of the Indian plains. It will serve to indicate the considerable variability in habit that occurs in members of the same generic group, and will also supply us with some interesting observations to indicate the path by which the communicating instinct has evolved from its simplest to its perfect state.

The first of these species is the *Camponotus paria*. It is distinctly smaller than the more familiar black ant, especially when the sizes of the soldiers are compared. Otherwise it is very similar in its external structure, but while the common species is coloured an intense black, the latter is clothed in a silky velvet which, on the abdomen, is mingled with a shade of yellow, giving it an ashy tinge. Thus, in order to avoid a more technical repetition, I will call it the "Ashy Camponotus." The second species is *Camponotus sericeus* and is slightly smaller than the ashy ant. But the chief point of difference is in the shape of the thorax, which in the ashy species is a uniform arch, while in this one it is abruptly truncated behind. Its colour appears to be a variable character, for in this district the ordinary black head of the species was changed into a conspicuous red. It, too, is clothed in a silky pile, with a scattering of erect hairs. Hence the accuracy of its scientific appellation, which names it the "Silky Camponotus."

Both these species keep strictly to the jungle; they never establish themselves in brick walls, nor do they invade human habitations after the manner of the black ant. The ashy ant haunts the larger trees, dispatching its workers up the trunks, often in company with those of the black ants. The silky species, on the other hand, is more addicted to the scrub. Its most favoured haunts are the bushes of the tamarix, where it seems to be everlastingly licking at the foliage as though some sweet fluid oozed out through the leaves. It also ascends the trunks of the acacia and less often some of the other trees. Both kinds are skilful in exploring the vegetation, the ashy ant examining it by the usual method of working round the circumferences of the successive leaves. The silky kind is well supplied with the valuable habit of throwing itself to the ground when danger appears. It is far more inclined to do this than is the black ant, a habit which is suitably associated with its environment, for it lives, at least in these parts, amid the grass and tamarix, in which jungle it is immediately lost to view the moment it falls to the ground.

Both species differ from the habit of the black ant in the places chosen for the situation of their nests. The black ant digs at the very foot of the tree, usually at its line of junction with the soil. These species move away some distance from the trunk and establish their formicaries in sheltered places, well hidden in the grass or scrub. Nor are they content, as is the black ant, with a gaping fissure; they usually shape the opening of their nests in the form of a circular hole. The silky ant is especially desirous of concealment. It drills a neat cylindrical tunnel in the soil which opens by a circular gate. There is nothing in the vicinity to attract attention, and consequently the nest is very difficult to detect when hidden in the tangle of leaves. The formicary of the black ant is visible to all; that of the silky kind is carefully concealed.

The black ant always posts a ring of soldiers round the entrance; they are the largest and strongest individuals in the commune, and are responsible for its security and defence. The ashy ant only occasionally mounts a guard, and then only five or six timid soldiers which have not the strength for any serious attack. At other times the aperture is left quite unprotected, and never do they guard it with that ferocious ring such as habitually assembles round the black ants' gate.

The silky species, on the other hand, never mounts a guard. There is nothing to be seen but the smallest aperture, just sufficient for the admission of a single ant. But look for a moment into the gateway and it will be seen how the security of this species is maintained. The red head of a worker is visible in the tunnel. It blocks the shaft about half-an-inch from the door, and the points of its gently separated antennæ are applied to the wall on either side. This is a sentinel which guards the aperture from within, partly by closing the passage with its body, partly by watching the circular gate. When a worker arrives, it communicates with the sentinel, and, if found satisfactory, is permitted to come in. There is a little formality about the mode of entrance. The sentinel first backs down the tunnel, since the shaft has been so designedly constructed that two ants cannot pass one another in the vicinity of the door. The sentinel is, therefore, compelled to withdraw to where the width of the gallery is increased. There it permits the new arrival to pass, after which it resumes its duty at the door. The sentinel, should danger happen to arrive, stubbornly holds its ground. I push the tip of a straw into the gate.

The sentinel bites at it, clutches it, and follows it out when I withdraw it from the door. But that is all. There is no excitement, no rush for aid, no sudden exit of infuriated soldiers such as issue from the black ant's nest. The gate is under the care of a solitary guard, which, though unable to put up much fight, yet is determined to bar the way.

The workers of the silky ant are fewer in numbers and arrive at the nest at longer intervals than is usual in the case of the more conspicuous black ant. The moment one arrives it darts quickly through the gate; in the same way those leaving hurry rapidly out. There is no halting, no lingering about the aperture; indeed, from the furtive haste that they display, it would seem that these ants were particularly anxious that no enemy should detect the site of their retreat. Thus we see that the Silky Camponotus possesses scarcely any power of attack. It seeks safety by means of concealment and by rapid retirement into the soil. The Ashy Camponotus is intermediate in pugnacity. It does not, like the black ant, pour forth in a legion eager to apply its poison and its jaws. It rather attacks with a more moderate vigour. It bites with its jaws and emits its fumes, but it cannot advance with that indomitable onslaught such as we experience when the black ant is enraged. Moreover, it is easily put on the defensive, and, if interfered with too vigorously, will permanently retreat into the nest. Thus the three species, though allied in anatomical structure, yet in character graduate from the height of ferocity to a temper of the other extreme.

For this reason we observe a considerable difference in their manner of dealing with the incidents of life. I place a wounded worker near the silky ant's gate. Now the black ant, under such circumstances, shows no hesitation; it quickly examines its disabled companion and then carries it into the nest. The silky species, on the other hand, displays considerable timidity. Each worker, as soon as it encounters the wounded one, makes a hasty plunge into the nest. It is a long time before one of them plucks up its courage, when, in fear and trepidation, it takes hold of the intruder and pulls it reluctantly in through the gate. I place a black ant soldier, which must surely be an enemy, at the door of the ashy ant's nest. But they make no attempt to repel the invasion ; they just dash for safety under the soil.

Another illustration of their difference in habit is seen in their hours of work. The black ant prolongs its labour after dark, but at sunset I see the ashy workers streaming down in the direction of the nest. There is no haste, no excitement ; it is a steady procession of quiet labourers returning after the toil of the day. In the morning they emerge, often in little parties, in order to commence the business of the hour. I have not seen these alternations of rest and labour in the activities of the black ant.

The mode of excavation supplies further details of the differences in habit between allied kinds. A nest of the ashy ant was under construction. The excavators were hurrying backward and forward methodically evacuating their loads. I noticed that three soldiers had stationed themselves at the door. They did not themselves engage in excavation ; they merely remained just within the aperture, with their heads fixed on a level with the ground. It was clear that these were the custodians of the gate, keeping watch over the general safety of the commune while the ordinary labourers turned out the soil. I placed a wounded ant of another species just within the gate. Immediately the excavators gave up their work and withdrew to the safety of the nest. The soldiers also retired a little way, but still their large heads remained fixed in the tunnel, about an inch within the door. The black ants, under such circumstances, would have advanced to the attack ; the ashy ants blocked the passage with their heads so that no intruder could get in.

There is another little matter associated with their excavation in which they differ from the method which the black ant employs. I have frequently noticed that, when ejecting the earth, they do not all work as independent individuals, but they enter and leave in definite groups. The members of each group all toil together; they cast down their burdens on the common heap, then run back in a straggling party, and all emerge in a body again. I never observed this regularity and system in the excavation of the formicaries of the black ant. The plan, I imagine, is definitely associated with the more constricted tunnel which this species constructs. For the black ant fashions a large gaping aperture through which workers can enter and leave indiscriminately without obstructing one another's progress or causing confusion in the passages of the nest. But the ashy ant digs a much narrower tunnel, and, unless some systematic machinery were adopted, the ants, when moving in different directions, would be very likely to obstruct one another and block the constricted road. Hence they have elaborated the valuable method of causing their excavators to work in groups. All will be entering or all emerging at any one time, thus there will be no opposition from different directions and no blockage is likely to occur within the galleries of the nest. Every modification in any society demands some alteration in the lives of the individuals in order to accommodate them to the new change. So is it in the community of ants. By constructing tunnels of the narrowest dimensions they manage to secure themselves against external foes, but they must modify their operations to suit their architecture; they can no longer dig at the individual's pleasure, but must combine into excavating groups.

Their food supply also shows points of difference. The smallest insects and the tenderest larvæ will sometimes be carried into their nests, but the silky ant especially seldom makes a capture after the manner so usual in the case of the black ant. Indeed, the nature of their nest is unfitted for the purpose, for if two ants are unable to pass in the tunnel it is obvious that they could not drag such captures through the gate. Some small fragments of a grasshopper, which I placed near the aperture, were certainly carried inside, but when I gave them a whole insect it was just pulled aimlessly about until at length they were robbed of it by a *Phidole* army, so much better equipped for this predaceous work. I similarly tested the ashy species, giving them an insect of only moderate dimensions, but one larger than they ordinarily convey. Now, the black ant would have treated it with the greatest expedition. Either a soldier would have seized it and carried it to the nest, or, failing in this, it would have gone for help and have brought a party to its aid. Not so skilful is the Ashy Camponotus. A number of workers assembled round my insect, but they did not attempt to drag it to the aperture; indeed, they seemed to know nothing of that art of combination by which ants transport a heavy load. All they could do was to laboriously dissect it and then carry the individual fragments to the nest.

I have not observed them attending on cattle, which is the main source from which the black ants obtain their food. On the branches which they frequented I often found membracids, but they were either feeding alone on the stems or had been appropriated by other kinds of ants. It seemed as though they did not know of the valuable method of coaxing the insect to render up its juice. Possibly they may attend them in other districts, but here they seemed to obtain their food only from two sources of supply—either from the tiniest insects which they chanced to capture, or more abundantly from the vegetable sap of plants which they obtained directly from the leaves and shoots. They feed one another after the manner of the black ant, and, since they seldom carry foreign materials into the nest, this transfer of fluid must be a continuous process in the chambers and nurseries underneath the soil.

The dissimilarity in the habits of closely allied species depends largely on the comparative development of the castes. The black ant maintains a number of giants with which to guard the entrance of the nest. But the soldiers kept by the Ashy Camponotus are merely dwarfs compared with these. There is certainly a clear differentiation into castes. The soldiers are easily distinguished from the minors, though there are many workers of intermediate dimensions which connect the two extremes. Let us first compare the soldiers of the ashy and the black ant. The former, in addition to their smaller bulk, are even more diminutive in solidity and strength. The coal-black appearance of the black ant soldier helps to give it a ferocious mien; the ashy soldier looks far less savage in its delicate, silvery dress. The chief point of difference is evident in their heads. That of the black soldier is a huge quadrangular mass, disproportionately immense when compared with its build; that of the ashy ant is but little above the normal proportions, though otherwise well built and strong. The jaws still further exemplify the difference. The black soldier mounts great projecting mandibles, curved and scalloped and with interlocking teeth which can easily cut through the skin; the ashy ant has comparatively insignificant weapons, useful enough for chewing at the leaves, but quite inefficient for the purpose of attack.

Turn now to the habits of the two species and observe how dependent are their daily duties on the structure *of this soldier caste. The black ant soldiers are the* custodians of the commune. Being possessed of greater power and pugnacity, they stand as a guard over the wide-open nest. The ashy ant only seldom fulfils such a duty, and then in a mild degree. It, therefore, does not need these ponderous soldiers; it relies for defence not on force of battle, but more on the careful concealment of its formicary and the narrow width of its gate. The great soldiers of the black ant also carry loads; they evacuate those boulders which are too heavy for the minors, and help to shift the more bulky captures which the ordinary workers are unable to move. Such duties, again, are not required by the ashy ant. There are no boulders to extract from its constricted galleries, and it is not in the habit of capturing large insects, for they would not pass through its narrow gate. Hence enormous soldiers are unnecessary for its purposes, and it is supplied with individuals of a more moderate build. For these it finds a suitable use, since it still displays a mild pugnacity, and sometimes it mounts a timorous guard which doubtfully watches over the gate.

The difference is still more marked in the case of the silky ant. Their workers also vary in size, but the larger ones so evenly graduate into the smaller that it is scarcely possible to divide them into bulky soldiers and individuals of a smaller caste. And so also it is with respect to their habits. They are more timid even than the ashy ant. Never do they carry anything but the smallest captures; hence it would be of no advantage to them if they possessed soldiers of exceptional strength. Certainly they place a sentinel at the door of their formicary, but it is not a guard, like those of the black ants, prepared to defend the nest by force; it is rather in the nature of a living plug for the purpose of barring the way.

There is thus a relationship between the differentiation into castes and the ordinary daily duties of the nest. Great soldiers are needed to fight furious battles, to shift unwieldy or ponderous loads, and to aid the strength of the smaller workers whenever necessity calls. But in the absence of such duties, the soldier caste becomes unnecessary. Either a few of a moderate build may be sufficient, or perhaps there may be none required.

But what is the purpose of the immense head which is the most striking feature in the black soldier ant? Why should it be of such inordinate size? For the head is so disproportionate to the rest of the body that it is as if we were to discover a race of men only about half again the ordinary height, yet with heads about three times the natural width, and armed with huge projecting jaws about ten times the normal size. For such is the standard of disproportionate development in the heads of the black soldier ants. Some good reason must exist for so exceptional a deviation, and for its strong concentration in the region of the head. The explanation, I believe, is to be found in their habits. These soldiers are maintained because of their strength, and the particular strength which an ant requires is almost altogether concentrated in its head. Its mandibles are the implements for the performance of its work ; it is with these that it does battle and moves great weights, and therefore, in the soldiers of the black ant, they have been increased so as to appear ten times the size. But if the jaws are enlarged, then their bases must be broadened, and they must be supplied with a more solid and secure foundation in order to support their greater bulk. Thus, the front of the head must be widened and deepened, for otherwise the jaws would not be firmly fixed. Furthermore, an enlargement to gain greater strength demands an increase in muscular power. Larger muscles must, therefore, be supplied, and this implies more space in which to enclose them and a more extensive area to which their fibres may become attached. I have not the means of dissecting this fine system of muscles, but on removing the integument from one side of the head I expose the thick fleshy machinery of the jaws and see it filling up a large portion of the cavity before reaching its attachment behind. Hence the enlargement of the head is a necessary adjunct which must increase proportionately with the growth of the jaws. It must be broadened in front to support the mandibles, its capacity enlarged to contain the greater muscles, and the surface of its integument sufficiently increased to supply attachments for the fleshy mass. The head is, therefore, enlarged in all its dimensions, and its anatomical development is no more disproportionate than are the more vigorous duties which it is called on to perform.

I pass now to the essential portion of this chapter—namely, the evolution of the communicating sense. The summoning of a party to render assistance is in many ways a remarkable act. I have discussed it in some detail when describing the black ant, so that it may be of interest to consider how this instinct has originated, and the steps by which it has come to its present state. The two species of *Camponotus* here under investigation will supply the material for the interpretation of this.

Let me first recall it in its full development, such as we witness in the operations of the *Phidole* ants. A single worker discovers a treasure. It races back to the nest with the news. In a few seconds an army comes bursting from the gate ; there are hundreds and hundreds in this issuing swarm, and without hesitation they dash over the soil until finally they reach and envelop the prize. But the full development of this remarkable operation is not realised until we closely investigate the act. Then we will discover that the army is independent of a leader ; it works out along the track of the ant that brought the news without requiring to be shown the way. It, in fact, retraces the path of the discoverer under the guidance of its sense of smell. This is the very height of the communicating efficiency. A worker arrives, proclaims the news, and without the necessity of its further co-operation the army secures the spoil.

The subject is worthy of our serious study, so let us turn to the species under discussion and determine the steps by which the instinct has reached such elaborate perfection as this.

I have not observed the Silky Camponotus summon forth a large party of workers to its aid. But I frequently witness a more instructive performance, which illustrates, I believe, the primitive foundation on which the faculty of communication is based. I see a pair of workers make their exit from the nest. One follows immediately on the other, and away they go in the direction of a tree. The first is clearly the leader of the pair. The second is being led. There is no possibility of doubt about this. They never change their respective positions ; the second keeps close up to and immediately behind the first. It scarcely ever falls more than half-an-inch behind, and it follows exactly in the footsteps of its leader through every turn and inclination that occurs. The pair thus advances over the soil with a peculiar jerky gait. The one in rear continually makes little forward rushes so as to touch the tail of the one in front. By so doing it knows that it is on the right track and that it has not lost touch with the leader in advance. The leader, too, assists in maintaining connection. It moves at less than its ordinary speed and in a rhythmical succession of jerks. Its tardiness prevents it from running away from its follower, and the jerks result in a synchronisation of movement with the forward rushes which the other makes in order to touch its tail. The maintenance of these repeated tactile communications is often a difficult feat. It is simple enough on the open soil where there is nothing to obstruct the road. But these ants make their nests in the grassy scrub. There are sticks and leaves and clods to be surmounted; there are stems to be ascended, and a forest of grass amidst the blades of which they must precariously climb. We follow them into this miniature jungle. Very soon they enter a difficult place. A sharp turn is necessary where some leaves intertwine. The second of the two ants falls an inch behind, and, as a consequence, tactile communication is lost. It runs about in every direction; it searches here and there amongst the twigs and leaves; its steady and deliberate advance ceases as it eagerly seeks for the leader it has lost. The leader, too, is aware of the separation; it no longer feels the repeated touches behind, and consequently it knows that its partner is astray. It also takes steps to restore the union. But it does not rush hurriedly about like its companion; to do so would be only to multiply the trouble; it adopts a quieter and more efficacious plan. It remains absolutely motionless in its place—that is, at the spot where the separation occurred. The lost ant, having searched all round about, at length comes back to the original place. There it finds the leader awaiting its return. Their antennæ touch; they recognise one another; the lost ant falls back into its old position; the leader again takes up the advance, with the second following as before.

In this we have the simplest form of communication and the most rudimentary example of a call for aid. It is simple, in the first place, owing to the number engaged; it is a case of just one ant bringing another; there is no attempt at a straggling troop, still less at a multitudinous swarm. In the second place, it displays only the weakest of links; if the follower happens to fall an inch behind its leader, then the connecting bond between the two is severed, and the follower can no longer pursue its course. In the third place, we notice the mechanism of communication; it is the simplest and most primitive of all possible kinds, merely the ordinary and intelligible instrumentality of touch. Lastly, we must observe, so undeveloped is the instinct, that the leader has frequently to assist the progress by waiting until its follower, which often goes astray, has regained its previous position in rear.

I now turn to the Ashy Camponotus, where I occasionally observe a somewhat similar but a more developed act. As before, I see one ant leading out another and advancing through the difficulties of an insect-jungle on their way from the nest to the tree. But there are certain differences in their manner of advance—minute details in many respects, yet of considerable importance to us. The second ant does not keep so very close behind its leader; it often falls two or three inches in rear, yet it does not lose its way. Nor is a continuous succession of touches necessary in order to enable it to keep its place. Occasionally, and more especially in difficult situations, it does run forward on to its leader's tail, but I often see them travel for a number of yards without any such tactile communication taking place. Nor does the leader assist in the maintenance of the union. It does not adopt that jerky method of progression since the synchronisation of movement is not required. If the follower goes astray, or if I interfere so as to carry it off, the leader does not halt, as does the silky species, but continues in its steady course.

Here, therefore, we find a definite advance in the instinct, a step towards that higher and more elaborate organisation which we observe when the swarm is called forth. But again we note that only two ants are employed, though they are linked in a more efficient way. The slightest disconnection no longer severs them; the repetition of tactile communications is unnecessary, and the whole responsibility now falls on the follower, since the leader has abandoned that simple habit of waiting whenever a break occurs. This surely marks a decided advance on the primitive mode of leadership by touch.

Now, since the instinct has reached that stage of development when tactile communication is no longer required, it might be thought that the second ant follows on the first by employing its sense of sight. Does it just watch the tail of its leader and follow where the latter goes? This is certainly not the case. As they thread their way through the ocean of leaves they often enter some difficult place. The second ant finds it hard to maintain its position; as a result it falls a few inches behind while the leader turns in and out amongst the leaves and is lost to the follower's view. But this does not break the connecting link; the second ant follows on the track of the first, even though the latter is out of sight. Again, I observe that the follower sometimes goes astray. The leader continues; it probably does not realise that the union is broken, since there is no application of touches to its posterior such as the silky ant requires to keep the union intact. The follower by its own efforts must regain its position, though in a minute the leader may be a foot in advance. It, therefore, rapidly hurries about searching round the point at which it lost touch. For a little while it is confused and cannot find its bearings, then it comes on some part of the track along which its leader has advanced. Immediately it is satisfied and reassured. Its leader may have passed far beyond its range of vision, perhaps even turned round the edge of the tree, yet the follower immediately appreciates its bearings and takes up its leader's track. It moves so hurriedly that it catches up its leader, and the dual progress is resumed. There can be no necessity to elaborate further. The primitive tactile communication has been abandoned; it has been replaced by the faculty of smell.

This conclusion is, of course, easily confirmed in the simple orthodox way. The leader and its follower have reached the tree, and without further difficulty are ascending the bark. They are now advancing free from interruption; the jungle of stems and leaves is behind them and they are now on an unobstructed road. I draw my finger across the bark between them, with the intention of disturbing the scent. Some slight confusion is the immediate result. The leader is unaffected and continues on its course; but the follower hesitates when it reaches my line. Clearly I have in some way opposed its progress. Nevertheless, it soon makes its way across, and resumes its journey as before. I then draw three moist fingers across the track. Considerable excitement and perplexity now follow, and only after a search in every direction does the follower at last circumvent my obstruction and in this manner find its way round. Tactile communication has absolutely vanished. It served as a guide in the rudimentary stages, but the olfactory sense has now been developed as the means by which one ant leads another from the nest.

It is but a small step now to the operation of the black ant, for, as has already been discussed in detail, a worker of this species leads out its party under the guidance of the sense of smell. Replace the ashy ant's solitary follower by a more or less numerous train, and as the second follows the first, so make each follow its predecessor, all guided by the same sense. The result will be the establishment of a condition of affairs such as we witness when the black ant summons forth its troop.

Indeed we frequently observe this more advanced manifestation also in the ashy kind. But since they are not in the habit of transporting dead insects or of bringing heavy burdens into the nest, they have less need of that elaborate call for aid which is of such essential value to the black ant. For the Ashy Camponotus feeds almost exclusively on fluid, each worker taking its individual fill and then returning alone to the nest. It is by the process of alternate gorgings and disgorgings that the necessary distribution of food is maintained. How can the summoning forth of a troop be an aid to such a domestic economy as this?

It is of value to the community in a simple way. The Ashy Camponotus does not call forth a troop because it requires to add to its strength; it does so because it has discovered a harvest which will be of value to others in the nest. I pour a spoonful of syrup into a watch-glass and place it where some workers are seeking for supplies. One of them soon discovers the treasure; it eagerly sips at the precious nectar until it has taken its fill. Then it goes hurriedly back to the nest, and after a minute again emerges with a party following in its train. These it brings with it on its backward journey until they all share in the supply.

But this summoning of the troop is developed to less perfection than in the case of the black ant. In the ashy kind it seems a more occasional occurrence, and the operation is less skilfully carried out. The discoverer may take a long time in collecting its party; I have known it to remain for ten minutes in the nest before issuing with the troop in rear. Often it seems unable to summon any to the scene. It may make frequent journeys between the syrup and the nest, no doubt at every entrance disgorging its contents, yet none of the others may accompany it back to join in the rich supply. There is certainly not the same readiness as in the case of the black ant; indeed, it seems as if the formicary of the ashy species contained only a moderate number of workers that were prepared to answer the discoverer's call.

Nor is there any great eagerness about their manner of exit, as is seen in the troop which the black ant summons forth. The black workers often come hurriedly out, then rush around the gate in advance of their leader, so ardent are they to be on the road. The ashy group emerges very quietly and slowly; it often waits apathetically around the entrance before it enters on its tedious march. It is also slower and more methodical in its manner of advance; indeed, in its deliberation it is like a funeral procession when compared with the greater display of energy which the black ant puts into its animated march. Nevertheless, in so far as keeping to the file, its progress seems as satisfactory as that of the black ant, for often the laggards fall some distance in the rear, yet they do not lose the road.

Just slightly improve the organisation of the ashy ant. Hasten up the activity of the individual workers, stimulate their enthusiasm, make the summoning of the party a more reliable performance, and the result will be that degree of efficiency such as the black ant is habitually accustomed to display. But the operation of the black ant is still far from perfect. We must remember how dependent is the party on its leader and how certain it is to fall into confusion if a separation from the leader should occur. Nevertheless we have seen certain facts in its organisation which suggest a progress to a higher stage. We have especially noticed how the discovering ant, when hurrying back for aid, will frequently meet another worker, on the way to which it will communicate the news. Furthermore, that the second worker, if the distance be not too great, will run back along the track of the discoverer and, finally, by its own efforts come on the treasure without the help of any further guide. This is a step towards the next stage of development. Advance this capacity to a further degree; improve the sense of individual recognition; intensify the wonderful faculty of smell; develop the power of retracing the track beyond the extent of a few inches to the full distance between the treasure and the nest; at the same time increase the enthusiasm and the numbers that pervade the issuing throng, and the result is that perfection in the communicating instinct which is ordinarily observed in the *Phidole* ants. There is no introduction of any new principle; it is merely by improving the machinery of the black ants that the high efficiency of the *Phidole* is reached. And they seem to have attained supreme perfection. For the discoverer just rushes into the nest; in an instant out comes the teeming legion which is standing in readiness within the gate, and away they break at the utmost speed, skilfully pursuing the scent of the discoverer whose services are no longer required.

Thus, what at first seems an act of considerable complexity can be reduced to very simple terms. When we commence to investigate the *Phidole* army we seem lost in a confusion of excited ants. We marvel at the manner in which they suddenly appear, the enthusiastic haste with which they hurry to the spot, their unerring and apparently unguided progress over an unknown road. It all seems a kind of miraculous occurrence, as though they moved by some supernatural sway. The fact is that we are lost in the perfection of the operation. The individual communication is so rapidly performed, the olfactory sense is so inconceivably acute, that our minds are blinded by its wonderful efficiency and we are unable to see the light. But these species under discussion have aided our vision. They have enabled us to understand the steps in the process and to elucidate the evolution of the communicating power.

Their lesson in communication can be summarised thus. It originated in one ant leading out another and maintaining connection by the very simple process of the second ant repeatedly touching the first. But this being a tedious mode of progression, and liable at any moment to result in a break, it was far too inefficient for the requirements of the ants and must soon have begun to improve. The follower then commenced to use its sense of smell, and, as a consequence, the tactile communication became less important, and, therefore, began to disappear. At the same time the leader ceased to render assistance, since the follower was now able to retain its position by the use of the more mobile sense. Additional workers now began to join in the procession, each one following on the one in front under the guidance of its olfactory sense. But still they remained dependent on their leader for conducting them along the right road. As the olfactory faculty continued further to improve, their reliance on a leader became proportionately less. Then the followers began to move of their own accord, provided that they were supplied with a line of scent. Their leader was still of some value to them; they frequently communicated with it to gain reassurance, and without it they still often went astray. One further advance in the olfactory sense brought them to the most developed state. They had now reached the condition of the *Phidole* ants; the few followers had grown into a multitudinous army which was quite independent of any leader and needed only a momentary contact with a worker to enable it to follow on the line of its scent.

Such I believe to be the origination and the mode of evolution of an instinct which, in its finished complexity, defies our attempts to understand. A tactile communication was its rudimentary beginning; its progress depended on successive refinements in the wonderful sense of smell.

Before leaving this study of the Ashy Camponotus there is another and very different class of observations which I must take the opportunity to describe. It relates to a strange type of insect-association which first came under my notice while investigating this species of ant. There is a genus, *Hypophrictis,* of Tineid moths, of which the larvæ live in the interior of flat cases constructed out of extraneous materials and silk. I often found these cases at the bases of the trees, and one kind I noticed had formed an association with these communities of *Camponotus* ants.

The cases constructed by the larvæ of this moth were in the form of flattened discs. Each was as thin as the conventional wafer, though its surfaces were separated so as to enclose a cavity which was limited by a sharp edge.

The disc was oval, with rounded ends, but its outline was sharply constricted in the middle owing to the presence of a kind of waist. A comparison will best describe the shape. Take an old-fashioned hour-glass ; lay it horizontally on the table and imagine it pressed out flat. At the same time broaden out its constricted waist, and the resulting outline will give some idea of the shape of this peculiar case. The average length of one of these discs was from one-half to three-quarters of an inch ; its greatest width was one-third of an inch, which diminished at the constricted portion to about one-quarter of an inch.

The case was composed of fine grains of sand closely interwoven with a network of silk. A texture was thus fashioned as flexible as paper, yet tough and durable and hard to tear. It combined the resistance of its stony structure with the soft and delicate pliability of silk. Its external surface was finely granular ; the minutest crystals of quartz and mica sparkled amidst the darker grains. Inside it was lined with an even layer of the most closely woven silk. Thus we see that the inmate distributes the materials as best suited for the purposes required. The external coating of siliceous granules is a barrier against the daily stress of weather and the physical misfortunes that may occur. The smooth internal layer of silk is a suitably soft and delicate material for contact with its own tender skin. It is a wonderfully secure and yet comfortable habitation, and, by the nature of its compact structure, will neither allow any damp to enter nor itself be disintegrated by the rains.

The surfaces of the disc can be separated at the edge except in the region of the waist. The larva has, therefore, two doors at its disposal, and can emerge from either end. At the waist, however, there is a permanent fastening ; there the surfaces are closely joined by connecting bands of silk.

The inmate looks like a segmented maggot, somewhat less than half-an-inch in length. It is pale yellow in colour, with some black about the head ; it has three pairs of legs on its anterior portion and sucker-like appendages at its tail. It can open and close its doors at will, opening them by thrusting itself between the surfaces, after which, on withdrawal, they close of themselves. But if too widely separated, then they must be closed by the larva; it does so by approximating the edges with its jaws and then securing them with a few threads of silk.

Its mode of progression is very peculiar, since its habitation must accompany it wherever it goes. It thrusts its anterior end out through a gate, clutches the ground with its three pairs of legs, and, still gripping the case with the suckers on its tail, pulls the structure a little way along. It is a very slow and laborious procedure, though, under favourable circumstances, the larva can expedite it in a rather remarkable way. If it happens to secure a good grip with its legs, it does not then just pull the case behind it, for by so doing it can advance no more than half-an-inch. It rather hoists up its tail so as to erect itself perpendicularly, after which it makes the case topple over forward so as to advance it the distance of its own length. By a repetition of this process of successive somersaults it considerably increases its ordinary speed.

What relationship can such lethargic discs bear to an active community of ants? At first, when I saw them near the ashy ant's nest, I thought that they just happened to be there by chance, and that there was nothing significant to note. But I was satisfied later that this occurrence was not casual, since I found them so repeatedly at the nest of the black ant, and almost always resting flat across the gate. They were most abundant in moist and secluded situations, especially along a well-wooded watercourse, where the formicaries were hidden in a close shade. For such is the natural resort of moths. They shun the sunlight where their enemies abound; by day their dull colours conceal them best in the gloomiest and most secluded haunts. There were a number of nests along this dingy channel at which the discs had taken up their abode. And the peculiar situation was specially selected, for I seldom came across them anywhere else except in the vicinity of a nest.

Let us, therefore, investigate why this should be. I took four from the aperture of one of the nests and transferred them to points six inches away. The next morning two of them were back at the aperture, the inmate of a third happened to have been dead, and the fourth had disappeared. In another nest I extracted three from their position and laid them on the ground an inch from the gate. In five minutes one of them had worked its way back, and had again wedged itself into the door. Later in the day the others moved in, and, when I visited them in the evening, they were all back in their place. Once they had fixed themselves in this desirable position they showed no inclination to leave it again; they anchored themselves with threads to neighbouring objects, and for weeks I observed them still lying across the aperture with their edges wedged into the circumference of the gate.

Thus it seems clear that the larvæ approach the nest, both because they specially desire the situation and because *they receive admission by the general consent of the* ants. And the reason is, no doubt, that they gain security by the occupation of such well-protected ground. For though their cases must shield them from many kinds of injury, yet they could be torn asunder by insectivorous birds eager for the soft morsel within. But they are free from all danger on that sacred ground which is under the guardianship of the soldier ants.

It is strange to see the association of these ferocious workers with the peaceful inmates of the earthen discs. Who would imagine that there could be any companionship between creatures so utterly distinct? The ants show them no opposition. They walk over the discs, frequently touch them with the tips of their antennæ, but never disturb them, nor pull them about, nor attempt to eject them from their position at the gate. If they found them undesirable they could easily remove them, since they habitually throw out all ordinary materials which happen to obstruct their entrance to the nest. Nor do the Tineids resent the strokings of the ants. Though naturally timid, and retreating into their shells on the slightest alarm, yet, even when walked upon by the soldiers, they pull themselves about; indeed, it seemed as if they received some kind of satisfaction from the attention and titillation given them by the ants. No doubt it gives them the sense of security, for when they feel the ants running over their shells they realise that they have entered a safe place.

But there is one more point in this strange association on which we have not yet touched. In these relations between creatures of different habits there is usually, I think, some mutual gain. The benefit to the larvæ is that they find protection; what is the advantage to the ants? The two discs, out of the four which returned to their positions, so applied themselves across the aperture as to partially close the hole. The three which returned, after being moved an inch away, so adjusted themselves that their edges overlapped one another and closed the opening as with a flat door. An aperture was left on either side through which the workers could enter and leave, but the gaping fissure which the black ants had made was changed into two lateral gates.

For this purpose I believe that they are of value to the ants. The black ant has to stand guard with a battalion of soldiers. They have to gather themselves around the yawning gateway or encircle it from inside with their ferocious heads. Anything which reduces the size of the aperture will clearly be of some service to them by diminishing the passage which they have to control. Sometimes the discs seem to force an entrance, but they must be much too large to enter far into the galleries, and could thus scarcely be of value for scavenging work. Their advantage, I believe, is in the reduction of the fissure; they change a rent into a constricted aperture, making it at times of such small dimensions as to resemble the gateway of the ashy ant.

And how well are they adapted for this unconscious work! They are thin and flat, they adjust themselves, and their edges can, if necessary, sufficiently overlap in order to suit the dimensions required. What could fulfil the purpose better than these natural living doors?

CHAPTER VI

THE BYRE-BUILDING ANTS—HERDING OF CATTLE

Distribution — Appearance — General Habits — Architecture of Byres—Employment of Larvæ—Worker on Special Task—Expenditure of Silk—Larvæ spin for General Good—Characters and Constituents of Byre—Lining of Byre—Seasonal Changes—Varieties of Cattle—Their Excretions—Care of Cattle—Value of Cattle—Driving of Cattle—Escape of Cattle—Byre a Breeding Chamber—Experiments on Byre

THERE is another ant, not unlike the *Camponotus*, which is very common and widespread on these plains, and is to be found, so far as I know, in every part of the peninsula of India. I met with innumerable colonies on the manjha. Their most favoured haunts were the branches of the tamarix, but they also climbed the thorny acacia and ascended the jungle grass.

This ant is known to science as the *Polyrhachis simplex*, Mayr. It is a species which merits particular attention, since it not only keeps cattle to supply its needs, but it also, in a very wonderful manner, constructs for them special byres.

It is a uniform, plain black ant, scarcely one quarter of an inch in length. In general build it is moderately robust, and, unlike the *Camponotus*, there are no separate castes; all the workers in the commune are of the same general appearance and size. Its oval head is cut sharp in front, where are fixed the dentated jaws; behind it is attached to the elongated thorax, which is armed with sharp spines. These form the most striking feature of the ant, and it is not easy to conjecture their use. There is a pair in front, short and thick, with their points directed out to either side. The two behind are large and prominent and their points are turned upward and erect. There is still a third pair on the waist or pedicle, which are slender, curved and angry-looking spears. Each is like a sickle on either side, and the two combined form a third of a circle, which embraces the abdomen in front. This last is a stout and heavy globe, with a few hairs at its anterior end. Otherwise, like the rest of the body, it is smooth, naked and black.

I will make some remarks on the general habits of the ant before I pass to the construction of the byres. It establishes its formicary at the base of a tree and sends its workers up the branches to gather in the precious juice. The ants have, therefore, learnt to adapt themselves to the requirements of an arboreal life. Like the *Camponotus*, they have an excellent sense of direction, and will not easily lose their way. Thus, they can wander far and wide amidst the foliage, and in their movements they are very clever in stepping from leaf to leaf. When alarmed they assume an attitude of expectation; they stand quite still, with body half erect and antennæ wide apart; then, if their apprehension of danger continues, they will, like certain arboreal beetles, let go their hold upon the foliage and drop down into the underlying scrub. Like other ants which haunt the vegetation, their safety is endangered in a storm. When the branches are violently shaken in the wind the workers take immediate fright; they hasten down to their subterranean nests or seek shelter in the interior of their byres.

Their sense of vision is moderately acute, and this aids them in their clamberings amongst the leaves; they are agitated by the odour of camphor and eucalyptus, hence they possess the faculty of smell. They have some power to communicate information; at least they can tell of the discovery of food. In one nest which I had under observation the ants seldom appeared outside. One day I found a worker on the prowl and gave it some syrup in a shallow glass. It sipped a little and then made off to the nest. Immediately afterwards a number emerged, and in a few minutes there were twenty round the glass. The individual worker must have informed its comrades of the valuable discovery outside.

I come now to the interesting feature of this ant—namely, the manner in which it guards its cattle within a specially constructed byre. The season is the early summer in the oppressive month of May. The hot and listless evenings have set in, and the cloud of pallid dust is in the sky. This is the time to explore the tamarix; there we are sure to find the ants employed at their wonderful sheds. We force our way through the dusty scrub and soon we come upon a populous colony busily engaged at work. They are running up and down the stem of a tamarix; in one place they have discovered a cluster of membracids, for the tamarix is a favourite plant on which these insects habitually feed. The ants apparently have lost no time in their efforts to make their find secure, for around them they are building a cylindrical wall so as to enclose them in a special shed.

Let us watch and see how the architecture is done. There are some sixteen or eighteen workers engaged; they have no doubt been specially detailed for the performance of this constructive work. Six of them are employed as carriers and builders. I see them hasten down the stem of the tamarix, search about the ground for suitable materials, and then again ascend the tree, each with its individual load. They work with industry and care, and they all seem very eager to get their burdens safely to the byre. One brings a piece of clay, another a fragment of straw, a third a twig of the tamarix, a fourth a downy plume of grass, and I see a fifth heavily laden with a little molluscan shell. This assortment of materials they have found below; they are the bricks with which the edifice is made. The ants fit them into the wall of the building; they do not pile them just haphazard, they act with circumspection and care. Each will often explore the whole of the chamber to find where its load may most suitably be placed. There are two other ants in addition to these, which I observe on the surface of the shed; I do not see them descend the stem or bring any materials to the wall. They just move about the surface, alter and adjust the fragments, and behave as though they are special supervisors to superintend and modify the details of the work. In the interior of the chamber are some more ants, which only occasionally appear outside. These are hidden from view; but I have little doubt that they are usefully employed in smoothening and adjusting the architecture from within. From time to time they come to the apertures and communicate with those outside, and in this way they co-operate with the outdoor workers in the architecture of this novel byre.

But the chief object of interest is supplied by the workers of the fourth group. At this shed there are two of them employed. Each holds in its jaws a full-grown larva, almost as large as itself. The ant has it firmly gripped by the back, about one-third of its length from the pointed end. Laden with this peculiar burden it moves slowly over the surface of the wall. It thrusts the larva out in front and makes it touch the various irregularities of the architecture as it lifts it from point to point. The larva at the same time gives out a filament of silk, which it anchors at every spot to which it is applied by the worker ant. In this way a tangle of silk is formed and the fragments of earth and straw and the plumes of grass are interlaced in a complex skein (see Plate IV.).

Such, therefore, are the principles of the architecture employed in the construction of these byres. Whatever materials happen to be available serve for the bricks and stones, but the mortar is supplied in a different way. The ants make use of their own larvæ to link the various fragments together in a network of silken threads.

This remarkable use which is made of the larvæ deserves a more detailed note. Sometimes there is only a single worker engaged at this peculiar task; more often I find two or three employed, and occasionally I see as many as eight at work on the same byre. The main part of the work is done in the interior; there the larvæ are carried about until they touch every possible point, and thus the whole of the inside wall becomes lined with an even layer.

But at times the larvæ are carried to the exterior, where they also spread their lines, though on the outside they never construct a layer ; they merely apply a few strengthening filaments sufficient to bind the parts. The byre is therefore rough on the exterior and on the inside is even and smooth. Moreover, the ants not only line the wall, but spread the silk over the stems that pass through the interior of the byre.

The manner in which the ant takes hold of its burden is another interesting little point. The worker grips the larva by the back, not far from the anterior end ; it presses the body to its chest, stands across it with legs astride, and with an antenna thrust out on either side it guides the delicate work. In this way the pointed head of the larva is made to project in front ; it is very flexible, and no doubt sensitive too, and it bends and turns to affix the thread wherever the worker may require. A noteworthy point about the operation is that the larva appears to appreciate the work. I do not mean to suggest that it knows anything of what it does. But all the time it continues to move its head, to bend and adjust itself, and to touch the various projections on the wall, as though it appreciated the requirements of its owner and the object for which it was carried about. Of course so lowly a creature can scarcely have any mentality at all. When taken from the worker it lies absolutely motionless, and it hangs passively in the ant's jaws when merely transported from place to place. But when it is employed on this particular work its silk-producing instincts are called forth. And these instincts are so perfectly adjusted to their purpose that the larva behaves, to all appearances, as though it realised the object involved.

The larva is a kind of living spinning-wheel carried hither and thither by the ant. While the worker thus employs its burden it thrusts its antennæ directly forward, one on either side of the larva's head. In this way it brings the sensitive points so as to approach the spots where the silk is attached. Thus the antennæ thoroughly explore the ground and the ant determines the suitability of the spots where it wishes the larva to affix the thread. The work is, therefore, done with every sign of precision and care. It looks at first sight a haphazard operation, as if the silk was just anchored anywhere, without any special method employed. But I have no doubt that each point is first tested by the ant before the larva touches its thread.

In addition, I think the antennæ serve as a kind of guide to the larva's work. They may be used to direct and control its movements, for as they lie one on either side of the flexible head they can, by their gentle touch or pressure, cause it to deflect to the right or left, just as a rider might turn the head of his mount by applying a rod at either side. The antennæ, by means of their preliminary exploration, and also perhaps by their guidance of the larva, thus control the application of the silk. How very efficiently they are able to do it a little observation disclosed. I kept some of these ants in a glass-covered box, and after some days they brought forth their larvæ and began to line the interior with silk. When they had finished I removed the layer, and though it was composed of millions of threads, yet so efficiently had the larvæ been guided at their work that all the filaments had been closely woven into a thin and perfectly uniform sheet.

The feeling of possession is strong in the worker when engaged in the laying of the silk. Nothing will induce it to release its larva; it clings to the living burden as though it were its own life. It will allow itself to be dismembered or torn in pieces without ever releasing its hold, and even after the worker has been crushed to death I have seen the active larva still fixed within its tight-closed jaws.

The ant thus engaged in guiding the larva is very attentive to its work. I have on a few occasions been able to remove it without causing it much alarm. I placed it on a branch a little distance from the shed, but it straightway returned to the chamber and recommenced its architectural work. But if its apprehension is at all aroused, then its first thought is for the safety of its charge; it will immediately cut short the larva's work and hurry it down to the nest.

I was a little surprised at one experiment which led to an unexpected result. I took the worker with its larva from a shed and transferred it to a different byre. I was prepared to see it immediately attacked and driven out of the alien shed—for the ants can recognise the members of their commune: they distinguish them from those of all other nests, and will usually, without hesitation, turn any strangers or intruders away. But this worker and its larva appeared to be accepted as soon as I introduced them into the shed. Certainly no sign of hostility was shown them; indeed in a few minutes the stranger set to work; it brought its larva to the incompleted wall, and there joined the other industrious workers in adding to the structure of this alien byre.

The ant which employs the larva to spin is, I think, specially detailed for this work. The larva is not taken by just any ant; it is the charge of this particular one. For, with some difficulty, I extracted the larva from an ant, in spite of the struggle on the part of the owner not to let go its hold. I then returned the larva to the byre. But the worker which found it refused to employ it, and just carried it away to the nest. I repeated the experiment at another byre, and again replaced the larva inside. A worker found it, took it in its jaws, but showed no inclination to attempt to spin. It merely carried off the larva to a more sheltered corner of the byre. A second worker then appeared; it too picked up the larva, but only to transfer it to a still more secluded spot. There it was allowed to lie. None of the other workers employed on the byre made any attempt to use the larva to spin. Thus I conclude that a special worker assumes this particular task.

The silk emerges as a slender filament extremely delicate and fine. The larva first emits it as a sticky fluid, which rapidly hardens into a thread; but it must retain its adhesive qualities for a moment in order to permit its fixation at each touch. The continuous expenditure of so much silk must necessarily exhaust the larva's supply. One is, no doubt, employed till the spinning-wheel ceases, and then another is brought into its place. I have sometimes opened one of these byres and found a larva lying in the interior unattended by any ant. This is an unusual occurrence, since the worker as a rule clings to its burden and will die rather than relax its hold. I think that these must have been exhausted larvæ whose round of duty had been done, and were therefore allowed to lie for a little while neglected in the interior of the byre. So also I have no doubt that, when one larva has expended its supply of silk, another is carried up from the nest in order to continue where it left off. For, as we watch the organisation of these ants, we shall at intervals see workers emerge from the nest and transport their larvæ up to the byre, and other workers similarly laden descend with their burdens from the byre to the nest.

This is certainly a most instructive process, and one of the most remarkable in the multifarious activities of ants. The production of the silk is very ordinary in itself; it is manufactured by many of the humble creatures, and the larvæ of the ants originally produced it in order to surround themselves in a pupal case. Other creatures with equal efficiency construct their silken skeins. The larvæ of some moths weave an open tangle and shelter themselves in the maze of threads, then later they spin a close-worked tissue to serve them as a strong cocoon. The spiders fashion their silken snares in order to secure their insect prey, and construct their firm soft-lined sacs to shelter their eggs and young. But in the case of the ants we find a different principle involved. For they are not following just a customary instinct; they have rather seized on an ordinary function which they apply in an extraordinary way. They have taken the machinery from the spinning of cocoons and they use it for the construction of their byres. Thus, the larvæ spin not only for themselves, but as a part of the general good. And such is the underlying principle of the commune that each should labour not for itself but for the common benefit of all. In every community this principle exists, and amongst the workers it is often carried to a refined and elaborate degree. But the *Polyrhachis* has advanced it a still further step, for it does not confine the principle to the workers, it brings its larvæ into the fundamental scheme. The ants have long since discovered the architectural value of their offspring's silk, and they employ their larvæ to weave and build in order that they may secure their cattle in the byres.

Now that we understand the method of construction let us look to the completed shed (see Plate IV.). The chamber is often of an oval shape, and then looks something like a large cocoon wrapped around the tamarix stem. But they vary enormously in appearance and size. In the early summer most of them are small. An average byre might be four inches in length and about an inch or more in width. Its walls are composed of fragments of grass, short sticks and little pieces of earth, and also, if fortune happens to provide, a quantity of plumed seeds. Apertures are left in the wall of the chamber to give entrance and exit to the ants. They are wide enough to fulfil this purpose, but too narrow to allow the cattle to escape. In the small and oval pattern of chamber there is often only a single gate; more usually there is an entrance at either end, and in the large capacious type of edifice there will also be additional openings at the sides.

At other times the byre is constructed so as to assume a rather different shape. It is built in the form of an elongated tunnel wrapped close around the central stem. Some are a foot or more in length, with numerous entrance doors. Sometimes they are even more extensive: a tunnel may commence at the nest below and radiate for a distance of many feet over a number of branches on the tree.

As the season advances the byres enlarge by the continual addition of materials to the wall. By June they have grown into capacious sheds, and are often divided into minor compartments by a number of partitions within. We sometimes meet with special varieties, each of a particular interest in itself. A byre, for example, of the globular pattern may sometimes be built round a main stem, where it divides into a cluster of twigs. This results in a multiple edifice divided into many parts, for the silken lining not only covers the wall, but is also carried round every twig that passes through the interior of the byre. As a consequence of this the interior becomes complicated, and a number of separate compartments are formed.

An exquisite little shed may occasionally be found composed exclusively of plumed seeds: there are no twigs, no grass, nothing but the downy plumes cemented together with silk. Such a structure, of course, can only appear when the grasses are in suitable bloom. It is an example of the very neatest architecture, with warm, soft and delicate walls, as though woven of a fine-spun wool.

I met with another pretty example of architecture belonging to the tunnel type. It was built, not round the stem of the tamarix, but in the concavity of a blade of grass. It was a long and narrow tunnel rather more than a foot in length. Yet it was so slender that its diameter was only that of a pencil, and it was carefully moulded throughout its whole length into the concave surface of the blade.

A few byres may occasionally be found in which only the most scanty supply of materials enters into the construction of their walls. This must be the result of the scarcity of débris in the vicinity of where the chambers are built. But the ants, apparently, persist in their work in spite of the absence of bricks. They spread abroad a superabundance of silk and thus build a fragile shed. It is a delicate structure, composed of a thin and translucent sheet, with an occasional twig or a plumed seed interwoven here and there.

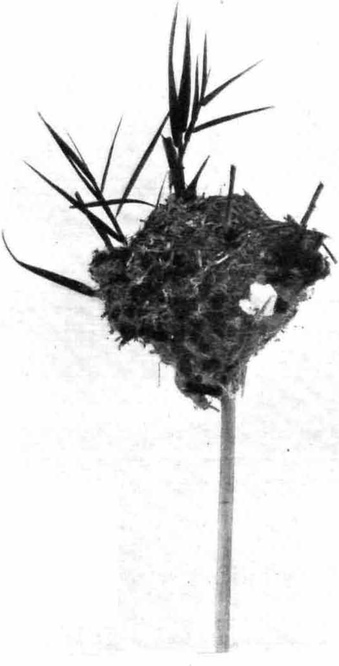


PLATE IV.—BYRE OF THE *Polyrhachis simplex.*

It is, therefore, clear that whatever is convenient will serve the ants for the architecture of their byres. Thus, the pieces of the tamarix are the chief constituent, but anything available, especially if it is soft, will be woven into the structure of the wall. I gave special attention to one group of workers which were busily engaged at the byre. I supplied them with a number of pieces of wool cut into suitable lengths. The pieces were of different colours, some white, some red, some blue. This was new material for the ants ; the plumed seeds were the nearest approach that they could ever have found in the dusty scrub. Here was a perfect building material and placed ready to hand. The ants clearly appreciated the gift ; they very quickly discovered the wool and availed themselves of the rich supply. Without any attention or respect to colour they carried off the numerous fragments, and, together with the tiny twigs of the tamarix, wove them into the structure of their byre. There could never have been a chamber spun like this before. Its walls were studded with the national tints of red and white and blue. Thus will the ants seek out what is suitable and soft when employed at the architecture of their walls.

I will make some remarks on the silken lining before I leave these wonderful byres. The filament of silk emitted by the larva is an infinitely slender thread. It cannot be seen with the unaided eye ; it is only from the successive movements of the larva that we know how the filaments are being laid. When many are superimposed a tangle results, and this becomes evident as a fine sheet ; but in order to detect the individual threads we must employ a microscopic aid. I place a portion of the sheet beneath the microscope and learn something of the fragile work. It is a texture of closely woven silk. We see a veritable tangle of threads, each clear and sharp and beautifully fine, some curved or sinuous, others straight or branched, and all woven into a complex labyrinth of delicate intercrossing lines. We marvel not alone at the number of the filaments, but at the rare complexity of the transparent web in which they are so elegantly intertwined.

The larva, I suppose, when generating the silk, emits a single thread which it draws across from point to point. And when we contemplate the final texture we cannot but wonder at the labour involved, for the larvæ must interweave many thousands of these threads in order to complete so inextricable a tangle composed of such a multitude of single lines.

At all times during the summer months the ants attend to the construction of their byres. They are fully developed by June and July, when many are as large as a man's fist, or like tunnels extend along the branches of the tree. In October the byres become fewer in number, and by the end of the rains many are empty and some are falling to decay. The ants are then becoming sluggish, for the winter cold is setting in. But they will still toil if opportunity offers. I have seen them in the first week of November carefully sheltering a group of coccids and constructing around them a byre.

I now pass to consider the cattle for which the ants so laboriously toil. Sometimes I find little coccids in the sheds. These are flattened, scale-like insects; they are not the customary cattle of the ants, and are usually found, at least on this manjha, in the byres on the jungle grass. At other times I meet with a cluster of mealy-bugs: it is a white and powdery mass of eggs, together with the adults and young. The ants, indeed, may sometimes intermingle their cattle, for I have found a mixed herd of membracids and mealy-bugs stabled in the same byre. They also tend on *Aphides*, and confine them in the usual way. These cattle collect in groups upon the grass, usually in the hollow of the blade. The ants build a roof over them, fixing it to either side of the groove. In this way the blade is converted into a tunnel, and the *Aphides* are safely housed. But incomparably the most important of the cattle of this ant is a species of membracid bug. It may not be so in other places, but here, where the tamarix grows in profusion, these bugs also abound. It is certainly from them that the ants receive the chief portion of their liquid food.

Different species of the membracids receive attention from the worker ants. A common one is the *Oxyrhachis tarandus*, and the other kinds closely resemble it in general appearance and shape. They are little stiff brown insects about one quarter of an inch in length. They are covered with a pair of well-developed wings, which meet above in the middle line, and like the slopes of a roof shelve away on either side. From the hard and jagged head project three radiating spines. Of these a pair are short and stout and stand out horizontally on either side; the third is long and curved and pointed, and is prolonged down the middle of the back until it reaches the apex of the wings. The whole insect, its triangular body and projecting spines, bears a somewhat close resemblance to a thorny excrescence on a stem. And no doubt it was in order to gain protection through such resemblance that this peculiar structure was originally evolved.

These membracids live on the exposed plant; they usually remain perfectly motionless, with their beaks plunged into the tissue of the stem. Sometimes they congregate in little groups, and, when disturbed, will either quickly run along the stem, or make a swift and sudden leap to some other part of the tree. They lay their eggs in the substance of the stem, and the different species prefer different plants. The kind I have mentioned seems to favour the acacia, but there are other forms which haunt the tamarix, and no doubt each has its special tree.

It is important to mention the young, for they are the most beneficial to the ants. They are soft, triangular-shaped creatures, usually coloured some shade of green, and are divided into many narrow segments by a series of transverse clefts. The base of the triangle is the blunt head, with the dark eyes on either side; the apex is the pointed tip of the abdomen, which projects like a flexible tail.

Now let us examine the excretion of these bugs, which makes them so beloved by the ants. The young give forth the chief supply. With the point of a fine needle I gently press one on the middle of its soft back. Immediately its flexible tail curves upward; it turns sharply over the middle of the body, and from the tip there shoots out a telescopic tube pointed with a spot of red. From this coloured tip we may see exude a tiny limpid drop. This is the fluid which the ants love, and the touch, the gentle pressure, on the insect's back has served to stimulate the liquid flow.

The adults too excrete a fluid, but the act is not so easily observed. They rest with their beaks plunged deep into the stem, and at intervals the liquid oozes forth. It appears in tiny droplets that escape from the tip of the abdomen; they are not easy to observe, since they are hidden away from view beneath the points of the angulated wings. The ants wait in readiness and sip the fluid as soon as it appears. They must sometimes imbibe a considerable amount, for their bellies may be seen to grow oval and tense, and expand from the pressure within.

This yielding of the fluid on the part of the membracids is of course a voluntary act. The *Aphides* behave in a similar way when under the influence of other kinds of ants. But it is said that the *Aphides* are reluctant to excrete except under the influence of the titillation of the ant; they would seem, therefore, to act for the advantage of the ant, and Darwin considered this as the best-known instance of one species performing an act for the exclusive benefit of another, and quite different, species. But the membracids freely give forth their fluid when unattended by the ants. They may be excited by the presence of their keepers and the gentle strokes of the antennæ may stimulate the limpid flow. But they certainly show no reluctance to excrete when the ants do not happen to be near. For I watched a membracid carefully through a lens while it rested alone on a stem, and I saw it turn up its pointed abdomen and eject five successive droplets, each with such force as to shoot it half-an-inch away. I do not consider that the membracids act in any way for the special advantage of the ants. They must necessarily get rid of the surplus fluid which they have sucked out of the tissues of the tree. They excrete it as waste in the ordinary way, and the ants just patiently wait for it to appear, and swallow it down as food.

The ants guard these cattle with every attention and care. They crowd around them on the open stem and sip up the precious fluid at all hours of the day and night. Even a few cattle are very valuable and a source of continual supply, for each young membracid, at intervals of about a minute, exudes its drop of juice and thus acts as a living fountain to bring forth vegetable fluid to the ants.

They receive still more protection when they are taken nto the interior of the byre. A few workers remain always with them ; they stroke and nurse and guard them and sip up the fluid when it appears. Should danger appear in the vicinity of the chamber these ants rush out to give battle with the foe. They will fall upon an enemy and drive it off ; they will fight as vigorously for the cattle in the chamber as they will for the offspring in their own nest. The ants have so constructed the chamber that the cattle are literally locked into the byre. The adults certainly are closely imprisoned, since they cannot pass through the narrow gates. And I have no doubt that they are confined against their will. For, at different times, I have opened a byre and watched the cattle run out along the branch. They appeared to be glad to effect their escape, and they often hastened it by a sudden leap or a swift flight to a neighbouring tree.

I have visited the byre at different times of the night and have always found some workers within. The cattle are never left to themselves ; workers come and go, but some always remain to watch over the cattle and continue on duty in the interior of the byre. Certain ants retire to their nests for the night, but not a species with habits like these which demand the fulfilment of an important charge.

Membracids of all sizes and all ages, both the tiny young and the full-grown adults, may be locked into the same byre. As a rule it is only a few workers that stay with them; otherwise the byre is usually empty, except perhaps for one or two larvæ which happen to be employed at the architecture of the wall. But occasionally I have met with other forms which for some reason happened to be inside. Once or twice I have found there the sexual ant, which must have ascended from the main nest, and at certain times the larvæ may be brought there for refuge, quite independently of their capacity to spin.

There is no doubt that these cattle are of prime importance to the ants, and from the juice of a single membracid a number of workers can gain support. For this reason the ants will undertake such labour and will toil for weeks at the construction of a shed merely to confine a few adult membracids or a little group of young. Sometimes a byre will be built for a single inmate, and this one alone will attract half-a-dozen ants. That one membracid can support so many is due to the fact that it is not a dependent, which renders just an occasional supply; it gives forth an intermittent stream of fluid, imbibing it at one end from the tissues of the tamarix and ejecting it at the other into the bellies of the ants.

The ants, though they pay such attention to their cattle, do not specially regard them as their own. It is not like the esteem which they have for their larvæ, or for their comrades in the same nest. For these they recognise as part of their family, and differentiate them from all others elsewhere. But the cattle are the property of those which find them, and one will accept another's herd. For I exchanged the cattle in different byres, and each herd was accepted by its new owners, and immediately began to excrete.

A point which I have not yet mentioned is the manner in which the cattle are brought into the byre. Often the ants must just find them on the stem and build a chamber round them while they feed. But at other times I think they must search the foliage, and, on meeting a membracid, drive it to the byre. I have sometimes watched a single worker, or more occasionally a pair of ants, urging a membracid up the stem. From behind they gently apply their antennæ, and thus seem to coax it on. Their method appears to be patient persuasion rather than any show of force. Slowly they drive the membracid up the stem, and should it wander away on some lateral branch they work round so as to cut it off. They thus confine it to the true road and continue to urge it on until it joins the herd in the vicinity of the byre.

Thus the ants often add to their stock by driving in cattle from the foliage of the tree. I have seen them also transporting the young, but these they lifted gently up and carried to the chamber in their jaws. It is only the adults which I have observed thus driven, and it certainly appeared to me strange that these ants, which can carry their larvæ with such ease and care, should slowly drive their cattle along instead of transporting them bodily to the byre.

Their capacity to guard and drive their cattle was displayed in another way. A byre was damaged by a strong wind and a small rent was torn in its side. Here was an opportunity for the cattle to escape, and the two membracids contained within came out through the little breach. They were both adults, and immediately they began to make their way down along the supporting stem. But the ants refused to allow this; they were determined that their cattle should not escape. Four workers set out from the byre for the purpose of rescuing the pair. They hurried round to the far side of the stray-aways; they stroked and urged them with their antennæ, and even sometimes bit at them with their jaws. In this way they checked the escape of the cattle, then compelled them to turn about, and, by continuing the same persuasive efforts, they drove them back again into the byre. Thus they recovered the wandering herd. They then carefully watched the breach so as to prevent any further attempt to escape, and later in the day they brought up a larva, which sealed down the broken wall.

The cattle develop in the usual way while imprisoned in the little shed. They obtain a sufficiency of liquid food from the stem round which the structure is built. The young grow into adults, and at certain stages they cast off their skins, which the ants carefully throw out of the byre. They are as heedful of the purity of these little sheds as they are of their own nests. But the membracids not only grow, they also mate within the byre. It serves them, therefore, as a kind of breeding chamber in which they can pursue the instincts of sex without molestation from the outside. And what a wonderful little structure for nidification this is. Consider its extraordinary mode of architecture, the nature of its enclosed inmates, and the original purpose for which it was made, and what other edifice can compare with it in the whole realm of insect life?

I come now to some simple experiments which I made to indicate the care and attention which the ants give to their cattle and the byres. I cut a small window in the side of a shed, and separated the edges of the rent. The workers within were immediately aroused, and came hurrying out through the breach. A period of excitement followed, but this soon subsided and the ants proceeded to examine the rent. The workers collected round the torn edge, and some of them appeared to make an effort to draw together the margins of the hole. Others went off to find fragments for masonry, and a few descended the main stem in order to bring up larvæ from the nest. In a short time the materials appeared. The workers then built them into the breach and the larvæ secured them with silken bonds.

I placed an obstruction over the gate—it was only a little twig of the tamarix, but sufficient to block the entrance to the byre. But the ants refused to allow it to remain; the passage, though narrow, must be open and free. A worker very soon dragged away the obstruction and threw it down to the ground.

The ants attend to the interior of their sheds and allow no refuse to accumulate within. I pushed some fragments of camphor through a doorway, so that they fell into the cavity of the byre. As the gate was narrow I had to squeeze in the camphor and the ants could not pull it out again. A wild commotion followed, and many of the ants came rushing through the gate to examine the exterior of the byre. The agitation and confusion was very apparent, for not only do the ants object to the camphor but the cattle dislike it even still more, and many of them came to the doors of the shed and tried to force their way out. They failed, however, to effect this, as they were quickly driven back again into the interior by some of the ants assembled outside. Soon the workers began to realise their difficulties, having found that by merely pulling at the camphor they could not force it through the narrow gate. They then set about enlarging the door. One dragged aside the fragments of grass, others with their heads pushed back the silken wall, but the work was very tedious and slow, and it took them a long time to tear down the bricks which they had so laboriously built up. At length, having sufficiently enlarged the gate and prevented the herd from breaking away, a few brave spirits seized hold of the camphor and dragged the fragments out of the byre. It was the work of a minute to transport them to the branches, where they dropped the nauseous substance to the ground.

They will deal with an enemy in the same way should it happen to enter the shed. I found a weevil on the foliage and thrust it through the gate. But it did not remain long within. In a few minutes the ants were around it and were dragging it to the outside again. Thus the byre receives the same care and attention as is given to the nest itself.

What a perfect and intimate association is this which links the cattle and the ants! Each, no doubt, makes for the other's good, and both benefit by the social bond: the supply of food is beneficial to the ants; the removal of the excretion is an advantage to the herd. We witness this dependence of creature upon creature in every path of life, though more often the relationship is to the injury of one; only rarely to the benefit of both. There are the birds which live in the company of cattle to capture the insects driven from the grass; there are the beetles which invade the formicaries of the ants, I take it to scavenge and cleanse; there is the motley host of insects and birds which attach themselves to the society of men; there are the parasites which lodge in all animal bodies, often to the destruction of their hosts; there are the deadly microbes which lie dormant in the tissues waiting until the vital powers decline. There is a just and inexorable balance which weighs life against life. All beings are inter-dependent; all are but threads in the complex skein which unites all living things. Here and there we note a thread, but the vast intricacy is hidden from us, and it is only the apparent links we see. It is one of Nature's simplest bonds that unites the cattle with the ants. And it must be a firm and long-standing link to have slowly evolved the useful instinct of constructing substantial byres.

CHAPTER VII

THE BYRE-BUILDING ANTS—GENERAL HABITS

Nature of Food—Feeding one Another—Characters of Formicary—Mode of Excavation—Posting of Sentinels—Interior Economy of Nest—Cause and Manner of Migration—Seeking Refuge in Byres—Constructing Arboreal Nests—Appropriation of other Nests—Final Survey of Work—The Law of the Commune

I NOW leave the herd and its stable and pass to some more general features of the nest.

Although these ants live mainly on their cattle, yet this is not their sole supply of food. I give them a few drops of syrup on a leaf, and they eagerly sip it up. They are fond of solutions of all sweet things, but they need the substance in the liquid state, for they despised the dry grains of sugar which I gave them, and immediately cast them aside. A continuous craving for moisture permeates their whole life. They will sip up liquids of every kind; scarcely anything seems to come amiss. They will bite at the tender shoots of the plant, and in this way extract a little sap. They will gather round the injury on a broken stem or feed at a laceration of the bark. White resinous accumulations may occur on the tamarix; they are tiny nodules of a viscid substance which have exuded from the tissues of the plant. Round these a few ants will frequently collect, in order to lick at the sticky lumps. The excretions of their cattle, the juices of crushed insects, the rain, the dew, animal and vegetable fluids, even the sweat, the blood, the sputum, will be eagerly licked up. They will suck the body juices from their own crushed comrades, even from their mangled queens. I have seen them sip at a solution of bitter quinine, a substance so offensive to their taste. It is, therefore, for fluid that they toil and search ; they do not hunt about for prey, but if they happen to find an insect they will not disdain to drag it to the nest. I have seen them take in a butterfly and a locust, and they eagerly carried off some termites, which appear to be the unfortunate prey of all. At another time I observed them dismember a cricket, the pieces of which they removed to their nest. But it may have been only for the sake of the fluid, without any intention of devouring the flesh. Nevertheless, I think that they will at times actually eat the tissues themselves, and I have seen them like a swarm of carnivorous ants gathered round a dead bird.

These ants feed one another ; the workers that receive the supply from the cattle convey a share to others in the nest. I observed the process in the following way, by which the details could be easily seen. These ants at certain seasons of the year construct arboreal nests. I will later describe their general structure ; it is sufficient to say that they are attached to the branches and look like enormous byres. I removed a nest from its place upon a tree and fixed it in another situation where there were no cattle to be found. Thus the ants were totally deprived of their usual supply of juice. After two days I felt sure that they needed fluid, so I gave them a little syrup in a glass. A worker soon came by chance upon the store, and in a few minutes a crowd of thirsty ants had collected round the sweet supply. They sipped deep of the grateful nectar, and each ant, having drunk to satisfaction, made its way straight back again to the nest.

As the wall of the nest happened to be very thin, being composed in one place almost exclusively of silk, I was able to see indistinctly into the interior and observe what actually occurred. I noticed that, after the ants had drunk and had returned again to the nest, it was usual to see one of them regurgitate its fluid to feed another inside. The ant about to receive the nourishment brought its mouth-parts to those of the ant that gave it, and in this way a quiet transfer of food passed naturally between the two. It seems, therefore, to be very probable that certain ants are specially engaged in the conveyance of liquid food. They collect it wherever it happens to be found and pass it on to other workers employed at some different task. And this must surely be an excellent arrangement ; it permits each to fulfil its particular avocation without all having to hunt about for food.

This same habit is developed to an extreme degree in the honey-ant of Mexico, which is really little else than a living receptacle for food. There is nothing approaching this extreme in the case of the *Polyrhachis* of the byres, though their abdomens are rather globular in shape and sometimes become so distended with fluid that the white lines between the segments are clearly seen. The division of labour in the Mexican ant has progressed to its furthest stage, since certain individuals are mere animated honey-pots to receive and redistribute the food. Here the ants also divide their labour, though in a much less elaborate degree. Certain workers act as suppliers, others as recipients of the food. Many of those employed on architecture look for sustenance to what these foragers eject. In the same way also must the males and females be fed, since they do not tend the cattle and rarely leave the nest.

It certainly seems a greedy sight to witness a crowd of worker ants assembled round their cattle on the stem. All are eagerly working their antennæ and drinking with avidity every droplet that appears. They wait and watch and fall on the fluid, and appear like an indolent party of gluttons when compared with those that are toiling at the byre. But this is not so. Undoubtedly they are hungry and eager for food, and imbibe whatever they find. But it is not altogether a selfish avarice ; they do not seek the fluid only for themselves ; it is a greed for the general good.

The structure and character of the main formicary is a point on which I have not yet touched. It consists of an excavation amongst the roots of the tamarix at the base of the tree on which the byres are placed. Unlike the nests of most kinds of ants, the aperture is not flush with the surface of the ground ; it is rather built up for a few inches as a cylindrical turret attached to the stem. The whole nest is so well concealed and so hidden away in the substance of the scrub that it is necessary to follow an ant into the undergrowth in order to locate its actual site.

It is composed of a system of galleries and chambers with their stores of larvæ and eggs. The turret of the nest is a vertical cylinder ; it is built of twigs and particles of earth all woven with silk in the same wonderful manner as that employed in the architecture of the byres. The interior is also lined with silk generated in the same way ; it is prolonged into every cavity and tunnel, and a similar layer is wrapped around the roots whenever they happen to project within.

The nests are sometimes very populous ; a single formicary may house hundreds of workers, which, when disturbed, make a fierce attack and drive their jaws into the skin. In the chambers are the precious offspring—eggs and larvæ and pupæ ; all sizes and all ages lie clustered in the same mass. Occasionally I have found membracids in the interior, but this is a rare event ; as a rule there is no trace of cattle in any part of the nest.

The excavation is conducted in the usual way, the ants carrying up their burdens and pitching them on a pile of earth outside.

It is also to be observed that the group of excavators emerge again with the next load after an unexpectedly short space of time. They could never have reached the bottom of the galleries, which often run eight inches into the soil, and have there collected fresh débris from the wall, conveying it again to the outside of the nest. It is not possible to see what occurs within the formicary, but I have thought it probable that different parties are engaged, each at its particular work ; that there is one group in the interior tearing down the earth and placing it in suitable loads, that there is another group which act as transporters of the débris to convey it to the refuse pile outside.

When the nest is complete, the turret built, and the workers are engaged at their various tasks, it may be noticed that the ants are usually in the habit of placing a guard at their entrance door. If we examine the top of the turret we will often see a head concealed within, and the tips of a pair of quivering antennæ just appearing above the open gate. This is the head of the sentry performing its own special work. It fulfils the duty with attention and care. Sometimes, like a stopper in the mouth of a bottle, its head is thrust firmly into the gate, and in this efficient manner it closely bars the way. The sentinel challenges every worker before it permits it to enter the nest. No stranger can possibly intrude nor any enemy dare invade the sacred galleries that lie beneath. And when this sentinel ends its duty and comes out upon the tree there is another ready to advance from within and occupy the vacated post.

I brought one of these nests back to my room in order to more closely observe the ants. One day a migrant swarm emerged and settled itself in a glass-covered box. The ants appeared satisfied with these new quarters and prepared to establish a nest. The box was sixty cubic inches in capacity, and never before could the ants have enjoyed so voluminous a chamber as this. Yet they lost no time in commencing to work. They brought with them a number of larvæ; these they employed to line the chamber with silk, and they even covered the smooth surface of the glass with a semi-transparent layer. Here, indeed, was a favourable opportunity to witness the delicacy of their mode of workmanship and the intricacy of the close network of lines.

But it also supplied a further advantage, for this was the time to learn something of the internal economy of the subterranean nest. From time to time I had a glimpse into the interior and gathered a few scattered facts.

The main body of the workers remains within the nest collected round the larvæ and the eggs. These latter are placed in no definite arrangement ; they are merely strewn and mixed together anywhere on the floor of the box. The workers are very attentive to the offspring, and are specially regardful of the physical conditions to which they happen to be exposed. The temperature must be suitable for their development or else the ants will move them elsewhere. I warmed the air at one end of the box, with the result that the ants seized hold of the larvæ and transferred them to a cooler spot. The nest must be perfectly dry, otherwise it will not satisfy the ants. I moistened one corner of the interior where the larvæ were collected into a heap. But the ants would not leave them on the damp floor ; they conveyed them to another and drier corner on the opposite side of the box. Moisture, I have no doubt, is very unpleasant to them. Hence, as I will later describe, they are accustomed to migrate after heavy showers and to establish themselves in the branches of the trees. Of course these ants, like all other species, insist on having darkness in their nest. In one place I allowed the light to shine through, but the ants very quickly moved from that area and carried their eggs and larvæ elsewhere.

I observed that they were excellent sanitarians and kept their abode scrupulously clean. They always gathered up the silken cases left after the young had emerged, and collected them in a special heap at one corner of the box. This was a sanitary dump on which they piled the refuse of the nest. I broke up the dump and scattered the pupal cases through the box ; but the ants soon swept the floor and restored the original pile. I introduced some pebbles and some fragments of straw, which of course were nothing but refuse to the ants. And they treated it as such ; they soon gathered up this extraneous matter and pitched it on to the common heap. I gave them a wounded ant of another species, such as they themselves occasionally drag in through the gate. They attacked it, dismembered it, sucked it of its body fluids, and then cast the limbs and dried integuments on to the sanitary dump. They had selected a corner remote from their eggs for the accumulation of this rejected stuff. And I have no doubt designedly so; for some eggs, which I transferred to the vicinity of the heap, were immediately picked up and carried back to the other side of the box.

During winter they remain permanently within the nest. It is only on rare occasions that a worker appears outside. They seem to live in a somewhat somnolent state. When disturbed they are moderately active, but otherwise, they just cling passively to the walls. If the chamber happens to become unsuitable, then the workers will desert the nest. I introduced a small fragment of camphor into the box. This caused great commotion. At first the ants tried to eject it, but they could not get it through the gate. And, of course, it was much too foul-smelling a substance to be merely thrown on the sanitary heap. One plan alone remained for the ants; they emigrated from the nest in a body and occupied another chamber elsewhere. It is the same course that they adopt under natural conditions when their home is inundated in a flood.

I have frequently referred to this subject of migration, so let us observe what actually occurs. It is commonly seen in the first summer months, and its cause must obviously be this. The chambers are full of eggs and larvæ; they exist in every stage of development, and fresh broods of workers are continually being born to the nest. The strength of the community rapidly grows. A time comes when the formicary cannot house its numbers and emigration must necessarily occur. This accounts for the remarkable migrations that take place at intervals throughout the summer months. They are the efforts of the commune to relieve congestion which must result from the over-population of the nest.

The manner of migration is very interesting to observe. I have described the method adopted by the *Camponotus*, in which an explorer first examines the ground, and having found a site leads others to the place. Their manner of migration is to follow the explorer in a group. The *Polyrhachis* adopts a different plan. Its method more resembles that of the *Myrmecocystus*, since certain workers assume the duty of extracting the excess population from the nest and carrying them away in their jaws.

Let us halt for a moment near one of the nests and witness the migrant flow. I happen to meet one on an evening in the rains when the air is beginning to cool. The sinking orb is almost level with the earth, and heaps of visible vapour are massed in the western sky. The sun, though lost to view behind the clouds, yet sheds its divergent beams around. At their edges is a fringe of gold, around them are spaces of the palest green, and above them is a sea of blue. Low on the horizon is a rosy gleam, while the river, rippling beneath the coloured rays, glitters with innumerable lights.

But we turn from the glory of the heavens and look to the little ants. A migrant stream is on the move. It is passing from nest to nest. I see a worker emerge from the top of its turret holding one of its fellows in its jaws. It grasps its burden by the narrow waist and rapidly hurries away. The one thus carried rests motionless and inert. It bends in its head close to its abdomen, turns down its long antennæ, curls its legs into a tight bunch, and succeeds, to a somewhat surprising degree, in gathering itself into a compact shape. Thus it willingly resigns itself to this mode of transport; indeed it lends what assistance it can. Onward it is carried into the undergrowth and is soon lost to view in the scrub. A second then appears; it is burdened in the same way. Others follow, and a regular procession goes scrambling through the verdure, each with a fellow in its jaws. A miniature forest lies before them and they must face innumerable difficulties and obstructions as they journey through the leaves and stems. It is remarkable how they manage to maintain their course. They do not follow on one another's track, and scent can scarcely be their guide. They are for ever ascending broken stems that come to a sudden end, or they find themselves on branches that bend away so as to lead them from the true course. But the industrious migrants never fail. They may be deflected again and again, but they seem to recognise the nature of the pitfalls, and they turn back on to the old line. The impulse that keeps them to the same course is that strange mysterious guide. Let us call it the sense of direction, though that is little more than a name. Like the *Camponotus* they seem to feel the direction they should take by some sense inconceivable to us. Nevertheless it guides them truly and well, and brings them to the final goal. They surmount innumerable difficulties and obstructions, but they make their way through the pathless jungle and lodge their living burdens in the nest.

These migrations take place at other times, with a different end in view. The first burst of the monsoon arrives; the thunder breaks, and the drops of welcome moisture fall heavily on the dusty ground. They percolate quickly through the parched soil, and the nest becomes unpleasantly damp. Still the torrent continues; the floods rise, and the moisture at last will penetrate the galleries established at the foot of the tree. The ants must now escape from their habitation and move to some drier abode. Other kinds of ants in this season of flood will suffer tremendous loss; in places millions must surely be destroyed, since the earth may for miles be a uniform swamp. But the *Polyrhachis* has an excellent resource at hand. It ascends from the ground into the vegetation and secures itself in the interior of the byres. The workers evacuate all their treasures from the galleries of the subterranean nest. Some carry their own companions; others bear the larvæ; still others the pupæ and eggs. Thus laden, they form a living stream, which flows up the branches of the tree. Those ascending are heavily burdened, and convey their charges to the new abode; while others, having carefully deposited their loads, are returning for another freight. Thus they escape the inundation of the year. They transfer all to the branches of the trees, and there, secure above the swampy ground, they store their offspring with their cattle in the byres.

This is a very valuable use for the ants to make of their byres. But it serves them only as a temporary refuge. They soon begin to build more permanent habitations, in the form of arboreal nests. Some of these are, I think, nothing but enlarged byres. The workers extend them, dilate them into wider and more capacious sheds, until what at first only housed a few cattle now contains the population of the nest. But in addition new structures are taken in hand; they are built on the same architectural plan, and in them the ants pass the rainy months after they abandon the water-logged soil.

In structure they are stronger and more massively built than in the case of the ordinary shed. Larger and stouter twigs enter into their architecture, and their interior is lined throughout with a denser layer of silk. Many are bulky, globular-shaped chambers larger than a man's fist (see Plate V.). Others are of a flattened, purse-like structure and hang suspended from the branch. When the grasses give forth their myriads of seeds, the ants gather the plumes in profusion and weave them into the substance of these new nests. They lay them on in a thick fleece, until the wall of the structure is soft and warm, and looks like a ball of down upon the tree.

Like the nests in the earth they are divided into compartments. They house no cattle; within is the cluster of eggs and larvæ and the multitude of worker ants. A powerful odour of formic acid permeates the interior of the nest. So charged with this vapour is the air of these chambers that, when peering closely through a rent in the wall, I have had to withdraw before the pungent fumes.

The ants will often, if opportunity supplies, appropriate some other abode. They may find the deserted nest of a bird from which the young have already flown, and this they will cleverly adjust to their needs and establish themselves within. The most attractive example I have met

PLATE V.—ARBOREAL NEST OF THE *Polyrhachis simplex.*

with of the kind was their adoption of a sunbird's nest. This brilliant gem of iridescent blue had built a nest in the shape of a pear. It was slung from its point by some fibrous threads and hung suspended from a branch. Its thick walls were built of delicate grass interwoven with silky plumes. On the outside was a scattering of broken leaves, a thin entanglement of spider's web, and the excrement which the *Arbela* moth ejects when it burrows along the bark of the trees. This was a snug and cosy habitation, infinitely soft and warm. The ants had found the entrance door situated at the side of the nest. Here indeed was a discovery to explore, for nothing that the ant might ever construct could equal the sunbird's work. No doubt they recognised the warmth of the chamber and the value of the protecting walls. In all likelihood they set to work with their usual industrious care. For they had lined the interior completely with silk; they had also spread it over the entrance so as to firmly seal the door. They had converted the nest into a closed habitation; the only aperture was a narrow passage which they had left near the pointed end. What edifice could have better suited the ants in their efforts to escape the flood?

I came across another delightful instance of the manner in which these ants, when opportunity offers, will appropriate another's home. There are certain spiders, of which I will tell hereafter, that frequent the blades of grass. They bend the blades so as to fashion little chambers, in which they house their delicate cocoons. The ants had made their own of one of these chambers, a neat and well-closed edifice of a perfect triangular shape. They had forced their way through a chink in the base; they may have destroyed the rightful occupants, or perhaps only entered after the brood was gone. Then they lined the interior with silk, and sealed the aperture through which they had entered with a little wood and straw. In this way they secured a staunch habitation, one with a triple wall. For on the outside was the leafy covering of the cell ; in the middle the silken sheath of the spider ; in the interior the ants' own layer.

It is scarcely necessary to mention the fact that the ants are as earnest in their care for these nests as they are for their formicaries in the ground. I took a worker from one of the communes and placed it near an arboreal nest. Being a stranger, it was instantly attacked ; it was first slain, then carried away. I placed another stranger within the aperture, but it was immediately thrown out. I introduced three strange pupæ into the sunbird's nest. Immediately the alien workers seized them ; they carried them as far as they could on the branches, and then dropped them to the ground. These few observations are sufficient for the purpose. The ants will protect the chambers on the trees as they will their subterranean nests.

By September the monsoon has spent its force. The air dries, the earth hardens, and the flooded streams begin to subside. The arboreal nests are no longer wanted ; their purpose is at an end. They have well fulfilled their object and have saved their owners from the flood. The ants now abandon them for ever. The cold season is about to commence, so the workers resume their more natural habitations dug into the substance of the soil.

But I have observed that the ants on exceptional occasions remain longer attached to these nests. I opened one early in the month of February. It was crowded with the usual multitude of workers ; they must have remained in occupation of the chamber throughout the coldest season of the year. They had massed themselves into a dense and compact heap, in which each lay motionless, sluggish and inert. They made some attempt to defend their home, but they had lost their dash and the ferocity of their attack, and they gave forth less of the pungent fumes. Yet even at this inactive season, when all life seemed to have been quenched in sloth, there were still some eggs and larvæ being cared for in this arboreal nest.

This concludes the observations I have made o. the

How wonderful, how instructive is the organisation of these ants! What a marvellous republic of busy life have they not effectively built up! And what an undeviating moral unity must strengthen and bind the whole! How incomparably more perfect and unyielding is it than the sternest of the ethical codes of men! Whence its origin? Whither does it tend? We know not; perhaps we can never know. We can but see the main essential facts; we know naught of the great power behind. It is the ingrained and predestined spirit of the commune developed through the endless past.

The individual is lost in the rich republic. By itself, it is as nothing; at least it is merely an insignificant atom that sacrifices all to the well-being of the state. It has no private interest, no selfish purpose to fulfil. For this is the law of every commune, even of the complex machinery of men, that the individual rights of the citizen must suffer in order to attain the public good. It is only thus that the community can prosper. The maximum of strength and solidarity is gained when the individual renounces all.

This law is established in the life of the formicary; it is an unquestioned and inexorable decree. It is obeyed without a thought or hesitation; there is no resistance, no dispute, no inquiry whether its object may be right or wrong. For there is no private interest in the formicary; the ants have sacrificed all. And what a sacrifice have they not made to ensure the prosperity of their state! They have undertaken a life of endless labour: the excavation of tunnels; the building of chambers; the construction of arboreal nests; the seeking, the tending, the housing of cattle; the weaving of millions of threads of silk; the nursing of eggs; the feeding of larvæ; the cleansing of galleries; the protection of gates; the collection, the conveyance, the rendering of supplies; these are some of the rigid duties governed by communal laws. This indeed is a sacrifice. The ants have yielded up their lives to attain the common good. But even more. The worker ants are sterile females which know no sexual joys. They have renounced even these. Their powers of reproduction, the most intense of all of nature's instincts, have been offered on the communal shrine. This is a sacrifice indeed. The well-being of the busy commune has been purchased at a great price. In exchange for efficiency and organisation and strength the workers have bartered the instincts of their love. Work and duty; those alone are the hard, cold watchwords, the only steps and beacons of their lives. For this is the supreme and inexorable law and the unswerving conduct of the nest, that each should consecrate itself on the altar of the common weal.

CHAPTER VIII

ARCHITECTURAL SPIDERS AND THEIR COCOONS

Varieties of Chambers — The Tunnel Chamber — The Triangular Chamber—The Quadrangular Chamber—The Sheathed Chamber—Maternal Instinct—The Strapped Triangular Chamber—The Chamber of Many Blades—The Chamber in the Flower—Structure of Cocoon—Protective Resemblance —Maternal Affection—Temporary Shelters—Summary of Architecture

THE tall jungle grass, the stately *Saccharum arundinaceum,* is all aglow with seed. Millions of silky plumes sway on long waving stems, and each again supports its spikelets of satiny seeds. We look out over the manjha: it is a carpet of glittering white. Its trembling surface might be a field of snow when it reflects this silvery sheen.

The rains are almost over. It is an excellent time to explore the grasses and seek out the spiders and their cocoons. For there are many kinds which make their homes amidst this foliage and fashion the most inimitable chambers in which to house their tender broods. The great heat has gone. I wander through the long tall grass and press aside the graceful plumes which wave magnificently above my head. I peer into the tapering leaves. At last I come upon a blade bent double on itself and secured with slender bonds. I break it open. Within is a cluster of tiny eggs enclosed in a sheath of silk. This is the object of my search: it is the spider's edifice and her cocoon.

There are different kinds of these little chambers, and each supplies a neat example of the spider's architectural skill. Here is a simple triangular structure made by bending the leaf upon itself; here is one in the shape of a spiral made by twisting the blade into a coil. We find others where the leaf has been many times rolled and the exterior sheathed in bands of silk, still others where the nest has been hidden away in the downy plumelets of a flower. Let us investigate these structures with a little care. I have elsewhere told of the spiders' architecture, of their exact and inimitable skill in the weaving of their circular snares. This is another class of workmanship, another product of the spider's art. Let us seek for some trace of the same skill, of the same perfection here.

I find them not in shady places, not beneath the shelter of the trees, but where the grasses grow luxuriantly in the free and open plain. Nor do I see them buried in the substance of the foliage, but rather near the summits of the blades, where they sway gently in the air fully exposed to view. It is clear that the spiders shun the shelter; they seek the air and light before they will commence to build. They know instinctively what is right and best. The full glow of the animating sun is needed in order to generate those sparks of life which nestle in the silk cocoons.

Let us first consider the chambers themselves, and for convenience sake I thus name their most distinctive types:

(1) The tunnel chamber.
(2) The triangular chamber.
(3) The open spiral chamber.
(4) The closed spiral chamber.
(5) The quadrangular chamber.
(6) The sheathed chamber.
(7) The strapped triangular chamber.
(8) The chamber of many blades.
(9) The chamber in the flower.

There are also many other types of structure, but since, so far as I have observed, they merely fulfil the purpose of a shelter, I will not burden the book by supplying them with special names.

The Tunnel Chamber

This is the most rudimentary, I take it the most primitive, of all the types. First a word as to the architect herself. She belongs to the great *Argiopid* family, is sturdy in build, with a dark thorax, yellowish limbs, and a brown globular abdomen decorated with a few faint spots.[1]

Her plan of architecture is as follows. It consists of just one act, the construction of a simple bend. She selects a blade of grass; she bends it sharply over until the opposing surfaces meet along their whole length. Now in every blade one surface is concave and the other is convex. And it is clear that the spider appreciates this, for she always bends the blade in such a manner that two concave surfaces meet. The consequence of this is that she fashions a tunnel out of the blade. It is closed above by a sloping roof formed by the acute bend; below it remains open, and this serves as a doorway through which the spider can enter and leave her cell. She clothes the interior with a layer of silk; she employs the same material to bind the edges together, and she gives the habitation an additional strength by spreading some filaments from wall to wall. In the middle of the tunnel she suspends her cocoon. There it is safely housed and protected from the wind and rain. It is the usual oval silken bag, with its cluster of yellow spheres.

We see in this the elemental type of architecture. There is but little cunning in its workmanship. It is just one simple bend.

The Triangular Chamber (see Plate VI.)

The architect of this edifice is a spider of the most unassuming type. She is of a pale yellow colour, uniform

[1] I am much indebted to Dr Gravely, of the Madras Museum, and Mr Srinvasa Rao, of the Indian Museum, for their kindness in examining my specimens of spiders. Unfortunately in some cases identification has not been possible, owing to the imperfect state of our knowledge with respect to this most interesting group.

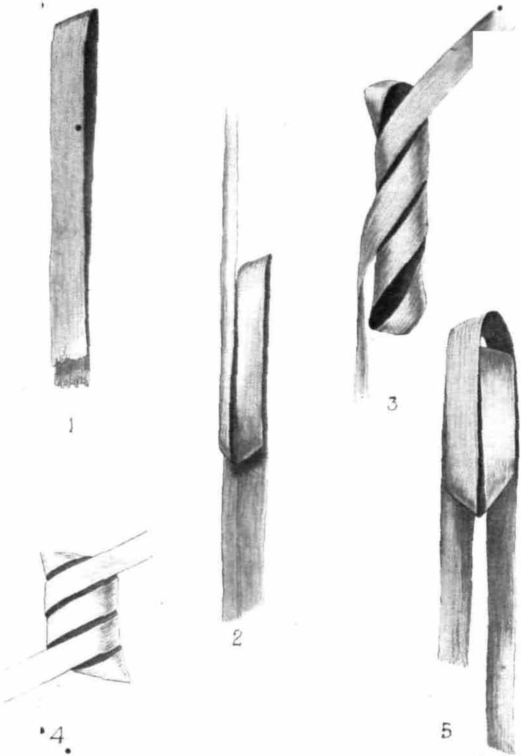


PLATE VI.—CHAMBERS OF ARCHITECTURAL SPIDERS.

The Funnel Chamber. 2. The Triangular Chamber. 3. The open Spir
amber. 4. The closed Spiral Chamber. 5. The Quadrangular Chambe

throughout, save for the little black points that mark her two rows of eyes. She is typically spider-like in general appearance. Her body is bare and fleshy, and, excluding her long slender limbs, scarcely more than one quarter of an inch in length. She is amongst the species that cannot be determined, but is probably one of the smaller examples of the *Argiopidæ*, those architects of the circular snares.

The workmanship of this spider is comparatively simple, yet at the same time is beautifully precise. She operates on a slender blade of grass usually rather near its pointed end. She gives the blade a double bend, first running it sharply down, then turning it up again. In this way she obtains three walls, which, when brought so as to fit one against the other, enclose a triangular cell. The edifice thus fashioned is very perfect in its shape; it is tight and strong and rigid, and there is a nice precision about the manner in which the edges meet. It is usually about an inch in length, and its width, of course, is that of the grassy blade. At either end it runs into a point, one of which, being directed upward, acts as a roof to throw off the rain.

Let us look into the interior. It is lined throughout with silk, a firm, smooth and glistening layer spread over the internal wall. By means of this the three sides are held together and the edges neatly closed without leaving the slightest chink. There is not a part of the interior where the pearly layer is absent. Indeed the chamber is in a sense a sheath within a sheath, the inner a silken fabric, the outer a leafy wall. It is undivided by any partition, yet it serves a double purpose: one part is a domicile for the parent spider, the other a nest for the developing brood. The eggs are enclosed in a delicate capsule and usually lie in the very centre of the cell. They form a comparatively small cluster, variable in number and closely packed. In one brood I count thirty-three; in another sixty-six. After the eggs hatch, the young for a time remain within the capsule. Later they break their way through the membrane and spread themselves over the interior of the cell. The mother is constant to her brood. I find her in the chamber nursing her young throughout the whole period of their growth.

A question arises. How does the spider come to occupy the interior of her natal cell ? She has no door through which to enter ; she is permanently imprisoned within. I think it is obvious that at the time of construction she must bend the blade around herself, and then from the interior secure the walls by spreading her sheath of silk. There are other spiders which build similar chambers and secure them with encircling threads. By this means they add still more strength to the structure and permanently seal it down. But the method is never adopted by this architect, the reason being that when she fashions the edifice she completes the architecture from within.

The Open Spiral Chamber (see Plate VI.)

This is the work of a pale yellowish spider about twice the size of the one last described. She is very modest in appearance. Her only conspicuous marks of colour are the longitudinal stripe of her abdomen, her dark brown mandibles and her rows of jet-black eyes. She belongs to the species *Sparassus lutescens* of Thorell.

Her edifice is a very graceful piece of work. She likewise constructs it by the usual process of bending a single blade. But she does not turn it over evenly. She rather first bends it obliquely, then gives it a spiral twist, then for the second time turns it over again. A loose cylindrical tunnel is the result, surrounded by a spiral wall. It is a neatly twisted and artistic structure about two inches in length. Compared with the triangle it is loose and open ; there is not the same close adjustment of the edges, nor the same firmness nor solidity in the walls. There is often a great nicety in the evenness of the turns, and what the edifice loses in strength it gains in beauty of effect. Owing to the mode of application of the twist an opening is left at either end, and this serves the spider as a gate through which she can pass in and out of her nest.

She lines the interior with a pearly layer. She lays it thick within the middle of the spiral. It is in that part that the turns come close together, and it is there that she will lodge her eggs. At the extremities she weaves only a few scattered filaments, for there stand her open gates. She fixes her cocoon in the best-protected spot, in the very centre, where the walls are strongest, where the edges fit most closely, and where she has already spread out her thickest carpet of silk.

The cocoon is a soft and closely woven bag of a graceful oval shape. It is pressed tight against the wall of the chamber so as to give the spider a free passage to move from end to end. And this is very necessary to the parent in order to ensure the safety of her cocoon. Given freedom of movement she can protect her precious brood all round, and repel a sudden invasion from without by meeting it at either door. Moreover, it is of value for her own safety. In times of greatest danger even maternal instinct fails, and the mother can then move to either end in order to throw herself headlong from the nest. Within the cocoon is the capsule of eggs, in shape like a flattened disc. The cluster is of the usual type. In one capsule I count fifty-six.

The mother remains true and constant to her brood. I find her within on almost all occasions. Even though she is supplied with open gateways it is seldom that I see her absent from her young. She is one of the kind with strong affections, and she remains faithful to the end.

The Closed Spiral Chamber (see Plate VI.)

Here we have another example of the spiral, but a more accurate and finished type. It is the work of a very similar spider to that which constructs the open pattern. She belongs to the same large genus, *Sparassus*, but is of a distinctly darker colour, and works in a somewhat different way.

Her mode of architecture is more finished and precise. She winds her turns more tightly together; she brings the edges into closer apposition; she leaves no gateways at the ends. Her principle of construction is the same as in the open type, but the resulting chamber is more secure and a more creditable piece of work. It is completely closed all round and its whole interior is lined with silk. Within we see a different picture from that displayed in the previous types. There we observed an oval capsule anchored firmly to the wall. In the closed spiral the egg cluster is shaped into a sphere. It is vivid white in colour, and rolls freely in the interior of the cell. As in the case of the triangle, the mother is a prisoner; she never leaves the natal chamber throughout the whole period of the development of her young.

The Quadrangular Chamber (see Plate VI.)

The spider which fashions the closed spiral is likewise the architect of this special type. But the work has a distinctive character of its own. It is not a cylindrical edifice; it is a chamber with four walls.

Its mode of construction is clear, but very difficult to describe. I will ask the reader to turn to the illustration. There he will observe that the spider has bent the blade at three distinct points. And not only this, but she has also in a wonderful manner so adjusted these bends that the four resulting segments of the blade are made to lie at right angles to one another and enclose a quadrangular space. An excellent little chamber thus appears. Its edges meet along their whole length; it has a curved roof above, a similar floor below, and is surrounded by four walls. In size it is about an inch in length, but being quadrangular it is more capacious than the previous types. Its parts are held together in the usual way—by an internal lining of silk. Since it possesses no gate of exit, it is of necessity a prison, and I find the parent in the interior with her brood.

The Sheathed Chamber (see Plate VII.)

I have little doubt that a species of *Argiopidæ* is the architect of this distinctive type. I have not actually surprised her at the work, but wherever I discover the edifice I am sure to find this species concealed in a shelter near by. She is robust and heavily built, and covered in short hairs. Her head and thorax are dark, almost black; her stout quadrangular abdomen is coloured in a lighter shade, and is prettily decorated on its upper surface by two rows of broken squares.

Let us consider the chamber itself. At first sight it appears of somewhat rough construction, as though it were fashioned by a clumsy worker who cared little for appearance or effect. But in reality it is a compact and firm structure; it is a stronger, a thicker and a more solid edifice, than those I have before described. The spider has not kept to a single bend, nor even to a double turn. She makes her chamber trebly safe. She folds the leaf four times, or even six times, turn over turn, so that bend is enclosed in bend. Moreover she binds a strap of silk round about each turn, and in this way firmly secures each successive bend. Finally she secures the whole with bands composed of many threads. It is often but a ring at either end, but sometimes she uniformly swathes the exterior in a strong embracing sheath. Thus each bend is first separately tied, and then finally the whole. A substantial wall of many layers is the result, a stout barrier against invasion. In size it is about the same as that of the more graceful spiral.

Its interior deserves a word of notice. It presents a different appearance from either the triangular or the spiral cell. I see no trace of the silvery lining; there is just an irregular tangle of thread spread across from wall to wall. These filaments support the eggs, a tidy ovoid mass fixed in the centre of the cell. The eggs are held together in a capsule and surrounded with a cocoon. This is not of the usual firm structure; it is rather an open fluffy fabric, a kind of silky cloud, a very soft and suitable covering when the chamber has no lining to its walls. The eggs are very bright, almost orange-coloured spheres. In one capsule I count one hundred and fourteen.

This edifice contains nothing but the eggs. Never on any occasion do I find the parent within. The details of its workmanship are quite unknown to me. Chance may some day reward my patience and I may catch the architect at work. Until then I can but examine the edifice itself and learn the few truths it has to tell.

At least it reveals this much, not an altogether insignificant amount in terms of character and mind: the architect works with infinite care; she aims at exactitude and strength. She is determined not to leave a crevice open. She is not satisfied with but a single wall; she reinforces it again and again. Unlike the others she does not seal her walls with an internal sheath; it is from the outside that she applies her encircling bands. And, as this is the final step in her architecture, she is consequently never found within. This much do we learn of the excellent precision of the architect by the mere inspection of the nature of the work.

But it tells us more. It tells us something of the noblest of all living tales. It tells us of maternal love. The cell is empty save for the brood of eggs. How different from the case of the triangle and the spiral, when the parent is always within! What of the architect of this chamber; where is the mother who has so securely sealed her brood? She has deserted them for good and all. Like the *Sphex*, which lays her egg in the tunnel on the ground; like the *Eumenes*, which lodges it in the dome of clay, so is the maternal instinct of this spider, just a glimmer of passing love. The *Sphex* seals her tunnel, the *Eumenes* secures her lid; then they leave the cell for ever; the thought of that particular offspring never enters their little minds again. So must it be with the spider which swathes her chamber with silk. Within are her precious eggs, all arranged with infinite care, all gathered into a compact disc, all wrapped in the softest and most delicate of sheaths. Around them is the strong-walled tabernacle, every crevice closed and the whole secured in bonds. The spider has toiled with persistent labour and has worked with exquisite care.

But that is the end of her maternal love. Her eggs are laid, her edifice is built, her encircling lines bind the separate parts in place. The instinct of maternity is satisfied. I have no doubt that she now deserts her handiwork, never to look on it again. Her duties as a parent are fulfilled. She trusts for the future to the strength of her workmanship; she leaves her offspring to the elements and chance.

The Strapped Triangular Chamber (see Plate VII.)

This is the most perfect of the many types of structure. I will describe it with a little care, as it forms a delightful instance of the spider's architectural skill. But here at the commencement I am again at a loss, since I know not the spider herself. She is of the inconstant kind that deserts her brood for ever. I can only tell of her workmanship and hope that others will find her out.

We must seek it in a different place from that in which we have met the preceding kinds. Let us go down into the swampy ground where the vegetation grows thick and coarse, and the long thin leaves of the grasses are intermingled with the stout blades of the rush. For it is here that this spider works. The leaves of the grasses are too slender for her purpose; she prefers to operate on the rushes, and fixes her habitation at the very summit of a pointed blade. If we search we can scarcely miss it: the leaf has been so obviously bent by some particular act of design.

Now consider for a moment this type of architecture and turn to the illustration facing page 132. The blade of the rush has been twice bent. It has first been turned down upon itself and then turned up again. But see how accurately this task of flexion has been performed. See how precise is the adjustment of the double fold. For the points at which the blade is bent have been so nicely measured that the free end of the blade, which is turned upward, fits most neatly and exactly into the pointed space which has been made by the downward turn. And of course the shapes strictly coincide. The downward bend has left a narrow triangular space with the apex upward, and this receives with wonderful exactitude the pointed extremity of the leaf. At the site of the lower bend there is sometimes left a little slit where the edges do not quite meet, and this I have no doubt is of service later to permit the final egress of the young.

The mechanism by which the turns are secured is equally perfect and precise. Two bands of silk are tied around the chamber. Each consists of a single thread, which has been twisted evenly round the structure, perhaps thirty, forty, or more times. In this way two strong straps are formed which hold the bend firmly in place. These straps are located at the sites of best mechanical advantage. Each is placed close to a bend, one immediately below the upper turn and the other immediately above the lower. The spider in this way employs her filaments to secure the maximum of efficiency and strength.

The tabernacle thus formed is the shape of a triangular prism. It has a rounded base below, and graduates to a narrow point above. In actual dimensions it varies in accordance with the size and nature of the leaf, but I find one of average capacity to be about two inches in length. The wall within is smooth and even, and in the upper half, where the closure is more complete, is lodged the cluster of eggs. They lie in a mulberry clump of globules collected into an oval mass, and the whole is surrounded and intertwined with soft and downy silk.

A few more points are worthy of attention in this

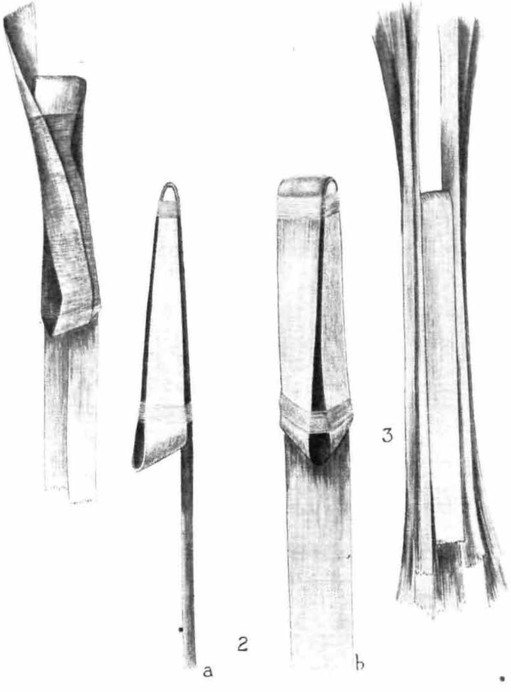


PLATE VII. CHAMBERS OF ARCHITECTURAL SPIDERS.

The Sheathed Chamber. 2. The Strapped Triangular Chamber (*a*) side vie (*b*) front view. 3. The Chamber of Many Blades.

production of the spider's art. The architect, at least in her operations on the rush, does not fracture the green leaf. Though the bend is complete, nevertheless the tissues of the leaf are uninjured, and as a consequence the chamber remains intact and grows evenly in all directions while the imprisoned eggs are developing within.

Another point beyond my comprehension is how the spider can bend down these powerful blades before she applies her encircling bands. It is a simple matter with the slender leaves of the grasses, but how does she bend the rigid rush? The blade of the rush at the point of flexion is often one quarter to half-an-inch in width, and so strong in fibrous texture that it seems incredible that any little spider could have the strength to turn it down. Perhaps it performs the feat when the blade is young and the tissues supple and easily bent. Again, how is it that the spider retains the bend in place while in the act of applying the first turns of her strap? But it is fruitless to conjecture. None can understand until the little architect is seen.

Since this spider works on the blade of the rush, the chamber which it fashions is more capacious than those hitherto described. But I once met with a delightful miniature of the type affixed to a blade of grass. It was no more than half-an-inch in length, and was most neatly bound right round the middle by just one tidy ring of threads. I suppose it was the work of some humble species as yet unknown to science, and no doubt a close relation to the artificer which builds on the blade of the rush. At least the chamber was a miniature of the same perfection, and the daintiest little tabernacle of its kind that I have ever happened to see.

The Chamber of Many Blades (see Plate VII.)

Here is a structure of a different type. It is fashioned not out of one but by the union of many blades.

The architect is of a powerful and formidable species, the *Sparassus lamarkii* of Latreille. Clothed in long hair, she supports a coal-black head armed with massive jaws. Her stout thorax is a delicate grey; her ponderous abdomen is a dull yellow above, and her hairy legs are banded with black and grey. She looks a ferocious creature, somewhat out of place amongst the gentler inhabitants of the blades. She, too, constructs her chamber amongst the leaves of the tall jungle grass. But she fashions a larger and more complicated edifice, in accordance with her greater size and strength.

The chamber in the first place is more capacious. One which I measured was four inches in length and sufficiently wide to permit a finger to pass within. Moreover the spider employs a number of blades in its construction, and unites them in a very ingenious way. She first turns down one blade, and in this way fashions a simple bend. This bend becomes the centre and foundation of the cell. Now if the spider can close in this bend on either side, then it is clear that a chamber will result. How does the spider effect this? I have not seen the architect employed, but the plan of structure of the edifice shows how the closure has been done. The spider appropriates the neighbouring leaves and gathers them into a cluster round about the bend. She then arranges them, half on one side, half on the other, in such a way that they fit edge to edge into the open sides of the bend. Two walls are thus fashioned; the sides of the central blade are closed, and the bend is converted into a cell. A four-walled edifice is the result. It is roofed above by the convexity of the central blade; two of its walls are formed by the limbs of the bend; the remaining two by the surrounding leaves arranged in the manner I have described. The chamber is without a floor. From below there is a free passage into the interior. It is the gate of entrance and exit for the spider, and is so well situated in the midst of the enclosing blades that it is altogether hidden from view.

The number of blades taken into use by the spider varies in different cells. It will depend on the width of the space to be closed and on the breadth of the available blades. Three blades laid evenly edge to edge is usually sufficient to close one side, and in most cases I find the number equal on opposite sides of the cell. But there is not always this precision in the workmanship. Indeed we never see a strict exactitude in the fulfilment of an instinctive act, especially in one of an architectural nature where use must be made of whatever is at hand. I have seen one side closed with only a pair of leaves, while on the other side twice the number were employed.

As in the case of the other chambers, the interior is lined with silk. And it not only forms an internal fleece, but in addition it binds the edges of the leaves and thus makes the walls of the edifice secure. The architect occupies the interior of her chamber, which is sufficiently wide and capacious to permit her to move about. In addition it contains a white downy mass; this is the loose cluster of spherical eggs enclosed in a separate sheath.

The mother watches carefully over her brood and vigorously defends her home. I scratch on the outside with the points of a forceps. Out she comes, an angry-looking creature, with her hairy, banded limbs wide apart. She sees the instrument. To her *it* is an enemy forcing an entrance, and she throws herself ferociously upon the blades. This is sufficient to indicate her constancy. She remains with her offspring to the end.

The Chamber in the Flower

I pass now to another of these spiders which employs the grass as a shelter for her cocoon, though she adopts a very different plan. She likewise selects the tall *Saccharum arundinaceum*. But she does not utilise the green leaf; she prefers to conceal her brood of eggs in the substance of the matured flower.

The spider herself is worth a word of notice, for her nest is as exquisite a little chamber as Nature can anywhere supply. She is a stout-built creature, short and thick-set, not more than one quarter of an inch in length. Her body is clothed in delicate hairs; in colour she is a brownish yellow, with prominent black stripes upon her thorax and abdomen, and darkish transverse bands upon her legs. She belongs to the family of the *Attidæ*, or jumping spiders, which do not burden themselves with the construction of snares.

I find her nests in profusion when the rains are drawing to a close. The tall grasses have then reached their greatest height and the soft downy flower-heads are spread in a snowy fleece. Each inflorescence contains a central stem; around it is attached a crowd of spikelets, and to these are fixed the innumerable seeds, each with its silken plumes. It is a beautifully soft and satiny mass and it glistens with a silvery sheen.

In the centre of this feathery spike the spider lodges her cocoon. It is composed of the usual thin silken case, a smooth and closely woven sheath which invests the ball of eggs. The spider draws the spikelets round about her nest. She binds them together with her customary threads and in this way constructs a capsule out of the cluster of grassy plumes. The cocoon is thus enclosed in a soft and warm wrap. It is well protected from damp and heat; the eggs are shielded from the inclemency of the season and are safely hidden away from view in the centre of the grassy flower.

I cannot pass by this delightful little nest without discussing in a little detail its different elemental parts. The cocoon is an elongated bag. It is oval in shape, pearly white in colour, and lies loosely over the central ball of eggs. As usual it is exquisitely fine in texture, yet it is firm and hard to tear. A multitude of threads springs from its outer coat, and these entangle themselves in the enclosing wall of plumes. In this way it is held by innumerable anchors and fixed firmly in its place. Its main substance is a fibrous sheath, strong, resistant, a thin but compact layer of tissue, a material of excellent perfection for the delicate purpose for which it is employed. I place this layer beneath the microscope. I see that it is composed of an amazingly dense and closely matted tissue of the finest interwoven lines. To all appearances it is a microscopic sheet of felt. Within this sheath is a soft and fluffy layer ; it is a downy lining spread over the interior of the sac, a beautifully smooth and yielding surface to support the cluster of eggs.

The eggs themselves are smooth, hard yellow spheres. They are gathered into a compact mass, a small cluster which scarcely fills one quarter of the sheath. It is a firm globule flattened into a circular disc, and is enclosed in a thin, transparent capsule which is attached to the fluffy lining of the cocoon. A few filaments are spread out in the interior of the capsule. They stretch from side to side amidst the eggs, and are sufficient to hold them in place. But it is only the loosest aggregation of little spheres. I slit the capsule and gently shake the cluster. All the eggs immediately separate and fall from these fragile bonds. I have no doubt that their number varies greatly. In one cocoon I count seventy-four.

What a wonderful system of encasing sheaths is round this little ball of spheres. Commencing from the interior there is first the delicate capsule in direct contact with the eggs. Surrounding this is the fluffy layer, the soft internal coat of the cocoon. Then comes the firm fibrous sheath, which is the main supporting substance of the bag. And round about this is the complex tangle which links it to the case of plumes. Enclosing the whole is the thick and warm coat composed of the matted spikelets of the flower. It is in truth a snug and exquisite abode. Was there ever any clutch of eggs confined to a softer or a silkier nest ?

But let us not forget the mother and her affection for her brood. She is a constant parent, and I find her at all stages of development in the interior of her cocoon. But she does not convert her nest into a prison. I notice that there is a small aperture at one end of the bag, a gateway, I take it, to permit her entrance and exit from the nest. The door is usually at the top of the cocoon. The mother sits just within. Beneath her rest her eggs, her head is at the gate; we may see the tips of her claws on the edge of the aperture and her bright eyes glaring out from the inside. She is in the place of readiness, fully prepared to defend her offspring, or in the face of exceptional danger to leap headlong from the nest.

I touch the bag. She is immediately on the alert. She comes to the aperture to investigate what is wrong. I poke in the tip of a straw. She clutches the margin of the gateway in her claws, gathers the edges together and thus closes the door. In this way she guards against invasion, but she puts up very little further fight. For I continue to annoy her, only with the result that she leaps out of her cell. If not valiant, nevertheless she is patient and true. I slit the cocoon throughout its whole length. Very soon she sets about repair. No doubt she does her best, but the work is not greatly to her credit. She certainly repairs the damage, but only with a few flimsy threads.

I found another very remarkable spider utilising the flowers in a similar way for the protection of her cocoon. I must describe the species with a little care as the chief attraction lies in her strange appearance and the characteristic attitude of immobility which she adopts. Unfortunately it is impossible to identify her precisely, but she probably belongs to the *Clubionid* group.

There is nothing of special note about her colour. She is a pale, almost uniform yellow, somewhat the shade of a piece of straw. On her head are the black specks that mark her eyes, and along the whole length of her back there is a narrow dusky stripe. It is rather her extraordinary elongated shape which attracts immediate notice. Her head and thorax are unusually long, and especially her abdomen, which projects behind as a slender, graduated cone. But this peculiar lengthening of her structure is made more manifest in the limbs, especially in the attitude which they assume when she sits without a motion on the grass. They are very long and slender. The front two pairs are thrust forward in line with the body; the hind pair in the same manner is stretched out behind. It is the third pair alone which clutch the grass. These are of normal shape and size. They are the true grasping organs; the other limbs, at least when in this attitude, are merely employed for the purpose of effect.

Now, why this peculiar attitude: slender legs thrust out in front, similar organs trailed away behind; a narrow, elongated body pressed tightly to the blade of grass? It is really nothing but a posture of pretence. It is one of Nature's schemes to guard her creatures from attack. The attitude is of protective value; it is a device to alter the natural appearance of the spider and to cause it to resemble a withered stalk, of which there are thousands scattered everywhere through the grass. Indeed I have little doubt that this is the purpose in view, and I need only note the behaviour of the spider in order to confirm the belief. For the spider herself acts as though she too understood that this was the purpose which Nature had ordained.

I sometimes meet with a most imperturbable example. She lies in close proximity to her cocoon. She is stretched out, extended at full length, absolutely motionless and pressed tightly to the blade of grass. I touch her with a straw. She takes no notice. Were she of another species she would make off, or more probably drop down quickly to the ground. But she remains at rest and shows not a trace of life. I touch her with my finger, I stroke her, I pinch her, I press her firmly against the blade. But still she makes no sign of motion; she might be a dead or inorganic thing. I perforate her thorax with a pin; I even amputate the tip of one hind leg. She flinches; she starts beneath the sudden pain; but it is only a momentary quiver, and she then clings all the more firmly to her place.

Why is this ? One explanation alone is possible. Nature has supplied the spider with an excellent disguise, and since instinct in its operation conforms to structure, the spider is moved by its natural impulse to remain absolutely motionless and seek safety in this disguise. She does not know that she is like the withered stem, but she feels that, in the face of danger, it is in immobility that her one real safeguard lies. Hence she will endure torture rather than make an effort to escape.

I repeat the same experiments. The spider still remains. It is not until I half sever her abdomen with a pair of scissors that she abandons this method of avoiding danger and rapidly takes to her heels. All do not behave with this stubborn resistance. It is the combined effect of two instincts: the one to escape from danger, the other to remain in the vicinity of her cocoon. At all events it was the best instance that I have yet observed of a dogged and persistent reliance for safety on the character of the protective scheme.

So much for the parent ; now let us consider the cocoon. In a manner similar to that of the last-mentioned species it is concealed within the plumelets of the flower. It is the same beautiful type of nest. Perhaps it is somewhat more spindle-shaped and fits more tightly over the eggs. These latter are of a pale colour, and I count one hundred and sixty in the brood. Otherwise with respect to the cocoon there is nothing of any special note.

Unlike the *Attid*, I have never found this parent in the interior with her brood. And this, I take it, for the very good reason that she is too thin and stick-like ; she could never introduce her long, awkward legs into the narrow cavity of her sheath. How, therefore, can I fix her as the real architect responsible for the chamber in the plume ? Only in this way: I continually find her just outside the nest, stretched like a withered stalk along the flower. This is strong circumstantial evidence. A spider which persistently clings to the exterior is probably responsible for the contents of the nest. But an experiment will supply still further proof. One morning I break into two adjoining nests and tear open the silken sheaths. I thus lay bare the tender broods and leave them throughout the day fully exposed to the desiccating sun. I return at evening, but I see no sign of any change. The brood is still without protection. No parent has claimed them, or at least none has felt the desire to repair the damaged nest. I look to them the following morning, and it is then clear that something has occurred. New filaments have been spun; the soft plumes have been drawn back into position, and both nests are neatly closed, as securely as they were before. On the outside of each, and lying full length along the flower, is the suspected *Clubionid*. She makes no attempt to conceal herself in the spikelets. Why, she is a veritable spikelet herself! On this evidence I fix the *Clubionid* as the owner of the cocoon.

In her, therefore, we see another stamp of motherhood, the casual, the intermittent type. She is not one of those which builds and lays, and then disappears for ever; neither is she of the kind which sits continually on her brood. She is but an occasional visitor, hiding in the grass by day, and at night returning to her nest in order to assure herself that all is well.

Temporary Shelters

As we search the tall grass in our efforts to unravel these plans of architecture, from time to time we will meet with chambers constructed for a different use. They are very similar in appearance to those described, but they enclose no eggs nor any trace of a cocoon. These are not chambers built for nidification; they are rather temporary shelters in which to house the parents themselves.

They have been fashioned in very much the same manner as have the receptacles for the cocoons. In one place a narrow tunnel has been formed by the process of a single bend. In another place the leaf has been turned into a triangle, sometimes as much as four inches in length. Then again we meet with a quadrangular shelter manufactured by the adjustment of three bends. And still another plan is to bind two blades together in such a way that their concavities meet. These shelters are but loosely formed and thinly lined; they are never bound with the same security and strength as are those which house the precious broods. I usually find the spider huddled peacefully within. It is a resting-place for her to lie concealed, and a cool retreat in which to pass the day.

Summary of Architecture

I will briefly recapitulate the essential features in these models of architectural art. The simplest of all is the mere tunnel in the blade fashioned out of one single bend. In this type the mother is constant to her brood, and allows herself an unobstructed passage to and from her cell. Next comes the triangular edifice. It is manufactured by means of a double bend; but in this chamber the mother is locked within, and so far as I know never leaves her young. We then pass to the open spiral, a more graceful though a less well-protected type. Here again we find a true and constant parent, though she is free to enter and leave her cell by a pair of wide-open gates. Of an allied character is the closed spiral. It is built on the same architectural principle, but is completed on a more perfect plan. The turns of its spiral are more carefully adjusted; the edges more securely meet, and, since it possesses no gate of exit, the spider is a permanent prisoner within. Deprive the spiral of its shapely twist and the quadrangular chamber appears. It is a completely closed and four-sided dwelling, and we always find the parent inside. Now we come to a different type —the chamber with the enclosing sheath. It is built of exceptional strength. Its walls are composed of many layers; not a sign of a crevice is left upon its surface;

it is encircled with bands of silk. Secured in a similar way, but of infinitely more perfection in its architecture, is the strapped triangle on the rush. This is an example of remarkable precision, for the point of the blade is made to fit into the bend in a manner which is most wonderfully exact. These two chambers sheathed in threads are made by an architect of another stamp. She deserts her edifice as soon as it is built. As a parent she is possessed of no affection beyond the shaping of the structure and the laying of the eggs. One more type and we are finished with the chambers on the blades. This is the spacious dwelling made by the union of many leaves. Above it is closed by a gentle roof; beneath it possesses an open door carefully hidden away from view.

Is there a softer and a cosier nesting-place than the spider's capsule in the flower? Look at the satiny coat of plumes and the successive silken layers of the cocoon. Surely no series of enclosing wraps could be more exquisite than these. They are the property of two spiders, very different in character and type. There is one which remains within the capsule and shares the downy cavity with her young. The other is of a more casual nature; she never occupies the interior of the capsule, but she usually remains somewhere in the vicinity, often stretched like a spikelet along the flower.

Thus we observe that there are many types of architecture, each an attractive study in itself. Other patterns must certainly exist. I have mentioned only those which I have seen upon this manjha affixed to the grassy blades and plumes. They will teach us lessons in habit and instinct not unworthy of our careful note. But here I have just told of the habitations themselves and the structure of the different types. For simplicity let us look to the tunnel in the blade, for neatness of adjustment to the triangle, for delicate shape and beauty to the open spiral coil. For strength and security look to the chamber with the sheath, for precision in workmanship to the strapped triangle on the rush, for an exquisitely soft and warm nesting-place look to the downy chamber in the flower. We have discovered what we set out to find. There is indeed a skill in the spider's architecture, and not a small degree of elegance too.

CHAPTER IX

EXPERIMENTS AND OBSERVATIONS ON ARCHITECTURAL SPIDERS

Experiments on Chamber—Experiments on Eggs and Brood—Instinct of Maternity—Experiments on Interchanging Spiders—Fixity of Instinct—Enemies of Nests—Attack of Ichneumon—Enemies of Young—Departure of Young—End of Chamber

I NOW leave the architectural instinct and pass to the consideration of a series of experiments which will throw light on the instincts of the architects themselves. The first problem to investigate is this: how will the spider behave if I damage her completed work? I have told elsewhere of how the geometrical spider is unable to repair her web; let us see if the architect of the chamber is equally deficient too.

I open a window in the wall of a triangle. The breach is about half-an-inch in length and includes about half the width of the wall. I make it in the middle of the chamber, so as to freely expose the eggs. The monsoon rain is falling, the grass sways beneath a heavy wind, and the spider must take urgent steps if she wishes to preserve her brood. How does she act? She comes to the window. She inspects the damage. It is perfectly clear that she appreciates what has occurred. At all costs she must save her eggs; at any moment they may be shaken through the breach. She does not hesitate. In a minute she has twisted herself so that her belly is against the rent. She then clutches the sides of the chamber and from the pointed tips of her spinnerets emits a skein of silk. Then she swings her abdomen from side to side, so as to spread the skein across the breach. She continues thus to oscillate her belly, attaching the skein first to one side, then to the other, and she does it with such regularity and method that her abdomen is like a pendulum swinging from side to side across her cell. At the same time she advances slowly within her chamber, so that she rapidly spreads a silken layer, composed of innumerable threads, across the whole length and width of the breach. This layer is very thin and delicate. Through it I can see the eggs inside. Nevertheless it is sufficient in these circumstances of urgent danger to serve as the earliest barrier of defence. This is enough for the moment, and I leave the spider for a day. On my return I find the repair complete. The patch has been thickened and strengthened. Layer has been superimposed on layer. There is now an opaque white firm fabric stretched across the broken wall.

I make a similar experiment on the spiral chamber. I remove a portion from the centre of the coil. The result is essentially the same. I return the next day, and I find that the breach has been securely closed with a strong and densely matted layer. There is thus no doubt that these spiders are attentive to their chambers and will struggle hard for the safety of their broods. They immediately recognise the presence of an injury and know well how to set about repair. They weave a silken fabric across the breach. It is perhaps not as strong as the original structure, nevertheless it is the best that the spider can give. And it serves as an excellent and efficient substitute for the tissue of the leafy wall.

I will mention one more experiment, which leads to a different result. In my previous operation on the spiral I made the breach in the centre of the coil. In this way I forced an opening direct upon the eggs, for it it just beneath the centre that the spider places her cocoon. Thus every impulse urges her to effect an immediate repair. I now operate in a different way. I attack not the centre, but the end of the spiral, and I completely remove that portion of the bend which curves round the spider's gate. As in the previous experiments, I return the next day, but to my surprise I see not a vestige of repair. And indeed why should I expect it? By my interference I have not exposed nor in any way endangered the immediate safety of the brood. I have merely given a freer entrance and exit to the spider by enlarging her natural gate. Hence the parent takes no action. She will not waste her silk unnecessarily. Her concern is not for her architecture; it is solely for the safety of her young.

Now let us look to this maternal instinct which binds the mother with such affection to her brood. Let us investigate those bonds of close relationship for which she builds and struggles and imprisons herself within a cell.

I draw back the wall of a triangular chamber and expose the ball of eggs. With the point of a knife I slit the capsule and scatter the eggs through the interior of the cell. What will the mother do now? Perhaps she will gather up her eggs again into a cluster, or she may desert the invaded nest. But she does neither; she simply does nothing at all. The weaving of the capsule is a very delicate piece of work, and to restore it is beyond the spider's capability of repair. Nevertheless she is content. Her maternal instinct is unaffected though her brood are scattered everywhere about the cell.

I pass to some other chambers of the same triangular type. In one I diminish the size of the brood by extracting about half the eggs. In another I increase the clutch by the addition of forty or fifty eggs taken from a similar triangle near by. But in neither case does my interference produce any result. The spider is unaffected either by the increase or the decrease. To her numbers are nothing, not even in respect of her own eggs.

But perhaps she possesses more discernment after the eggs have developed into young. I find a triangle in which the offspring are about half-grown. I turn out the scrambling crowd, leaving only six behind. Now will the mother remain satisfied with this? Her brood is almost annihilated; she has lost the gentle touch of that compact, seething swarm. I leave her for a day in the pillaged nest. On my return I find that she has sealed the chamber and she is quite content inside caring for her little six. I now double the size of a swarm by adding others from another chamber, of course of the same type. I meet with a similar result. As in the case of the eggs so also it is with the half-grown or the full-grown young. Numbers, more or less, are nothing to the spider. She cares nothing about a decrease or an increase in her offspring. She is equally satisfied be the number less or more.

It is clear that the maternal instinct is uninfluenced by numbers; let us consider if it is more rigid with respect to the character of the brood. I transfer the complete capsule of eggs from one triangle to another. These triangles are of course the chambers of the same species. It is a simple matter to make the exchange. I turn back the leafy wall of the edifice and make a window in the lining sheath. I then separate the capsule from its supporting filaments and extract it through the hole. I introduce the capsule taken from another chamber and it lies loose within. The wall is then replaced and secured with a fibre of grass. What will the parent do now? Will she make off in search of her own eggs, or will she be satisfied with this foreign brood? After twelve hours I reopen the chamber. The spider is within, and to all appearances she is perfectly content. She has spun new filaments to support the capsule; she has restored the silken lining where I had made a breach; she has linked down the edges of the wall where I had torn it away, and now she comes forth to the attack when I endeavour to pry within. She is as anxious about these alien eggs as if they were her natural brood.

I attempt a similar experiment with respect to the full-grown young. The spider which twists the leaf into an open spiral is the victim of this test. It is a simple matter to rob the spiral. The plumelet of the flower makes an excellent brush. I run it backwards and forwards through the chamber and thus easily sweep the brood away. The mother resents my interference. She is agitated; she clings perplexed to the outside of her chamber; she runs in and out through her wide opposing gates. Sometimes she attacks the plumelet with her jaws, and in fact puts up a rather spirited defence. But in spite of it all she is very soon childless, and there is not a youngster in the cell. The offspring from another spiral are in readiness, and I introduce them into the pillaged nest. I leave the spider to investigate. I give her ten hours to decide whether she will accept these offspring or not. I return. She is still in her spiral. Some of the youngsters have disappeared; probably they have fallen out in their efforts to accommodate themselves to the new home. The remainder have grouped themselves in the usual spot, beneath the middle of the spiral coil. The alien mother is in their midst. She comes out to defend them when I interfere, and she does so with all her strength. I am satisfied with the result of the experiment. I see not a trace either of maternal or of filial recognition. Parent and offspring are perfectly satisfied. Neither appreciates that the other is not, and has not always been, her own.

But here is a more remarkable instance of the mother's apparent lack of interest in the nature and character of her brood. I open a triangular chamber which contains a clutch of eggs. I slit the fragile sheath and scatter them through the cell. I then increase the progeny by adding to it a number of half-grown young taken from a similar type of chamber near by. Now here is a sudden and strange experience for the mother. Not only is there an increase in the number of her brood; not only is she encumbered with an alien family, the produce of another's womb; but it must appear to her as though some of her eggs had suddenly sprung into life and started to scramble hastily about the cell. Yet not even this seems to affect the spider. She behaves as though all were well. The increase in the number, the intermingling of different ages, the introduction of an alien swarm—all these, though combined in the one experiment, yet make no apparent difference to the spider. She continues to cling tightly to her cell. She remains a true and constant mother, even with this heterogeneous brood.

It seems evident, therefore, that the mother has little power to appreciate either the number or the character of her young. But these experiments have all been made with respect to individuals of the one species. Let us investigate what will occur when I interchange the broods of different species. I extract the half-grown young from an open spiral. They are pale, well-developed little creatures, and well able to run about freely in their home. I introduce a brood taken from the sheathed chamber. They are of a bright yellow colour and look very different from those which they replace. I again give the spider a day to make her choice. The result is this: she throws out the offspring; she apparently will have nothing to do with those of another species.

Perhaps it may be otherwise with the eggs. She may be unable to recognise the difference there, for to the naked eye they all look much alike. I make the exchange. I extract the capsule from a soft chamber in the flower and transfer it to the hard triangular edifice on the blade. The new eggs resemble the old ones; they are very similar in number and size and shape. Perhaps the spider will be as content with them as she was originally with her own. But it is not so. I return at evening. I find that the mother has forced her way out of the cell. She has abandoned this unnatural brood for ever. I see the edifice invaded by a crowd of carnivorous ants, which are carrying off the last remnants of the spoil.

Now this is the final conclusion of these experiments. The instinct of maternity is strong in the spider. She will repair her chamber of nidification when damaged;

she will stand by her eggs even when they are scattered from their sheath; she will cling to a few remaining offspring after the main body has been swept away. But the instinct is only a thoughtless impulse, an intense desire to link herself to eggs and young. There is no sense of *recognition* about it, no particular and lasting love for the offspring of her own womb. The maternal instinct clamours vehemently for satisfaction. The presence of a progeny is necessary to fulfil it, but it need not be the spider's own. Yet her passion is not completely blind. It will not drive her to break that still more powerful instinct which makes every species segregate itself from every other species, and thus permits Nature to collect her creatures into separate specific groups. This last is a supreme and indomitable force. Her maternal instinct insists on having progeny; they need not be her own offspring, but they must be of her own kind.

I now leave the interchanging of the broods and pass to consider what will happen when I interchange the architects themselves. I first operate on the triangular chambers. I remove a spider from her edifice and place her in another of very similar appearance constructed by an architect of the same species. The chambers are of about the same dimensions, and each contains a neat little capsule of eggs. Thus the transfer is not of a very ruthless nature and I expect that all will be well. I return the next day. The spider is within. She has repaired the damage which I caused when introducing her to the chamber, and she seems in every way satisfied with the conditions of her new home.

But let us pass to another type, and exchange the mothers after the eggs have developed into young. I find a neat little spiral chamber constructed on a finished plan. The occupant is inside; she is nursing a crowd of young. It is an excellent picture of maternity, this parent and her precious brood. I touch the chamber and some of the little offspring come scrambling out, but they soon find their way back again and reassemble around their mother seated patiently inside. I disturb the domestic peace by extracting the mother from her brood. I transfer her to a very similar chamber belonging to the same species. I easily coax her into the strange cell, though she is at first a little reluctant to enter. It is not that she fears the unaccustomed edifice; it is rather that she is alarmed at my interference and wants to drop down into the grass. But with a little persuasion I induce her to enter. She is soon in the midst of the crowd of alien young, and I leave her for a day to make her choice. I return the following morning. I find the spider safely hidden away inside. The scrambling young are all about her. She seems fully satisfied. She will not only adopt another's offspring, she will accept another's home.

I make a more violent exchange. I take a mother from a spiral where she is nursing a brood of young. I transfer her to a similar spiral where there is a capsule of new-laid eggs. It is early morning. I am unable to wait long. The sun is rising in the heavens, and the burdens of official duty call. But I watch for half-an-hour. At the end of that time the mother is still inside; she has shown no desire to abandon the foreign home. But perhaps she merely employs it as a shelter. I will return at evening and visit her again. Shortly before sunset I come to the nest to see how the experiment has worked. I find the spider a happy occupant of the cell. She has been forced into a foreign chamber; she has been torn from her full-grown young and supplied with a capsule of eggs. Nevertheless, for all that I can see, she is perfectly content with the exchange.

The converse experiment meets with a similar result. I extract a stalwart mother from her spiral and coax her into another made by one of her own kind. She has been seated on a clutch of eggs, and the chamber to which I introduce her contains a swarm of lusty young. This is another violent exchange. The parent has been dragged from a peaceful home and has been forcibly driven into a struggling, seething throng. It is again morning. I mark her with a speck of paint so that I shall recognise her on my return. I visit the nest at evening. There she is seated in the strange cell, to every appearance perfectly happy in the company of her foreign brood. I see the young ones gather themselves about her; I see them climb upon her body and cling to her hairy legs. I press the chamber; she hurries to the outside, and I see that there are young ones seated on her back. I cease to interfere. Immediately the strange unnatural affection calls her; she re-enters the foreign chamber and fondles the alien brood. She is fully satisfied. She has lost her eggs and she has lost her home. But it makes no difference to her. I greatly doubt if she even knows it. Her simple instincts are satisfied. Any home as well as any brood will do.

I leave her for the night. Perhaps after dark she will evacuate this spiral and make a search after her true home. The next morning I make another visit to see what has occurred. I find her still within the dwelling. She has had a night and a day to investigate her quarters, but she is content with her new home. So long as she sees the walls around her, so long as she feels the offspring's gentle touch, nothing else matters. She claims no further instinct of possession. This spiral as well as any other will serve the purpose in view.

The parent, I have shown, will accept any offspring, provided they are of her own species. So also it is with the chambers: she will quickly desert them if they are not of the same type. I took a mother from a nest within the flower and lodged her in a spiral cell. But she very soon abandoned it, and I never saw her again. The architect of the spiral I then transferred to the empty nest within the flower. But the result of the experiment was the same. She refused to accept the change. I took a spider from her triangle and placed her in a spiral, where she was soon enveloped in a brood. The operation again was of no avail. She first thoroughly explored the interior and then deserted the home. A mother will refuse to accept a chamber foreign to her own kind.

There is no necessity to investigate any further. These experiments on maternal instinct tell us what we wish to know. They teach us of the fierce intensity of its passion, of its inability to distinguish its own offspring, of its strict confinement to its own species, of its readiness to accept another's home.

I must now introduce another experiment, which will expose the innate force of instinct from a somewhat different point of view. It will indicate its rigidity of action, and the inability of the spider to alter the established methods of her work. I operate on an open spiral. I undermine the foundations of the capsule which contains a brood of young. It is a simple matter to sever the anchoring filaments and draw the capsule out of the cell. I place it on the outside of the chamber close to the entrance gate. The spider soon comes out and is perturbed at finding her young exposed—for the capsule has been slightly injured and some of them are trying to escape. The sun is shining. Something must be done, else the young will soon be injured by the heat. Of course I naturally anticipate that the spider will take hold of her capsule and convey it back into the shelter of the nest. She is well equipped with the implements necessary for the task. There are her powerful jaws. With them she can cling firmly to the wall of the chamber when I try to drag her to the outside. They are instruments of sufficient strength to penetrate the human skin. The obvious procedure for her to adopt is to seize the capsule in her jaws and pull it back into the interior of the nest. It should be a very simple operation indeed for one that can construct this graceful cell. But it is not so. She investigates it; she thoroughly explores it, but she never makes the slightest effort to grasp hold of it in her jaws. Perhaps she will anchor it to her spinnerets and in this way drag it in; for such is the procedure of certain other spiders when they are in the habit of transporting their cocoons. But she is equally unable to do this. Clearly she is very perturbed. The shelter of the cell is no more than half-an-inch away, yet she seems lacking in the simple ability to transport her precious capsule there. Why is this? She is certainly not deprived of the means to do so; she could transport her prey easily enough. It is because such a mode of operation never happens to enter her thoughts.

But see what she does do. She commences to spin. She applies herself to the capsule and emits filaments which anchor it to the outside wall. Wherever points of vantage happen to exist, there she attaches her threads. She even attempts to weave a delicate skein over the young, as though she wished to prevent their escape. She swings her abdomen; she draws out her lines; she frequently rests, in order, I take it, to elaborate fresh supplies of silk. But what she cannot do is to drag her brood back again. I return the next day. The capsule is still outside, firmly anchored to the same spot. A few of the youngsters have found their own way into the interior and apparently the mother is happy with them. The remainder have disappeared. In their tender, half-developed state they have probably been destroyed by the sun.

The interpretation of the little experiment is surely this. In its natural state the capsule is a fixture; it is never one of the ordinary duties of the spider to transfer it from place to place. The only mode of action she ever applies to it is to anchor it, or to envelop it, with threads. Whenever the capsule needs any attention then the spider's instinct is to spin. To affix her jaws to it, to drag it, to transport it in any way is an operation quite out of keeping with the ordinary, accustomed methods of her life. To act in this way would mean the introduction of a complete innovation; it would require an act of originality which is quite beyond her powers. She can deal with her capsule only in the way that she has always dealt with it. She can do nothing but spin.

I now pass to another question. It is not all tranquillity for the spider in her long and patient vigil with her young. Her chamber is exposed to many dangers, and, except for those which are secured in sheaths, she must defend it to the very end. It sways in the air near the tip of a blade and is fully exposed to view. There are a number of enemies prepared for pillage if given an opportunity to break in. I frequently find a chamber torn forcibly asunder; there can be little doubt but that it has been plundered by insectivorous birds. At other times I find the wall perforated with a hole. It is a small and ragged opening where some predaceous insect has gnawed in. The carnivorous ants which infest the vegetation are a serious menace to the safety of the brood. If every crevice in the wall is closed, then the ants are helpless and the offspring are secure. But give them the slightest opening and they will pour into the interior to fall upon the eggs or young. It is more than likely that one kind of spider will devour another's brood. For I sometimes find the wall of a chamber eaten, the contents looted, and a spider of another species peacefully sheltering within. Perhaps she is merely seeking an innocent refuge, though I suspect her as the destroyer of the cell. I have opened the chambers to find beetles intermingled with the eggs, which I suppose they were using as food. Then again I have seen the eggs replaced by the maggots of diptera, showing that some fly had forced an entrance there. But incomparably the most serious danger to the nest is from the attacks of the ichneumon wasps. They thrust their ovipositors through the leafy walls and implant their eggs within. I think none suffer so much from the attacks of this parasite as the chambers with the encircling sheaths. They are built of double strength, but they have no fond parent always on the watch to guard them against the insidious foe. The presence of the mother in the interior is a greater protection for the eggs than is a wall of many layers and a system of encircling bands. I open one cell. The spider's progeny has disappeared. In their place is a graceful, yellowish, oval cocoon, blotched darkly at one end. A filament projects from either extremity which anchors it to the chamber wall. I preserve the nest. In a few days the cocoon bursts and a black ichneumon wasp appears.

But I once had a fortunate opportunity of witnessing the parasite at her destructive work. It was on a cloudy evening in the rains, when the heavens were ready to burst. I was admiring an excellent example of the strapped triangle fixed to the blade of a rush. Unexpectedly one of these active parasites appeared. She alighted and moved so confidingly over the chamber that I was able without much difficulty to watch her movements closely through a lens. She was an agile little insect of slim proportions, and not more than one quarter of an inch in length. In appearance she was typical of her class. Her colour was a uniform black and her thin transparent wings were marked with dark transverse bars. Unfortunately she was obscure not only in appearance, but also in the entomological scale. I have sent her for study to one of the best authorities, yet I cannot supply her name. No doubt, like so many of the minute and humble insects of this country, she is still unknown to science.

Let us watch her actions. She hurried about in the usual excited manner of her class. She investigated the whole exterior of the chamber. She was all eagerness and attention. Nothing seemed to disturb her; she realised that she had found the object of her search. Her long curved antennæ were instantly in play. All the time vibrating, they never ceased to touch, to test the surface of the chamber, and in some way to discern the position of the eggs that lay beneath. She made no attempt to force her way through a crevice; that is not her plan of reaching the cocoon. At length she appeared to be satisfied with her search, and began to direct her attention to one particular spot. There she fixed herself. Down went her abdomen until it was turned at right angles to her body, and the tip of her ovipositor was applied to the surface of the leaf. Then came the plunge. The sheaths of the ovipositor were drawn well back; the slender needle was exposed, and with a gentle though decided pressure the leaf was pierced, and the weapon was forced into the interior of the nest. It was thrust in to the hilt until the tip of the abdomen came in contact with the leaf. There it remained for a moment, during which time the fatal egg was laid. Then it was partially withdrawn, though not extracted altogether from the wound. Again it was thrust in, then again and again. The thrusts were made in different directions, though all through the one wound. In this way the parasite dispersed her eggs within the whole substance of the cocoon. At last she ceased to work her probe, and soon withdrew it completely from the cell. She was off immediately on another search, selected a second suitable spot, and there plunged in her dart again. Thus she continued with a stubborn persistence until she had infected the whole brood. She did not work aimlessly; she knew exactly the correct point at which to strike. That is certain, for I opened the chamber, and there lay the spider's clump of eggs beneath the very spot where she had pierced. Soon her own offspring will develop and will destroy the spider's young.

There is thus an unceasing war against the eggs even when sheltered in their leafy nests. But what of the widespread destruction of the young as soon as they leave the home! Their numbers are incalculable on this grassy plain, at least, of those which lodge their nests within the flowers. In the autumn the manjha is a sheet of plumes, and its surface is a glittering white. In one half or one third of these satiny spikes is hidden a spider's nest. Sometimes I see two or three secured in the one plume. And each is tightly packed with nearly a hundred eggs or young. What a vast profusion of tender life is this, and what a powerful manifestation of the spider's procreative power! And yet, like the downy seeds of the grass themselves, which are swept as snow before the wind, perhaps not one in a thousand of these tiny offspring will survive. Assuredly they suffer great destruction as soon as they leave the nest. Many must fall victims to the insectivorous birds which hunt through the tall grass, and others no doubt come to a speedy end in their first precarious journeys through the air.

One word more: just a note on the final act in the life-history of these little cells. The young have grown into a lusty brood; they seek to shake off the domestic bonds, and clamour for their individual lives. The maternal duties too are over, and both parent and offspring are ready to abandon the home. It is a simple matter in the case of the spiral. Before them are the open gates, and when the inclination moves the brood they can straightway make their exit into the world. In the triangle they are closely sealed all round, and a slit in the lining membrane is required in order to open a crevice in the walls. No doubt the parent effects this; the slightest tear will cause a separation of the edges, and the young can make their way out. In the sheathed type the barrier is of a stronger nature; it is an edifice of many layers. But by this time the elements have made their mark upon the architecture. It has borne the heat, the rain and the beating of the monsoon gales. It is by now a battered structure; many of its encircling threads are broken, and its walls are withering beneath the pressure of the bands. A chink has by now appeared somewhere in its substance through which the young can effect their release.

I see them emerge from July to September, throughout almost the whole period of the rains. As a rule, they pour out through a fissure in the wall. Each at its very first fall from the nest emits a slender thread. There it hangs, suspended by its filament, still retaining for a little longer a frail, an almost invisible, connection with its home. Others join it, and soon a crowd of animated specks swing downward from the leafy nest. They meet; they join one another; they climb about from thread to thread. Wherever they touch they emit a filament, and thus very soon they construct a tangle through which they spread themselves as brownish points. There they congregate for a time in the close vicinity of their nest. It is a lively and expectant swarm scattered through a complex labyrinth of threads. I touch the cluster and the tiny offspring break away. It is the instinct of protection at its very earliest stage; each puts forth its invisible thread and drops down out of the common fold. I watch them for a little while in the gentle breeze; I hope to witness the final severance from the home. As the wind strengthens, each little spider swings out upon its filament, though still attached to the common skein. The thread strains and tugs on its attachment. At length it divides, and the spider at last is free. The final link is severed that binds it to its natal cell. It is now swept aloft; it floats away upon the air to seek its own fate in life. One by one the others follow and the swarm grows slowly less. I can see them for a few yards as they sail out on the elements at the mercy of the strengthening breeze.

The young have vanished, yet the empty chamber stands. Its broken walls have still some strength; its internal fibrous lining is intact; within is the silky débris of the nest, and a pile of delicate tissue where the young have cast off their skins. Though torn and deserted, it is not altogether worthless; it has some value as a chamber still. Spiders of other kinds will make use of it and there hide themselves from the midday sun. Weevils or click beetles may shelter themselves within; or the cattle-tending ants may appropriate it, and, having swept it and lined it with new silk, will convert it into an arboreal nest. To the very end it has a value, some little purpose to fulfil.

But the winter is at hand. The grasses shrink and wither beneath the cold, and the slender blades soon pass into decay. With them the leafy chambers fall. They fade; they shrivel; they fall asunder into straws; though often they retain their encircling sheaths almost till they pass into the dust.

CHAPTER X

THE DOME-BUILDING SPIDER

Winter on the Manjha—The Spider and her Snare—Characters of Spider—Haunts—Advantages of Communal Life—Mode of Escape—Time of Architecture—Commencement of Snare—Construction of Labyrinth—Appearance of Labyrinth—Laying of Radii—Fixation of Spiral—Appearance of Dome—Estimation of Industry—Contrast with *Araneus*—Conclusion

It is mid-December on the manjha, and the winter cold is at its height. The swollen streams have disappeared. Wide tracts of sand are now exposed and crumbling dunes are being heaped where floods were previously spread out. The biting winds have begun to blow. They roll the sands into rippled layers and sweep aloft the finer grains into sheets of driving dust. The vegetation withers and begins to fall. The downy plumes have long since scattered; the yellow stalks now desiccate and split, and the dry and sapless stems now shrivel in the lifeless cold. The teeming wealth of life is gone; most has been destroyed for ever; some is hibernating in the shelter of the soil.

Yet insect life still struggles to persist. It is only a thin and hardy fauna, but there are some which brave the inclement air and see the whole winter through. On the warmer days a few butterflies appear; it is only an occasional *Terias* or *Danais* lured forth by the midday sun. From the jungle we may drive a few vigorous moths; perhaps in the leaves we may come upon a mantis, or more rarely on a pair of weevils even now at their sexual rites. Most of the ants have taken to the ground. The *Camponotus* and the byre-builders are no longer seen, but sometimes a line of impoverished harvesters still struggles with its burdens of grain. The army of locusts has disappeared, so have the industrious bees and wasps, and the motley crowd of beetles is no more. Still the insectivorous birds can find a few carabids, and we can sometimes observe a sluggish scarab exploiting the pads of dung. Round about the shrinking pools there are signs of more abundant life. The *Tridactylinæ* still cling to the muddy edge, though now an exhausted swarm. The dragon-flies still sail along the surface, and even at times deposit their eggs. The whirligig beetles still pursue their circles, and the little skaters glide along the water without making the slightest ripple on the pool. The wagtails and the pipits that collect along the brink, and the swallows and the bee-eaters that search the air, indicate how insects struggle to exist wherever the earth is moist.

The spiders' cocoons are still upon the stalks. Those nests that were hidden in the downy plumes are now conspicuous nodules attached to the bare stems. In some the parent is still within, nursing her tardy brood. The tubes of the *Stegodyphus* are still anchored to the scrub, but the netted sheet is long destroyed. Sometimes the architect is imprisoned in her tunnel; more often there is only her carcass to be found enveloped in a crowd of young.

Life indeed is scanty on the manjha. What can engage our attention now? There is one creature which persists and toils throughout the season. Let us examine it when all else is hidden from our view. It is a spider which spins a delightful web shaped like a silken dome.

The species referred to is known to science as the *Cyrtophora citricola* of Förskal.

Spiders in their nature are cannibals and hunters; hence as a rule they lead a solitary life. But there are some which congregate in large communities, and I have little doubt that this close companionship makes for the benefit of all. Such is certainly the case with this member of the *Cyrtophora* which constructs a kind of circular snare.

But its web is not a work of the ordinary type. It is not, like the well-known geometrical snare, merely a wheel of delicate spokes supporting a spiral thread. It has a specially modified and more complex structure. It consists of a tangle of rigid stay-lines from which the circular portion of the snare is suspended like a hemispherical dome. Nor is it, like the circular snare, a glutinous contrivance to which the victims firmly adhere; it is rather a true entanglement, one in which the capture vainly beats its wings, only to be enveloped in a maze of lines.

Its mode of operation is very simple. Insects in their flight fall against the stay-lines, and in their struggles to escape tumble down upon the dome. The spider is lying in wait; she hangs back-downward from the centre of the dome, and the victim falls upon her from above. She rushes on her prey, seizes it, and drags it through the network of the dome. Then she envelops it in a skein of silk, and conveys it to a place at the centre of the dome, where she sucks away the body juice. Nothing but the dry shell is left, and this the spider shakes out of the dome into the tangle of subjacent lines.

Thus we have here a very different mechanism and structure from that of the ordinary snare. And it is worthy of a little observation in order to determine how it is made. For a single glance is sufficient to show that this is a most fragile and delicate dome. It is composed of such innumerable lines, all so closely knit, yet all so geometrically exact, that it far exceeds in elegance and beauty even the slender architecture of the garden *Epeira* or that of the *Araneus* of the streams.

First a word as to the spider herself. She is of a somewhat stout and ponderous build, and about half-an-inch in length. Her head and thorax are almost hidden from view by her abdomen, which is heaped up behind. They are welded into a conical or pear-shaped mass. The base of it is fixed to the front of the abdomen; the apex is directed forward and supports a line of widespread

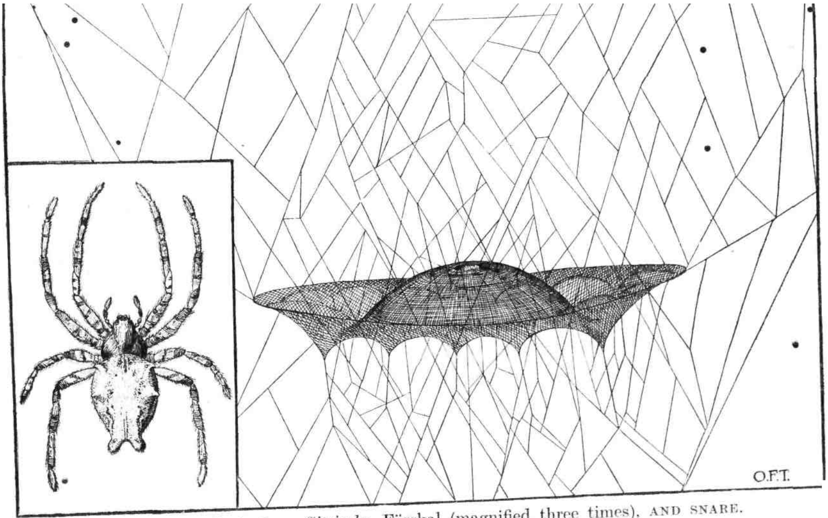


PLATE VIII.—*Cyrtophora Citricola*, Förskal (magnified three times), AND SNARE.

eyes. Her abdomen is by far the most conspicuous feature. It is heavy and large and rough, and its surface is raised into pointed tubercles like an armoury of teeth all round. Two stout ones rise up from the angles in front, one from the middle on either side, and two project from the posterior extremity, giving it a bifid point. Her legs are stout and moderately strong, and on the tip of each of her massive jaws there is a sharp and well-curved point. She is very variable in the colour of her dress. I find some examples of a delicate yellow; others are almost black. There are indistinct and darkish bands upon her legs, a pale sinuous line on either side of her abdomen, and on the middle of its dorsal surface in front two short light yellow stripes. She has clothed herself throughout in a silky fleece; it is a short and thick-set coat of compact velvety fur.

This spider is a resident of thorny shrubs. On the manjha the most favoured haunt was the acacia before it had grown into a great tree. She prefers still more a prickly cactus, especially if the plant happens to grow quite close to some pool or swamp. For the insects gather in the moist air; the spines on the cactus supply the points to which the spider can affix her threads, and the silken dome can be spread abroad in the wide spaces between the leaves. There was very little cactus on the manjha, but in other parts of Central India I have seen the webs enclose the plant in one vast uniform sheet.

For these spiders congregate in a dense commune. From the same support hang many domes, often in successive tiers. Filaments connect them on either side, and tangle blends with tangle through a complex labyrinth of threads. One dome is superimposed upon another, and each is linked by under stay-lines to the entanglement next beneath. Thus hundreds of individual snares are often woven into a single commune, and the cactus may be clothed from head to foot in a dense and tangled skein. But there is no conflict in this strange society. It is a true and real commune, and all live in harmony and peace. Though each possesses its individual architecture, yet the connecting threads between the snares appear to be the property of all.

Some special advantage must accrue to the spiders by the adoption of this social life. This is the rule in social communities, and the spiders would not have renounced their solitude unless for some particular gain. Consider this silken tangle. It stands as a wall, an impassable barrier of interwoven threads; it is a tangle to ensnare innumerable victims and from which there is no chance of escape. It is not merely an isolated contrivance, just to catch the occasional prey. It is rather a vast and widespread texture to ensnare everything that passes by. And what escape is possible from such a complex stratagem as this? Even should an insect escape from one labyrinth it only tumbles deeper into the artifice of the next. Nor does it face a single enemy; there are a number of spiders waiting to receive it, and many may dash out from adjacent domes to chase it amidst the common lines. Here, therefore, is a distinct advantage gained by a communal life. By their union the snares have become a barrier to engulf a multitude of prey, and the victim in its struggles to escape the tangle only plunges deeper into the net.

But there are other advantages, perhaps more important than this. Birds are very dangerous enemies of spiders, and the latter often gain protection by assuming some special disguise. But in the entanglement I think the spiders are secure. What birds would ever attack them in this stronghold? Even if they braved the long spines of the cactus, they could never penetrate the silken wall. They would find themselves immediately enveloped in the texture, and blinded in a cloud of web. But there is a more artful enemy, one more insidious and destructive than the bird. It is the army of solitary wasps and the numerous parasitic flies. The wasp overwhelms the full-grown spider, which it stores in its midden cell; the parasite is the more subtle enemy, for it strikes at the eggs in the cocoon. But there is safety in the labyrinth of threads. No wasp nor fly dare plunge into this tangle to be enveloped in a maze of silk. Thus the spider gains security, and suspends its nest in the substance of its tangle in the form of a white cocoon. The sac is stuffed with little yellow eggs, and though fully exposed to every view is yet safe from parasitic flies.

Some spiders hide their eggs beneath the stones ; there are others which conceal them in the bark of the trees. The *Lycosa* drags them to the depths of a burrow, or trails them behind her attached to her spinnerets. The *Sparassus* constructs a geometrical tabernacle and encloses her precious eggs within ; the *Attid* enswathes her tender brood in a capsule made of grassy plumes. These are some of the protective methods devised to shield the developing young. But the *Cyrtophora* avails herself of no such plan. Her cocoon is fully exposed to view in the entanglement of intercrossing lines. The system of threads is itself a barrier ; this is sufficient to guard the eggs and protect them from parasitic foes.

Thus all live together in one harmonious group. Other species, too, sometimes join the society. There is a spider, known as the *Ulobarus ceniculatus*, which weaves a circular snare ; and it habitually establishes itself at the outskirts of the entanglement, where it, no doubt, derives a share of the advantages which the social instinct supplies to all. This, therefore, is a real commune. I take a spider from one part of the entanglement and introduce it to another part elsewhere. It does not attempt to escape or desert. It waits till nightfall, when it finds a suitable corner in the stay-lines and there constructs a dome. I interchange two spiders, placing each in the other's dome. They appear content with their new surroundings and each accepts the alien snare. I extract a spider from its half-completed dome ; in a little while I see another invade the architecture and appropriate the network for itself. Nevertheless, though all live in harmony, yet each has its struggle for life. The stronger will take the victim from the weaker, and the swifter will take the quarry in the chase through the connecting lines.

Though they are all protected in this crafty artifice, yet they also have their individual methods of escape. Immobility is a spider's first instinct when alarmed. The *Cyrtophora* huddles all its limbs beneath it, and trusts that its resemblance to some inorganic fragment will allow it to be passed unseen. Failing in this, it takes to its heels and seeks safety amidst the stout cactus spines. And here, indeed, it is thoroughly secure, as he who tries to capture it well knows. When further pressed, it drops to the ground; it throws itself down through the tiers of domes, breaking up the fragile structures in its fall. Then, on reaching the ground, it lies absolutely still. This is the old accustomed ruse. It hopes to escape by simulating death and becoming lost in the undergrowth and leaves.

When a capture happens to strike the stay-lines, the spider often dashes forth and immediately takes up the chase. But it also adopts another plan. It remains fixed in its usual seat, and from there forcibly vibrates the architecture so as to shake the victim down on to the dome. In the same way it thrusts out offensive objects, and also the dried carcasses of the insects after they have been completely deprived of their juice. So also does it throw its whole handiwork into vibration whenever a stranger invades its home. On rare occasions, when fortune favours, two insects may strike the snare and become entangled at the same time. But the spider is not baffled. It pounces on one of them, pierces it, and leaves it struggling on the web. Then it rushes on the second, and having thoroughly dealt with it and enveloped it in silk, returns again to the first, which it finally and completely subdues. I doubt if it injects any virulent poison. Its fangs are powerful, and can penetrate the human skin. But they leave no sense of numbness nor any irritation at the point where they bite. They quickly subdue the struggles of a capture, but death is by no means an instantaneous act. Unlike many kinds of spiders, the *Cyrtophora* is unable to quell its victim in one vital stroke.

Let us now consider the spider's architecture, and endeavour to determine the way it is done. I explore the cactus day after day in the hope of finding an architect at work. I know the customary habits of the *Araneus.* Shortly before sunset she begins her snare, and after she has first devoured the tattered fragments which remain of her previous work. I hope to find the same instinct in the *Cyrtophora.* I visit her again and again at sunset, but I never catch her at her toil. She is closely related to the *Araneus,* yet this is not her time of work. I damage and tear away a number of snares. I wait for hours beside the cactus, expecting to observe an architect advance and reconstruct what I destroyed. Again my patience is in vain. These are certainly elusive little creatures; they will not easily reveal the secrets of their work.

I bring some home, and enclose them in a glass-covered box. The problem is quickly solved. As soon as the sun has set the spiders stretch some threads across the box. They carry the filaments from side to side so as to construct between the roof and floor an irregular tangle of lines. By morning they have woven a kind of network; it is just a maze of rigid filaments which I suppose correspond to the stay-lines of their snares. During the day they remain quiet and spin no further threads. But at dark the work begins again; it is nothing very elaborate; they just add a few more lines to the tangle, and that is all. I keep them for a week imprisoned in the box. At night they move energetically about. Here and there they add a filament to the confusion of tangled lines. By day they hang like huddled lumps suspended motionless to the threads. But they make no effort to construct those domes, the architecture of which I long to see. All that the prisoners in the box can teach us is that their labour is performed by night.

I rob the cactus of fifty spiders. I take them to my garden and establish them on convenient trees. There they are at liberty in their native air. I need only wait with a lamp till nightfall in order to see the commencement of their work. So at least it seems to me, and the necessary preparations are made. But, as usual, it is not so simple as this. The spiders do not like the trees which I have given them. As soon as I release them they immediately ascend; then they fix themselves motionless on the branches, many of them beyond my reach. I visit them again after the sun has set. I see them shooting forth their filaments; these must surely be the first lines and I am about at last to observe the work. But no. The free ends of the filaments float out upon the air; they anchor themselves on the distant trees. The discontented spiders have established a bridge; each climbs out along its filament and disappears.

They have abandoned the tree with which I supplied them. My efforts to establish a vivarium have failed. I now thoroughly search the garden, shining the light into every shrub. Out of my original fifty spiders I manage to discover six. They seem to have permanently established themselves on the bushes; two have even commenced their work. Here, at last, are some contented creatures which seem to be prepared to spin. It is only a small and scattered group, but it will tell us what we wish to know.

The spider lays the foundations of her snare in the usual, accustomed way. From her spinnerets she emits a multiple thread which floats away upon the wind. At its end it terminates in a sheaf of fibrils. This is the cluster which gives it support and anchors it to some distant point. The spider keeps a tarsus on the near end of the filament. With it she pays out more and more line until she feels that the further end has attached itself to some leaf or branch. When this occurs the spider knows that the first line of her architecture is in place. She then proceeds to lay additional lines. She may either climb around the twigs and thorns, attaching her filament to suitable points, or she may allow herself to drop on a thread and fix it to some point below. In this way she fashions an irregular framework in which no mathematical instinct is employed.

Her next operation is the construction of the stay-lines. This is a slow and tedious process, and occupies the spider under observation two whole nights. The architect moves about in every direction, upward and downward, to the right and to the left, attaching and reattaching filament to filament until she fashions a complex maze. It is an intricate and disordered tangle, like that which the spiders spread within the box. There is, no doubt, some system in the work ; the spider acts according to some method even in the attachment of these tangled lines. But whatever it is, it escapes my observation. I can watch her for hours feeling through this maze, waving and expanding her sensitive legs, testing her lines, measuring her distances, and without doubt weaving this silken labyrinth on some simple and predestined plan. I have too much faith in a spider's geometrical instincts to believe that one line is laid haphazard. What seems a confusion of filaments to us is merely confusion because we cannot understand. Such is the case in this labyrinth of threads. We cannot detect the spider's methods, we can only witness the result.

The architect works with persistent energy when engaged upon this maze of lines. But she breaks her labour with long intervals of rest, probably necessary periods of repose to permit the elaboration of fresh silk. After the first night of toil the tangle is half complete. Throughout the day the spider hangs passive on a stay-line. Her legs are turned in beneath her ; she is like an inert inorganic mass. The following evening, at dark, she again takes up the toil. Additional filaments are placed within the labyrinth. The tangle becomes more complicated. Triangles join with quadrilaterals and with polygons of every size and shape, until the architect is finally satisfied that the tangle is sufficiently complete.

The general appearance of the completed labyrinth supports what I have just said. It bears witness to the fact that the architect has laboured under the influence of some mechanical guide. For the tangle of stay-lines is not shaped just anyhow. It is roughly built in the form of a cone, the apex of which is directed upward, and the base of which is widely spread in order to support the dome. There is some order also in the constituent lines and the angles at which they join. For the most part the lines unite above and stretch downward and outward through the maze. The apices of the angles are thus directed upward, and the open mouths look down so as to face the future dome. Nor is all this without an end in view. The labyrinth is built of a conical shape in order that it may have a circular base to support the subsequent dome. The angles in network are directed upward so that the entangled insect, when enclosed within them, can escape only by descending into the dome. And the dome, of course, is the fatal net where the architect is waiting for her prey.

By the end of the second night the tangle of stay-lines is complete. And on the third night I observe the architect commence the construction of her dome. Patience at length has brought its reward. For this is a fabric of the finest texture. The most delicate work of the geometrical spiders is the dome of the *Cyrtophora's* snare.

The spider selects a point in the labyrinth which will be the future centre of her dome. From there she carries out a horizontal line, the end of which she fixes at the outskirts of the maze. She returns to the centre, carries out a line in another direction, which she anchors at the outskirts elsewhere. In this way she spreads out a series of radii. They are all horizontal ; they all diverge from the centre ; they are all fixed externally to the periphery of the labyrinthine maze. These are the foundation spokes which will serve as the framework of the dome.

This, in principle, is the mode of architecture which we observe in the ordinary snare. Take, for instance, the

Araneus nauticus. She too extends her radii all round her circular snare. But her work is very simple to observe. Her lines are stout; in numbers they are few and wide apart. Moreover, she works by daylight, and there is nothing to conceal our view. It is otherwise with the *Cyrtophora* and her far more delicate work. With difficulty we observe the spreading of her radii. The threads are so extremely fragile; the artificial light so poor; the labyrinth so confuses and obscures our vision that we can seldom get a clear and unobstructed glimpse of this system of diverging lines. It is more by the systematic movements of the architect than by the actual vision of her threads that we are able to follow the steps in the workmanship and understand the method employed. Indeed, were not the mechanism of the *Araneus* known to us it would, I think, be almost impossible to determine this more delicate work.

For where the *Araneus* spreads out twenty radii, the *Cyrtophora* extends three hundred and fifty, all in about the same space. And as their numbers are proportionately great, so also in transparency and texture they are proportionately delicate and fine. It is, indeed, a beautiful radial system; all the spokes are so evenly distributed, and all at their outer ends are only one-twentieth of an inch apart. They are marvellous in their close arrangement, in their wonderful geometrical exactitude, and in the extreme tenuity of their threads. The very strictest of geometrical principles must underlie so precise a work. Had we no other help to guide us we could scarcely ever unravel them here. But the architecture of the *Araneus* again comes to our aid. We know the way in which she measures and calculates, and we see indications of a similar mechanism in the construction of the *Cyrtophora's* dome.

We know that the *Araneus* takes her seat at the centre and employs her fore legs as a pair of dividers to measure the angles between her radii, and satisfy herself that all are in place. The *Cyrtophora* works in a similar way.

We cannot follow the nicer details, but we can see the trembling limbs diverge to search the spaces between the lines. We know that the *Araneus* makes her radii equidistant by measuring on the circumference a distance of four paces between every pair of spokes. The mechanism of the *Cyrtophora* must be somewhat different to this. She cannot make four paces on the circumference: her spokes are much too closely laid. But it is certainly at the circumference that she calculates the distance, for we can there detect her systematic movements which indicate that she is measuring the interval between her lines. And certainly her methods are wonderfully precise. Her radii are all laid with geometrical exactitude; it is the same perfection as in the circular snare.

One other little point before we leave the radii. Occasionally, while the architect is engaged at her spokes, we will observe that she suddenly halts, then drops from her place upon the radius and carries down a line beneath. What is this? It is one of the under-stays, which in the completed architecture will serve to hold down the dome. These stays are thus carried from the radii and anchored in the entanglement below. Their manufacture is merely the diversion of a moment. As soon as the attachment of the under-stay is made the radii are again resumed.

The radii are now complete. A widespread wheel of horizontal spokes extends through the midst of the maze. The framework of the dome is in position, and it is the third night of toil. The architect now begins to lay her spiral. She commences at the centre, where she suspends herself back-downwards from the inner extremity of one of the spokes. She then begins to circle round and round her wheel, stepping across from radius to radius and paying out her filament as she goes. This filament she attaches to every radius, and it becomes the close-wound spiral of the dome. She moves slowly and very deliberately as she weaves this perfect work. It is not, like the architecture of the *Araneus*, merely the work of half-an-hour. It is the exquisite product of infinite labour, the toil of half the night.

Now and again we observe that she stops and interrupts her spiral round. She has discovered a gap in her multitude of radii, an open space where, in her previous operations, she neglected to lay one down. Nor is it likely that she could spread this myriad of spokes without a single fault. But she quickly recognises every omission, and soon remedies the defect. For a moment she abandons her work on the spiral, runs out a new radius, and then takes up her circle again. Watch her carefully in her spiral round and we shall see the geometrical principles of her work. We cannot experiment on her spiral as I was able to do with the *Araneus* of the streams. It is far too fragile and delicate a structure, and too well enclosed in the labyrinth of lines. We can scarcely see it, still less apply our experiments to it. But with the help of what the *Araneus* teaches, we can observe her geometrical powers.

She is moving nimbly round and round, stepping from spoke to spoke. Her inner set of legs are, of course, towards the centre; her outer set towards the circumference of the dome. Watch her outer legs. Quick as are her movements we can yet see them deliberately feel each radius; we can observe how they grope and search the air should a radius happen to be missing from the wheel. This is the spider's testing apparatus; with these legs she is checking her previous work and satisfying herself that all her radii are in place.

Look at her inner set of legs, those directed toward the centre, to where the turns of the spiral are being successively laid down. The hindmost leg is turned backward so as to hook itself around the slender thread which escapes from the spider's spinnerets. It draws the filament from the abdomen and anchors it to the correct spoke. It is the needle of the little seamstress with which the beautiful fabric is woven. The fore and intermediate legs are also very delicately employed. At every radius we see them stretch inward so as to touch the filaments of the spiral which have just been laid down. They are measuring; they are estimating the correct distance at which to fix the filament to the spoke. But we fail to see the nicer details through the dim labyrinth of enclosing lines. There is no doubt that these legs are the organs of measurement, but we cannot detect with strict precision the individual use of each. The *Araneus*, we know, employs her fore leg alone in order to measure the distance between her turns. The *Cyrtophora*, no doubt, works on a similar plan, but in this feeble artificial light I cannot definitely decide. All I can see is her first three legs stretch out and touch the previous turns of her spiral. With her fore leg certainly, and perhaps with the aid of her second and third, she measures the distance between her turns and secures the perfect parallelism of her lines.

And, like the *Araneus*, she too reverses in her work. She is laying a spiral as she circles to the right. All of a sudden she halts, seals off her filament, makes a fresh attachment, and then starts off on a new circle to the left. Thus, wonderful little architect, she is ambidextrous. For different purposes she employs with ease the limbs of either side. The legs that a moment ago were groping for the radii now measure the distances between the turns; the hind leg that before merely carried her in her circles now draws out the filament from her spinnerets.

Onward she goes, hour after hour, circle after circle, never ceasing for a moment in the ordered sequence of this perfect toil. Within a space of half-an-inch she inserts no less than twenty turns of her spiral, so minutely delicate is this tissue of her lines. Cramped, yet nimble in all her motions, with every leg employed, each at its own special work, on and on she circles, testing, measuring, attaching, weaving an exquisite silken texture and surpassing all the rest of the *Epeiridæ* in the fine and inimitable delicacy of her art.

At length her dome is finished. Thousands and thousands of attachments have been made. The architecture of the snare has involved the seamstress in three whole nights of toil. The fixation of the spiral alone has occupied her for five laborious hours. How very different is this from the architecture of the *Araneus*, which from beginning to end occupied no more than thirty-six minutes.

Thus the dome consists of a close-wound spiral attached to a multitude of spokes. It is horizontal and is suspended in the midst of a labyrinth of lines. But it is not, like the ordinary idea of a dome, an absolutely even segment of a sphere. Its surface is drawn somewhat out of shape by lines which pull on it from above and below. There are some which spring from its upper surface and secure it to points in the labyrinth above; there are others which act like under-stays and bind it down below. These drag out the smooth surface of the dome into many-angled points. Nor are these under-stays arranged haphazard. There is no place for mere chance attachments in so subtle and exact a work. These under-stays are uniformly separated; moreover they are all so accurately placed that they hold down evenly the under surface of the dome at many equidistant points.

There is an aperture in the centre of the dome. It is at the point where the spider takes her seat and where the construction of the spiral was commenced. At first sight it looks like an open gate, a kind of passage to permit the spider to ascend from below into the labyrinth above. But I doubt if this is its real purpose or that the spider ever uses it as such. I have often seen the architect give chase into the labyrinth, but she did so by working round the circumference rather than by ascending through the centre of the dome.

Just consider for a moment the complexity of this handiwork and the infinite amount of labour involved in order to bring it to its perfect state. I try to make some kind of estimate, to roughly calculate in mathematical terms the degree to which the architect has toiled. I choose a snare of moderate dimensions; it is only six inches in width. As close as I can measure in so delicate a texture I count 350 radii within the compass of this narrow dome. At their inner ends they are so close as to be almost incalculable; at their outer ends they are only one-twentieth of an inch apart. I look to the spiral. For every inch in diameter forty turns have been laid, so that in the construction of a dome with a radius of three inches 120 circles have been made. The complete dome, I repeat, is so compact that it is woven into a diameter of only six inches, yet so delicate is the nature of its exquisite architecture that the spider has supplied it with over 41,500 meshes, and has untiringly attached her slender filament 42,000 times. It seems almost incredible that so much labour could be woven into so small a shape. In the finest of human fabrics does the intermixture of constituent threads ever approach such abundance as this? I greatly doubt it. The spider's ability to weave a tissue is infinitely superior to the art of man. For if man could gather so many fibrils into so small a space, then assuredly he would mass them into the densest texture, while the spider leaves an open net.

And when we think of the labour let us not forget that these numbers apply only to the dome. This occupies the architect only a small part of her time. How many attachments have been made in the labyrinth on which she laboured the two previous nights? Moreover the snare which I have selected is one of only moderate size. Search the cactus and we will find some considerably larger, perhaps as much as three times the width. They have demanded a still greater labour, and many more attachments were required.

What industry, what perplexity, what beauty is this all woven into a lovely web! And what simple geometrical instincts underlie it to make it so perfect and precise! Is there any structure of more consummate excellence in all the architectural devices of life?

One word more. This spider is an excellent and an accurate mathematician. Her instincts are in many ways like those of the *Araneus*, at least in the construction of her circular work. Just compare her for a moment with the *Araneus*, whose architecture I have elsewhere described.[1] The aim of the *Cyrtophora* is a labyrinth and a dome ; that of the *Araneus* is a plain circular snare. In our comparison we may altogether neglect the labyrinth. It is only the fine-spun dome of the *Cyrtophora* which bears any resemblance to the circular snare. Both are built on the same principle, for each consists of a spiral filament affixed to a number of radiating spokes. The snare of the *Araneus* is a wide-open structure with meshes comparatively few ; the dome of the *Cyrotophora* is closely spun and the tissue is infinitely fine. There are some twenty radii in the snare of the *Araneus* ; there is a multitude in the *Cyrtophora's* dome. The *Araneus*, as soon as she completes her radii, binds them together at the centre with a hub ; the *Cyrtophora* distinctly differs from this, since she uses no hub in her dome. The *Araneus*, as soon as she completes her hub, then attaches a temporary spiral to her spokes ; the *Cyrtophora* makes use of no such structure, her spiral is permanent from beginning to end. The *Araneus* starts her main spiral at the circumference and circles in toward the centre of her snare ; the *Cyrtophora* commences her thread at the centre and works slowly outward to the circumference of the dome. One concluding contrast, perhaps the most important of all. The spiral of the *Araneus* is a viscid filament, the essential part of an adhesive snare ; the spiral of the *Cyrtophora* is a simple thread, the constituent of a labyrinthine floor.

This contrast brings me to the last point which I will make with respect to this snare. I have compared the spirals in the two architectures, and the question which seems of interest is this. Is the spiral in the dome of the *Cyrtophora* strictly comparable with the main spiral

[1] I fear much of this chapter will prove unintelligible unless the reader happens to be acquainted with the architecture of the ordinary snare. I have discussed this subject in detail in *A Naturalist in Himalaya*.

which we find in the circular snare? I do not think so. The one is non-viscid and is wound from within out; the other is viscid and is wound from without in. There is nothing in the architecture of the *Cyrtophora* which is homologous with the viscid line. The spiral of the dome must rather be compared with the temporary spiral of the circular snare. My reasons for believing so are these. Both are commenced at the same stage of the architecture —that is, after the radii are complete. Both are wound in the same direction, from the centre toward the circumference of the wheel. Both are similar in structure, since each is a non-viscid line. The difference between them is certainly considerable, though it is rather one of degree. The temporary spiral consists of but a few turns, and later in the course of the architecture is destroyed; the spira of the *Cyrtophora* is of infinite length and remains as th permanent filament of the dome.

The dome looks at first sight like an ordinary snar enclosed in a maze of threads. But this, as I have shown is not strictly true. The dome is fashioned on the sam broad principles, but it also possesses certain feature which are peculiarly its own. These features I have trie to disclose, and have endeavoured to tell what I hav learnt in the workmanship of this wonderful dome. It i a fascinating type of architecture to observe. I know no which to marvel at the more, the infinite delicacy o its netted structure or the inimitable architectural skil involved.

CHAPTER XI

THE OPERATION OF THE FLAIL

Home of Spider—Characters of Spider—Difficulties of Observation—Architecture of Tube—Mechanism of Flail—Comparison with Human Implement—Shaping of Tube—Characters of Tube—Architecture of Snare—Characters of Snare—Lines converted into Springs—Mechanism of Springs—Mode of Entanglement of Prey—Structure of Flail—Capture of Prey—Variety of Victims—Conclusion

THERE is another species of spider on this manjha which constructs a very interesting snare. This is the *Stegodyphus pacificus* of Pocock, and in her manner of workmanship she differs essentially from anything I had seen before.

The snare consists of a conical tunnel, which expands into a viscid sheet (see Plate IX.). The tunnel is the shelter in which the spider lives ; the sheet hangs down like a silken net spread abroad to entangle the prey. Sometimes it weaves this net amidst the grasses, more often on the bushes and the trees ; but its most favoured haunts are the branches of the acacia, where it can fix its filaments to the spines. As I have seen no mention of this peculiar web I wished to understand the method of the work. But the spiders on the manjha gave me little assistance. They were so shy, and so scattered, that I failed to detect the secrets of their work. It was necessary to strengthen the local community by bringing in foreigners from elsewhere.

The reinforcements were obtained in the following way. It was the month of October. The rainy season had passed away, and there was a thrill of winter in the air. I joined a small party in pursuit of game on their way to the Vindhyan Hills. Our destination was the jungle in the vicinity of Sasaram. It was an obscure and secluded place near where the most ancient cliffs of India rise from the Gangetic plain. What a change to look upon these hills—

> "The hills,
> Rock-ribbed and ancient as the sun."

How different from the vast even-land! And here we saw the two unite as where the ocean touches on the shore.

At our feet was a wide expanse of land as level as the open sea. It was dotted with villages, spread with fields; here and there stood a leafy peepul, or a tall and stately palm. Behind us was a sheer and broken wall, the ruins of a far greater range. There was nothing very striking in its present height, nothing to compare with the mightier and more recent barrier to the north. Its imposing feature was not its mass but its sudden contrast with the surrounding plain. The range was raised into rounded cliffs; they were evenly upheaved, uniformly carved, and their faces were hewn into vertical clefts wherever they faced the plain. Buttress after buttress followed in succession; they were so uniform in structure, so regular in build and height, that they might have been shaped by some great human architect rather than by the insistent hand of time. But it was their contrast, above all, that made the chief impression on the mind. The even land might have been the ocean and the cliffs a rocky shore.

We chose for our camp an amphitheatre in these hills. It was closed almost completely by precipitous cliffs, with only one narrow opening to the plain. A wild luxuriant jungle covered the whole of this retreat. It lay dense along the valley floor, and spread itself in diminishing thickness from the base to the summit of the walls. It was a true and virgin forest, rich and green and beautiful, sown by Nature's hand alone, still untouched, perhaps, in places, still untrodden by the wasteful and destructive steps of man.

Here was a home beloved of the *Stegodyphus*, for she is a denizen of the shady woods. On these branches she freely built her tubes, and spread below her viscid barriers to oppose all insect life. But this was no place to study her with care; she must be brought to more convenient soil. It was a simple matter to transplant her to the manjha. About fifty of the shelters are cut away, each with its owner enclosed. They are carefully packed in a tin box, and the spiders seem fairly content. Some remain for a week in confinement, others for twice as long; yet all live harmoniously together, and all in time are released. They are established on some bushes in a corner of the manjha. Their tunnels are secured with threads to the branches, and the owners placed within. Some, after a little while, desert, but the majority stick to their homes. A strong colony is in this way formed; it is convenient for easy and repeated observation; it will disclose the main principles of the work.

The *Stegodyphus* is a robust and powerful spider of a heavy globular build. The head and thorax are comparatively small: in front they are raised into a prominent arch but are markedly depressed behind. They are combined, as usual, into a single piece, which is coloured a reddish brown. More conspicuous is the large and ponderous abdomen. It is smooth in outline, oval in shape; in bulk it is probably three-fourths of the spider, and is thrust far over the thorax in front. The legs are moderately stout and strong; the jaws are of the ordinary powerful type, and, in the usual place beneath the abdomen, there is a prominent cluster of spinnerets. Thus this species is of a bulky build, though only three-quarters of an inch in length. Covering the whole surface of its body is a dense and hairy coat. Over the head and thorax it is uniformly grey, and it spreads forward on to the mandibles and palps in a similar silken layer. On the abdomen it darkens to a yellowish brown, where it is further adorned with a varying pattern of dark reddish or brownish spots. On the upper surface of the legs it again passes into grey, though beneath it is sharply banded with black and whitish bars. Lastly, there is on the under surface of the abdomen a patch of velvety black.

Such are the members of the vigorous colony which we have now established on the trees. We have left them nothing but their bare retreats and we now wait to see them weave their snares. But, as usual, difficulties immediately arise. Not one in the colony will work by day: they are amongst the strictest architects of night. We must solve the trouble as we did before and visit them with the aid of a lamp. So far all is simple; it is only now that the real difficulty begins. We soon discover that the *Stegodyphus* is shy to a provoking degree. The very slightest disturbance alarms her; she will work only in absolute solitude, when everything is silent and still. But the main point of exasperation is that the mere gleam of a light is sufficient to frighten her; it will cause her to cease her immediate labour and hide herself away in the interior of her tube.

This is a difficulty which we cannot overcome. It is impossible to follow the continuous operation; we cannot, as in the ordinary geometrical snare, observe the sequence from the beginning to the end. Now and again we note some movement; from time to time we catch a glimpse of some particular act performed; but it is little more than a momentary observation; the spider for a minute may endure the light, but she will then take alarm, and creep away into the cavity of her tube. We must learn what we can by a process of patchwork. We must piece together the broken details and the many disconnected facts observed. Each is a link in the complex chain; each has its own appropriate place in the lesson we wish to learn. Many of the links, no doubt, are missing; let us consult the few we have. They may not disclose every feature of the architecture; but, at least, they will teach us the essential principles of a somewhat remarkable work.

The snare, I have said, consists of two portions, the tube and the adhesive web. Let us first consider the architecture of the tube. The spider commences by making a scaffold composed of a framework of lines. This is a

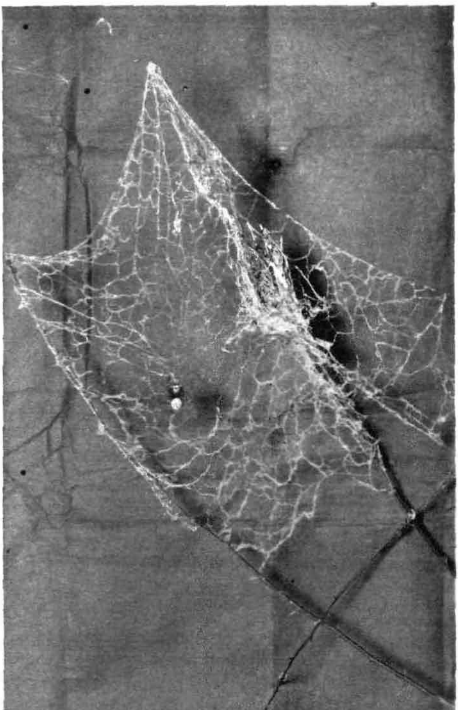


PLATE IX.—SNARE OF THE *Stegodyphus* SHOWING SPIDER, SHEET AND TUBE.

very ordinary feat. She chooses her place upon a branch. Round about her she draws some threads, anchoring them to suitable points. There is no system, no special method in her operation; she merely surrounds herself with an open network of irregular non-viscid lines. This is the fundamental framework, the scaffolding of the future tube. And, since the spider spreads it round about herself, it becomes naturally of a cylindrical shape.

The framework of the tube is now in position; and the spider's next duty is to cover it in a dense coat. The tube is the spider's permanent retreat; she occupies it well into the winter months; within it she lays her eggs and rears her tender brood; hence it is a structure of the first importance, and it must be built of some special material so as to be soft and warm and snug. It is useless for her to persist in the attaching of lines. These will provide an excellent scaffold, but to continue is merely to complicate the network; it cannot supply the substantial coat. The manufacture of this requires a special mechanism; she has an excellent one at her disposal, which, for want of a better term, I will speak of as "the operation of the flail."

It is employed in the following way. The spider is fixed near the entrance to her tube. She is clinging to her scaffold with her back downward, and is commencing to spread the coat. We observe that her hind legs are fixed in a characteristic way. They are so bent that the tips are turned in beneath the abdomen, and the tarsi are applied one against the other so as to form a kind of transverse bar. This bar extends the whole width of the spider; it lies close against the ventral surface of the abdomen, immediately in front of the spinnerets. It is this bar which constitutes the spider's flail.

As we watch we see the mechanism at work. The legs are thrown into a rapid tremor; the bar vibrates; it is thrust sharply backward and forward so as to beat against the lines of filamentous silk that are escaping from the spinnerets. The vibration continues, and we observe that the silk has undergone a change. It is no longer a fine transparent filament; it has been converted into a filmy cloud. It is clear that the spider's ordinary lines have been beaten into a fluffy mass. After a minute or two the operation ceases. A heap of cloudy fluff has accumulated round the spinnerets. The legs then separate; the tip of one is pressed in beneath the cloud; the mass is then hoisted upward and fixed to one of the scaffold lines.

What actually occurs is this. The flail beats against the emerging silk, and in the process of rapid vibration it literally jerks it from the spinnerets. But, in addition, it hammers it into an open texture. It breaks asunder the constituent elements; it separates the individual strands and thus converts it into a delicate tangle of finely divided fluff. The silk escapes with extreme slowness, and scarcely more than an inch of cloudy substance is manufactured at each operation of the flail. This much is then raised by the legs into position; the flail again resumes its work and hammers out about another inch. The vibration occurs with remarkable rapidity. I count two hundred and twenty beats in a minute, and the leg by the dim artificial light looks little else than a quivering blur.

It is a rather extraordinary process, as strange as any that I have witnessed in the mechanical devices of architectural work. And see the highly efficient manner in which it fulfils its ends. The fluff is raised and attached to the scaffold; heap after heap is added to the mass; it is an infinitely slow process, but in time the reticulated skeleton of the tube becomes clothed in a felt-like layer. Other spiders, such as the *Hippasa*, also construct a tube. But they have not arrived at the perfection of the *Stegodyphus*. Their plan is to emit a sheaf of filaments and to weave the bundle into the tunnel wall. It no doubt fulfils all that they require. But the resulting tube is a more open structure. It has none of the thickness nor softness nor warmth nor strength which is achieved by the operation of the flail.

To what in the human arts can we compare a mechanism like this? In the course of my professional duties I sometimes note the deterioration in my stocks of wool, and observe how the soft, loose-woven tissue collects into matted lumps. I employ an Indian from the neighbouring town to break open the texture again. He brings with him an implement which he calls a "dannuhi," and this, I think, bears a fair resemblance to the action of the spider's flail. The dannuhi is a heavy triangular implement. Two sides of the triangle are composed of wood: they constitute the solid frame; the third, which forms the base of the triangle, consists of a tense string of gut. The operator seats himself on the hard ground. Before him are the lumps of matted wool, and suspended from the ceiling is the dannuhi, supported by an elastic rope. In his left hand he holds the frame; in his right he grasps a special mallet and strikes it sharply on the tense string. With the blow the dannuhi falls, and the string comes down upon the matted wool that lies immediately beneath. The threads separate, the little fibres fly, and the lumps of compact tissue open into a flocculent mass. The strokes continue. The operator methodically applies his beats, and wherever the string of the dannuhi falls there the woolly tissue flies immediately apart. In a little while the whole is torn asunder, and the compact lumps of matted wool have been changed into a big cloudy heap.

Similar in principle to this is the mechanism of the spider's flail. Its function is to beat the tissue into a finely divided cloud. It meets the lines as they emerge from the spinning-wheel; the very moment they appear they fall beneath the living flail. With a rapid and methodical beat it hammers out the compact thread; it opens the fibrils, it spreads the silk, it scatters the individual elements of the line into a delicately woven skein. The threads from the spinning-wheel are wonderful in themselves, but how still more wonderful they become when dispersed by this remarkable flail.

Thus she constructs the wall of her tube by a process of adding to her original scaffold the loose and fluffy products of her flail. She attaches them irregularly, spreads them about in every direction, and, after many days of patient labour, they grow into a firm sheet. For part of the time she works in the interior; she spins first at one side, then at the other, always turning her ventral surface to the point where she applies her fluff. At other times she comes to the exterior, and, working there in a similar manner, she increases the thickness from without. Thus the wall of the tube develops, growing in substance and in strength. It is an infinitely slow and laborious process. Only a very tiny heap of fluff results from one working of the flail. Moreover, the spider toils only by night, and the beating of the flail is so tiresome an effort that she needs many intervals of rest. The labour of construction is thus very intermittent. She hammers at her thread for a little while, then retires to rest within her tube. It is, therefore, a most patient and prolonged operation, and it may take the architect many weeks of work before she has finally completed her tube.

As she heaps up her fluff so, and at the same time, she shapes her tunnel from within. I see her in the interior stretching out her tube. She is turning about, expanding her limbs, and moulding the structure into a suitable shape. Sometimes she thrusts her fore legs through the gateway and gathers up any loose tissue outside, which she quickly moulds into the edge of the wall.

After infinite toil the tube is finished, so let us now look to the completed work. It is shaped in the form of an elongated cone, from two to four inches in length. At the entrance it is wide and open, but within it gradually diminishes in width till at the end it tapers to a point. It is broad enough to permit the introduction of a finger and thus gives the spider sufficient room to move and turn about. The walls are dense enough to shield her from the sun and to protect her from the damp and rain. Internally they are lined with an even layer, but on the outside the workmanship is rough; twigs and leaves are entangled on the walls, and the empty shells of numerous insects are incorporated in the substance of the coat.

The spider so arranges the position of her tube that the gate is at the lowest level and the opening looks downward toward the ground. The interior, as a result, remains warm and dry; otherwise it would be flooded with the rain. She is very particular about this special point, as a little experiment will show. I removed one tube, inverted it, then replaced it in such a way that the aperture looked up toward the sky. But the spider refused to accept the change. The next evening she set to work. She made a breach at the bottom of her cone and there opened a new gate. In this way the position of the entrance was restored, and for a time the tunnel possessed two gates, one at either end. I had to leave before the labour was over, but I have little doubt that, at a later date, she closed the upper of the two.

The tube is finished: let us now pass to the architecture of the snare. The spider comes out from the interior of her tube and spreads out on either side of the gate a few strong horizontal lines. Later she adds to them, strengthens them, reduplicates them, and thus extends from the mouth of her tunnel a reticulated silken frame. She is intermittent in her efforts. From time to time she re-enters her tube; there she applies herself to the adjusting of the interior and to the rapid operation of her flail. Again she resumes the horizontal tangle until it is sufficiently complete. She has fashioned in this way the upper supports from which her apron will subsequently be hung.

She then proceeds to lay the main lines of her snare. I cannot follow her continuously, she is so extremely wary and shy. Let us note the scattered facts. On one occasion I see her slowly advance and carry out a slender line. She works her way along the vegetation, and finally affixes it about a foot from the gate. Then she climbs back along it, reduplicating it, and returns to the tangle near the tube. This is one of the main lines of the apron;

it is non-viscid, tense and strong. Sometimes, like other spiders, she must allow herself to drop in order to secure an anchorage for these threads. I have not witnessed the actual fall, but from the position they often occupy they could be secured in no other way. These main lines are roughly parallel; in the case of certain larger species this is specially marked, but in the snare of *pacificus* they are unusually irregular, with numerous connecting threads. They are placed about an inch or rather more apart. In themselves they have no power of entanglement; they are the main supporting cables to which the adhesive filament is attached.

The spider, while engaged in laying these lines, is continually groping in the air. She sweeps her legs in different directions and searches for the neighbouring threads. In this way she recognises their actual position, and tries to keep them to somewhat parallel lines. Her method of fixation is very precise. She presses her spinnerets firmly against the point, and rolls her abdomen from side to side; she has to make what is clearly a decided effort before the thread is firmly fixed.

The supporting framework being in position, her next step is to spread upon it a specially adhesive thread. Her main lines are the ordinary products of her spinning-wheel; her adhesive filament is the manufacture of her flail. Again it is difficult to follow the operation, but the method is essentially this. The architect clings to a pair of parallel lines. She sets her flail to work and beats out a short length of silk. She lifts it up with a hind leg and attaches it to one of the lines. Then she advances a little, beats out another length and anchors it to the opposite line. In this way she lays a transverse thread so as to connect the two parallel lines. It is loose and wavy, very adhesive, and of the usual characteristic open texture that results from the operation of the flail. The spider continues to advance; she anchors her thread first to one side, then to the other, working in a slow methodical manner, since she has first to beat out her line.

Her procedure is therefore one of alternate attachments, a spreading of a transverse adhesive filament between a pair of parallel lines. The filament thus presents a sinuous appearance and, since a similar one is fashioned between each pair of lines, the result is a kind of open net. The meshes are sometimes neat and regular, indicating how methodically the spider has worked. More often we observe a considerable tangle, which shows that the architect was clumsy and confused.

The resulting net is of considerable size. That of *pacificus* usually equals about the area of a handkerchief, but the larger kinds may spin them four feet in height and half-a-foot in width. It is a powerful square-meshed fabric, a kind of reticulated apron, spread tightly across from branch to branch. The tangle above secures it to the foliage; below it is anchored by powerful cables either to the subjacent foliage or to the ground. It is a tense and elastic barrier; no insect, once entangled, can tear itself from the adhesive lines. Even the large and powerful locust is enmeshed in so secure a net.

But I have not yet mentioned its most interesting feature, the nature of the adhesive line. The viscid filament of the circular snare is adhesive by virtue of its gum. Let us look to the observations of Fabre. The great naturalist believed its structure to be like this. In the first place it is not a mere, single line, but a beautifully twisted cord composed of many threads. These are transparent, highly elastic, almost invisible, and yield without breaking to the struggles of a captured prey. In the second place they are hollow; each is a capillary tube: an infinitely narrow channel filled with a solution of gum. In the third place the walls are in some way porous; they permit the gum to ooze through their sides and moisten the exterior of the thread. Such is the appearance which this marvellous line presented to the observation of Fabre.

Now the adhesive line of the reticulated apron is different in almost every respect. Nor is it in any way less wonderful than the filament which I have just described. I pass a slide of glass beneath the network of the snare and remove on its surface a few of the adhesive lines. They attach themselves immediately to the smooth glass, and remain there firmly fixed while the microscope reveals how they are made.

We know that this thread has been hammered in the flail, hence we, in part, anticipate the appearance we expect to see. We do not look for one uniform filament, but for a tangle of delicate lines. And at the first glance it is as such that the structure certainly appears. It looks like a confused network, infinitely close and fine, with the threads packed tight and gathered into loops, but in which no very definite order nor arrangement can be seen. But as we examine thread after thread we begin to observe some method in the system; we follow the filaments through the apparent tangle until they assume a well-ordered shape; and in the end we realise in detail how the threads have been altered by the beating of the flail. We see that each of the beaten lines is composed of four separate threads. In the ordinary way they would fuse together so as to form a single line. But here they have come beneath the hammer of the flail immediately they emerged from the spinnerets. As a result they have been beaten into an open texture; the strands have been separated and drawn apart; the even and apparently structureless filament has been scattered into a loose tissue of threads. There is not a trace of moisture on them; they cannot, therefore, owe their viscidity to gum. They are not capillary tubes, nor is there any reason to think that their walls are provided with pores. Thus they present a very different structure from the filaments described by Fabre.

Let us study the lines with more particular care. The constituent strands are beaten apart, but they have been separated in no haphazard way; they have been given a special and remarkable structure when they passed through the mechanism of the flail. Each filament has been closely coiled; the coils have been pressed tight together so that it appears like an elastic spring. And since four strands enter into the composition of one line, hence what at first appeared a confused tangle is really an aggregation of springs. I stretch the line, the springs open; I slacken it, and the coils come together and meet. Hence its remarkable elasticity and strength. I extend it still further, and the springs completely open; they are now mere undulating threads. In reality, therefore, the line is of considerable length; it has been shortened many times by being gathered into these close-wound coils.

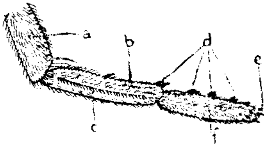
I have tried to calculate the delicacy of this workmanship, but it is difficult to be very precise. I can say this much: there are at least 1500 turns of the spring to every inch of line. Now I have little doubt that each of these turns is manufactured by one stroke of the flail. It is the function of this instrument to hammer out the coils, and nothing can better illustrate the precision of its action, its accuracy, its delicacy, its regularity, than the fact that it can beat out 1500 coils along every inch of line. And not only this, for it is an instrument of multiple power: at the same moment it can coil into springs four separate threads.

Such, therefore, is the structure and the appearance of this line. It is not adhesive by virtue of its gum; it bears no resemblance of any kind to the filament of the circular snare. This is a marvellous mechanical device, a system of multiple springs.

How can a mechanism of this kind act so as to ensnare a prey? Four elastic springs are combined in a single line. They lie side by side in an open bundle, and thus in all four directions their minute and invisible coils project. It is the loops of these slender coils which supply the first adhesive grip. For the seizure is essentially a mechanical device. In the snare these lines are loose and slack; hence the springs are ordinarily closed. The coils are of microscopic size, but are so infinite in number that any minute object which happens to touch them is immediately secured within a loop. Even the smallest granules and the invisible particles of dust are hooked beneath these subtle coils. Nothing that touches the cunning line can escape the tenacity of the spring.

Now on every ordinary substance, on the twigs, the leaves, the bodies and limbs of the innumerable insects, there are minute projections of every kind, just the very objects to get instantly entangled in a loop. An insect strikes the snare. Some point upon its body, a scale perhaps, or a minute hair upon the leg, is sure to come within a loop. The prey is hooked. It no doubt feels the invisible grip, though the strain is but a delicate touch. It pulls upon the loop ; the spring unwinds ; it is drawn far out, but so numerous are its coils that it does not fracture ; it holds its victim by an elastic thread. The other filaments too feel the strain ; as a consequence the texture opens ; the adjoining springs are more widely separated, and innumerable points of capture are exposed. The insect kicks and struggles to escape ; it pulls still tighter on the springs, but by virtue of their elasticity it is immediately jerked back. There are countless other coils now waiting to receive it ; they are the traps which it has itself exposed. They hook themselves over every point ; the legs, the wings, the body get involved, and hundreds of minute projections are soon gripped within elastic loops. All further efforts are now of no avail. The struggles only open the machinery still wider ; more and more coils of capture are exposed ; additional springs are brought into operation, and other lines in the vicinity are involved. The capture is now firmly secure ; escape is impossible from such a complex grip. It is held in the mechanism of a thousand springs, and battles vainly in the subtle toils.

I look on the product of a spider's spinning-wheel as one of the most exquisite manifestations of life. Escaping as a viscous fluid, it hardens as it meets the air. Then drawn from the wheel by a gentle strain it lengthens into a slender thread. We marvel at its physical qualities, its tenuity, its transparency, its elasticity, and yet withal its efficiency and strength. But how much more wonderful does its structure seem when we witness these four fine filaments emerge, when we see them pass beneath the hammer-beats, and when we realise that every single stroke sweeps them into microscopic coils. How much more wonderful does this line become when we know that its fibrils have been fashioned into springs, and that every two inches of the beaten thread has been wound into three thousand twists. Perfect indeed is the simple line, but how much more exquisite has it not been made by the action of the living flail.



Spider's Leg showing Structure of Flail

(*a*) Tibia ; (*b*) Protarsus ; (*c*) Ridge with short hairs ; (*d*) Spines ; (*e*) Terminal claws; (*f*) Tarsus

Before we leave this remarkable mechanism let us look at the implement itself. Surely such delicate workmanship must need machinery of a special kind. It is therefore surprising to find the hind tarsi of the ordinary, characteristic appearance and shape. There seems at first sight to be nothing peculiar or worthy of special observation in the flail.

I place the tarsus on the microscopic stage (see Figure, p. 203). It is of the usual jointed structure and is clothed in a thick coat of hairs. Let us look to the last two segments, the protarsus and the tarsus. Like the remainder of the limb they are enveloped in a silky fur. But in addition we observe along the anterior margin a line of rigid points. They are arranged in pairs, look firm and strong, and project through the surrounding fur. They are separated by uniform intervals ; three of them are on the front of the tarsus, and the fourth near the distal end of the protarsus. There is also a conspicuous one further up on the protarsus, and a rudimentary one near the terminal claws. But it is the four evenly separated pairs which deserve our attention here.

I imagine that these four pairs of points must supply the simple machinery of the flail. They are evenly distributed, uniform in size, and are fixed to the very portion of the hammer which comes in contact with the threads. Moreover, they are arranged in four definite pairs, and so there are four constituent filaments which go to the composition of a line.

The precise operation of such machinery I make no pretensions to explain. But I foresee no special mechanical difficulty; it is possible by certain movements and adjustments for a pair of points of suitable shape to twist a line into spiral coils. Whether the spider so employs them or not I cannot more definitely decide. But their general appearance, their position and arrangement, suggest this particular use. I was surprised to find that on the other legs there were spines of a similar kind. They were distinct on the tarsi of the second and third limbs, though I could not detect them on the first. These limbs are never employed as a flail, and this, of course, is a serious objection to the use I attribute to the spines. Nevertheless I strongly suspect that the duplicated spines are the agents employed, that each pair in some way applies itself to a thread, and that it is given some turning or quivering movement which twists the thread into a coil.

Now that we understand the mechanism of entanglement let us observe the spider's manner of attack and how she deals with her struggling prey. She is seated just within the opening of her tube. Her head is at the gate, her legs are on the main lines, and she is, therefore, sensible of the slightest quiver in any part of her net. An insect strikes against the subtle lines. It is not a mere fly nor fragile moth, nor any of the weak and tender kind such as fall into the circular snares. This is a strong and broad-meshed net, and is spread for much larger game. It will hold the powerful tiger beetles or the scarabs or even the vigorous locusts many times the spider's size. The victim, a locust for example, is immediately enmeshed. The spider is in waiting at the gateway and instantly feels the thrill. Out she comes, climbs leisurely down the apron, clinging to her parallel lines. She makes no great haste as do other kinds of spiders; no doubt she realises that from her snare there is scarcely a possibility of escape. Her attitude changes as she approaches her prey. Then she makes a rush, clasps it in her fore tarsi and rakes it into her jaws. Then, seizing it by a hind leg, she holds it in a firm grasp. For a while she makes no further effort; she merely clings with an unyielding grip. The great locust struggles, but she refuses to let go her hold. Unlike certain other spiders, she appears to have nothing to aid her strength. She injects no poison to help her in the battle; she has no knowledge of the vital spot which would quell all movement at a stroke; she makes no attempt to draw out threads so as to envelop her victim in a sheath. All she has is her bulldog grip and her exceptional muscular strength. She just clings tenaciously to the locust, while the latter battles for its life.

The capture has fallen on the opposite side of the snare. She must, therefore, pull it through the texture before she can transport it to her tube. She sets to work, presses the threads aside with her tarsi, breaks them, separates them, and drags forcibly on the locust in her efforts to pull it through the snare. She sweeps her legs all round about it in search of the entangling lines. Some she severs with her tarsi; others she draws into her mouth and cuts with her powerful jaws. At length the locust is released from its entanglement; a large rent has been made in the substance of the network, and the spider drags its unwilling victim to its own side of the snare. The next step is to haul it up the apron to the tube. This is a laborious process. The locust continues to kick and struggle; it puts up a stubborn resistance; its hind legs hook in all the meshes, and in its progress it lacerates the network of the snare. It tears the viscid filaments from their foundations and thus destroys the original symmetry of the web. The conveyance is strictly a trial of strength, in which the spider ultimately prevails. She at length reaches her tube, drags the locust head-first into the tunnel, and there devours it at her ease. She commences at the head. It is a slow and protracted feast. There is no crushing, no tearing of the tissues; she simply sucks so as to slowly imbibe the juice. I see her at evening take in a victim and she is still devouring it at dawn. Again we observe the deficiencies of this spider; she has no poison at her command. For a long time the struggles continue within the tube; the locust is not stupefied by a subtle poison; it is deliberately sucked to death.

At length the feast is over. The victim has been emptied of its last drop and only a desiccated shell remains. This may now be cast away. If so, then the surrounding attachments are severed. Jaws and tarsi set to work; they cut or separate the entangling threads, and the empty shell is pushed out of the snare. More often it is allowed to lie neglected somewhere near the entrance to the tube. Then as the spider extends her tunnel the carcass becomes entangled in the substance of the wall. The fluff is heaped all round about it, and the shell either remains attached to the surface or becomes embedded in the silky coat. Thus the spider makes use of her captures to the end: she employs the rejected corpses of her victims to strengthen and consolidate the material of her tube.

How curious and varied is the entomological collection thus incorporated in these spiders' tubes! A boxful of the tunnels is a museum in itself. It is only a heap of imperfect shells; but they are specimens with a living story; they will tell us of the spider's food. Examples of every order of insect may be gathered from these cemeteries in the walls. We are certain to find those most juicy morsels, the bright green grasshoppers, the murderous mantids, the powerful short-horned locusts many times the spider's size. They will reveal the story of their hapless fate, how the pointed-headed *Tryxalis* leaped into the snare, and the graceful leaf-like *Holochlora* became entangled in its sudden flight. We may also disinter the remains of the neuroptera, those insects with the lace-like wings. There are the shells of the tender termites, which, when the nuptial swarm emerged, fell into the invisible toils. There, too, are the green and golden dragon-flies, and their elegant allies, the ant-lions, with blotched and hyaline wings. There, too, we shall observe the yellow-banded hornet, the fierce and venomous *Polistes*, and other well-armed wasps. How furious must have raged the contest on the sheet to overthrow these savage foes! Amongst them also are parasitic forms; there are examples of the solitary bees and wasps, species which mould little earthen chambers or dig subterranean tunnels in the ground. And we notice occasionally the fragments of an ant, no doubt some wanderer which has found itself entangled while searching for provender on the branches of the trees. What a varied collection of beetles might be gathered from these silken tubes. Representatives of every size and kind seem to have fallen into this cruel net. I disentomb the stout-built scarab; it must have been scouring the wood in search of dung when it fell against the adhesive sheet. From other tubes I add to the collection, and the pile of broken shells before me tells of the fierce battle for life. Here is a robust and dull-coloured cockchafer, here a little brown click beetle, here a pale green weevil, here a bright and coppery buprestid, here a blue metallic chrysomelid, and here a brilliant tiger beetle decorated with vivid spots. There are others, too, of the great beetle tribe, and many broken shreds and fragments and miscellaneous limbs and shards. Embedded in the same close tissue are examples of the butterflies and moths. I find little dull-coloured *Geometridæ*, which at dusk have emerged from some shady place, and striking forms of *Noctuidæ*, marked with conspicuous triangles on the wings. I also find the widespread orange-coloured *Terias*, the *Danais* with its black and tawny wings, and the handsomely adorned *Hypolimnas*, with its marks of iridescent blue. There, too, are obscure examples of the diptera, different forms of stinging heteroptera, and many kinds of nauseous bugs. It is indeed a motley heap of corpses that remains after the spider's feast.

Such are the habits, and such the architectural achievements of the *Stegodyphus*. I have no further notes which bear reference to her mode of life. Perhaps more of her simple secrets might be gleaned were she not so elusive and shy. But let us be satisfied with what we have learnt, for she has revealed to us all we should expect.

How often have I looked upon the circular snare, and gazed with wonder at the inimitable work! I marvel at the delicacy of the texture, the beauty of the architecture, the subtlety of the contrivance and the mathematical perfection of the lines. Is there anything to exceed the elegance of this in all the varied handiworks of life? It may not be excelled, but it assuredly is equalled by the seamstress which I here describe. Her work indeed is no mean architecture; it is the most subtle that I have ever seen. Let us give her what is just and due; let us place her with the first of Nature's architects which construct the varied nests and snares. For none rank higher than the wonderful spiders which coil their lines into spiral springs by the skilful operation of the flail.

CHAPTER XII

THE DUNG-BURYING BEETLES

Scavengers of the East—Scarabs as Scavengers—Characters of *Onthophagus*—General Habits—Mode of Excavation—Experiments on Instinct—Special Senses—Experiments on Pressure Sense—Appreciation of Dimensions in Space—Inflexibility of Instinct—Object of Limitation to the Vertical Line

THOSE who live in temperate regions can scarcely appreciate the powers of Nature to remove the refuse of life. In the crowded population of a modern city an artificial machinery has been set up. With great labour, at considerable cost, aided by the most elaborate resources of the engineer, fortified by the most stringent sanitary laws, we have devised a complex and elaborate organisation, a system of drains and sewers and traps and aqueducts, in order to sweep away that burden which otherwise would bring forth pestilence and death.

But it is different in the more fruitful East. Save in a few of the largest cities the teeming millions of the Orient know nothing of our sanitary schemes. They adopt the most primitive of needful measures. All their refuse returns to Nature in the simplest and the crudest way. Of this we are clearly conscious on our very first investigation of their ways. Explore the vicinity of any village and you encounter a bed of filth; walk through the narrow streets of a city and the air is redolent with the smell. Were it not for Nature's scavengers the East would be the cess-pit of the world. Man assuredly would annihilate himself in the emanations from his own filth. For his offal and his refuse are just cast aside; they are thrown again to Nature for her to deal with as she will. And she destroys them in her own good way. Otherwise a slow corruption would ensue and a plague would envelop the land.

But a host of living scavengers has arisen, some in relation to man himself, others to the animals which he takes under his care. On them he depends for purification; without them a pestilence would surely reign and society dwindle away. It needs but the slightest and most casual observation to make the acquaintance of this invaluable host. The pariah dogs sweep the offal from the streets; the foxes and the jackals eat the carcasses by night; the hyæna crunches the hardest bones; even the badger is known to unearth dead bodies, and the wild boar to feed on the decaying flesh.

Look at any time into the cloudless sky and we are sure to see some great bird soaring while it scans the earth for carrion beneath. An animal is killed or dies by the wayside, and the feathered army is soon on the scene. The ravens or the crows will collect about it and voraciously deprive the carcass of its meat. What a sight it is when the clouds of vultures come, first swooping down in headlong flight, then tearing like mad gluttons at the flesh. One of the great eagles may sometimes join them. In India there are seven of the fine genus *Aquila*, and all of them will take carrion for food. And when the vultures have consumed every fragment of the flesh, even the skeleton is not always lost. For in the hills the majestic lammergeyers arrive to smash and devour the bones. Then there is the host of audacious kites, which fall on every piece of refuse and carry it off in their claws. There are the more particular scavenging vultures which congregate about every town and village to devour the excrement of men. There is even a species of stork, the adjutant, which has renounced its natural food in the water and has taken to devouring the carcasses and offal which accumulate around the larger towns. The rivers have voracious scavengers of their own. The tortoises eat up all kinds of flesh, and the crocodiles wait around the burning-ghats for the human corpses to be cast into the stream.

Equally important are the insect scavengers, a vast and innumerable array. The larvæ of many kinds of flies grow and develop in the filth. The flesh-flies and blue-bottles seek out the carcass; the house-flies prefer the dung. Their maggots eat through the putrid substance as they burrow and screw themselves along. At times they may appear as an insect plague, which indicates what stuff they have destroyed. There are many other scavengers which belong to this great diptera group. The jumping larvæ of the *Sepsis* may be found in excrement; the *Phora* breeds in decomposing matter; the larvæ of the delicate fungus-gnats live in decaying stuffs. Ants, though in themselves insignificant in size, yet, by virtue of their numbers, do incalculable work. They send out their armies to retrieve dead insects, and they will congregate in thousands round the body of a bird until they have picked it clean of flesh. Cockroaches feed on the refuse of the houses. They are the important scavengers of the kitchens, which they purify of crumbs and scraps. And what a multitude of scavenging beetles exist whose lives depend on filth. There are the rove beetles, which inhabit decomposing matter, the *Hister*, which we find in carcasses and dung. In the hills are the *Necrophori*, which inter corpses in the soil, and in the plains the *Nitidulariæ*, which gnaw the ligamentous remnants from the bones.

But incomparably the chief of this great array are the members of the enormous family of dung beetles, the *Scarabæidæ*.

They seek the excrement of men and cattle, gather it into nodules or rounded pellets and bury it beneath the surface of the soil. Since the greater part of their life is spent hidden in the earth, or lodged in the substance of some fæcal mass, they are not obvious to every eye. Nevertheless they exist in prodigious numbers, and the quantity of refuse which they remove is immense, almost beyond belief. So far as I can estimate by rough observation I believe that, in certain active seasons of the year, two-thirds of the excrement of this vast country must be carried by scarabs into the substance of the soil. Without their valuable aid the land would be an open sewer. Remember that it supports a teeming population of some 300,000,000 souls. And save for the few collected in the cities the whole of this great multitude of people depends on the work of Nature's scavengers to clear its filth away. It is possible to estimate in some degree the amount of refuse discharged each day as a consequence of the animal activities of men. I will not enter into numerical details but taking into account human ordure alone, I believe that in India during May and June as much as forty or fifty thousand tons of excrement must be carried by scarabs each day into the soil. And this does not include the dung of animals, which may easily double or treble the amount. It seems an almost incredible number. I advance it with no pretensions to the strictest accuracy, but I think it gives us a just impression of the incalculable value of this tribe of beetles as the leading scavenging army of the East.

And more than this. Without their aid what material would be lost to agriculture and scattered as dust before the wind! In our Western countries we look to the worms as the agents which form the vegetable mould, and which level and plough the land. They were Nature's instruments of agriculture long before the art of man. In the same class we must place the scarabs; they are amongst the foremost of the cultivators of the soil. It is not alone that they tunnel through its substance, that they upheave the deeper layers, and thus, in no slight degree, interchange the materials of the ground. Infinitely more important is the fact that they carry down the nutriment to the roots of the plants. They are the vast manurial army of the tropics, the natural fertilising agents of the soil.

From the point of view of their habits and instincts they may be divided into two main groups. There are those which mould the dung into pellets and roll them to some distant point; there are others which bury the dung in the earth at the place where it happens to lie. The rollers of the pellets are the more conspicuous of the two, and I will later tell something of their ways. I will here discuss the less active forms, those which bury the dung where it lies. I select the *Onthophagus capella* of Hope as a typical example of the group (see Plate X.).

It is a very plain and unattractive insect; the largest is no longer than one quarter of an inch and in colour is a uniform black. In structure it is built so as to suit its haunts, being shaped in the form of a wedge. Its head is flattened so as to serve as a shovel; the anterior margin is sharpened to an edge, and firmly fixed to the vertex above is a set of three blunt horns. Its substantial thorax is broad and smooth; above it is raised into a rounded back, which is decorated with tiny pits. The wings are hidden beneath powerful shards, and these, too, are prettily adorned with lines of delicate points. Its legs are, perhaps, its most attractive feature. They are decidedly strong and are bent into a curve. In all of them the tibiæ are peculiarly dilated, and support a row of spines. But the tibiæ of the fore legs are more specially constructed; they have been modified into powerful rakes. Each is armed externally with four blunt points and terminates in a slender spear. At the end of the rake is the inconspicuous tarsus; it is only a rudimentary tag. Such are the essential features of the *Onthophagus*. The two points which deserve our special notice are the manner in which the head has been shaped into a shovel, and the legs have been modified into rakes.

The *Onthophagi* by virtue of enormous numbers make up for their dwarfish size. At evening the half-wild cattle of the manjha used to drink at the streams and pools. There they left their droppings on the sand, and the dung beetles, perhaps for miles around, were attracted by the stercoral smell. It was easy to find and collect the *Onthophagi*. Break open the substance of any pad of dung and these beetles will be found within; dig into the sand beneath the lump and there they will surely be interred. By day they remain concealed in their burrows, but at nightfall they assume a more active part. They emerge from their seclusion in the dung or soil and take a heavy flight into the air. They go to seek out new fields of pasture, fresh lumps of juicy dung in which to lodge for the ensuing day. In these nocturnal journeys they travel far and wide, and are guided to the object which they seek by the acuteness of their sense of smell.

It is interesting to watch a group of *Onthophagi* assemble round a mass of dung. They are so full of eagerness, so greedy to be at the feast. Let us watch them for a moment and follow the strange purpose of their lives. Their sense of smell has brought them to the mass. They immediately press in beneath the edge and in a moment disappear from view. They then force their way upward into the lump. With their shovel-shaped heads they furrow out a road; with the rakes on their fore legs they thrust the débris to either side; with their remaining legs they take a purchase behind them and force themselves into the substance of the mass. They tunnel through it in every direction; they dig and wallow in the filth, and for a variable time they remain within, soaked in the stercoraceous juice. But the time comes when they must leave the mass. They then gather up a sufficient supply, which they carry straightway into the soil.

This beetle never conveys the dung to any distance; on all occasions it sinks its tunnel directly beneath the pad. It digs its shaft in a very similar manner to that by which it burrows through the dung. It descends head-first and heaps up the earth behind it. Its sharp head is the implement of excavation with which it cuts and chisels the soil. Its fore legs are its serrated rakes. With these the earth is scraped back beneath its belly; there it is taken in the remaining legs and thrust still further behind. In this way the scarab descends; it is a combination of ploughing and furrowing and raking by which it sinks its shaft into the soil. But the loosened earth must not only be thrust back; it must also be raised to the mouth of the shaft. The act is performed in this way. When the loose débris is pushed back by the legs it comes to lie on the blunt tip of the abdomen, which is fixed like a plug in the cylindrical well. As soon as a sufficient load is in position the beetle backs slowly up the shaft. It drives the earth behind it, hoisted on the tip of its abdomen, until at length it reaches the summit of the shaft where the earth is pushed through the gate. In this way a vertical well is sunk. It is perfectly cylindrical and about two or three inches in depth.

A supply of dung is collected from above and conveyed down to the bottom of this shaft. This will serve the beetle for food. At the foot of the well there is no fear of interruption. This is the beetles' private store, which has been rescued from the throng above. Owing to the shaft being hidden underneath the pad it is difficult to observe the interment of the food. The beetle goes straight from the substance of the excrement into the mouth of its well. But an allied species with similar habits disclosed to us one day how the work was done. The pad which covered the open shaft was merely a thin layer. The tunnel, as a consequence, opened on the surface, and the beetle could easily be observed at intervals dragging its provender underground. It made no attempt to mould the dung; it just seized a fragment with its fore legs and then backed with it into the hole. After a lapse of a minute it was out again, when it carried down another load. Thus its method of gathering and accumulating dung differs distinctly from that of others of the tribe. The rollers always first mould their provender and then push it off with their hind legs. The *Onthophagus*, on the other hand, takes it in its fore legs and backs down with it into the tube.

I have sometimes kept watch on a special piece of dung and observed the rapidity with which these scarabs cleared the whole mass away. By their tunnelling they pulverise it into little fragments. All the soft and succulent material is removed in twenty-four hours; there remains only a handful of shreds and fibres enclosed in an external skin. For the beetles do not come to the outside of the mass. This is baked in the hot sun into a hard and desiccated layer. They enucleate the soft internal substance; they deprive the interior of all its nutriment and leave behind an empty shell.

If we dig in the ground beneath the shell we shall find where its substance has gone. Here and there we shall come upon some pellets, little lumps of a roughly oval shape, about one quarter of an inch in length. But more often we shall meet with dry shreds and fragments from which all the moisture has been removed. In addition we shall discover nodules of earth soaked with the excrement of the beetles themselves. But collect it all into a single heap and it is only a fraction of the original mass. The reason is clear. The beetles have not only carried it down, they have also devoured the dung. At least they have sucked out all its juices, and moisture composes the greater part of the whole. They have left nothing but the hard indigestible débris, which is soon blown away as dust. And look at the beetles themselves. They exude along their tracks long strings of excrement which stain large patches of the earth. Dissect one, and we find the digestive passages stuffed with the products of the dung. Its gullet is dark with an ochreous fluid, and the abdomen is tense, from the main canal being full of the stercoral juice.

I confined a number of these beetles in a cage in order to understand their work. I wished first to determine the extent of their power of ploughing their way through the soil. Are they mere burrowers and nothing else? Or can they, like the *Necrophori*, which bury a carcass, gnaw through the roots and fibres of the plants which everywhere permeate the ground?

Let us see. At the bottom of the cage is a layer of sand. It is firm and slightly moist, just the natural material in which these scarabs are accustomed to dig. There are twelve of them housed within the cage. A few are running about on the surface, but most are buried in the sand. I lay on the sand a piece of fine-meshed net and place upon it a pad of dung. The beetles are immediately aware of its presence. They smell the odour of the excrement as soon as it is placed within the cage. Those on the surface press in beneath the net; those which happen to be buried in the sand immediately begin to revive. Some come direct to the surface and straightway undermine the pad; others dig a subterranean tunnel and thus come upon the dung from below. In a short time all have been aroused, and a crowd of hungry, energetic beetles is massed beneath the pad of dung. But they are unable to actually enter the excrement owing to the layer of netting between it and the sand. They certainly make every attempt to do so. But the threads effectually bar the way. What will the beetles do now? Will they be able to divide the threads and thus cut their way into the mass? It is not a very difficult operation. The threads of the net are no greater obstruction than the fibrous roots of the grass. There they lie, a dozen of them, all on their backs beneath the net. They thrust their legs upward through the meshes; they press and heave against the dung, and the whole mass rocks beneath the force. Some strive to burrow through the net. They force their shovel heads up between the threads; they twist themselves round so as to dilate the meshes, which they enlarge into circular holes. But I see no further progress. All they do is twist and struggle in their efforts to reach the dung. But labour of this kind is all in vain; yet they seem unable to do more. They cannot divide the little threads, though it would immediately secure their ends.

After two days I visit them again. I lift up the pad to see what has occurred. There they are in the same position, kicking blindly and fruitlessly on their backs. Their legs are still thrust up through the meshes, and they are still heaving against the dung. As a result of the continuous twisting of their heads one or two threads have been frayed away. But none has been designedly severed; none has been divided with their jaws.

I have also wrapped the dung in the net and enclosed the beetles within. They, of course, endeavour to carry down the material and bury it in the underlying soil. But they are as helpless as the beetles in the previous experiment. They certainly put all their strength into the struggle, but they cannot divide the threads. They are closely imprisoned within the network, though if they just cut a few threads with their jaws they could immediately make their escape.

These beetles are therefore essentially burrowers. They have wonderful powers to cleave the soil, but they cannot cut the fibres and the roots. As excavators they are much less efficient than the *Necrophori*. For these beetles not only tunnel freely, but they sever the subterranean stems. The *Onthophagi* could never effect this. A few threads form to them an insuperable obstacle, and any entanglement of roots in the earth must clearly impede their work. Thus they love to burrow in the sandy soil, where no fibres exist to obstruct their progress and interfere with the construction of their shafts. For this reason, I suppose, I find them in such numbers along the bed of the shrunken stream. This is the most suitable soil for the excavators. They can tunnel it more easily than those verdant places where the ground is interlaced with roots.

I now pass to another inquiry. Do the beetles show much intelligence in their actions, or are they bound by the force of instinct in the varied operations of their lives? I examine the problem in this way. On the sand I lay a sheet of paper. This takes the place of the net and supports a pad of dung. Now the dung does not cover the whole surface of the paper. All around is a projecting edge of about three-quarters of an inch. What will the *Onthophagi* do now? Of course they will immediately smell out the dung. Then they will burrow underneath the paper or between the paper and the pad.

They will then pursue the accustomed course. Those beneath will try to climb up through the paper in order to reach the dung; those above will try to penetrate the paper in order to enter the soil. We have seen that they cannot cut the meshes of a net, and I have no doubt that this layer of paper will as effectually bar their course. But there is here no need for them to vainly struggle as they did in their efforts to perforate the net. For I have allowed only a narrow fringe of paper to surround the heap of dung. The pad, in fact, is a little island separated from the encircling sand by a margin of three-quarters of an inch. This should supply no difficulty to the beetles. They need only crawl round the edge of the paper in order to gain their ends. It is only a width of three-quarters of an inch. By so doing those below can ascend into the dung, and those above can descend into the soil.

I make the experiment as simple as I can. I place a dozen of the beetles on the excrement and wait to observe the plans they adopt in their efforts to perforate the ground. In an hour I look to see what has occurred. The dung is resting on the sheet of paper. I see the mass rising and falling, so I know that the beetles are heaving at it below. I can hear the scraping of their claws against the paper, so I realise that they are striving to cut their way through. I lift up the pad of dung, and beneath it is the little crowd. Some are shovelling and raking at the paper; others are kicking and careering on their backs. All are vainly struggling in a blind and ineffectual toil. They are all just trying to dig down through the paper. Not one has yet learnt to make its way round the edge and thus enter the sand beneath.

The next morning, after twenty-four hours, I look to the prisoners again. They have had the whole night to explore their surroundings, and it is during these dark still hours that they are most active in their search. But I see no sign of any change. They are all still clawing in vain against the paper; all are pursuing the strong course of instinct and are striving to descend into the earth. Round about them is a strip of paper only three-quarters of an inch in width, but they have not the intelligence to pull the dung across it and immediately reach the sand. Nature has supplied them with an excellent instinct—that of sinking a vertical tunnel directly beneath the pad—but when I oppose a slight barrier to the fulfilment of that instinct, then the beetles are completely lost. Again I look at them after three days. Some have by now deserted the dung; others, indeed, have managed to escape through a break in the framework of the cage. But a few still cling to their old behaviour, and fruitlessly beat away their lives squeezed in between the paper and the dung. Not one has had the sense to lift up its burden and carry it round the edge.

The result is the same when the beetles are in the earth and endeavour to ascend through the paper into the dung. They are as helpless in every way as those which are trying to descend from above. The layer of paper is a veritable prison, and they merely beat themselves against the wall. The gates are open on every side, but the beetles are unable to pass through. It needs the gleam of originality to see them, and of this I cannot find a trace.

I employ other substances in place of paper. I try a layer of wool, with the result that the beetles in their efforts to burrow only get entangled in the threads. I try a layer of cloth, of glass, of tin; but in all cases with the same result. The beetles do nothing but endeavour to penetrate, and therefore struggle in vain. Instinct is the true and powerful guide in the normal circuit of an insect's life; but raise some barrier against the instinctive act; introduce some new obstruction which in the ordinary course of nature the insect would never meet, and instinct will then assuredly fail. The creatures it impels are obedient to its sway; they pursue the course which it directs, and just struggle inflexibly on.

I considered it worth my while to observe what kind of senses insects must possess which pass their lives in stercoraceous filth. It would be difficult to credit them with a fine sense of taste. And I suspect that they possess none. For I soaked some dung in a solution of quinine and gave it to the beetles for food. But they did not seem to object to the bitter substance. In a few minutes they were buried in the mass, and they set about devouring the excrement with the same avidity as ordinary dung.

It is otherwise with the sense of smell. Guided by this faculty they find their harvest; they recognise the odour of fresh dung from a distance, and come upon it in their journeys by night. It is the smell of the substance that draws them from the sand and makes them bustle round the interior of the cage. There is no need for them to see the dung; if it is given them enclosed in a cardboard box they are filled with the same zeal. Even if I place it at some distance on the top of the cage some of them will come forth from the soil. I soak some dung in a solution of camphor and lay it on the floor of the cage. But not one of them will touch this camphorated dung. They immediately appreciate the peculiar smell, and it drives them to the bottom of the cage.

They have an excellent faculty of appreciating pressure, and this must clearly be of service to them. It must aid their efforts to tunnel through the earth and force their way beneath the edges of the pads.

A few experiments will explain what I mean. I supply the beetles with a pad of dung supported on a fine-meshed net. As I have already said, they congregate beneath and endeavour to burrow their way up. I now raise the net a little from the sand. The dung rests suspended in a hammock, but there is an interval of about an inch between it and the underlying sand. The group of beetles immediately scatters. They now no longer make any attempt to congregate beneath the pad of dung. It is obvious that they smell it, and many of them hasten about the cage in their efforts to find it out. But they cannot come beneath it, nor can they sink their shafts unless they feel the weight of it upon their backs. It is the sense of pressure which serves them as the true guide. I lower the hammock to within half-an-inch of the sand. But the result is exactly the same. As the beetles crawl beneath the hammock the dung just barely touches their backs. This, however, is not sufficient. The beetles will not, or cannot, dig unless they feel the full weight of the mass pressing them bodily down on the sand.

And there is a degree of nicety in the development of this sense of weight. I place the dung in a brass box. This makes an unnaturally heavy burden and quite different from that which the beetles find in the ordinary course of life. A great excitement follows. The insects obviously smell the food though enclosed in a metal case. They search about; they find the box, and they first endeavour to press underneath. But they soon desist. In nature they have never experienced this weight; therefore it cannot be dung now.

I modify the experiment. I give them the dung enclosed in a little cardboard box. This does not appreciably alter its weight, for the box is extremely light. And consider the result. There is the same enthusiasm, the same search for the hidden dung. But in this case when the beetles undermine the box they remain concealed underneath. They feel the customary degree of pressure, the same that they would ordinarily experience when they dig into the dung of the fields. The result is that they congregate in a cluster beneath and endeavour to ascend through the box. They no doubt imagine, if they are capable of forming any such impression at all, that they are trying to dig in the usual way into an ordinary heap of dung.

Consider it again from another point of view. I endeavour to deceive the beetles; I supply them not with dung, but with another substance of much the same consistency and weight. The problem that arises is this, if the beetles are guided by the sense of pressure, then they should easily be led astray. They ought to collect beneath this strange substance in the belief that it is dung. I knead some bread and water into a pulp. It is a firm, soft and doughy mass, in weight much like a pad of dung. I introduce it into the cage where a dozen beetles lie buried in the sand. Near it I place a dry clod of earth. This, in consistency, is quite different from dung, and will serve as a simple control. In this case I place no excrement in the cage. There is, therefore, nothing to arouse the beetles, and the only time they will find the pad is when they happen to wander about. I, therefore, leave them for two hours before I look to them again. I then examine what has occurred. I find four beetles under the moist bread, none beneath the dry clod. From time to time throughout the day, and also on the following day, I come again to the cage. The result is the same. I always find a few beneath the bread; never one under the clod. On one occasion as many as seven had tunnelled up into my imaginary dung. Surely this is sufficient, and I conclude that the beetles are easily deceived. The sense of pressure alone has led them to mistake the moistened bread for dung.

But there seems a possibility of error here. The moist bread rests on the dry sand, and perhaps it is only to seek the moisture that the beetles burrow and congregate beneath. The experiment must be modified and rendered more exact. I select a larger cage. At one side of it I place the doughy bread; at the other the hard dry clod. The two are similar in size, and this will equalise the effects of chance. I now thoroughly moisten the sand; it is more like what the beetles ordinarily find in the bed of the neighbouring stream. They will have no desire now to seek the bread in order to quench their thirst. In this experiment there are twenty in the cage. Some are buried in the soil; others are crawling on the sand. As before, I examine the result after an interval of two hours. The mouths of three tunnels now open beneath the bread; there is a cluster of beetles struggling close by; and as soon as I disturb the little group they disappear down these vertical shafts. There has been no disturbance of the soil either beneath or anywhere near the clod. At dawn, on the following morning, I come to the beetles again. I raise the moist bread. Underneath I see the sand furrowed and tunnelled ; I note that little hillocks of ejected soil have been piled up all round the edge. In the centre I see six of the thoughtless beetles foolishly stretched on their backs, the attitude which they naturally assume in their efforts to perforate the bread. Assuredly they are misguided by the sense of pressure ; They are betrayed by instinct into the blind belief that they are lodged beneath a pad of dung. I look at the under side of the bread, and on it are the diggings where the senseless creatures have tried to penetrate the doughy mass. I raise the clod of earth. There is not a beetle underneath, and the sand is absolutely undisturbed. I think we are justified in our conclusion now. The moist bread supplies a sense of pressure similar to that of a pad of dung. The beetles are deceived by the influence of that pressure. When they feel it, their instinct impels them to dig, though their digging is, of course, in vain.

One further addition, and the experiment becomes complete. The beetles are buried in the sand, and as before, I place the bread and the clod one on either side of the cage. I now suspend from the roof of the prison a lump of odoriferous dung. It hangs by a thin string, and the beetles will not easily reach it in their ordinary explorations of the cage. The odour of the dung will now excite them ; it will even reach them through the layer of sand and will call them from their tunnels to the feast. They are now affected by those two main stimuli which so largely influence the movements of their lives : they can experience both the sense of smell and of pressure within the interior of the artificial cage. So it is in nature, but with this difference. In nature both the smell and the pressure emanate from the same lump. Both are products of the dung. In the cage we have separated the two elements. The suspended dung emits the odour but supplies no pressure sense; the moist bread on the sand furnishes pressure but affects no sense of smell. What will the beetles do now? Just what we are led to expect. See the way they emerge from the soil, and we are satisfied with their sense of smell. Visit them again after a few hours in order to test their pressure sense. Lift up the bread. Beneath are the tunnels and the beetles themselves, and all round is the ejected sand. Lift up the dry clod of earth, and there is nothing whatsoever underneath. The facts of the experiment speak for themselves. The *Onthophagi* in their burrowings are guided by two factors. They find the dung by their sense of smell; they recognise it by their pressure sense.

I pass now to consider a somewhat different point. There are certain insects, for example many kinds of ants, which, I think, are quite unable to form any conception of the different dimensions of space. I have described elsewhere something of their ways, and I doubt if they know whether they move in the vertical or the horizontal line. But it is certainly otherwise in the case of these beetles which tunnel underneath the dung. When in the pad they seem to burrow quite aimlessly about, but when they enter the earth they habitually construct a straight and vertical shaft. I feel sure that they appreciate the directions they take, and that, even when imprisoned in the dark earth, they can recognise the dimensions of space.

A few simple experiments will indicate this. I half-fill a glass tube with moist sand to about three inches in depth. On the surface of the sand I place a pellet of dung with two beetles enclosed. What will they do? Why, of course they act in accordance with their instincts. They plough about for a little while in the dung and then sink a vertical shaft in the sand. This is just what we would naturally expect.

I modify the experiment. At the bottom of the tube I place the beetles and the dung, and I bury them in three inches of sand. The insects are quite in harmony with their surroundings. They easily dig their way up through the sand and escape by the mouth of the tube. Similarly, if the beetle is placed at the bottom and the pellet of dung on the top of the sand, the beetle will quickly construct a tunnel and climb up so as to reach the food. These correspond with the natural activities in the ordinary course of its life.

But I modify the experiment by a further step. The tube has hitherto been in the vertical; I now place it in the horizontal line. The dung and the beetle are at the bottom, and three inches of sand half-fill the tube. I lay the tube at full length upon the table and wait to observe the result. The beetle shuffles about within the dung. It soon finds that it is imprisoned and makes an attempt to escape. It tries to dig down, but the glass prevents its descent; it strikes upward, only to meet the same barrier there. At one side the whole width of the tube is open. If it will only dig horizontally, then it can immediately escape. But there an insuperable difficulty lies. In its natural life it ascends and descends so as to carry its food down a vertical shaft; it has no need to dig in any other direction, and never thinks of doing so now. Occasionally it does come an inch or so into the sand; but soon it returns to the fruitless efforts of trying to dig upward or downward through the glass. Merely turn the tube to the vertical direction and the beetle will quickly escape. Retain it in the horizontal and the prisoner is closely confined. Hour after hour it will struggle to get free; it will thoughtlessly beat itself against the walls of its prison, though the gate is wide open at its side. I leave the beetle for a day and a night. In the morning I see it still within, close to the bottom of the tube. The sand and dung are broken and intermingled owing to the struggles of the prisoner to escape. I turn out the contents of the tube. I wish to liberate an insect which cannot free itself. But it is now too late for this. The beetle is dead. Its efforts at release have overcome it; it has died in its wide-open gaol.

This, however, is an extreme case. At other times I have observed a beetle meet with better success. I enclosed some between two plates of glass fixed an inch apart. The plates thus formed a transparent box through which I could see what occurred. At one end of the box I placed four beetles, together with a layer of dung. The remainder of the box I filled with sand and left it open at the side. I placed the box horizontally on the table, and the only way the beetles could escape was by burrowing sideways through the sand until they reached the open end. But the result was much the same as occurred in the tube. The beetles struggled upward and downward, only to impinge against the plates of glass. After twenty-four hours they were still confined, and were lying motionless in the dung. But after another twelve hours one had succeeded in wandering an inch into the sand. On another occasion I repeated the experiment of confining them in the glass tube. After twenty-four hours they were still imprisoned, though on the next day three out of the four managed to find their way out.

However, I think the conclusion is clear. Buried in the earth, the beetles can appreciate the different dimensions of space. In their natural lives they ascend and descend and sink their cylindrical shafts in the soil always in the perpendicular line. To dig in the horizontal is quite foreign to their nature; it is an instinct which they never employ in the ordinary routine duties of their toil. Place them in such a way that they must modify their behaviour. Enclose them, for example, in a horizontal tube where they can burrow in only one line. Do this and their instincts will assuredly beguile them. All they will do is to beat against the barriers. Although the path lies open at their side, yet some of them will be irretrievably lost.

It is little more than the old, old story. It indicates the inflexible power of instinct and the irresistible nature of its force.

Now, what is the reason and object of this? There is always some valued purpose for every instinctive act.

When an instinct is fixed in some rigid way it is thus fixed for the creature's good. The *Eumenes* lays her pellet in the ordained place; otherwise she would build a clumsy cell. The *Araneus* circles in a blind routine; otherwise she would weave an asymmetrical snare. And so it must be with the tunnels of the *Onthophagi*. But where does the advantage lie? How does the instinct to keep to the vertical make for the beetle's good? On the contrary, might it not be a gain to the insect if it could tunnel just anywhere at will?

But Nature has a definite purpose in view, and in keeping the beetles to vertical lines she secures an essential end. For the beetles construct their tunnels immediately beneath the dung. In the excrement they scramble and compete with one another. Each is endeavouring to secure its share and hide it away in the earth. Moreover, since they exist in considerable numbers, the competition is generally severe, and the booty is never safe from plunder until lodged in the bottom of the shaft. Once it is there, then all is well. The owner can devour it at ease. But if the beetles could burrow fortuitously through the soil, if each could move about in every direction and dig on all sides wherever it pleased, then the plunder of not a single beetle would be safe. Each would invade the other's spoil, and the same competition would take place in the earth as is enacted in the overlying dung. The object of excavation is to hide away the spoil so as to secure it for the owner's use. But if the beetles could dig in every direction then the object would clearly fail.

But a still more important purpose is this. The female beetle deposits her egg in an oval capsule of dung. It is composed of the finest particles of the excrement, and must surely be a succulent and tasty morsel for any other beetle to devour. This is the most valuable of all her treasures, and she must hide it with especial care. But she has only one method at her disposal. She must hide it in the same way that she hides her food, so she sinks a vertical tunnel in the soil and conceals the capsule below. Nevertheless it is safe from danger lodged in the bottom of the shaft. Enemies surround it on every side, but they cannot reach the capsule of dung.

Thus, Nature has secured a valuable end by keeping the beetles to the vertical line. Since none can dig fortuitously, protection is ensured to all. A crowd may be buried under one pad, and only a narrow wall of earth may separate shaft from shaft. Yet this is all that is required. Instinct has ordained the rest. The beetles cannot perforate the narrow walls, since they must keep to the vertical line.

CHAPTER XIII

THE DUNG-ROLLING BEETLES—GENERAL HABITS

Characters of *Gymnopleurus*—Habits—Rivalry at Patch of Dung—Manufacture of Pellet—Contests—Rolling of Pellet—Surmounting of Obstacles—Burial of Pellet—Sense of Ownership—Exchange of Beetles—Robbery of Pellet—Evolution of Instinct

THE *Gymnopleurus miliaris*, Fabricius (see Plate X.), is one of the most common of the whole tribe. But it demands the keenest enthusiasm of the investigator in order to pry into its ways. For these beetles frequent those secluded haunts where men are accustomed to retire. There they wallow in human ordure. Indeed the scarabs which subsist on the droppings of the cattle are epicures when compared with these. But let us persist, though this is a disagreeable work. We may find something to enlighten, perhaps even to exalt us, from what at first only fills us with disgust.

The *Gymnopleurus* belongs to the sub-family *Coprinæ*. It has the habit of moulding the dung into pellets, which it rolls enthusiastically over the ground. The example I have chosen is an energetic insect, lively and active at its work. The female is slightly the larger of the pair. She is about half-an-inch in length, of a dull black colour enlivened with a tinge of green. Her body is bare and finely granular, and is prettily ornamented on its dorsal surface with a pattern of quadrate spots. There are twelve on the thorax and six on each shard. They are conspicuous more by their structure than their colour. For each is perfectly smooth and glossy so as to contrast with the rough surface all round. The thorax is of the typical shape and build, it is stout and strong and even and raised into a rounded back. The abdomen is concealed from view beneath the pair of close-fitting shards.

The head and the limbs deserve more notice. The principle of their structure is the same as in the *Onthophagus*; the one supplies the beetle with a shovel, the other with a pair of rakes. Consider first the head. It is markedly flattened and curved. It is powerfully made; its surface is finely granular, and it is fixed behind to the massive thorax by means of a rigid neck. Its upper surface is shelving and curved, being turned upward a little in front so as to pass into a sharp edge. But, unlike the *Onthophagus*, this edge is not even, the head is, in fact, a serrated shovel armed with six blunt teeth. Now let us look to the legs. They are longer and more slender than those of the *Onthophagus*; the hind pair are so long that they may project behind to almost the length of the insect herself. In addition each is bent into a graceful curve, and this converts them into geometrical instruments by which they can determine the spherical shape. The tibiæ of the fore legs are specially adapted to the work which they have to perform. Each is flattened into a wide spade; the inner margin is even and blunt, the outer graduates to a sharp edge, which is cut into four pointed teeth. Thus these tibiæ are diggers and rakes combined, implements fitted in every way for their work in the pads of dung.

A rich and ignoble harvest falls to this scavenger of men. I seek them at the onset of the summer rains, when the preliminary showers of early June cleanse the dusty sky. It is an hour after the sun has risen; the air is cool; the soil is moist, and I wait in the seclusion of the tamarix grateful for the privacy that such a place affords. The *Gymnopleuri*, vivified by moisture, emerge from their subterranean retreats. They come to the surface; they explore the air with their antennæ; they find the odour of the excrement, and break away in flight. I meet them as they arrive. Each comes swiftly, though somewhat heavily, through the air. Its hard metallic shards are raised and its clear expanded wings quiver with a gentle hum. It falls clumsily to the ground. Its marvellous faculty of scent has carried it almost to its very goal. It alights. Its antennæ, thrust out before it, search for the odour of the dung. Soon it localises the mass; it runs toward it, climbs up upon the excrement and prepares to explore what it has found.

There are others already on the mass before it. Some are of its own species; others are of allied kinds. There is the brilliant *Gymnopleurus cyaneus*, clothed in a metallic gloss, and with dark green, glittering shards refulgent in the morning light. Its habits are much the same as those of *G. miliaris*; they compete together on the same mass, and each in the same fashion rolls its pellet away. There, too, are many of the *Onthophagus* group. We are sure to see *O. bifasciatus*, a smaller beetle with a greenish head, and with its thorax and black abdomen marked with rosy bands. But this little species likes to work unseen and buries itself in the substance of the filth. We may also meet with *O. capella* and other closely allied kinds. But they, as I have said, never fashion a pellet; they carry the dung direct into the soil. Most of these are inconspicuous beetles with a plain and unattractive dress. If fortunate we may see a more gaudy kind. This will most likely be *O. pactolus*, a beetle with a body of shining bronze, and a bright green diamond patch upon its back. We may also observe the *Phalops divisus* drag irregular fragments from the lump and lodge them in a prepared shaft, or we may see the little *Trox* just feeding on the ordure after it is crumbled and dry.

All these beetles are competing with each other in their efforts to secure the food. It is a mad struggle for the means of livelihood, where each has its own resource. Some are digging, others moulding, others rolling pellets along the ground. There are some forcing passages into the excrement, others striking shafts into the earth, others dragging along shapeless masses, still others devouring the ordure where it lies. There is a rivalry amongst all in the group, and here and there a battle may ensue. The rain has aroused them all from their lethargy; they are not dependent on the sun. As the large drops fall we see them gather in a busy energetic group about the dung. Many dig only on the surface, but at times we observe that the mass pulsates from the thrust of those that excavate within.

They are usually joined by other rivals. The house-flies and the blue-bottles are instantly on the scene, and later on the carnivorous ants gather in from the surrounding ground. There are often signs of real beauty even in this mass of filth. The scintillating gleam of the blue-bottle, the sapphire and ruby of some of the scarabs place them amongst the gems of insect life. But there is a still more handsome visitor than these. The bright-coloured butterfly, *Hypolimnas bolina*, occasionally joins them on the patch. She seems so out of place, this aërial beauty with her wings glowing in iridescent blue and centred with large spots of white. Yet she too sometimes revels in the dung as she comes to sip the moisture from the pad.

It is a splendid example of insect activity brought into being by the season of the year. The scavengers work untiringly; they labour the whole day long. By the following morning the pile of ordure will have disappeared. The scavengers will have buried all beneath the soil, and nothing but a mound of ejected earth will mark the stercoraceous grave.

Let us follow the fate of the *Gymnopleurus miliaris*, and observe the manner of its work. Its first business is the construction of a pellet. It may set about the work alone, but if fortune favours it may happen to find a mate. It begins by examining the mass and seeking for a partner to share its toil. If it meets with a member of the other sex, then they will join forces and combine in the shaping of the pill. They may even celebrate a closer union; while they dig and grovel in the stercoraceous filth they may join in nuptial love.

At length they commence the work in earnest. Let us observe the shaping of the pill. The beetle begins to dig. It often selects some little prominence on the patch as a foundation round which to build. The excrescence thus chosen will become the nucleus of the future sphere. It wraps its hind and median limbs around the nodule; it thrusts its flattened head into the dung. With the sharp anterior edge of the shovel it then digs a circular trough around the nodule. It also assists with its fore legs, and in this way it maps out on the pad the size of its future pill. This cutting of the circle is a simple matter. The beetle, having taken its stand upon the nodule, merely rotates around its fixed point, and thus shapes a circular groove. A globular lump, roughly spherical, is formed. The beetle then takes its seat upon it, wraps its hind and median legs about it, thrusts its rakes into the furrow and gathers more and more dung into the lump. It turns about so as to deepen the furrow on every side, and thus it adds all round to the substance of the growing sphere. Thus it works, digging deeper and deeper into the trough, raking up the dung into the future pellet, until the structure is almost separated from the mass. It is all the work of a few minutes. Then with the fore legs it makes smooth the surface; it chisels away the little excrescences and presses down the rough exterior with the strokes of its flattened limbs. The pellet is in this way soon moulded into a sphere. A thrust or two with the fore legs then severs the pellet from the parent mass and it tumbles down from off the pad. On the ground it receives a little further attention, a few more presses with the head, a few more strokes with the fore legs. These are the final touches in its architecture; it is now ready for the road.

The pellet itself is a perfect sphere. Some are a little larger than others, but the usual size is about that of an ordinary marble. It is, of course, soft and easily pressed out of shape, but as it rolls it gathers round itself a layer of earth which serves as an external skin.

A single female may roll the pellet, or perhaps a solitary male. If either has found a suitable mate then the pair will combine in the turning of the pill. It is not always a peaceful occupation; before they get clear away from the patch they may have to defend their prize. There are others amongst the greedy group of scavengers which will forcibly steal it if they can. Another female of the same species may attack the legitimate pair, or the brilliant *G. cyaneus* may come forward on the same quest. Three females may sometimes struggle for the same pellet and the victress will carry off the prize. One female may persistently attack another, and the latter may refuse to accept defeat until driven repeatedly off. Then, recognising failure, she may abandon her property, only to direct her assault on another's fortification and perhaps carry the citadel with success.

But the beetle in possession will fight bravely for its own. A female will take her station on the summit of her pill. This is her place of vantage and there she will await the onset of the attack. As the enemy advances and rushes on the pellet then the owner on the summit is ready for the charge. She immediately thrusts forward her powerful spades, inserts them beneath her opponent's body, then by suddenly jerking them forward she lifts her enemy into the air and hurls it an inch away. Again and again the marauder may return; but the owner puts up a stubborn resistance; her serrated legs are always in their place ready to meet the charge. As a rule, there is no closer battle, though a female will sometimes find her fore leg clenched between her opponent's head and back. Then the contest will be more prolonged and, thus locked together, they will fight their battle tenaciously on the ground. On rare occasions the contest appears even; for I have seen a pair of warriors divide the booty and each make off with an equal share. They reserve these vigorous efforts for their internecine disputes. I placed on the pellet a *Trox*, which is a beetle of different habits and does not construct a pill; but the real owner would not attack the *Trox*; she simply rolled her pellet away.

There is also another kind of contest which results in a division of the spoil. It is in the nature of a clever robbery by force. The attacker charges violently on the pellet. The real owner offers no resistance. She behaves as though stricken with panic; she just clings motionless to the top of the pellet, hoping, perhaps, to escape her enemy by the old ruse of simulating death. But the attack continues though the beetle in possession remains absolutely still. The opponent then mounts the citadel, shears off the greater part of the pellet and makes away with the lion's share. The rightful owner recovers to find that she has lost all. Her attempt, if it is such, to simulate death is but a poor protection here.

Let us follow the pair. They have fought their fight; the battle is won; they still retain their pellet and are rolling it hastily away. They work in combination. They do not behave like the sacred scarabs, where one partner clings inert to the pellet and the other performs all the work. This is a more active and a more real union. The two beetles join their forces to secure a common end. One stands before, the other behind, the pellet. One pushes, the other pulls, and between them they roll the pellet along. The smaller one, the male, takes his place, as a rule, before the pellet. He is the pusher of the ball (see Plate X.). He literally stands on the tips of his fore legs, his head to the ground, his abdomen erect in the air. He clutches the pellet with his hind and median legs, and in this attitude backs himself along, pushing the pellet as he goes. His partner on the opposite side of the pellet assumes the reverse attitude and acts in the opposite way. She is the puller of the ball. She stands erect on her hind legs; with her fore and middle legs she clutches the pellet, with her hind tarsi she clings to suitable objects on the ground, and thus she supplements the work of her partner by pulling the pellet along. But the action is not altogether a simple pushing and pulling motion. The beetles work their legs alternately so as to cause the sphere to roll. It is the same movement that a man employs with his hands when he presses them alternately on the surface of a barrel which he is rolling along the ground.

They turn the pellet with energy and skill. They work in close conjunction as members of the same team. They are always in difficulty and trouble. Earth and brushwood block the route, and they must surmount the many obstacles which oppose their precarious path. They struggle repeatedly to ascend some slope, but the pellet rolls back on them again and again; they find themselves on the face of a precipitous hill, and as the pellet tumbles down, they cling fanatically to their hold. At times they may happen to be shaken from their grip, and then they must wander round about until they smell out the pill again.

They display a considerable degree of skill in surmounting the various obstacles of the path. There are the sticks, the tufts of grass, the little clods of earth, and the innumerable obstructions of a similar kind which lie scattered along the broken road. The pellet cannot be rolled through these impediments; it must literally be hoisted over them, otherwise its journey will end. And the beetles are well able to effect this. The pellet comes to a sudden halt; a fairly substantial clod of earth impedes its onward roll. The beetles continue to push and pull, but the pellet refuses to advance. One of the pair, the enterprising female, now runs off to explore. But she does this only if the pellet is fixed and stubbornly refuses to budge. Her mate retains his hold upon the pill. Having examined the cause of the obstruction, she returns; the two of them then exert their strength and proceed to hoist their burden over the clod. One of the pair, this time the male, thrusts himself underneath the sphere. His head is on the ground; the tip of his abdomen is in the air, and he thrusts up the pellet, raising it with his hind legs. The other, the female, sits on the top. She stretches up her hind legs and feels for some suitable projection above. If she finds one she clings to it with her hind claws, and strives to drag the pellet up. But it is the upward thrust of the male from below that supplies the principal hoist. By this effort the structure is raised higher and higher. At last the beetle is standing on his head; his brow, so to speak, is pressed upon the ground; his quivering hind legs are fully extended and directed straight above him into the air. Between their tips is the spherical pellet trembling as though about to fall. It is a comical sight to observe this kind of clownish act. But it serves its purpose well. By this vigorous hoist the load is raised until its height is sufficient to clear the obstruction, when it topples over the clod.

In this way they surmount a succession of difficulties; they are wonderfully persistent and determined in their efforts, and if they fail at first to overcome an obstruction they will return to it again and again. They are easily alarmed; at the slightest provocation they will immediately interrupt their work. Their first impulse is to lie absolutely still and cling tenaciously to the precious ball. They flex their heads, bend their antennæ beneath the shelter of the shovel, and curl in their slender legs. They lie still without a motion, it is the stillness of apparent death. For a minute, perhaps for five minutes, they remain in this quiescent state; then they recover, reassure themselves that the danger is passed, and resume the rolling of the pill. If their alarm is greater they are not satisfied with this simple trick. They will then desert the pellet and scuttle off over the ground, or else take to their wings and break away in flight.

They maintain a true direction and keep firmly to their course. I do not imply that all the beetles will roll their pellets away from the dung towards the same cardinal point, though I have seen a crowd of the sacred scarabs behave in this remarkable way. What I mean is that each pair has a fixed direction; there is a settled point towards which it must convey its burden, and it will not deviate from that point. Obstructions and difficulties of all kinds may oppose it. Some it will have to surmount, others to circumvent; but it will always come back to the old direction and strike on in the old course.

Occasionally a pair of beetles will appear to be dissatisfied with their pill. They cannot roll it with complete ease. They may have manufactured it of too large a size, or perhaps, in the exigencies of a difficult journey, it may have become pressed out of shape. But they soon appreciate the trouble and proceed to remedy the defect. They make smooth its surface, perhaps remould it ; they may even shear off the superfluous portion if it happens to be too large. Whatever be the fault they soon repair it and start off in the old course again.

The beetles come at length to the end of their roll, and their next business is to bury their pellet in the soil. Perhaps they specially select the spot as being in some way suitable to dig. But there is nothing apparent to the eye. They will excavate in the hardest pathway as happily as in the crumbling sand. It seems as though they just felt the impulse to dig, and digged anywhere at all. At times this impulse appears to be generated by the presence of some difficulty which they cannot surmount. A hill may confront them which they cannot ascend, so they excavate their tunnel at the base. I injure a beetle by snipping off a limb ; it often desists from the labour in hand and sinks its pellet in the earth. No doubt the instinct to construct a pill is naturally followed by the instinct to roll, and the instinct to roll by that to dig, each in its own rhythmical time. They are three successive and dependent links in the one instinctive round. And I suppose that when the beetles have rolled to the required distance the instinct to dig will assert itself, and the beetle must then commence to dig wherever it happens to be.

The excavation begins. It is the female that undertakes the work. She digs and shovels while her partner sits immovable on the sphere. She leaves the pellet. Down goes her head and the sharp anterior margin is driven into the soil. With the chisel-edge she cuts away the earth ; with the rakes on her fore legs she scrapes it back, and then, with the aid of her middle legs, she thrusts it up out of the hole. She excavates first at one side, then at the opposite side, and by thus rotating in alternate directions she constructs a cylindrical shaft. Soon she backs out of her tunnel, forcing up the débris behind her as she comes. She emerges, runs to her pellet, examines it, then resumes her work at the shaft. She disappears from view, but at intervals pushes up the loose earth, until a little pile accumulates outside. She again emerges, but this time not merely to look at her pellet. Her purpose is now more well defined; she takes hold of her burden and rolls it to the mouth of the shaft. The male all the while clings motionless to his place. He appears to take no interest in his partner's work; he just sits tight, merely awaiting events. Excavation continues. The pellet blocks the mouth of the tunnel. The beetle is digging underneath the pellet; the earth is being upheaved all round; the foundations are being undermined and the pellet is rapidly sinking into the shaft. Perhaps for some reason it will not slip easily down. The excavator comes to its assistance. She gives it a turn or two with the object of trying another diameter so as to secure a better fit, or she may dig into the tunnel on one side with the same object in view. She acts in this way very efficiently, and whenever the shaft will not suit the pellet she cuts it to a more adaptable shape. Thus the pellet sinks, carried down by its own weight. It disappears from view. The ejected earth falls in on it from above, and the inert male, still clinging to the sphere, is interred beneath the crumbling load.

After twenty-four hours I revisit the spot. A little pile of broken earth marks where the tunnel has been sunk. I carefully dig away the soil so as to follow down the vertical shaft. I trace it in a straight line for about an inch. Then it terminates in a blind end. I see no sign of any chamber, nor is there any remnant of dung. The two beetles have been busy with their burden in the interval; they have totally devoured it all.

These are the general habits of the *Gymnopleuri*, at least in their operations on the dung. I happened to encounter them in considerable numbers, and was able to conduct a series of experiments on their somewhat remarkable work. Let us pass now to consider what these experiments will reveal.

First let us inquire into the sense of ownership, the feeling which the beetle bears for that burden which it so laboriously rolls along. The pellet may be the property of a pair, or it may belong to a single female or to a single male. But, whether the property of one or two, it is of course their handiwork, and they remove it without delay. But is there any real sense of ownership? I mean does each owner recognise its own pellet and retain it because it is its own? Has it a special desire for this particular pellet because it was fashioned by itself? Certainly not. I abstract a pellet from a pair which are busily engaged in rolling it along. I give it to a female who has no pellet; she accepts it and whirls it away. I pilfer it from between her claws and give it to a solitary male; he too accepts the pellet; it will save him digging one for himself. The pair which I robbed originally I supply with another pill. It is sometimes larger, sometimes smaller, sometimes of equal size. But this makes no difference. The pair are satisfied with what I give them. They roll it eagerly away. I supply them with a pellet abstracted from a different species—in fact, from the refulgent *G. cyaneus.* This pellet is accepted also. I give them one of my own construction, a much less shapely handiwork than theirs. Nevertheless they are satisfied. They certainly improve my imperfect structure—they make smooth the rough surface and cut the excrescences away—nevertheless they greedily accept it, and when they have remoulded it to their satisfaction they start off again on their roll. The results of these experiments need no elaboration. The beetles have no sense of particular ownership. Any piece of dung will suit them, provided it is shaped into a sphere.

But one thing is certain. The pellet must be composed of dung. There is a spider, the *Lycosa*, which constructs a silken pellet as a capsule for her brood of eggs. Take away her pellet; replace it with a pellet of cork or paper, and the *Lycosa* is content. She clings to the new and worthless pellet in the belief that all is well. It is not so with the *Gymnopleurus*. She may not recognise her own particular pellet, but she is not so completely deceived. I rob her of her stercoral sphere. I supply another in exchange. It is made of a little moistened bread and is similar in shape and size. It is likewise of much the same consistency; as is the case with the pellet of ordure it is cold and pulpy to the touch. The *Gymnopleurus* takes it for a moment, but she is immediately dissatisfied and will not give it a single turn. She will have nothing to do with the alien pellet and straightway begins to abscond. I restore her original property. She accepts it, is content, and rolls on as before. I try her with other materials. I give her a sphere of cork, another made of matted and moistened wool; but the result is the same: she will have nothing of any kind unless it is a pellet of dung. I try to make my pellets more resemble dung. I smear them with the juice of the excrement, no pleasant operation, but the beetles still refuse to take them in exchange. It is not until I enclose one in a capsule of ordure that the beetle will accept it as its own.

Now, what conclusion can we arrive at here? Why will the *Lycosa* accept a pellet of any kind in exchange for her pellet of silk, and why is it otherwise with the *Gymnopleurus*, which accepts nothing but a pellet of dung? I think the explanation is not difficult to find. The *Lycosa* drags her pellet behind her suspended from her spinnerets. She feels that the object is there attached, and so long as it is of suitable size and shape she is satisfied that all is well. She possesses no other sense by which to differentiate the nature of such things. But it is otherwise with the *Gymnopleurus* and its pellet of dung. Size and shape and consistency—in fact, the elements of the sense of touch—are not sufficient to satisfy her means of recognition. She possesses in addition a wonderful sense of smell. And this sense must be satisfied, too, before she will accept the sphere. My artificial pellets are refused because they have no stercoral smell.

So much for the exchange of the pellets. The beetles have little special regard for their property; let us see if they show more respect for one another than they do for their pills of dung. A pair is working in double harness, the female in front, the male behind. They employ their usual energy, and the pellet is rolling on. I break the partnership. I first abstract the female. The male, though a little discomfited, again takes up the work. He does not hesitate to continue although he has lost his mate. I find another pair, and this time I extract the male. As in the previous case, the female seems equally unconcerned; she rolls away the pellet regardless of the fact that her mate has disappeared.

Let us continue. A lonely female is rolling her pill. She has had to mould it by herself, having found no partner on the parent mass. I take up a solitary male who is in the same predicament and is turning a pellet on his own. I rob the male of his pellet. I hand him over to the female who has failed to find a mate. They approach each other. Their antennæ meet. She immediately accepts him, and he too, no doubt, is happier by the change. At all events they are both satisfied; they join forces and roll the common property along.

The reverse experiment meets with a similar result. A solitary male is employed at his pellet. I supply him with a female picked up haphazard from the ground. He accepts her. There are no blandishments, no caresses. Each assumes the correct place at the pellet; they are now joint owners and away they go.

Of course the conclusion is clear. The beetles have no settled partners. They accept any one that happens to appear. It is much like their attitude towards their pellets. They seem prepared to take any one or anything that happens by chance to turn up. It is a poor manifestation of conjugal love, but as such it has been ordained.

Any sphere of dung is acceptable to any beetle; so also is any male acceptable to any female, and any female to any male.

Let us carry the inquiry a step further. Perhaps these solitary beetles are unfair examples. They have shaped their pellets all alone. They have not had the opportunity to study and choose their mates. It is by sheer ill-fortune that they have had to launch upon their lonely toil. Surely there is nothing very surprising in their readiness to accept the first partner that appears. But once they have decided to share their fortunes, once they have harnessed themselves in the double yoke, there must then be some bond of sympathy between them, some slight feeling of preference, at least some sense of recognition of their mates.

Let us see. I find a pair trundling its load. They are true partners. They met on the main mass; they moulded the sphere together, and harmoniously they launched it on its course. The pellet is their common property, and the partnership is as close as we can anywhere expect to find. I abstract the male. The female is now alone with her pellet. What will she do? She is not in the slightest perturbed. She has lost the mate who shared her fortunes, but she shows no trace of concern; without any hesitation she resumes her labour and rolls on the pellet alone. I now supply her with another male, one that she has never seen before. But it is all the same to her. She accepts the new partner. He does as well as the one she has lost, and between them they turn the load.

Thus the female cares nothing for her own mate, not even for the one who joined her at the very outset of their toil. And the reverse is equally true. I try the opposite experiment. I abstract the female from a genuine pair. But the male cares nothing for the loss, and later he accepts the new partner which I happen to supply. These things to the *Gymnopleuri* are as nothing. Any pellet or any partner will do.

But a beetle will not accept another belonging to the same sex. Certainly we may often observe a pellet in the charge of two females, or perhaps a pair of males. But this is not a true partnership; it is indeed the very reverse. It is the same kind of relationship that M. Fabre has shown to exist between a pair of sacred scarabs when they roll their enormous balls. It is in fact an attempted larceny; one is trying to rob the other of its gains.

A female is alone; she is turning the pellet by herself. I supply her with another female. They meet; the fans of their antennæ open; they touch; they hail one another as antagonists, and the one in possession jerks the intruder away. A solitary male is similarly employed. I give him a partner, also a male. But he refuses to share his load. A partner of the same sex is nothing but an enemy, and he prefers to bear his burden alone.

But we may easily be deceived, as for instance in such a case as this. I supply a solitary female to another of the same sex. There is some consternation, but no actual fight ensues. The true owner jumps down in front of her pellet and then begins to push it away at the greatest possible speed. The interloper with equal rapidity seizes hold of the opposite side and from there commences to pull the pellet with equal skill and haste. Never did a pellet roll more quickly than this. A female is harnessed at opposite sides; one pulls, the other pushes; each works as though her life depended on her efforts and as if her only object was to outrun the one at the opposite side. To a casual glance it might at first appear that each was satisfied with her partner, and that all this show of enthusiasm and haste was but the symbol of exuberant glee. But no. This is not the eager thrill of comradeship, it is the hurry of an insect endeavouring to escape. It is a case of attempted robbery. The one is trying to preserve her property, the other to purloin it. When the real owner observed the enemy which I had introduced, then her first instinct was to save her pellet, so she harnessed herself before it and made off at precipitous speed.

But the invader was too quick. She too saw her opportunity; with a rush she came round to the opposite side of the pellet and took up her station there. In this way each got a hold of an opposite side of the sphere, and each tried to secure the prize by turning it at full speed; and, since each works so as to wheel the pellet in the same direction, it is whirled over the ground at an exceptionally rapid pace. The incident is an act of theft; each is endeavouring to secure the loot.

I will conclude this chapter with a few remarks on the manner in which it seems to me that this pill-rolling instinct may originally have been evolved. For it is impossible to watch these beetles engaged at their task without being struck with wonder at the habit. And it is natural to consider by what steps its ultimate perfection can have been acquired. I think the process can be in part understood; for even at the one patch we see signs of the gradation of the instinct—evidence, I take it, of those slow degrees along which its evolutionary development has grown. We will first observe dung beetles of the genus *Trox*. They are but feeble excavators and scarcely burrow at all into either the earth or dung. They keep chiefly on the surface and feed on the excrement where it lies. The habits of the *Onthophagi* advance us a stage further. They also are incapable of transporting the dung, but they are powerful excavators, and in the vertical shafts which they sink beneath the patch they conceal their share of the spoil. I observed a third species, the *Phalops divisus,* which seemed to mark a further step. It dragged a lump of dung along the ground, but adopted a most primitive way. It clasped the fragment between its rakes and the chisel-margin of its head, and as it moved backwards, it hauled the load into a tunnel already constructed in the earth. It is a wide step from this to the *Gymnopleurus,* the maker of the perfect balls. But if we observe them with a little care, we shall notice that on certain occasions, when the dung is dry and difficult to mould, the most that the *Gymnopleuri* can effect is to shear off an irregular fragment and endeavour to roll it away. The beetle certainly strives hard to shape a pellet, and in the end usually succeeds; nevertheless it must sometimes remain content with an almost shapeless lump of dung. And finally we witness the last stage in the process, the construction of the perfect ball.

These are not very closely connected links between the simplest and the most advanced extremes. But at least they indicate the variety of methods by which these hungry visitors to a patch deal with their stercoraceous food. And there is evident to some degree a gradation in these methods, a possible indication of the line of development along which the perfect instinct has grown.

CHAPTER XIV

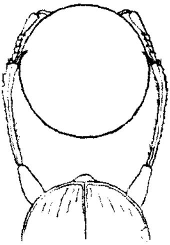
THE DUNG-ROLLING BEETLES—EXPERIMENTS

Experiments on Shape of Pellet—On the Geometrical Organs—On the Rolling Instinct—Female, the Initiator—Experiments on the Rhythm of Instinct—On the Functions of the Legs—Injuries in Nature—Special Senses—Appreciation of Directions in Space—Sense of Direction—Value of Directive Sense—Experiments on Directive Sense—Inexplicability of Directive Sense

I HERE continue to discuss my experiments. Some will disclose the mode of architecture; others will bear on the instinct involved in the performance of this peculiar work.

The *Gymnopleurus* has sufficient geometrical instinct to clearly appreciate the shape of her pill. Very occasionally she may fashion it into a somewhat oval form; but this is a rare occurrence; the pellet in almost every instance is a true and perfect sphere. The question, of course, arises: How does she attain this accurate geometrical shape? Watch her at the work of construction. While she is deepening the circular trench and raking up the dung into the rounded lump beneath her, we notice that she so places her hind and median legs as to wrap them round the growing sphere. They are curved in outline so as to neatly fit around the globular mass, which when completed into a sphere they evenly and naturally embrace. Moreover, while engaged in the act of construction, the beetle also rotates. Her legs of course move with her while they half enclose the lump; they therefore act like a pair of callipers which, as they rotate, successively measure in all directions the different diameters of the sphere. I have no doubt that by this means she estimates the degree of rotundity of her pellet, and that when she feels her long legs fit neatly round the structure, first in one diameter then in another, she is satisfied that the pellet has attained the shape of a perfect geometrical sphere. She is, therefore, in a sense a geometrician provided with special instrumental means for the performance of her perfect work (see Figure, p. 249).

At first it seemed to me very improbable that the stiff and hard integuments of these legs could possess any tactile sense, at least of such a nature as to secure the geometrical exactitude of this sphere. But I notice that there is attached to the whole length of the tibiæ a series of short, delicate and inwardly directed hairs, and these hairs must come into immediate contact with the surface of the pellet when the legs are employed so as to encompass the sphere. It is these little rigid hairs, I strongly suspect, which are the organs of tactile sense.


Hind Legs employed as Instrument of Measurement

A few experiments will indicate her capacity to appreciate geometrical form. A pair are engaged in rolling their pellet. I slice the globule in half. The geometrical perfection of the work is broken; they have now two hemispheres in place of a single sphere. The beetles cannot roll these fragments; it is only the sphere which will easily rotate. What, therefore, will they do? They are at first a little perturbed, for this is a new event quite out of their normal life. One sits motionless on a portion of the pellet; the other for a minute simulates death, then explores the ground in the vicinity, after which it returns to the broken pill. Both then start to examine the bisected globe. It is a rapid survey. They take a turn about amongst the pieces; they try to make them roll. But in this last effort they fail to make any advance. Almost immediately they recognise the changed conditions, and as quickly appreciate the method of putting them right. One beetle clings to one hemisphere, the second attaches itself to the other half. They stretch across the gap between the halves, gather up the dung with their fore legs, rake it across the gap, and heap it into an irregular lump. This they then mould into a better shape. They knead it with their rakes, chisel it with their heads; together they press out the gaps and fissures on the surface until they make it even and smooth. In this way they soon reconstruct their hemispheres into the usual perfect ball.

I advance the experiment a further step. I divide the pellet into four quarters. The beetles are now still more disconcerted. Often they find my interference too severe and they immediately desert the pill. But if they remain they will behave as before; they will quickly react to the new conditions, gather up the fragments, reshape the pellet, and roll it on again.

I alter the rotundity of their pellets. I convert one into a cube, another into a quadrangular mass of a narrow, elongated shape. The behaviour of the beetles is the same in each. They attempt a few turns of these angled pellets, but find it futile to go on. They wrap their long hind legs around the cube, and, finding that they cannot evenly enclose the mass, they learn that it is no longer round. They are immediately sensible of the change of shape, and they know how to convert a cube into a sphere. They first proceed to the edges and begin by shearing off the angles from the cube, or if it is a rectangular mass they cut off the extreme ends. The separated fragments they then rake into the mass; then make smooth the whole in the usual way and thus re-form the sphere.

I try another experiment. I flatten out the pellet; I, in fact, convert the sphere into a disc. How will the beetles meet the difficulty now? This is a severe test, so let us see how they perform the feat. They are naturally at first a little alarmed, but soon attempt to manipulate the disc. They commence with a futile effort to roll the flat circle along. It is a droll sight. The disc rotates edge over edge, and only with difficulty can it be turned at all. They will sometimes now desert the pellet, probably thinking that their troubles are too great. But some are built of more determined stuff; they refuse to submit to defeat, and will set to work and use every effort to restore the shape. There is no hesitation. As in the case of the hemisphere and the cube, they seem to comprehend the change that has occurred and to understand the manner in which to put it right. I think the female is the prime mover, the initiator, the one that first takes up the work of repair. They seat themselves on the flat surface of the disc; they proceed to the margin, and quickly chisel off a narrow rim all round the edge of the disc. Then with their fore legs they rake up the strip of excrement thus removed, and draw it inward to the centre of the disc. In this way they adopt the only possible method of converting the disc into a sphere. When I flattened out the pellet I pressed its substance from the centre to the edge. The beetles now do exactly the reverse; they again build up the material in the centre by raking it inward from all round the edge. And surely they must appreciate the alteration in shape when they act so efficiently as this. They thus rapidly fashion the rough outline of the sphere. Then comes the kneading with the legs, the final testing with the antennæ, and the pellet is as perfect as before. They have reconverted the disc into the sphere; they give the structure a few trial turns; they are satisfied and away they go.

This is sufficient. The beetles' faculty of perception is clear. They can appreciate the nature of the altered circumstances, and in solving the difficulties that confront them they exhibit an excellent resource.

But I must not press the conclusions too far. The experiments indicate that the beetle understands the shape of its pellet and possesses the power to restore the form if altered in any way. But this is all. The experiments do not disclose the actual mechanism employed. I have stated that the geometrical instruments are the legs, but without the help of further experiments we cannot substantiate this.

Let us proceed to the lump of dung where the pellets are in the act of being made. A female is digging in the pad. She is shaping her pellet and is raking up the material into the substance of her future sphere. See how her hind and median legs are neatly and evenly wrapped around the nodule. As I have already said, I believe they are the implements with which she measures the shape of her sphere. With a sharp pair of scissors I amputate one hind leg. This to an insect is not a serious operation, and I hope that, after a little while, she will again resume her work. For a minute or two she is overcome with shock. She simulates death, lying without a motion on the dung. But she soon recovers and returns to the architecture of the sphere. The conditions are altered now. What I take to be her organ of measurement is gone, for I believe that by encircling the pellet with her legs she can appreciate the spherical shape. Of these the hind legs are by far the more essential, and she has only one of these now. What will be the nature of her geometrical work under conditions such as these ?

Let us watch and observe what occurs. The mutilated beetle resumes her task and takes up the shaping of her sphere. She works according to her accustomed plan, raking up the débris as before. But it is clear that difficulties have now arisen. Her power to estimate form is gone. She wraps one hind leg around one side of the pellet ; the opposite stump she waves helplessly in the air, trying to make use of what she has lost. Nevertheless she persists in her work, striving in vain to construct her sphere. She struggles on ; she digs and rakes with her usual enthusiasm, but her skill as a geometrical architect is lost. In the end she completes her pellet. It is a poor effort ; it is moulded all out of shape. But, deprived of her implements, she can do no better : she can make only a formless mass.

I confirm the observation by a second experiment

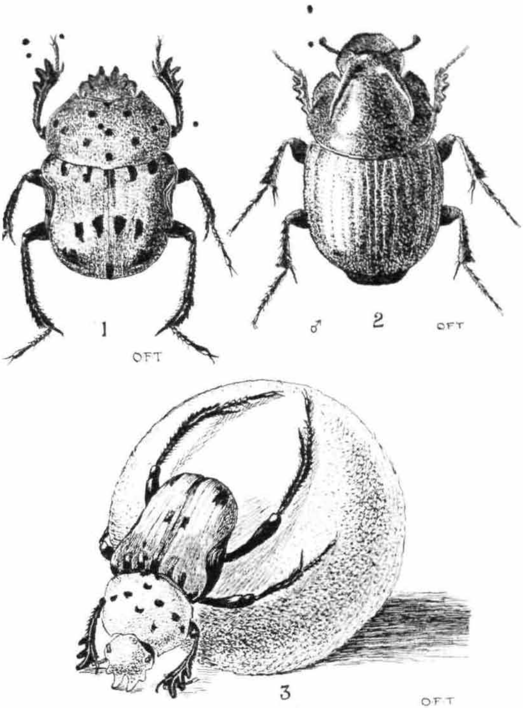


PLATE X.—(1) *Gymnopleurus milians*, magnified four times.

(2) *Onthophagus capella*, magnified six times.

(3) *Gymnopleurus* ROLLING PELLET, magnified four time

conducted in a slightly different way. I have shown that, when the shape of a pellet is altered, the beetle can re-form the lump. It can, in fact, convert a disc into a sphere. I find a female rolling her pellet. I snip off one of the hind legs. She lies motionless for a minute; this is so acute an interruption that she immediately huddles herself into a heap. I take my opportunity while she simulates death, and I press out the pellet so as to give it the shape of a disc. I wait for a little while and she soon returns to life. Now, what will happen? In most cases consternation will occur. The beetle is not always so in love with her pellet as to retain it after meeting such an injury as this. As a general rule she will abandon it; she will run off for a little distance and then take to flight. Sometimes she will behave differently. Perhaps she realises that she can go no further, for she straightway begins to dig and buries both herself and her sphere. There are a few, however, which will not be disconcerted. These are the ones to which our experiment applies. Even after the loss of a leg they will return to their pellets and endeavour to resume their task.

Let us observe the result. The question is: Can she reshape her pellet after a measuring organ is lost? She returns. She examines the disc. She gives it a turn or two. She tries to roll it, but she feels that there is something wrong; and, in spite of her injury, she endeavours to put it right. She does some cutting at the edge of the disc; she rakes a little of the débris to the centre, but she acts with none of that clear appreciation which we observed in the uninjured pair. The disc will not roll, therefore it is clear to her that something is wrong, but since one of her organs of measurement is missing she is unable to put it right. She cannot now re-form her pellet, at least with the same exactitude as before. She does gather up the stuff into a little hillock; she gives it a few feeble turns; she then makes a further effort to give it a suitable shape. Success is the just reward of such labour, yet she meets with none at all. Her organ of spherical calculation is gone, so she cannot reconvert the disc. True, she gathers the flattened excrement into a sort of lump, but it is far from being a sphere. She again tries to rotate it, but it is too shapeless to roll. At last she submits to failure. A few more turns convinces her of this and she sails away in flight.

Here, therefore, in the case of the *Gymnopleurus,* we are taught a similar lesson to that which certain other creatures have disclosed. Those species which are endowed with the faculty to construct bear on their bodies the simple machinery to construct on mathematical lines. How many burrowers in earth and wood are enabled merely by the act of rotation to utilise the particular shapes of their bodies for the construction of cylindrical bores! I have shown how the spider's geometrical work depends on simple mathematical methods, on the instinct to calculate the number of its paces and to measure the distances from point to point. I will show later how the cell of a solitary wasp depends on simple measurements too. So also it is with the *Gymnopleurus.* Her pellet is no rough handiwork; it is not something which approximates a sphere: it is an excellent piece of geometrical architecture, as perfect as human hands might make. And how simple are the geometrical methods she employs! Her hind and middle legs are her spherical callipers, but the hind ones, being the longer, are incomparably the chief. Possessed of such implements, and the instinct to employ them, she fashions a perfect sphere.

I now leave the geometrical discussion. It is always a subject pleasant to deal with, since it leads to conclusions definite and exact. I pass to a matter more open to argument—namely, that which deals with insect behaviour and the psychological interpretation of their acts. Let us first consider the experiments; the interpretations will follow in their course. The beetles are rolling a pellet in the ordinary, accustomed way. I place a small obstruction before them; the pair hoist their burden over it in the manner before described. I confront them with a larger obstacle, in fact a miniature wall up which they are unable to ascend. They come to a stop. The female leaves the pellet to explore. She soon returns, and they roll their load along the foot of the wall until at length they reach one extremity where they work their way round.

I dig a narrow trench across their path. Beetles and pellet both tumble in. They are surprised at the unexpected fall, and lie still for a minute clinging motionless to their load. Again the female shows the initiative. She goes off to seek out the cause. On her return they indulge in every possible device. They heave the pellet up with the intention of hoisting it out of the trench; they roll it from end to end of the furrow, but are blocked wherever they turn; they even dig into the soil beneath in their efforts to find a way out. But the furrow is too deep to permit their escape. Every solution fails; so they just abandon the pellet and, no doubt, go to mould another elsewhere.

There is little to be learned from these experiments, at least with respect to the insect's mind. When they meet an obstruction their first instinct is to hoist, and thus elevate their burden over the top. Failing in this, they roll the pellet to one side and try to make their way round. Their last resource is to excavate and bury the pellet where it lies, or else to abandon it for ever and commence their labour anew. It is in all probability a display of intelligence when the female goes off to explore; but the hoisting and the circumvention are mere instinctive actions; the beetles employ them without discrimination whenever their journey is checked.

The inimitable observer, M. Fabre, drove a pin through the pellet of a sacred scarab and thus nailed the sphere firmly to the ground. The pellet was now immobile, nor was the cause of the obstruction evident from the exterior since the head of the pin was pushed down into the ball. The scarabs first endeavoured to resume the roll. But, having failed in this, they then thrust themselves like a pair of wedges beneath the load, and by the pressure first of their bodies, later of their legs, they hoisted the pellet by degrees up the pin until it was finally freed. But, as this great observer points out, there was nothing intelligent in these acts. The mechanism of the living wedge and the upward hoist was the same mechanism that they ever employ in surmounting the common obstacles of their path. It is in this way that they clear the sticks, the stones, the little clods of earth that everywhere strew their course. There were intelligent methods that they might have used, but ordinary instinct sufficed.

I tried the same experiment with the *Gymnopleurus miliaris*. The pellet is transfixed; the pin nails it to the earth, and the head of the pin is buried in the sphere. It is futile for the beetles to try to roll the ball; indeed they scarcely make the attempt. One almost immediately wedges itself beneath; the other takes its seat on the top of the ball. The one below heaves; the pellet rotates around its fixed axis, but obviously cannot move on. The pair become perplexed. The one underneath now emerges and joins its mate on the surface of the ball. They examine it on every side. Then they again commence to push and pull. But the pellet only twists horizontally on the pin, and this seems to confuse them still more. They must feel that their efforts are employed in vain. They then explore the whole surface of the pellet, above and below and round about on every side. They scrutinise it with the greatest care. Their antennæ diverge; the fan-shaped ends expand, and the broadened tips quiver as they move. They pat it all over with their fore legs; they encircle it with their remaining limbs; they thrust their heads into the substance of the ball and sometimes even strike the pin. In this way they examine and re-examine the whole surface of the sphere. At length they proceed to hoist. One, the male, again presses underneath. With his body he wedges up the ball, just a little way up the shaft of the pin. Then he turns so as to stand upon his head; he fixes his hind tarsi to the under surface of the ball, and in this attitude thrusts it further up the pin. The female remains all the time quietly seated above. The pellet is not yet quite free; it is almost balanced on the top of the pin, but the upward thrust of the male is scarcely sufficient to make it clear the head. The female now comes down from her post. She joins her mate beneath the ball, and they both combine in the common thrust. But the female, being the larger of the two, possesses the longer reach. She is thus able to force the load a little higher and advance it beyond the reach of the male. This is sufficient. The ball now clears the head of the pin and topples over on to the ground.

It is the same experiment, with much the same result, as that described by M. Fabre.

But let us modify our plan of experimentation and we will meet with a different result. I transfix the pellet with a thin wooden stake and, as in the pin experiment, I nail the structure to the ground. The only real difference is this. In the pin experiment the head of the pin was buried in the pellet; in this experiment there is an inch of the stake projecting through the top of the ball. Perhaps this will give the beetles a clue to the difficulty and cause them to adopt some different plan. Here is an obstruction quite outside their ordinary experience: a stake driven through the centre of their pellet can scarcely be an ordinary incident of life. Yet see what the beetles will do. There is not a moment's hesitation; they make just one attempt to turn, and they find that their pellet is fixed. Then, without the slightest delay or without any apparent sign of deliberation, they go straight to that portion of the stake which projects through the top of the ball. It is indeed astonishing to observe the way they go direct to the seat of the trouble. Down go their heads at the sides of the stake just where it leaves the ball. At that point they thrust their shovels into the mass. They dig down with the chisel-edge; they gather up the pulp with their serrated rakes; they enlarge the furrow on either side, until it forms a cleft that almost bisects the ball. The two halves of the sphere then fall apart. The pellet has been freed by a process of vertical division, and the plane of division is in the axis of the stake. If the cleaving of the pellet happens to be unequal, then the beetles may retain only the larger portion, which they gather up, remould, and then roll off as before. But they often behave with greater providence than this. They deftly manipulate one half so as to gather its substance up into the other half; the combined portions they then dexterously mould so as to re-form the original sphere.

How are we to explain behaviour such as this? Is it not that the beetles appreciate their difficulties, and difficulties, be it marked, far outside the ordinary experiences of their lives; and then, having appreciated these difficulties, adopt rational means to overcome them?

Such a conclusion deserves further confirmation. I again stake a pellet, but this time with a horizontal peg. The beetles are rolling their sphere at the foot of a little wall. I thrust in the stake horizontally, so as to nail it, this time, to the wall. The beetles are a trifle alarmed; they lie still for a minute, just a little apprehensive at feeling their pellet come to a sudden stop. They soon wake up, reassure themselves, and proceed to investigate the cause of the halt. Again I witness the same occurrence: the immediate recognition on the part of the insects of the nature of the calamity which has occurred. They proceed direct to that particular point where the stake appears through the side of the ball. At that spot they dig, and they soon liberate the pellet by cleaving it in the vertical line. They then unite the halves and roll the structure away.

I will confirm it once more. I thrust the bare stake into the ground. I lift up the pellet, to which the beetles remain attached, and I place it on the top of the stake. I press it down so that the top of the stake penetrates about the centre of the sphere. Here again is a type of experience which must be quite new to the *Gymnopleuri*. Their pellet, by being fixed to the top of the stick, is raised an inch clear of the ground. This is a state of affairs which they can never have known before. Nevertheless their behaviour is essentially the same. They proceed to the under surface of the pellet, pass straight to where it is pierced by the stake and free it by a process of division in the manner described before. The halves, of course, fall to the ground, but the beetles fall with them, and they reshape the original structure there.

My experiments certainly have not confused the beetles. Let us advance a further step and try "confusion worse confounded." I suspend the pellet in the form of a pendulum. A piece of string is the medium of suspension and is attached above to a convenient twig. The pellet is the bob at the lower end; it swings freely just clear of the ground. In order to attach the bob I fix the string to the usual stake which penetrates the pellet through and through. Now the beetles can just reach their pellet; nevertheless it is quite free to swing and, of course, oscillates at the slightest touch. In this experiment there is no problem of inertia, nothing to make the beetles believe that their pellet has become fixed. And, since they feel it move beneath their efforts, they persist in trying to roll it on. One seats itself on the bob of the pendulum; the other hangs below. It takes its usual purchase with its hind tarsi on the ground; it can just reach the pellet with its fore legs, and in this extended attitude it endeavours to make it roll. The pellet goes forward, but of course immediately swings back again. It makes a second and a third effort, which are followed by the same result. The partner now descends from its post. They join action; they thrust and turn; they swing suspended from their pellet; they push off once more after every rebound, and vainly return again and again to their efforts to advance the oscillating sphere. The beetles are puzzled, but they are far from being overcome. They abandon their attempts to roll. They climb up on to the bob, and very soon they come upon the stake by which the pellet is affixed. They now behave in the way we have already seen. They cleave the pellet along the axis of the stake; the separate portions fall to the ground, and the bob is liberated from the string.

I repeat the pendulum experiment, but this time I raise the bob so that the beetles cannot touch the ground. They sway about on their sphere, swinging helplessly with it in the air. But, as before, they at length solve the problem: they cleverly sever the sphere.

Thus do the *Gymnopleuri* behave when in perplexity; thus do they extract themselves from difficulties which they have never experienced before. I cannot see that these are mere ordinary efforts, the common behaviour of everyday life. These are not the methods which the *Gymnopleuri* employed when they hoisted their pellet off the pin, nor are they those by which the sacred scarab overcame its difficulties in the original experiment of M. Fabre. I think that here we see a gleam of something different, of something higher in the mental scale.

But this capacity of the *Gymnopleurus* to overcome a difficulty does not pass beyond somewhat narrow bounds. It can shear a ball in order to liberate it from a stake. But I have seen no higher manifestation than this. Consider for example an experiment of the following kind. A pair of beetles are rolling their ball. I bring it to a standstill, not, in this instance, by transfixing it with a stake, but rather by blocking it on all sides. I place four stakes in the form of a square so as to enclose the pellet within. This is the condition of affairs. The ball is stationary, being penned in by the four stakes, yet is perfectly free to turn. The beetles can easily pass in and out, but the ball cannot escape between the pegs. In fact the pellet is caged. Here again is a strange impediment which can scarcely occur in their natural lives. Perhaps a pellet may sometimes get fixed in a miniature forest of stalks, but it can never become so firmly enclosed as it is within my four stakes. What will the beetles do?

Can they manipulate their troubles now? No great effort of mind is needed in order to solve the problem involved. Chisel a little off the opposite sides of the pellet and it will slip out between the posts; compress the sphere into an ovoid shape and it will similarly manage to escape. Can the beetles appreciate this and adopt such intelligent means?

They are at first thoroughly embarrassed. They explore the pellet all round; they examine it above; they wedge themselves underneath; they investigate the four stakes; they come out and make a tour of the surrounding ground. But there is none of that immediate appreciation of difficulty such as there was when the pellet was staked. They make no attempt to shear the sides of the pellet, no effort to change the geometrical shape. What do they do? They return to their old instinctive ways, to the mechanism of the wedge and hoist. One, underneath, heaves and thrusts and elevates the pellet on the tips of his hind legs. The other above pulls it up, taking her purchase from one of the stakes. The pellet rises; it turns round and round within the cage. They try to push it, first between one pair of stakes, then between another pair, but the pellet will not pass out. The mechanism of the wedge and hoist utterly fails here. The hoist is insufficient to raise the burden over the top and the pellet is too large to pass out between the stakes. But the beetles' ingenuity ends here—if indeed such actions can be said to possess any ingenuity at all. They show no signs of further intelligence; they just struggle on at the wedge and hoist. In the end they may abandon their fruitless efforts and leave the pellet lying in the cage. At other times they secure a better fortune, though it is merely the result of chance. For the pellet, as a consequence of their aimless manipulations, in the end may become so bruised and broken that it manages to slip between two of the stakes. If this occurs, then the beetles are content, and they quickly remould the mass. But it is no credit to the beetles. Their behaviour has been thoughtless in the extreme. They have here been put to too severe a test, and their power to overcome their difficulties is lost. They are now no better than the sacred scarabs of M. Fabre ; they can merely elevate and do no more.

When we endeavour to interpret the psychology of insects we enter on difficult and doubtful ground. But we must arrive at some conclusions, and the generalisation which I make is this. The *Gymnopleuri* can appreciate new conditions ; they can realise the nature of strange events such as they have never experienced before. Moreover, they react to meet those changes as if they were intelligent beings. But this power of intelligent reaction is limited to occurrences of the simplest kind. I will not push the conclusions further, but so far the experiments seem to lead.

Another point with respect to their mentality is this. In the partnership the female is the more important of the two. Physically she is the more powerful, mentally the more active of the pair. She is the initiator, the explorer, the organiser of their lives. She plays the main part in the shaping of the pellet ; she goes off to seek out the trouble should the pellet cease to roll ; if any alteration in plan is necessary she is the one to initiate the change ; if the pellet is injured and must be re-formed it is she that begins to refashion it first ; finally she is the excavator, and without doubt selects the place to dig.

What a contrast to humanity, where the converse is so strictly true. Man in his greater strength bears more of the physical burden of the day. And the mental contrast is equally great. For assuredly as man is the initiator so is woman the preserver of our race.

I have frequently discussed the rhythm of instinct, and have shown how each step in an insect's labour is often but a link in a fixed machine. Let us see if this principle applies to the beetles which roll these pellets of dung. A female is digging into the main mass. She has completed her circular furrow, and a partially constructed sphere of dung is raked up between her slender legs. I remove the half-completed pellet and I supply her with another already moulded to a perfect sphere. She accepts the exchange, gives the new pellet a few finishing touches and then rolls it away. Is this a sign of recognition on her part? Does she appreciate the fact that she has been saved half the labour of construction, and that by accepting my pellet she has secured a distinct gain? Not at all. We have seen that, when she is engaged in rolling her pellet, she is prepared, if the pellet is taken from her, to accept any other in exchange. It is the same here. She accepts the new and perfect pellet in place of the half-completed sphere, not because she appreciates anything of the change, but merely because she knows nothing about it, and the new is as good as the old.

Let us advance a further step. A beetle has just alighted on the mass. Again it is a female who has come to secure a pill. In a minute she will begin to dig and fashion her share of the spoil. I abstract her from the pad and place her on a completed pellet a little distance away. Here is a distinct gain to the beetle. She is saved the work of digging and raking, all the labour of constructing the sphere. All she need do now is roll the new pellet away. But she does not seem to appreciate the advantage; she is dissatisfied; she soon turns away from the pellet and wanders back to the mass. I repeat the experiment. I take other beetles about to commence the moulding of their spheres. I give them the completed pellets; but the result is the same. I have not observed one of them to accept the completed sphere.

I will not draw too forcible a conclusion and say that the force of instinct is unswerving, and that when the beetle is about to dig, then at that time it is compelled to dig and is utterly unable to roll. It may be so, but the more we learn the more cautious we become. This, at least, is certain, that the force of instinct is overpoweringly strong, and that, when the beetle is about to dig, all its natural impulse impels it to dig, and that, though

I supply it with considerable advantages, yet I cannot induce it to do anything else.

Now consider the converse experiment. I find a female rolling her pellet. I deprive her of her burden and return her to the pad. What will she do? She will, of course, appreciate the loss, but will she reconstruct anew? She appears very perturbed. She wanders all over the dung, obviously searching for her precious sphere. But she shows no inclination to dig. The last thing she felt was a pellet within her legs, and she wants the same round substance now. All around her are others of her kind; some are furrowing, some are shaping, and she is moving over a sea of dung. But she stubbornly refuses to join in the toil. When I robbed her she had arrived at the rolling stage, and, therefore, she now feels that she must roll. If she is to satisfy her instinct then she cannot do anything else. She explores every corner; she leaves the pad; she returns; she again departs and makes a wide circuit of the surrounding ground. Perhaps by chance she finds a pellet. If so, then instinct is satisfied, and immediately she rolls it away. Perhaps she gives battle with another female and robs a true owner of her gains. If so, then she is again content. Perhaps she adopts the more subtle ruse and tries by stealth to acquire a pill; if so, then the force of instinct is fulfilled and she whirls the spoil away. But, failing in these, she is lost. She searches with every persistence and care; but at last she abandons the task and deliberately takes to flight. I have never seen a beetle, thus deprived of her pellet, commence construction again.

What conclusion can we reach when we witness behaviour like this? Again I will not say that instinct is blind; but it is a powerful and overwhelming force. The beetle, when removed from the pad and placed on the pellet, is under the influence of only one feeling—namely, a desire to return to the pad. The beetle, taken from the pellet and placed on the pad is moved in the same way: it must go and search for the pellet on which it was last employed. Such is the guide; it is the indomitable force of instinct which directs the little insects through their lives.

I pass to another point. I have already mentioned the importance of the legs in the construction and the revolution of the ball. A few experiments will indicate more clearly the individual importance of each. Imagine that the beetle is pushing its pellet. Its head is to the ground; its abdomen is in the air; its hind and middle legs are pressed against the pellet and its fore legs take a purchase on the soil. I amputate one hind leg, and the beetle, after recovering the shock, resumes the turning of its load. It still possesses the power to roll. It has a middle and hind leg against one side of the pellet; only a middle leg against the opposite side. This results in an unequal thrust, and as a consequence the pellet is ever turning from its course. The turn is always to the injured side; therefore on that side the beetle must employ a greater effort in order to keep the pellet straight. It must use its amputated stump with exceptional force, and it is only by continued persistency and labour that it keeps the pellet from swerving from its course. It is an excellent illustration of the all-powerful directive force of instinct impelling the beetle to maintain its line.

In a similar manner I amputate both hind legs. The beetle is still well able to advance. It makes the fullest use of its middle legs, and these are sufficient to cause the pellet to roll. Of course much additional labour is involved, and the broken stumps too are pressed into the work. But the slightest obstruction brings the pellet to a halt, and the owner continually loses its foothold and tumbles over on its back.

I amputate both hind legs and one middle leg. Nevertheless the beetle continues and pushes vigorously with its three stumps. I go a step further, and snip through both middle and both hind legs. Even after this operation I find a beetle that still persists in its efforts to get its sphere along. It has now only its four stumps by which it can bring pressure to bear on its pellet; consequently it employs the tip of its abdomen as a kind of additional aid. And thus, under circumstances of the maximum difficulty, it sticks tenaciously to its work. Indeed, not only does it attempt to roll, it even proceeds to dig. With its head it chisels; with its fore-legs it rakes, and it employs its amputated stumps to thrust back the triturated soil. Even thus mutilated, it succeeds. It fashions a burrow of suitable shape, and buries its pellet within.

The fore legs seem of even greater value than any of the other legs. In the work of construction they serve as rakes, but in the rolling of the pellet they are of prime importance too. I amputate one fore leg while the *Gymnopleurus* is engaged in pushing its ball. This results in greater inconvenience than any of the previous experiments produced. I have removed one of the implements by which the beetle takes its purchase from the ground. On one side the underthrust is lost. Nevertheless the beetle continues to struggle on. It is always swerving to the injured side, and it cannot correct itself with the same ease as it did when its hind leg was gone. And not only is it deprived of its power of thrust, but it has also lost its special ability to cling to objects on the ground. Hence it cannot maintain its hold. The pellet, therefore, tumbles down every decline, and the owner continually falls. I amputate both fore legs, and absolute helplessness is the result.

We thus clearly understand the individual function of each of the different legs. We also observe to what a slight degree does an insect feel their loss. A momentary fright, a sudden jolt, such is often sufficient to make a beetle desert her ball. Yet I can snip off a leg and she will stick to the pellet; indeed I have succeeded in amputating four, and still she continued the work.

To an insect the loss of a part of the body is not always a very serious thing. At least they can often exist in nature when mutilated to an extreme degree.

It is more the voice of fancy than of fact that

> "The poor beetle, that we tread upon,
> In corporal suffering finds a pang as great
> As when a giant dies."

I will just mention a few particular examples of mutilation which I have casually happened to observe. I have occasionally come across worker ants which had been severed across the waist. Only the head, thorax and legs remained; the abdomen was completely lost. Nevertheless they moved quite freely, even energetically, amongst their comrades; they showed no signs of any discomfort even with such a deformity as this. I once found a black, hairy caterpillar with so large and deep a rent in its back that the entrails protruded from the wound. I suppose some foolish bird had seen it and had stabbed the untasty morsel with its beak. Nevertheless the caterpillar showed little inconvenience, and continued to browse on a green leaf. On another occasion I met with a spider enclosed within its spiral cell. All its legs on one side had been broken off; not even the ragged stumps remained. Yet the spider seemed quite content within its chamber, where it was nursing a brood of young. One more instance, for many might easily be found. I came on the remains of a buprestid beetle lying on a garden path. It must have fallen a victim to some bird, for the soft and juicy parts of its body had been completely torn away. Its abdomen had been eaten; the tissues had been picked out of its chest; nothing was left but the head, the shards, the hard integument of the thorax, with the stumps of the two front legs. It was nothing but an insect shell to which the head remained attached. Nevertheless the buprestid was quite alive; it moved its head and antennæ; it tried to crawl and even to extend its shards. When touched it bent down its head, curled in its antennæ, pressed its broken stumps against its empty chest; in fact, though a mere shell, it went through the accustomed ruse of simulating death just as if it were a perfect insect endeavouring to escape its foes.

But we must return to the *Gymnopleurus*. I have introduced the digression in order to indicate what accidents may often occur in nature, and what calamities insects are able to endure without deflecting from the accustomed habits of their lives.

These beetles possess faculties of special sense with which they appreciate the outside world. See how they recognise the movements of one's hand ; it leaves no doubt as to their visual sense. That they mould their spheres with geometrical exactitude is evidence as to their sense of touch. Their sense of smell is exceptionally acute. By the recognition of the scent they discover the ordure, and the substance often does not lie for a minute before the *Gymnopleuri* have found it out. I bring a piece of camphor before their antennæ and they retreat from the unpleasant smell. I drop a solution of the substance on a pellet and the owner immediately deserts the ball. I similarly apply a drop of the diluted oil of eucalyptus, also of the sweet-smelling oil of aniseed, but the beetles are straightway aware of the odour and will have nothing to do with the balls.

The *Onthophagi*, as I have already shown, behave as though they were able to appreciate the different dimensions of space. In their tunnellings they keep strictly to the vertical line, and the action of this rigid instinct makes for the security of their individual stores. But it is otherwise with the *Gymnopleuri*. Though both belong to the same family of insects, both feed on the same substance, both carry their provender into the soil ; yet the *Gymnopleurus* is not bound to the vertical as is the *Onthophagus*. It can burrow freely in any direction it likes. I place four *Gymnopleuri* in the bottom of a tube and cover them with three inches of earth. At first the tube is fixed in the vertical, and the beetles are not long in burrowing upward so as to escape through the top of the soil. I repeat the experiment. Two females and two males are again lodged in the tube. This time it lies horizontally on the table ; nevertheless the result is the same. In half-an-hour a horizontal tunnel has been driven through the earth and the beetles have made their way out. How different is this from the case of the *Onthophagi*, which struggled in vain to ascend and descend, only to beat themselves for days and nights against the walls of their open gaol.

This difference in instinct between the two species bears a direct relationship to the manner of their lives. The security of the food supply of each *Onthophagus*, the very existence of the egg in its stercoral case, depends on the inability of other *Onthophagi* to dig through the earth in a horizontal direction and thus invade it from the surrounding soil. The *Gymnopleuri* adopt another method in order to secure their offspring and supplies. They roll away their pellets as fast as they can, so as to diverge from the danger-point. In this way they gain protection, for they first scatter themselves broadcast on the surface and thus bury their plunder at isolated points over the greatest possible space. It is by the principle of wide dispersion that the *Gymnopleuri* become secure. The *Gymnopleuri* scatter for the same reason that the *Onthophagi* go direct to ground. Hence it would be no advantage to the *Gymnopleuri* if Nature had limited their powers of excavation and had supplied them with the instinct of being able to dig only in the vertical line.

But the *Gymnopleuri* do possess some sense of direction, and of a nature very interesting to observe. For it has often appeared to me rather remarkable how a pair of these beetles, when rolling their pellet, will stick so firmly to the selected course. In one place is a pair rolling in one direction ; in another place is a pair rolling in a different direction, yet each, in spite of innumerable obstructions, will stick to its own special line. Hence, since the beetles refuse to be deflected from their course, it follows that the pellets must always be rolled strictly in straight lines. Further, that all the pellets on all occasions move away from the pad. An easy way of appreciating the fixity of this sense is to allow the beetles to roll their pellet down the inside of a glass tube placed in their line of march. They are scarcely alarmed at the novel enclosure but push on to the end of the tube. There the pellet comes to a halt. The beetles struggle to get it on. They elevate it; they endeavour to hoist it over the obstruction, but they have here met with a barrier which they cannot possibly surmount. The point worth notice is this. Their efforts are all made in the one direction; they strive to roll the pellet through the closed end of the tube. It is only after repeated failures to advance that they will return back along the tube, and then, after emerging at the mouth, they will immediately correct themselves and resume the old direction once more.

This, I have no doubt, is a deeply laid instinct and of the greatest value to the beetles themselves. I have tried to understand the cause of its existence, and I believe its purpose to be this. A pad of dung attracts a multitude of scavengers. They gather about it, some on, some in, some underneath, the mass. All compete one with the other, all are hungry, all insatiable, all are striving, each in its own special way, to secure a goodly share of the spoil. And having gained it, then in order to keep it, each must hide it away in the ground. A continual struggle for loot is in progress; nor is speed alone essential for success; the beetles may have to fight battle after battle before they have made sure of their prize.

The problem is an easy one for the *Onthophagi*. They need but carry their burdens down vertical shafts and there they know it is secure. So long as they defend the entrance, there is no fear of invasion on the flanks. The instinct with which the beetles are supplied makes suitable provision for this. But it is otherwise with the *Gymnopleurus*. It too must escape its enemies. It has had already to do battle on the patch, and there are numbers on the road before it ready to rob it of its spoil. These felons as a rule congregate near the pad and plunder the honest labourers before they have got clear away. The mode of escape is obvious. The beetle must roll as hard as it can so as to escape the danger-zone. Once clear of the neighbourhood of the patch, it will have fewer enemies to fear. It can then proceed with more leisure to a safe distance and hide its pellet away.

The purpose of the fixed direction, the value of the straight line, ought to be obvious now. For, since the beetles roll in undeviating lines, and always away from the pad, the directions they take are like the spokes of a wheel; they all radiate from a central point, and this point is the seat of danger from which they must as quickly as possible escape. If they were to roll just anyhow they would find themselves turning first to one side, then to another, coming round again upon the original patch, meeting with enemies everywhere, and being robbed again and again. In the end the pellet would be buried just anywhere and its pillage might easily ensue. All this is avoided by the owners of the pellets rolling rigidly in one fixed direction and always away from the patch. It is a most valuable, instinctive process; it ensures the widest possible dispersion of the pellets, and effects their rapid and immediate escape from the perils of the danger-zone.

How does this guiding instinct work which keeps these little insects to their course? It is very difficult, perhaps impossible, to understand. I try to perplex them by moving them in different directions, and by this means I hope to so confuse their instinct that they will no longer recognise the true line. But the result is failure. A beetle is rolling its pellet. I lift it up and advance it six inches on its path. It is not in the slightest confused, but keeps straight on. In the same way I take it back six inches on the road, but it returns to the old track again. I withdraw it another six inches, and the result is the same. I find a pair which has just completed the construction of its pellet and has commenced to roll it away. They are leaving the patch behind them as they make off in a straight line. I lift them, together with their pellet, across to the opposite side of the patch. They resume their old direction, which, of course, brings them into collision with the patch. They are back again on their old pad; they have returned to the spot which, had I not moved them, they could never possibly have reached. But even this does not seem to confuse them; they push their load over the top of the pad and keep straight on. I lift them back a second time. One, unfortunately, falls off, but the other sticks to the ball. It again resumes its old course, comes up a second time against the patch, but does not appear in the slightest perplexed. I bring it back a third time. The result is the same: a collision with the patch, a circumvention of the dung, and a return to the true course. I make a fourth attempt; but this time the beetle falls off, and the experiment ends.

It is no easy matter to discompose the *Gymnopleurus* and deflect it from its ordained course. I construct a rotating platform across which the beetle can roll its ball. While in the act of crossing, I rotate the floor. I first alter their direction by turning the platform through a quarter of a circle. But the beetles wheel round so as to resume their old course. I rotate them through a semicircle—that is, I make them face the opposite way. Then again I turn them through three-quarters of a circle. But I always see the same result: the beetles turn back so as to resume their previous course. I twist them a number of times in the same direction, but they will not be confused. I rotate a pair for about twenty turns; when they have resumed their road I rotate them again; I continue to repeat the operation so as to submit them to six successive series of rotations, sometimes making the turns to the right, sometimes to the left; but the result is essentially the same. There may be some temporary hesitation, a short pause and a little confusion, before they realise where they are. But the final result is always the same. They go back on their previous path, and I cannot confuse their directive sense.

With a mirror I reflected the sunlight on them, thinking that they might be guided by the position of the sun as were Lord Avebury's ants by the position of an artificial light. But the beetles were neither dazzled nor confused; they just took no notice and kept straight on.

How persistent, how incredible is this directive sense! How vain are our efforts to realise what it means! In the desert I have watched the sacred scarab, and have seen a hundred of them, one after the other, all arrive from the same point, and having shaped their pellets, roll them back towards that point again. I have observed the harvesting ants of the Punjab, when engaged in their funereal duties, convey their dead in an unerring course that led them farther and farther from their home, and after having suitably disposed of the bodies strike back again undeviatingly to the nest. For hours I have watched the Himalayan hornets flow in a stream across the woods and fields and never depart from the adopted course. I have witnessed the emergence of the termites at the onset of the summer rains, and have remarked how the insects, after clearing the brushwood, all combine in a fluttering swarm and sail off towards the same point. Near the Euphrates I have marched for days through multitudes of locusts which invested the desert like a verdant sea, and I observed how the indomitable, directive instinct drove the vast army into the flooded river until millions were utterly destroyed. I have watched the butterflies on the Himalayan snow-line flow for months up the mountain-side in a continuous, migrant stream. I have followed them in their ascent up a lofty range 17,000 feet in height, and there I have seen this all-powerful force drive them out over the snowy altitudes where they must have perished in an icy waste.

What is this unswerving impulse which guides these little creatures in their lives? It acts without doubt for the advantage of the many, though it often sends a myriad of single beings to destruction. It is a deep and fundamental instinct that binds them to this fixed course. And they know not whither they go. At such a loss am I to understand the essential meaning of these facts that

I have looked for analogies to physical laws. I have thought that as an inorganic body moves in accordance with Newtonian principles, that once it exists in a state of motion it can never turn from its original course unless compelled by some external force to change that course, so also it may be a principle of organic nature that every creature, unless deflected by some agency, must keep rigidly to a straight line.

But this may be only mental riot, so I shall leave the beetles and the thought. We opened our inquiry in a bed of ordure and were repelled by our obnoxious task. Nevertheless we have persisted and this is the result. It has led us into many views and facts, and the task may have been worth our while. We have gained something in the way of reward from our grovelling in the bed of filth.

CHAPTER XV

THE SOUTH-WEST MONSOON

Signs of Approach—Preliminary Showers—Burst of Monsoon—Rainless Intervals—Bird Life—Music of the Rains—Activities of Ants—Of Beetles—Of Orthoptera—Of Termites—Of Butterflies and Moths—Of Spiders and other Forms—Nocturnal Visitors to the Light—Battle of Life—Conclusion

THE season of spring in temperate latitudes is the birth-time of living things. It marks the period in those virile zones when Nature bursts into most joyous life. The birds with swelling notes commence the duties of the nest ; the insects, vivified by the warm glow, awake from their long winter sleep, and the gnarled woods put forth their shoots and don their first tender leaves. Not so in the balmy tropics where the hand of Nature moulds her creatures to a life more passive and inert. It is not the invigorating gleam of spring, it is rather the deluge of the summer rains, the first burst of the south-west monsoon, which animates the teeming myriads in the soil and calls them into active life.

Let us consider this violent change of season. Let us observe the generative force which it brings to bear on organic life, at least as it appeared to me in the year 1921, when it broke over this neglected manjha.

Sixteen days before the full torrent burst the elements were unruly and disturbed. Hot, boisterous winds seethed over the arid plain. They drove before them a mass of granules in a dense siliceous cloud. Vortices of dust were whirled along the ground ; eddies were swept over the waterless bed, and the finer particles were borne aloft into a cloud of drifting sand. A greyish volume like a dense fume permeated the whole sky. Elevated to a height of thousands of feet, it so obscured the loftier strata of the air that the sun, though still high in the heavens, either paled into a silvery orb or was blotted out from view. Transient wisps of watery cloud appeared through the enshrouding veil. Thicker in the early mornings, they used to back away at night. By day they condensed into ragged shapes, now accumulating, now dispersing; they were the foremost signs of the gathering vapour that was rolling inland from the sea. The elements subsided as the sun declined. The atmosphere then cleared; the winds abated; the shroud of sand sank slowly to the earth, and the hot oppressive air settled to breathless calm. At sunrise the fury again began. The firmament darkened with a fresh pall; perhaps the loom of distant thunder echoed through the dusty sky. The temperature rose to almost 110° F., and with it came the inseparable burdens, the broiling days and the sleepless nights. The atmosphere was stupefying and inert. The mind grew torpid, the body sank beneath the load of the oppressive heat. For this was the period of main discomfort, those days before the onset of the rains. And these were the changes that marked their coming—the winds, the dust-cloud, the breathless heat; these were the first signs of the unruly storms that presaged the advancing flood.

For three or four days this turbulence held sway. Then the great force of the elements declined and the cloud of dust hung lower in the sky. Still it obscured the rays at sunset; there was as yet no real setting of the orb; no evening glow of soft and coloured light. But the eventful signs grew clearer. The clouds that foretold the advancing vapour now massed themselves more thickly in the sky. In the mornings we saw long, trailing wisps, or even lines, of broken flocculi that crossed the heavens in a stream. Often they aligned themselves in serried ranks and assumed the most elegant and attractive shapes. Piles of heavy cumuli used to crowd themselves in regular array, or a graceful pattern of tiny wisps used to spread itself across the whole sky. The body of the storm was approaching and the preliminary showers had almost come. On the horizon there appeared a low bank of nimbus; it advanced slowly to the zenith and the first few drops of moisture fell. These were only the faint suspicions of a shower, the earliest predictions of the torrent that was growing and following in their wake. The rain-cloud was but a transient mass; it soon again dispersed, and the sun broke through the dissipating heaps in divergent streams of light. The next day the clouds again approached; this time in a denser mass, which discharged a heavier fall. The period of preliminary showers had come.

Another stage in the change of season opened. Every day the heavens darkened. The visible vapour, now accumulating, now dispersing, gathered itself into every shape. Occasional storms of dust occurred, often with a thunder peal. The sky thickened with a black pall; then came the flash, the crack, the echoing roar, and a volume of cooling rain poured down, to be sucked into the arid soil. Day by day the preliminary showers increased. They grew in intensity and frequency; but they were not the true deluge, they were only the harbingers of the real flood. Nevertheless, in a minor way, they freshened the parched land. They moistened the dry earth; they purified the sea of verdure of its dust, and beautified the vast expanse of jungle in a vivid flash of green. They cleansed the air of its sandy shroud and displayed the broad horizon in a clear, transparent view. The manjha, now freed from its obscuring mist, unfolded itself into an extensive plain. Dim, half-hidden objects now rose into distinctive shapes. A confused patch became a verdant jungle; a dark formless mass stood out as a goodly grove; where before there was only an impenetrable haze there was now a sparkling stream. And as we carried our eye over the manjha, gazing on it from some little height, we saw a vast expanse of unbroken landscape extending for miles around. It was as though our vision was limited only by the natural curve of the earth, and we felt as though we looked out over an ocean clothed in a vivid green.

For thirteen days these showers continued. With increasing intensity and at diminishing intervals they discharged themselves into the greedy soil; but not till the 22nd day of June did the real torrent fall. Then at last came the final burst, the deluge of the true monsoon. On the horizon there loomed up dense banks of heavy cloud. It might have been a preliminary shower, but it hung in a blacker and more ominous mass. The sky grew darker with the advancing vapour. It slowly and steadily climbed into the zenith and the menacing sound of thunder came rumbling from its threatening breast. On it rolled, gathering volume in its march and driving before it a roaring tempestuous gale. The winds broke loose, the trees bent, the leaves were whirled aloft; then a few cold drops of moisture fell, to beat heavily on the expectant earth. Then suddenly came a crashing peal, and the gates of heaven opened and the seething, battering torrent gushed out from the blackened sky. It poured in a fierce deluge, sheet after sheet of rain. The wind calmed beneath its insistent flow, but the heavens still tolled out its onset, reverberating at every burst, shaking as it were the very substance of the earth as they rang out each fresh volume with a roar.

The true monsoon was ushered in. Hour after hour the vast waters fell, and the earth swelled with the added moisture as it now percolated deep into the soil. The rivers expanded in their broad beds; lakes appeared; new rivulets formed, and half the desiccated manjha now became a running swamp. Every stream swept down its débris; every field became a watery sheet, and the whole surface of this even land lay deep in an inundating flood. The cool moist season of the year had come, the period of the summer rains. For three months they watered the soil; all life opened to receive them and vivified beneath their animating flow. Many of the days were dark and gloomy, with the sun hidden behind banks of cloud.

others were marked by a continuous downpour; on others again a bright interval occurred and the fierce rays of sunlight blazed out upon the moistened earth. The temperature lessened by some ten degrees, and there was little difference between the extremes of day and night. The air was saturated with watery vapour; there were days when the wet and dry bulb readings stood together even on the scale. Again and again the thunder-clouds rolled up; the deluge fell, then dispersed, then again recurred, and again slowly passed away. The gathering, dissipating, inconstant clouds scattered into beautiful and varied shapes. Often they massed themselves into rugged piles, black heaps of dissolving nimbus against a background of deepest blue.

At times for a week on end a rainless interval occurred. The clouds dispersed; the soil dried; the haze of dust again rolled up, and the murky sky shimmered with its earlier heat. Yet the air remained dense with moisture, hot and vapid, the nights as stifling as the days. But at last another downpour fell. The air cooled. Living things revived. The vegetation again flowed with moisture, and the insects crept out upon its dripping leaves. By day they thronged the ground and foliage; at night they moved with a noisy buzz, some falling heavily against the walls, others beating themselves around the artificial lights. All were struggling and competing in their intense desire to live.

Thus did the south-west monsoon pour its vivifying deluge on this soil, and all life awakened at its call. Let us consider this revival from the winter sleep, at least the most striking features in that teeming wealth which quickens beneath the animating flow. The birds now acquire a fresh enthusiasm; they gather into more active flocks, and those that seek after insect food come out on the augmenting swarms. In the trees we hear their soft sweet notes; in the air we watch them swiftly turning as they take their heavy toll of life. The pied-crested cuckoo, dressed in white and black, now comes to search out fresh broods of grubs, and the whistling teal, scarcely seen before, now explores the newly formed pools. The terns, the herons, the water-fowl of all kinds now scatter themselves far and wide. Hitherto they were confined to a narrow stream ; they can now spread themselves over an extensive flood. Clouds of hirundines now congregate in the air ; bee-eaters and drongos shoot out from the trees and chase the innumerable insects that rise at evening from the moist ground. At the same time come the flocks of pratincoles seeking after the same quest. At sunset they leave the swollen rivers and move inward over the plain. There they join the swifts and swallows, and circling with the same grace and ease of movement they sweep the air at considerable heights. All have acquired a fresh enthusiasm and revel in the vigour of the rains.

But let us turn for a moment to the insect horde. I can but briefly touch on this great assemblage and glance at its most striking forms. For it is the insects which feel the full force of moisture and emerge in a living swarm. We cannot but observe the myriads of ants which move in increasing throngs. Many have been active all the year, but they now pour from their subterranean vaults, in busier and augmented streams. We see the formidable *Camponotus compressus* ascending every tree. At the foot is the flooded nest where the excavators are now engaged in ejecting the sodden earth. The smaller workers are being dispatched into the branches ; they are exploiting the living fountains on the foliage, and are descending swollen with the limpid juice. The massive giants are assembled round the gate. The rain has imbued them with added strength, and they dash ferociously on everything that comes their way. We see a compact group advancing over the soil. It is a rescuing party dispatched abroad to carry in some creature overwhelmed in the flood. In other places we see workers evacuating their nests ; they are transporting their possessions up the trunks of the trees to establish themselves in a drier home. Often we see a legion assembled around the gate. With them are a crowd of sexual forms: the robust females and the more slender, active males. It may be but a gathering to enjoy the air, or perhaps an event of more importance, the advent of the nuptial flight. For the rains call forth the generative powers; the females seek the foundation of new communes; a few brief hours of doubtful love mark the death of all the males.

On the same tree we may see the *Prenolepis*, an agile, diligent ant. Urged by the impelling force of moisture they pour from their formicary in a migrant stream. Some are laden with eggs, others with larvæ; amongst them are a few soldiers of exceptional size, and a number of the winged sexual forms. Pry into some sheltered place and we may see them massed in a stationary throng. There are many thousands of them there. It is a legion which has just emerged from the nest and is waiting for its place in the migrant train. Where vegetation grows we shall see *Messor*, the harvester, seeking out new roads where old ones have been washed away. We shall now see their well-ordered march in busier and denser files. We shall see some returning laden with the harvest, others issuing empty-handed from the nest. All pass without confusion on their paths like men along a well-beaten road. In sandy places we shall see the predaceous *Myrmecocystus* scouring the ground for prey. The rain has instilled new energy into it and has forced it to send out its special parties to lay the foundations of fresh colonies elsewhere. We shall see this wonderful act in progress—that remarkable mode of geographical dispersal by which one group of workers establishes a formicary by transporting thither their comrades in their jaws. In the thicker jungle we shall see the cattle-tending ants engaged at the construction of their byres. We shall see them struggling to escape the inundation, evacuating their larvæ from the flooded nests, and bearing them for safety up the branches of the trees. There they will keep them till the season ends, either storing them in special arboreal nests or else lodging them with their cattle in the interior of their byres. They are a vast and busy multitude, these seething swarms of ants.

At this time too we meet a host of beetles which we have seldom seen before. At the first blast of sunshine the useful scarabs issue from the soil. Fresh with enthusiasm and full of greed they revel over every patch of excrement and struggle for the spoil. All the scavengers are now abroad; some are digging in the stercoral mass, others are excavating in the sandy soil, still others are moulding their spherical loads, which they hurriedly wheel away. All are filled with the energy of the season; the buryers, the rollers, the feeders on the surface; all compete one with the other in a gluttonous rival throng. A crowd of other refuse feeders joins them, and there is a mad scramble over every heap of dung. At this time too the *Carabids* appear. They are mostly a dull-coloured and unattractive tribe. Protected by their hard cases, and emitting an offensive juice, they explore the ground in search of prey. Amongst them we see the large, six-spotted *Anthia*, with its thick shards soldered to its back and deprived of the use of wings. By night it roams the soil, seeking out its insect prey; by day it lodges in natural holes, or loves to conceal itself in the clefts of the trees, and when disturbed shoots forth an irritating fluid which pricks like needles in the skin.

The different kinds of Longicorns are amongst the other striking forms that emerge. Of great size, and with immense antennæ, they come forth to exercise their powerful jaws. Animated by the showers, they emerge from the soil, or else escape from their tunnels in the trees, and come, falling heavily round the lamps by night. At this season, too, we see the active tiger beetles. They now collect in greater numbers on the moist and welcome ground. They have come out from their burrows in the sand to join in the carnage of life. There is the pretty, twenty-spotted *Cincindela* marked like a leopard on its shards, which swiftly hunts over the sodden fields, and congregates at moist patches on the soil. At the river bank is the *Cincindela grammophora* making its sharp and deadly rushes on the sand. With piercing eye it singles out its victim, and with toothed and pointed fangs penetrates it through and through. In some places they gather in immense numbers; I have seen them rising before me in a swarm, and the sound of their wings on the damp air was like the noise of a rushing wind. A little later appears the handsome eight-spotted *Cincindela*, glittering in metallic green and blotched with red and blue. Swift were its dashes on the sand, skilful its sallies in the air, and there was no escape for any victim that fell into its over-crossing jaws.

On the fresh and dripping foilage the blister beetles gather to the feast. There is the conspicuous *Mylabris*, with its black and orange bars; there are the many kinds of *Cantharis*, each with its metallic sheen. They now feed on the juicy foliage and eat away the centres from the flowers. We see them simulating death on the least alarm, and squeezing out the vesicating fluid from their limbs. But it is at night that the scintillating gems appear. It is then, in the wettest parts, that we see those living lights, the stars of the insect world. On the earth is a fixed and steady gleam; it is the lamp of the glow-worm raised aloft illuminated by the touch of moisture and bursting into a brilliant flame. Above is the twinkling of a thousand fireflies that sparkle in the humid air. Often they seem to flash in unison, now darkening for a moment, then sprinkling the trees around in a myriad of shining stars. This is the most wonderful vision of the rains, this glow of insect light.

In the moist luxuriant grasses swarms of orthoptera appear. There is the vast community of short-horned locusts which leap from stem to stem. There is the graceful *Holochlora*, a delightful instance of protective colouring, its thin, green wing-covers spread with veins, the very image of the growing leaf. There are the many and varied kinds of mantids, each in its own special haunts. We see one watching rigidly for its chance, or first stalking, then fastening on its prey. There are the little stick-like forms which keep to the withered stems; those with pale, green wings which cling to the fresh leaves. There are others which resemble the open flowers, and still others, brown and mottled, which seek their victims on the bark of the trees. At this season the crickets are driven from their burrows and come out before the advancing flood. From its tunnel in the sand the *Schizodactylus* appears. The rising river has driven the monsters from their shafts; by night they spread their carnage over the soil and join in their cannibal feasts.

Nor must we forget the clouds of termites which at the first shower come pouring from their nests. Eruptions are in progress on every side, and numerous living craters burst with insect life. We see them pressing out from the apertures in the ground, squeezing themselves from the earthen galleries where the workers have made an open breach. At evening we see them rise in a fluttering swarm and fly off on their race for life. We observe the fixed direction they maintain, the great heights to which they ascend, their exhausted return again to earth, where they ultimately lose their wings. Amidst them we see the attacking host that destroys them at every turn. On the ground, in the trees, at all altitudes in the air, the insatiable birds are awaiting their chance to decimate the issuing stream. And after sunset come the reptiles and the bats to join in the sumptuous feast. There is never more carnage in the insect world than at the eruption of the white ants.

At this time too we hear the *Cicada* ring forth its vibrant tune. It is not the continuous music of the hills; only here and there a solitary male calls from its point of vantage on the tree. We hear the powerful rasping sound intermingled with the tremor of the frogs, but distinct above their unbroken chorus by its shriller and more penetrating note.

Fresh broods of beautiful butterflies now appear upon the scene. Some are gay and brilliant kinds; others assume a special dress distinctive of this season of the year. In the open tracts are the brightest forms. There we see the *Delias*, with its scarlet marks; there the clouds of yellow *Terias* alight everywhere upon the flowers. We see the pale lemon *Catopsilia* darting swiftly over the wet grass or the iridescent *Hypolimnas* sporting itself in some sunny glade. Beneath the shelter of the acacia darker kinds occur. There the little brown *Yphthima* beats its laborious flight; there the *Melanitis* flutters for a moment, then of a sudden disappears, having transformed itself into a withered leaf. But chief amongst them are the splendid swallow-tails, of which four at least were frequently seen in handsome though not in gaudy dress.

Every nook in the dripping foliage is the abode of the unobtrusive moths. They love the seclusion of the moist crannies and the retreats beneath the vegetation near the ground. We see the delicately patterned *Noctuidæ* abounding in the long grass; we see the swift and powerful *Sphingidæ* descending at dusk on the open flowers; we see the protectively coloured *Geometridæ* pressed close against the bark or stems, or hidden away from view in the darkest hollows of the trees. But these moths are a vast army in themselves, created by the animating force of the monsoon. And not they alone, but also their successive broods of caterpillars, abound on every side.

But I must cease. I can give no idea of this wealth of life called into being by the summer rains. What of the host of heteroptera that drain the vegetation of its sap? At evening I can sometimes smell their odour as it permeates the still air. What of the army of other creatures, though not of the true insect kind? Look at the rapacious spiders; they too follow in profusion close upon their insect prey. There are some which live a roaming life and hunt and leap amidst the grass; there are others which stretch an expansive sheet amidst the leafy carpet near the ground; there are others which spread upon single blade a subtle and inimitable snare, and still others clothed in softest velvet and scattered like brilliant rubies on the earth. If we search the foliage we may light upon those ant-like mimics so different in structure from their own kind, or we may discover those leafy chambers on the blades which the spiders fashion round their delicate cocoons.

It is now that the fierce scorpions prowl by night, armed with their poison and their sting. It is now that the young *Myriapods* mass themselves in heaps, while the parents wander peacefully about linked in their endless love. And what of all the other kinds, dormant in the soil, that awaken at the touch of rain? It is now that the molluscs rouse themselves from slumber and crawl out on the trees and grass; it is now that the crabs emerge from their burrows to occupy the streams and pools; it is now that the worms ascend through the soil to build up their turrets of mud.

Such is the profusion of organic life; such is the procreative power of Nature beneath the animating force of the monsoon. But there is another side to the picture. All is not exuberant and fruitful joy; carnage too reigns everywhere around. It is but the simple law of life. Where Nature gives in bounteous plenty, at the same time does Nature most rigidly destroy. With strict exactitude is the living balance kept. There is no profusion in the harvest of Life which is not garnered by the reaper of Death.

This is not the place to discuss the battle. But look at the hirundines, the drongos, the bee-eaters, and the varied throng of insectivorous birds that gather up their victims on the wing. Look at the robber-flies, the dragon-flies, the tiger beetles, and the rest of that predaceous army which prey on insect life. Look at the crowd of ingenious *Epeiridæ*, with their deadly snares spread everywhere amidst the grass. It is their time too, the hour of the destroyer and the destroyed. Look indeed at the very floods themselves. With them they bring abundant life, but death too follows in their certain train. The waters rise; they spread themselves far and wide over the plain. What destruction must they not cause! What a myriad of creatures must be swamped in their relentless course! We see the beetles and the caterpillars escaping up the grass; many, like the crickets, no doubt evacuate their burrows; there are others, like the cattle-tending ants, which transport their offspring up the branches of the trees. But what of the more delicate creatures which cannot escape the waters? What of the tender larvæ in the soil which are smothered in the inundating flood? Millions upon millions are assuredly destroyed. Yet this is but the work of a few hours; it is as nothing when compared with the persistent carnage, the ceaseless war of creature against creature in the pitiless battle for life.

Thus do the waters give, and thus with equal certainty do the waters take away. The rains burst. Tropical nature glows with life. Millions of living things emerge, and a green luxuriant vegetation spreads itself over all the land. The silent jungle soon becomes alive. We see the brilliant colours of the birds; we hear the joyous sparkling notes; and at evening comes that vibrant thrill, the music of the insect world. Is it not a wondrous revelation, a vision of beauty and happiness and peace? It may be so; though this is but a surface view. Probe deep into the lives and struggles of the creatures and we bear witness to the God of War.

This concludes my record of observations on the natural history of the *manjha*. I have gleaned what I could from these neglected tracts, and if I have garnered something new, then my efforts have not been in vain. It is a record of peaceful and of lonely hours, yet amongst the happiest that I have known. For there is a close companionship in Nature; she speaks to those who listen and reveals herself to those who see. I have tried to hearken to her wondrous story and but repeat the tale that she has told. If those who read the unadorned record are pleased with the simple lines, then their hearts, too, are in unison with Nature, and they will hear the echo of her voice.

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