IN THE HIMALAYA.

Frontispiece

A NATURALIST IN HIMALAYA

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WITH PLATES AND TEXT FIGURES

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PREFACE

THIS volume is what its name suggests. It is a record of observations in natural science. It is an endeavour to gather many and varied facts into one common theme. The observations which it describes have been collected at intervals between the years 1914 and 1916 in the Himalayan valley of Hazara. They have been made slowly, gathered intermittently and then arranged with some attempt at order so as to appear in a collected whole.

My narrative will fall into different parts in accordance as my observations refer to different forms of animal life. I will commence with a brief description of the valley itself in order that the reader may appreciate the more striking geographical features of the district in which the subsequent observations were made. In the next four chapters I will discuss the habits, instincts and general economy of certain species of ants that are to be found everywhere in the valley. I will then pass to a series of observations on the natural history of spiders, especially with regard to the wonderful geometrical powers employed in the construction of their circular snares. In the tenth, eleventh and twelfth chapters I have collected a number of varied facts and suggestions that relate to the economy of insect life. In the thirteenth and fourteenth chapters I have discussed some matters of interest with respect to the mammals and birds of the valley, while in the last chapter I have endeavoured to describe in simple language the essential features of its rocky structure and the sequence of changes through which it has passed in the long lapse of geological time.

My interest has been chiefly directed towards the habits of animals, especially in so far as they relate to the psychology of instinct. The book contains nothing of a pure systematic nature. My object is to give some impression of the more striking manifestations of life that are to be seen in a Himalayan valley. So many of my observations are concerned with insects and other humble forms that it may be thought I have paid them undue attention when compared with my record of the mammals and birds. But it needs only the slightest insight to the works of Nature to see how wonderful she is even in her very simplest types.

I have had drawings made of those species to which I have given most attention, and trust that these will add interest to the subject matter of the text. The few photographs of scenery which I have introduced do not in all cases bear directly on the chapters in which they appear. Their object is to give the reader some impression of the rugged features of the Himalaya.

I cannot expect that my record is likely to interest any but those who have a special taste for Natural History, and have bestowed some little observation on it. Nevertheless I have endeavoured to express myself in untechnical language, confident that a subject, because it is intelligible, is none the less scientific or exact. I have not tried to escape from theory, nor have I refrained from forming an hypothesis where it has seemed to be justified by facts. The volumes of reference at my disposal have been few; and indeed if my work has any merit, it must rest in the fact that almost all it contains has been taken not from the works of others but rather from what Nature in her goodness has thought it fitting to disclose.

THE AUTHOR.

April 1920.

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CHAPTER I

A HIMALAYAN VALLEY

Definition of Himalaya—Appearance of the range—District of Hazara—General features of Hazara—Its valleys, hills and forests.

It would be no easy problem to define the Himalaya, the Abode of Snow. It is a mountain system composed of many ranges whose terminations are unknown. The southern and northern limits of the system are apparent at a glance. To the south it rises direct from the plains of India; to the north it blends with the lofty plateaux of Thibet and the Pamir. But where would the geographer place its eastern and western ends? Thirty years ago he would have marked the line of the Indus river as its furthest limit to the west and that of the Brahmaputra as its termination in the east, but such boundaries would scarcely hold to-day. For these are mere arbitrary limits that bear no true relation to the origin or structure of the whole. These rivers have cut deep clefts across the successive ranges; they in no sense define or limit them. The precise limits of the Himalaya are unknown; the complex system merges to the west in the mountainous country north of Afghanistan; on the east it is lost in the unexplored regions of Northern Burma and the Chinese borderland.

Viewed from the south the Himalaya seems to rise like a sheer wall direct from the alluvial plains of India. The snowy range is visible from a great distance. On a clear day the white outline of the peaks can be seen over a distance of 150 miles, and a conspicuous summit may display its white crest against the sky at more than 200 miles away. This prospect over so vast a distance is visible only on the clearest day. Otherwise the mountains are concealed from view. The atmosphere is so often permeated with a fine dust that the vision of distant objects is obscured, and the Himalaya then appears, not as a white glistening line of snow, but as a gloomy uninviting mass hidden in a veil of dust and not unlike a bleak headland appearing through an ocean mist.

On approaching nearer to the mountains their lines grow more firm, their summits more distinct. From the level plain we seem to gaze upon a rocky wall. We are too close beneath the mass to see the successive ranges rising in ascending slopes, and the confronting barrier of the lower hills conceals the scene of chaos that lies behind. The mountains seem to stand like a sheer precipice towering above an alluvial bed, and to limit the broad expanse of plain with an almost perpendicular wall. It is the sudden contrast between plain and mountain that is the striking feature in the landscape. Their junction more resembles the face of a great cleft than the denuded slope of a gentle fold. The contrast is abrupt. The eye moves unchallenged over the vast expanse of plain till it meets the sheer Himalayan wall. It is like gazing from a boundless ocean on to a rocky coast.

Valleys lead into this mountain barrier and penetrate the snowy range. They mark the course of the main rivers along which the drainage of the system flows. I pass to one of these valleys at the western end of the Himalaya close to where the Indus river emerges on to the plains. This is the valley that leads into the district of Hazara, a narrow tongue-shaped strip of British territory projecting northward into the ranges. I take it as a typical example of a portion of the Western Himalaya and will consider certain aspects of its natural history in some little detail.

This district of Hazara is a long and slender wedge of British soil driven in between two independent territories. It extends from 33° 44′ to 35° 10′ N. and 72° 33′ to 74° 6′ E. Its total length from north to south is about 120 miles, and its width varies from 56 miles at the base to 15 miles at the termination of the wedge. This strip of land has definite boundaries. To the south its foot-hills sink into the plains of the Punjab; to the north it rises into massive peaks 17,000 feet in height that blend with the still loftier summits of Western Kashmir. Its lateral boundaries are distinct. On the west it is limited by the Indus river and the country of the independent frontier tribes; on the east it joins the territory of Kashmir.

The upheaval of the Himalaya has involved the district of Hazara. It has raised its surface into a system of mountain ranges that course across it in parallel folds. From the north-east to the south-west these folds traverse it in successive tiers. The lower ones to the south are clothed in forest; the higher are draped in glaciers and snows. All are hewn into diverse forms and are peopled with many and varied species. It is this great upheaval that has given the wonderful variety to the landscape, that has moulded the district into mountains of every shape, carved it into valleys of every stage of growth, and has bestowed on it every degree of temperature from the oppressive warmth of the sub-tropical valley to the cold of the perpetual snow.

The general features of the country are best seen from the summit of a hill seven or eight thousand feet in height. A wide expanse of landscape is then exposed to view. Far away to the north-east the mountains of Kashmir rise aloft in snowy peaks and ranges. Their ice-clad summits rise in a bare glistening mass above the green wooded slopes of the nearer hills, but their distance is so great that it is impossible to appreciate their true magnificence and the stupendous scale on which they are built. The western boundary lies closer to us. It is dark, dreary and uninviting. Rugged black ridges of inhospitable mountain rise upward from the Indus. Pine forests cover many of its slopes; narrow paths wind along its spurs, and on the peaks and projections of its ridges can be seen the block-houses of stone that mark the last outposts of the empire. This is the frontier. The main ridge is the barrier between British territory and the land of the independent Afghan tribes.

To the south the eye sinks down on the vast plains of India. Like a sea they extend outwards from the mountains and fade into the far horizon. Hundreds of miles of unbroken plain expand and a whole country is spread out beneath the view. Everything is dwarfed

MAP OF WESTERN HIMALAYA.

[*Face p. 4.*]

to miniature. Seeming clumps of greenery are forests, villages are cities, and glistening threads are noble rivers. All are dimmed beneath a haze of shimmering heat. Further and further we trace this sea of land into the hot mists that envelop it, till, in the far horizon, sky joins plain through the quivering haze and heaven and earth seem one.

Such is the distant prospect from a peak in Southern Hazara. The nearer view is a less imposing one. The sub-Himalaya that stands around is built on a less rugged scale. Peaks and ridges of eight to ten thousand feet in height rise from broad fertile valleys four to five thousand feet below. In parallel ranges they sweep across the country. The higher slopes are clothed in dense forests of conifers, but lower down the dark brown rocks support but little verdure and project in bare unsightly masses through a rank mountain grass. Terraces creep up the sides of the narrow glens or rise like giant steps up the rounded mountain spurs that stretch out into the valleys.

The cultivated tracts lie far beneath nestling amongst the hills. As fertile plains they spread themselves before the eye. In the spring, when clothed in crops, these valleys are beautifully green and shine with a dazzling yellow from the brilliant fields of mustard. But in the autumn, when the harvest is saved, the green and gold expanse is replaced by a dismal brown. The parched hills then merge into the duller plains; the forests stand out in pleasing contrast, and here and there dotted over the uninviting valleys are the cemeteries marked by little clumps of trees, still green or fading into autumn yellow, like oases in a desert. The art of man is evident throughout the scene. Flatroofed villages, all facing southward, stand scattered through the valleys; others for protection form a stronghold on the summit of a low hill or on the ridge of a rocky buttress extending outward from the mountain side. The tiers of fertile terraces that climb the flanks of the hills indicate the industry of the people. Not content with the alluvial plains, they have followed the narrow streams up the mountain sides and forced the cultivation into every nook and cranny on their margins. They have employed much labour in this work. The terraces are irrigated by an ingenious system of stony channels that convey the water from a mountain stream. Their isolated houses of mud nestle in sheltered glens or hide in forest clearings, or stand perched on mountain spurs at almost inaccessible heights.

In the bed of every valley is the river, seen from the mountain summit like a winding silver thread. They glisten in their slow sinuous course as they wind through the fertile land or with almost torrential force rush over their stony beds. All are tributaries of the Indus that, far away to the west, like a narrow glistening streak, hides beneath the rugged mountains and separates this country from that of the wild tribes beyond.

I made many short journeys into the surrounding mountains, climbed the hills, explored the rivers, the forest and the glens, but could never tire of standing on a wooded peak and gazing on the massive ranges to the north, contemplating the endless southerly plains or wondering at the stupendous scale on which Nature has built this rugged land and the beauty with which she has clothed it.

The main bulk of Southern Hazara is composed of Tertiary limestone elevated into hills some eight thousand feet in height. In bulky masses they raise their ridges high over the fertile valleys. Encircling their broad waists is a natural girdle which defines the dark forests of conifer that densely clothe their summits from the barren slopes below. It is a pleasant recreation to wander from the deep valleys upward over the treeless mountain zone into these dark Himalayan forests. The murky valleys are soon forgotten as we ascend to cooler heights. We come upon the treeless zone. It is green with long mountain grass through which peep the blue bosses of the limestone. As we ascend higher we meet the forest of conifers, first a few dwarfed and scattered pines that struggle to exist a thousand feet below the forest. At six thousand feet we leave behind the treeless slopes and ascend into the gloomy woods. At the very outskirts we are greeted by birds of brilliant colour. Green parrots, shrieking as though in wild alarm, sweep high above the trees; perched over a torrent is a verditer fly-catcher clothed in a most lovely blue, softening under different shades of light into emerald or turquoise; and above us, flitting from pine to pine as if rejoicing in its unequalled brilliancy, is the fiery scarlet of the minivet. It is mainly the birds that beautify these forests; their many varieties, their splendid colours, their striking contrast with the duller species of the valley, make these pine woods an ornithological paradise.

We penetrate deeper into the forest under the shade of giant conifers. The woods are very peaceful. A sharp, cool air invigorates the body relaxed by the damp heat. On every side stand pines and firs of enormous bulk and stature. The blue pine and silver fir, intermingled with the spruce and deodar, clothe the hillside in a dark green. The colour is softened by a lighter vegetation mainly composed of the cherry, ilex, chestnut and sycamore. The trees drip with moisture. The sun is dimmed by their broad expanse; all life is still beneath their looming shade. Tiny flowers of every tint raise their heads above the tangled undergrowth, some of the only spots of colour in the gloomy scene. We climb higher and penetrate deeper into the forest. The gloom deepens and active life seems to be absent, but it is only lost in the immensity of the scale. The birds are scattered through the ocean of verdure and are hidden in the lofty trees. Living creatures in reality swarm in the dark forest. Peer into every mossy nook, search amongst the ferny dells, break asunder the dead, crumbling tree-trunks, and thousands of living creatures will be revealed to view. Troops of monkeys go crashing through the trees. Woodpeckers of brilliant plumage clamber nimbly up the giant conifers or sweep through open glades in long undulating flight. Flocks of titmice hang upon the branches, doves rise in alarm from the green undergrowth, beautiful blue magpies flutter heavily from tree to tree, the hills re-echo to the low call of the cuckoo and the sweet note of the whistling-thrush, or the nuthatch chops and hammers on the leafless top of an old gnarled pine. In every dark recess spiders have hung their pendent webs or have spread from branch to branch their inimitable snares; beneath the stones they seek a shelter or chase their victims over the moist ground. If numbers govern, then the spiders rule the forest. Shake the branches of the conifers and a cloud of tiny flies are awakened from their slumber and flutter out into the day. The forest teems with active life if we could but see it; it is hidden from our view in the vast immensity of the scene.

Over all there reigns at times a strange uncanny silence. No wind rustles in the dark pines, the distant twitter of a bird but seldom greets the ear; the one sound that breaks the solitude is the low rumble of the mountain brook as a thousand feet below it leaps from rock to rock in an endless succession of torrents and cascades. When evening approaches the forest grows still more peaceful and sublime. The setting sun at times glows with a rich orange tint, and, as its dying rays steal through the leafy chinks, the foliage glistens with every shade of vernal. The silence deepens, but the rippling brooks sing louder through the trees, and as the first stars peep through the canopy of heaven the majesty of the Himalayan forests sinks into a perfect peace and solitude.

Such is a very brief description of the general features of Hazara. It is a necessary introduction to the study of its life. I never had an opportunity of visiting the northern and massive extremity of this geographical wedge, but for years explored over and over again the valleys, gorges and dense forest-clad hills that trend gently to the south. For the naturalist it is in an interesting little corner of the world. Here each spring he will see the long stream of migrant birds moving northward by slow degrees from the stifling plains of the peninsula to the breeding-grounds of Siberia; and each autumn he will greet their sure return. He will see a smaller host of local migrants which in the cold of winter descend into the valleys and in summer ascend to the higher and cooler hills. In the glens, the fields, the gardens, the woods he will find insects numerous and full of interest, and many a happy hour he might spend with the living creatures of the pools and streams. Fortunate is he who can spend some years amongst the mountains of Southern Hazara and amongst the living beings whose natural history I shall endeavour to describe.

CHAPTER II

HARVESTING ANTS

General habits—Appearance of ant—Sexual forms—Collection of seeds—Effect of heat, cold, shade, rain, darkness—Cessation of toil—Division of labour.

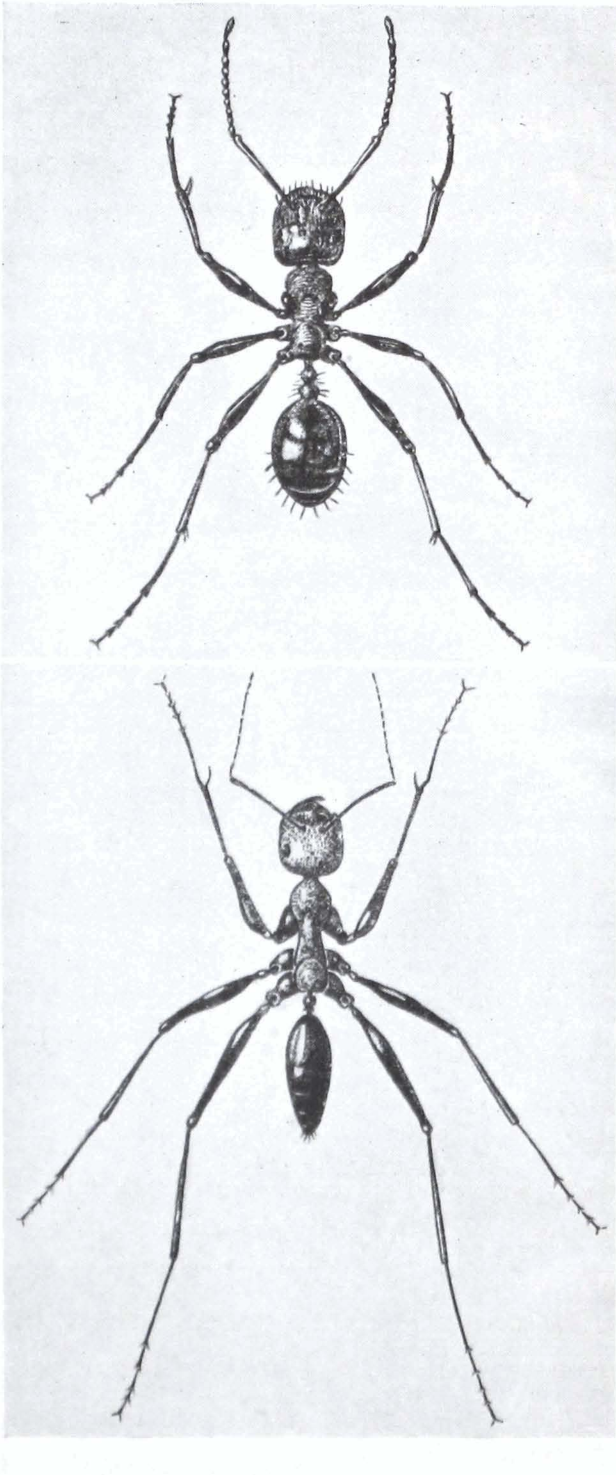
I WILL commence my record of the natural history of this valley with an account of the habits and instincts of that common and conspicuous ant, *Messor barbarus*.

In all places, at moderate elevations, this harvester pursues its labour. On the dusty roads, in the shady gardens, on the bare hillsides, and amidst the fields of Indian corn, long trains of ants, some empty, others laden with the spoil of harvest, move in an unceasing flow. At one spot a colony of ants establishes a formicary ; tunnels are dug into the earth and subterranean granaries are excavated in which to store the harvest. From the entrance to the formicary a solid track, smooth and well defined, leads out to where the harvest is collected. Should the nest be a populous one, a number of similar roads may radiate in different directions. These roads vary in length ; the longest I have seen in these hills measured thirty yards. Following the road outwards, we find that its further extremity gradually fades away, expanding into the collecting area where the seeds of the grass or Indian corn are waiting to be gathered in. To and fro along the road the ants move in different directions; those returning to the nest are laden with seeds which they carry to the hidden granaries; those leaving the nest are hastening empty-handed to the foraging-ground in search of a fresh burden.

Messor barbarus is an industrious though not a very agile ant. It is a dark red insect with a smooth and polished surface. Its head is square and strong, its thorax massive, and its large abdomen oval, black and shining. The members of the same community vary greatly in size. In the same nest are seen large workers one-third of an inch in length and smaller workers only one-sixth of an inch in length, and connecting the two extremes are many intermediate forms. The largest workers, though twice the length of the smallest, yet still more exceed them in their robust build. A dense multitude must throng each nest, for the roads are often crowded with their numbers.

The nests at these elevations, an altitude of 4000 feet, do not contain such large numbers of individuals as those seen in the plains of the Punjab. At higher altitudes the communities are still less populous, and in these smaller nests the common red species, *Messor barbarus*, tends to be replaced by a blackish form dignified by a distinct specific name, *Messor himalayanus*. A few thousand feet higher the harvester entirely disappears. I have occasionally seen them at 6000 feet far away on the extreme frontier. And once I found an impoverished nest of *M. himalayanus* on a mountain summit at 8000 feet, an altitude which, I think, must mark the extreme limits to which they ascend.

This ant commences active operations early in



The Harvesting Ant (*Messor barbarus*) × 5.
The Carnivorous Ant (*Myrmecocystus setipes*) × 3.

[*Face p.* 13.]

March. Throughout the winter not a harvester is seen, but the first warm days of spring vivify them from their sleep and a start is made in the establishment of a nest. A few workers, drowsy and indolent, emerge from the ground. They move slowly about waiting for the warm sun to dissipate their sloth. Soon they commence to work. Each ant emerges from the nest holding in its mandibles a little load of earth; this it throws to one side and returns for another burden. Other workers join the original pioneers and excavation advances. In these early days the work is sluggish and intermittent owing to the changing weather; a bright sun moves the ants to toil with energy, the rain or cloud or bitter wind drives them inert to the nest. An important duty at the commencement of the season is the clearance of the last year's galleries. The ants occupy themselves in ejecting the chaff and husks from the nest. Even in this work they display some system, not casting about the refuse haphazard, but collecting it into a heap at one special place. Slowly the tunnels are deepened, the granaries are enlarged, piles of debris accumulate about the orifice of the nest, but as yet no attempt has been made to gather in the harvest. An important event must first occur; the sexual forms must emerge before the storage of food begins.

Towards the end of the month they appear. The winged males and females creep slowly from the nest and out into the open. The workers pay them much attention, caressing them with gentle strokes of their antennæ. But the prospective parents are eager to be away; they soon climb to points of vantage on the tips of the neighbouring blades of grass and fly off into the air. The sexual forms having dispersed, excavation continues and is soon completed. The ants next seek the harvest. They spread out in all directions from the formicary, searching the ground for seeds. As soon as they discover a suitable area—it may be twenty or more yards distant from the nest—they rapidly wear away a regular thoroughfare between the collecting area and the nest, along which they pass and repass in a busy throng, either hastening to the nest laden with their little stores of provender or hurrying out to renew their burdens. From the unceasing tramp of millions of tiny feet a well-worn and conspicuous road is formed. There is no right of way, but there is no confusion; all pass backward and forward with perfect regularity; in fact the air of business, the bustle, and the all-pervading order remind one of the swarms of human beings hurrying along the highways of our great cities.

The gathering of the seeds is well worth observation. The ants move out along their road, reach the distant end and spread themselves over the collecting area. Some explore the ground, others ascend the plants to cut the seeds that have not yet fallen. Each ant, having secured a suitable seed, makes straight for home. Over every obstacle it pushes or drags its burden, much heavier than itself. With wonderful strength and energy it surmounts the stones and little hillocks that oppose it, or winds its way through a miniature forest of grass. It at length reaches the beaten track, hurries at a great pace along the smooth road, ignoring all its comrades in its eagerness for home. Arriving at the door, it enters, carries its load down the tunnel until it finds the granary. There it yields its burden to other workers whose office it is to receive the seeds, strip them of their husks, and eject the useless chaff on to the neighbouring refuse heap. The ants are not very particular as to the nature of the seeds they select for storage. I have collected twenty different kinds of seeds garnered by this harvester. Nor do they always confine themselves to nutritious seeds, for on an almost barren hillside I have seen them collecting dried fragments of grass, more, I suspect, from the force of instinct compelling them to collect something rather than from any value they could derive from the grass. I have watched them storing the pith of the Indian corn which could scarcely have any nutritious value. On one occasion I observed them selecting their harvest from a heap of bird-droppings, and often they explore a pile of horse-dung, which they tear to pieces, transporting the half-digested fragments to their home. They occasionally gather insects to the nest. Termites, the legitimate prey of almost every living creature, are eagerly seized, lodged in the formicary, and the wings, like the husks and chaff of the seeds, are thrown out on the refuse heap. To most ants the Termites are a tasty morsel. MacCook has observed the agricultural ant of Texas, which also stores nutritious seeds, bearing to the nest such numbers of Termites that "the vestibule became choked, and a mass of struggling anthood was piled up around the gate."

The conveyance of the seed is a great labour, but a still more difficult duty for the harvester is to grasp the seed in such a manner as to make it suitable for transport. The seed must be held by one extremity so that its bulk is directed forwards in front of the ant's head and elevated from off the ground. It is thus often very difficult to grasp, and places the ant at a mechanical disadvantage, but in no other position is the ant able to carry it. I have watched the ants persistently struggling with the seeds in the endeavour to obtain a suitable grasp. They often display much cleverness and determination in the way they seize the seed, first at one point, then at another point, and test it in every direction before they finally reject it as an unsuitable load. Nevertheless, numbers of seeds are cast aside, not because they are unwholesome food, but because they cannot be carried.

Messor, like the harvesters of Europe and America, not only picks up fallen seeds from off the ground, but ascends the plants and cuts off both ripe and unripe seeds with its mandibles. But I doubt very much if, like some ants, they ever employ so intelligent a division of labour as to detail certain of the community for the purpose of cutting and dropping to the ground ripe seeds, and assign to others the duty of carrying the fallen seeds away. Certainly when I placed some food in a shallow watch-glass fixed to the summit of a perpendicular stick close to the nest, the ants that climbed into the watch-glass never threw down fragments to those below, but each one carried its own little load along the difficult journey round the edge of the watch-glass, down the stick, and back to the nest; yet in this experiment they might have expected to learn how much better a policy it would have been for them to divide their toil, as many of them, while struggling with their loads along the edge of the watch-glass, overbalanced and tumbled to the ground, and thus had a practical lesson in the shortening of the journey and the diminution of their labour.

Although not very particular as to the nature of the seed which they take into the nest, they are very careful to satisfy themselves that it is quite dry. Moist seeds are always rejected, and in rainy weather, when the seeds are unusually damp, the ants, after collecting them, spread them around the orifice of the nest and allow them to lie there until sufficiently dry. I found that the ants were very fond of fragments of walnut and carried them eagerly away, yet, if moistened with water, not a particle would be lodged in the nest until first thoroughly dried in the sun. The garnered seeds are not always ripe, but may be removed from the plant while still green. Sometimes the seeds have broad green leaf-like expansions, especially in a species of dock (*Rumex hastatus*), which is a common source of harvest. And as each ant holds its little burden in the air, the green leafy seeds sway from side to side, and the returning column reminds one of the descriptions of the leaf-cutting ants of tropical America, and recalls the vision, to which Belt compares them, of a moving Birnam Wood.

I have mentioned that nest-construction begins in March, but this is only the case at altitudes of about 4000 feet. In the plains of the Punjab work commences much earlier in the year. I have there noticed the winged forms emerge in large numbers at the end of January. In all probability the species will be found active on the plains during any month of the year. Moderate sunshine is the main stimulus to labour, cold to sloth, while all industry ceases in an intense heat. On the first days after emergence work continues only in the sunshine, later, as the hot season advances and while the days are still pleasantly cool, the harvesters toil the livelong day, careless either of sunshine or shade. Still later, when the heat increases and the sun's rays beat fiercely on the earth, the ants evade the warmth that they first enjoyed and abandon all work except in the cool hours of the morning and evening. They are not such slaves to the sun as the harvesters of America, which so delight in the warmth that they refuse to construct their nests in shady places, and will either desert the nest or cut down the overhanging leaves if the latter should intercept the full light of the sun. The *Messor* ants do not object to a well-shaded nest; in fact in midsummer it is an advantage to them, for the ants will then work through the heat of the day round about the nest, and continue to collect the harvest wherever there is suitable shade. They will not then extend their operations into the full sunlight until the cool of the evening. Rain greatly disturbs the even life of the formicary. It checks all industry, obliterates the roads, washes the sand and gravel down the orifice to obstruct the tunnels of the nest. In these hills the rains are frequent and intermittent, and the ants have as a consequence to perform much unproductive labour after every downpour. From within the nest they pull away the obstructing debris grain by grain and are ultimately set free. On one occasion, after an unusually heavy storm, the ants did not escape from their prison until two and a half hours after the rain had ceased. The brisk and active manner in which they ran about the opening suggested that they were highly pleased at their release.

It is interesting to observe the sudden change that takes place in the general operations when work ceases for the day. I have endeavoured to make clear that, when gathering in the harvest, all the returning ants carry in their jaws a contribution to the general fund and all the ants leaving the nest are empty-handed. But if the ants be observed shortly before sunset the normal progress will appear reversed, for thousands of ants possessing no burden will be noticed hurrying from the field of harvest along the beaten track and entering the nest. The cause of the sudden change is that work has ceased for the day. Innumerable ants have been searching diligently for seeds but have been unrewarded. Evening approaches, and by common consent they cease their labours. Though failing to secure a load, they all converge to the common track and hurry along to the nest. Here and there a more fortunate worker, dragging laboriously a large seed, is infected with their haste and, though struggling along more violently than ever, is left hopelessly behind. On they come in an apparently endless stream ; they pour into the nest, for work has ceased for the day, and they retire to rest for the night.

The principle of the division of labour is an indication of the degree of organization attained in any community. Order, system, internal and external economy largely depend on different members, each performing its own definite task. The principle is illustrated in the life of the harvester. The large class of worker, or soldier-worker, assumes a different part in the general management of the formicary from that taken by the host of smaller workers. They do not join in the routine duties of excavation; they rarely carry a load of debris to the refuse heap; they quietly crawl about the opening while the smaller workers toil laboriously on. If we watch a nest during excavation, it will usually be found to have two or three soldiers stationed at the entrance. From time to time they leave their post of duty at the gate and creep about over the husks and excavated earth as though to satisfy themselves that the work is proceeding satisfactorily. Then they again return to the entrance. At first sight it appears a strange dispensation of nature that the largest and strongest should be the laziest in the community. But this is far from being the case. Interfere in any way with the general routine of work and none will more resent the intrusion nor attack more ferociously than these sluggish soldiers; place any impediment in the way of excavation and the soldiers will be tireless in their activity until it is removed. It is difficult to escape the impression that the soldiers stationed at the entrance maintain a general supervision over the smaller workers in their task of excavation, direct the scheme of operations, dictate the methods by which new difficulties are to be overcome, and stubbornly defend the nest against all intruders.

I will mention one instance displaying the energy and special duty of the soldiers in the protection of the home. I found a nest of *Messor himalayanus* situated on the side of a limestone cliff with its occupants busy as usual storing up supplies for winter. At the time I first detected the nest no soldiers were stationed at the gate. Eighteen inches distant from the entrance to the *Messor* nest a complete migration of another ant community (*Acantholepis frauenfeldi*) was in progress, and thousands of the tiny workers were moving rapidly, in perfect order, to their new abode, and many of them were laden with larvæ. The migration was no doubt due to the recent rains flooding the deserted nest which was situated at a lower level amongst the stones not more than ten feet away. The fact worth noting was that, though the migrant stream passed in close proximity to the *Messor* nest, yet the discipline of their advance was maintained with such regularity and order that no antagonism occurred between the two species. The discipline of the migrants and the industry of the harvesters continued without either party causing the slightest interference or opposition. Seeing this harmony between the two species, I disturbed the stream of migrants. Immediately the whole body of ants was thrown into a state of great confusion. All was flurry and excitement; ants rushed hither and thither and the commotion spread back along the advancing line. Discipline was lost, and the orderly progress of the insect-army was changed into an excited mob of migrants. Many rushed into the nest to seize the larvæ and transport them to a place of safety, while others dashed from place to place communicating the news with their antennæ and spreading a report of the disturbance throughout the whole community. Now as soon as I disturbed the line of migrants and spread confusion amongst their ranks, the two species, which before worked harmoniously, at once came into furious contact, and many of the migrating ants in their excitement rushed right across the *Messor* nest which before they had passed in peace. Two large *Messor* soldiers then came to the entrance of their nest, and one took up the position of guard on either side of the opening. Whenever a worker of the other species approached within an inch of the entrance, one of the soldiers would instantly rush forward and endeavour to seize the intruder; but although the soldiers were too heavy and clumsy to capture the agile *Acantholepis*, yet they succeeded in guarding their nest successfully against the host of excited migrants. None of the smaller workers attempted an attack, but continued to perform their domestic duties under the safe protection of the two soldiers. Thus do the soldiers of the species *M. himalayanus* perform distinct and specialized duties in regard to the protection of the nest.

The following is another instance of the division of labour in this community. A number of the ants were excavating a nest from beneath a small stone situated against a sloping bank. The earth which they removed had accumulated into a heap, and numbers of the workers were engaged in carrying their loads from the inside of the nest on to the surface of the heap. The surface of the mound thus formed was flat, and the extremity furthest from the nest formed a miniature precipice overhanging the ground below. I observed that the ants emerging from the nest never threw their loads down the precipice, but laid them on the surface of the mound. The ants, however, had stationed a special worker on the brink of the precipice, and, as fast as the excavating workers deposited their loads on the flat summit of the mound, they were taken over by this special worker, carried by her to the edge and pitched down the precipice. This appeared to be the particular duty of the one ant. Each worker could with very little more trouble have advanced another inch with its burden and thrown it over the precipice; but it was apparently a better division of labour and in some way more economical for the community, that each worker should take its load only to the summit and there deposit it, but that the size, shape, and general construction of the mound should be the peculiar duty of one particular worker.

But apart from these special instances, we observe the same principle employed in the routine of daily life. The harvesting of grain and the casting out of husks are duties which are carried on simultaneously in the same nest. In this work the ants divide their labour: certain individuals harvest grain but do not undertake the removal of husks; others eject the husks but take no part in the storage of grain. And not only do these ants divide their toil amongst their many members, but they sometimes advance still further in the division of labour, that most valuable of all functions to any community, in that they occasionally reserve one aperture of the nest exclusively as an entrance for those workers carrying in the harvest, and another aperture solely as an exit for those other workers engaged in throwing out the husks.

Thus do the harvesters divide their labours in due regard to the business of their lives. The strict economy of the nest needs the untiring help of all. But each individual has its own duty; each its own particular place in the long monotony of daily toil.

CHAPTER III

SENSES AND INSTINCTS OF HARVESTING ANTS

Sense of smell—Sense of direction—Communication—Play and sport—Peacefulness—Mode of defence—Emotions—Economy—Migration—Pliability of instinct—Aberration of instinct—Folly of ants.

THE special senses of ants are well worthy of investigation.

It is generally admitted, and I am convinced it is true in the case of the Indian harvesters, that ants find their way mainly by the sense of smell. It is very easy to demonstrate the acute development of this sense by surrounding the opening of the nest with a narrow ring of powdered camphor. The ants become very excited; they often recognize the odour fully an inch distant from the ring and dart backwards in apparent distress and alarm. With the exception of a few brave spirits that in their confusion dash across the ring, those at the mouth of the nest are cut off from the outside world, neither can those cutting and carrying the harvest enter within. Labour, however, does not cease, for the outside workers, after vainly endeavouring to brave the powerful odours of the camphor, deposit their burdens outside the ring and go off in search of more. It is the possession of this strong sense of smell that enables the harvesters to keep to the same road and pursue an unerring course to and from the nest. Unusual landmarks placed

A VALLEY IN THE HIMALAYA.

[*Face p.* 24.]

beside their road do not in the slightest confuse them, but if the finger be drawn gently across the track they instantly recognize the interference, appear to have lost their way, and not until a number have crossed and recrossed is the orderly progress again resumed.

I placed a strip of cardboard an inch in width across the track of the harvesters. This caused intense commotion, and not until many hours had elapsed did the ants carry their loads over the narrow cardboard strip. When the stream was restored I then removed the strip and the ants were just as much confused as before, although I had given them back their original road. They were unable to recognize their old track, since the odour had disappeared while covered with the cardboard. I transferred the strip over which the ants were freely moving to another track and placed it down in a manner similar to the first, but the ants were not now in the slightest confused; they carried their burdens without any hesitation directly across the cardboard strip. In this last little experiment the strip of cardboard had been given the natural scent by the numbers of harvesters that had run across it on the first track, and it thus became indistinguishable from the usual road to the ants which hastened along the second track. In the employment of camphor to test the sense of smell we stimulate the pugnacity of the soldiers. Camphor is a substance which the harvesters dread; from its powerful odour they dash headlong away; nevertheless, so plucky are the soldiers, that I have seen one grasp a large fragment of this stupefying substance in its jaws and endeavour to drag it away from the nest.

When a harvester leaves the general track in search of seeds it is, I think, by the sense of smell that it finds its way back again to its track. To test this I placed near the nest away from the track a perpendicular stick with a little platform on the summit on which were laid some chopped walnuts. I transferred a few ants to the platform, and after a little time they continued to come backwards and forwards between the platform and the nest, on all occasions making a straight course from the foot of the stick to the opening of the nest. While an ant was selecting a suitable morsel on the platform I moved the stick one inch to the right. The ant descended the stick with its load, but when it reached the ground, instead of making direct for the nest it wandered aimlessly about, carried its load further and further away until finally I lost it in the grass. It could not have been a special sense of direction that guided the ant from the foot of the stick to the nest, for the movement of the stick one inch did not appreciably alter its relationship and direction in respect to the nest, yet the ant was hopelessly lost. I believe the ant, when away from the common road, on its return journey follows the line of its own scent, and when it deviates from that line it is lost. And if this be true, then the sense of smell must be developed to an inconceivable degree. It is in itself surprising to watch the thousands of ants moving along the common track, each guided by a powerful sense of smell; but it is far more wonderful to see a single ant, away from the beaten road, scenting back along its own track and unerringly working over the same line that it previously followed, though that line may have been crossed and recrossed in the interval by hundreds of other ants. A harvester must, therefore, be capable of detecting its own scent from that of every other individual in the nest, and it follows that every single ant in a community must have a different scent.

Marvellous as is the sense of smell, it is impossible to consider it as the sole guide in the activities of the harvesters. During certain operations they seem to be impelled to take the right course by some mysterious sense of direction quite incomprehensible to us. This is well illustrated by the manner in which the ants find their way home when engaged in funereal duties. Certain ants bury their dead, and are even said to follow the corpse with reverence to the grave. The harvesters do not inter their dead beneath the soil nor do they indulge in any funereal ceremonies, but are nevertheless very careful in disposing of the dead bodies of their companions. When a dead ant belonging to the community is discovered, one of the workers takes it in its mandibles and carries it far away from the entrance to the nest. The dead are taken sometimes to a very great distance; on one occasion the ant conveyed the corpse sixty feet from the nest before it had discovered a suitable cemetery. The place chosen for the disposal of the dead is far away from the area of activity of the ants, never in the direction of the harvesting operations. When watching these funereal duties nothing is more striking than the wonderful manner in which the ants are able to maintain the true direction over unknown ground. I killed twenty of the members of one community. Two cemeteries were selected for the disposal of their bodies, one due west and the other due east of the nest. I observed an ant which carried its dead companion sixty feet from the entrance to the formicary. After taking up the body, it struck off in a westerly direction; the other members of the community never moved west, as the harvest was being transported along a line running due south. Nevertheless, this ant maintained a true westerly course. All kinds of obstacles confronted it: large stones forced it to deflect either to the right or to the left; it had frequently to rest its burden on the ground and seize it in some more favourable manner in order to raise it over an obstruction; sometimes it was forced to carry the body up the stems of plants or to make wide deviations to avoid some difficulty; at other times it had to cease its endeavours to carry the corpse and was compelled to turn about and drag it irreverently over the ground. As the ant moved away sixty feet distant on the unfrequented side of the nest, it must have been travelling over unknown ground; all landmarks must have been strange; every obstacle forced the ant to turn in various directions, yet it always returned to a true westerly course. Other ants followed with more corpses though not on the direct track of the preceding ant, yet the course was always a true one; it never deviated from a due west. I am unable to understand how an ant can maintain a true course over unknown ground unless it possesses some peculiar directive sense beyond our limited comprehension. I expected that the ant, after the disposal of the corpse, would return back along its own track, using its powers of scent, or possibly the landmarks on the route, as a guide to its return journey. I carefully marked the outward track, but, though the ant made a straight course for home, it did not retrace its actual footsteps. It travelled from a foot to two feet distant from its outward path, and consequently I do not think the sense of smell could have been its guide. I placed barriers between the returning ant and its outward track so as to conceal any landmarks, and I introduced stones and sticks as new landmarks along the line of its return, but they did not in the least confuse the ant. In front of one ant I placed a forceps, a razor, a sheet of paper, a book, and a mirror. The ant could never have seen such unusual landmarks along any track, and if it made use of landmarks as a means of recognizing its return journey, then such strange obstacles as these must have convinced it that it was on the wrong track. But the ant was not confused; it worked its way round the obstructions and kept straight on. Nothing interrupted its homeward course; nothing seemed to be its guide. It was difficult to escape the conclusion that a powerful sense of direction was the strange impulse that led it to its home. Drawing the finger over the ground in front of the returning ant did not excite it in the slightest, though, if the same be done across the main track leading from the nest, a great confusion ensues, and only after much hesitation will the ants pass over.

This wonderful faculty by which the harvesters engaged in funereal duties find their way home, and which we must call a sense of direction, is, like other instincts, capable of confusion. An ant had carried the dead body of a companion nineteen feet distant from the nest and was on the return journey. I took up the ant and transferred it back to a point six inches behind on its own track. After a pause the ant took a few hesitating turns and then made straight for the nest. After the ant had progressed a little further, I again took it up and brought it back six inches. This time the ant was more confused and wandered about for a longer time before it found itself able to strike a direct course. After it had discovered the true direction and was travelling in confidence towards home, I again brought it back six inches. This time, though much nearer the nest, its confusion was still greater; it repeatedly crossed and recrossed over its own track, wandered about in all directions, and, even after it appeared to have formed a hazy idea of the position of its nest, it continued to deviate widely from its course and often wandered some distance backward. For the fourth time, and when only two feet from the nest, I brought it back six inches. Its confusion was now intense; it seemed hopelessly lost; it hurried hither and thither, passed and repassed the entrance of its nest, and only after a long and laborious search did it happen by chance to fall upon its home.

I have not the faintest conception of how this sense of direction works. It is certainly not in the power of the ants to command it at all times. I took an ant from the opening of its nest, placed it in a dark tube, removed the tube to a point ten inches distant and then released the ant. The little creature was completely lost; it wandered aimlessly about in every direction; not a square inch of ground on either side but it vainly explored again and again until at length it came fortuitously on its nest. Other specimens removed to a similar distance wandered as far as fifteen feet away from the nest, and others found themselves so hopelessly astray that they gave up the search and hid themselves beneath the stones.

What can we say of an instinct such as this, at one time so sure a guide, at another time so utterly at fault? I withdraw the ant returning from its cemetery six inches on its track and it soon regains its road; I transfer it the same distance from its nest and it wanders aimlessly as in a dream. In one case the sense is certain, in the other it is lost. But why, I know not. The sense of smell though wonderful is comprehensible; the sense of direction is an inexplicable mystery.

That many ants are able to communicate intelligence one to the other is an undoubted fact. I shall later illustrate the high degree to which this faculty has been developed in another species found in the valley. The harvesters, however, can claim the power of communication only in a moderate extent. The one kind of information, and that a most important one, which these ants can undoubtedly communicate to each other is the presence of danger. When one ant in the society is alarmed, the news spreads amongst all the members with extraordinary rapidity. On one occasion, when the ants had collected into little groups of ten to twenty individuals and were sheltering from the rain in a dull torpid state, I touched a solitary ant that was resting quite separate from any of the groups. The ant hurried away in alarm to the nearest group. As soon as it touched one of the ants in the group with its antennæ, the information was rapidly spread from individual to individual and the whole group broke up in wild alarm. As each excited ant reached another group the same flurry ensued, and in a very short space of time all the torpid groups were dashing about in disorderly commotion. Thus a single ant had imparted to the whole nest a sense of impending danger.

It is surprising that these ants do not appear to have the power of informing one another of the discovery of food. With most of their lives employed in collecting seeds, it might have been expected that their faculty of communication would have been developed to this degree. But such is not the case. I placed some chopped walnuts, of which the ants are very fond, a little distance from the nest. I marked the first ant that discovered the nuts with a speck of white paint. After carrying off a morsel it returned again and again, but never brought any companions. All the ants marked in this way possessed a very excellent memory for location, but they were utterly unable to bring others to the place.

If an ant is lost it can gain nothing by questioning another ant. I have frequently watched an ant seeking in vain for the orifice of its nest, meeting with other ants and rubbing antennæ with them. No doubt in this way it recognized its comrades, but it found no help in regaining its road. It was clear that to ask the question "Which is the way to my nest?" is a mode of communication far too refined for so humble a creature. However close may be the intercourse that takes place between the lost ant and its companions, the former never receives any information that may help it to find the way to its nest.

I will mention some special habits which I have observed from time to time in the daily life of this harvester. The illustrious Huber remarked that ants of the species *Formica pratensis* play games, indulge in sport and enjoy themselves on the surface of their nest. The harvesters occasionally indulge in a similar pastime. One fine evening, about an hour before dusk, I noticed a group of harvesters assembled around the aperture of their nest, and playing about in so leisurely a manner that one might believe they were indulging in a general recreation after the day's hard work, and were enjoying the cool of the evening before retiring to rest. The ants were creeping about in a lazy, quiet manner. Some were rubbing one another with their antennæ as though they were giving a display of their affection. Others were cleaning themselves after the toil of the day and paid special attention to their antennæ, which they continually stroked with their legs. Others were more active and engaged in play or mimic warfare. Workers would snap at one another as if in friendly battle. Sometimes one ant would seize the other; a playful struggle would ensue; then a third ant would join in the contest and all would tumble over and over like little children rolling about in fun. The ants would then cease their friendly wrestle and run off to find another opponent and have another tumble. Like little puppies they seemed to enjoy snapping at one another and then springing away before the offended ant could retaliate with a mock display of anger. But there was no bad feeling, no true quarrel. The group was engaged in what appeared to be playful rivalry, and every ant seemed to be enjoying an idle recreation.

The harvester is of an unwarlike disposition. In all likelihood if a community were to use all its organized force, its rigid discipline, its undivided efforts in an attack on other species, but few could withstand its onslaught. Fortunately for insect life it is not a warrior but a peaceful husbandman. An attack on the enemy is so foreign to its nature that it scarcely understands the mode of battle. When in danger it trusts not in attack but in defence. It protects its nest by raising up ramparts rather than by advancing to engage the enemy.

I placed a wounded specimen of the ant *Camponotus compressus* close to the mouth of a *Messor* nest situated on a gravelly path. The ants seemed surprised and terrified at its presence; some dashed about in evident alarm; others glared ferociously with open jaws at the intruder; occasionally a more daring spirit would seize the enemy by a leg or antenna, but would instantly flee on the slightest resistance of the stranger. The curious fact was that, with all their wonderful discipline and organization, the whole nest appeared unable to make a concerted attack on a single wounded *Camponotus* ant which had invaded their territory, yet half a dozen of them acting together could have immediately removed it. Though unable to attack in any force, they were well aware that their nest was in danger. Workers hurried round the mouth of the nest, seized flat pebbles many times their own weight and carried them back to the entrance. Each worker placed its stone over the orifice of the nest, and in an incredibly short space of time the interior was secured by a strong barricade. The workers continued to strengthen their fortifications until the opening was completely blocked with stones, and the nest was then not only fortified, but the opening was so concealed that it appeared quite uniform with the surrounding ground. By these tactics many of the ants cut off their own retreat, yet they succeeded in the more important object of shielding their stores and offspring from attack. It is clear that the harvesters in their struggle with the enemy rely solely on defensive action.

That ants possess tender emotions is a matter of much doubt. I feel it difficult to credit them with any real feelings of kindness or affection. But on certain occasions they do behave as if they showed a sense of sympathy towards their fellows. I flooded a nest of *Messor barbarus* by pouring about a pint of water down the entrance. The workers outside immediately ceased their harvesting duties and commenced to force their way into the flooded nest. It was almost pathetic to observe the careful manner in which they carried out their half-drowned companions. One could scarcely resist the idea that some feeling akin to compassion or sympathy must have influenced the ants when each was seen carrying an insensible companion from the inundated home and laying it carefully in the sun outside the nest, where it rapidly recovered and took a place itself amongst the rescuers. It is difficult not to explain the behaviour of these insects except in terms of human feeling, but in this we should be very cautious or we may greatly err.

The ants are economical in the use of material and are provident in seeing that little goes waste. Even the ejected husks and chaff are sometimes of further use, as the ants will stuff them into the mouth of the nest and thus block the opening when danger threatens. They are very careful that none of the collected grain is lost. Sometimes, when the nest is situated on the face of a vertical bank, the harvesters have considerable difficulty in dragging their loads through the aperture, and in their various struggles and manipulations to effect this, the seed sometimes slips from their grasp and falls down on to the refuse heap. But the prudent harvesters are prepared for such accidents and the seed is not lost. A number of workers will be seen scrambling about on the refuse heap, seeking for any seeds that may happen to fall, rescuing them from the useless husks and conveying them back to the nest.

Migration of ants from an overstocked formicary is, I have little doubt, an important factor in effecting the spread of many species. It is very usual to witness certain species of ants transporting their larvæ in a long migratory stream to form a new colony in some suitable crevice. But it is rare to see a migration of harvesters; they do not appear often to increase their geographical distribution by such simple means. However, I once did observe what seemed to be a modified migration, for it could scarcely be considered a removal from an old to quite a new nest, but rather a transference from an overstocked part to a less congested area of the same nest. The ants had collected in a swarm about the apertures; energetic workers carried the larvæ from out of one opening and hurried down another; the excavators continued their toil of digging, but the vast majority of the ants had joined together in a dense and idle throng. I never saw such a concourse of harvesters or such a display of idleness in ant life. The few engaged in transporting the larvæ laboured with enthusiasm, but the remainder were wrapped in sloth. The ground around, and as far as I could see into the tunnels of the nest, was a seething mass of crawling, lazy workers.

The monotonous course of a harvester's life is to travel empty from the nest to the ant-field, select a seed and return laden to the nest. I will later show in the case of the geometrical spiders and certain insects that when an instinctive routine has been established, the creatures are in such bondage to that routine that, in face of all obstacles, the course of instinct must be fulfilled. Now the harvester, unlike some other species, is not an absolute slave to its routine. It can break the daily round of action in order to suit altered conditions. For if the seed be taken from a harvester on its return journey to the nest, the ant, after vainly searching for its lost property, will not behave like certain other insects would, and pursue its fruitless journey empty-handed to the nest, but will break its routine, turn about, and return for another load. Also, if when travelling empty to the field of harvest, it discovers a seed on the main track, it is not impelled by instinctive routine to continue its journey to the field, but will pick up the seed, face about, and hurry off to the nest. Nevertheless, I observed one foolish harvester, whose instinct seemed a more powerful guiding force than its intelligence, instead of turning back towards the nest after picking up the seed from off the track, struggle on in its instinctive routine and continue to carry the seed towards the harvesting ground further and further away from the nest.

The refusal to submit to unswerving instinct is made manifest in this way. Block the entrance to the formicary and note the behaviour of the laden ants when they arrive at the closed door. They immediately put things right. As soon as they arrive at the nest, they lay down their burdens, drag away the obstruction, and when the opening is cleared, again take up their loads and continue their journey.

Instinct, even of the sternest kind, may often err. It is not unusual to witness harvesters storing useless materials in their nest. And I think they sometimes do this against the better judgment of other workers. For on one occasion I saw a harvester dragging along a stone, and though it was forcibly compelled by another worker to drop its useless burden, yet it again returned to the stone and persisted in lodging it safely in the nest.

Instinct may lead them astray, if some of their own community are injured and then placed near the opening of the nest. I have often made this experiment, and observed with astonishment the signs of hostility and resentment that the ants show to their injured comrades. They look on their wounded sisters not as companions in distress, but rather as enemies. They rush on them with every sign of anger. This seems a curious case of aberration of instinct. The ants instinctively recognize that the presence of an injured companion must necessarily imply the proximity of some enemy to cause the injury, and, when they are unable to detect the enemy, they vent their hostile feeling on their dead and wounded comrades. Even after some of their number have taken on themselves the duties of burial, others will sometimes follow the body a short distance to the grave, not for the purpose of paying their last respects to a dead comrade, but, by continually snapping at the corpse, to mark their hatred and resentment at what they falsely believe to be an enemy.

In such ways do the harvesters err, yet they share their errors with every other insect. I give them credit for a greater degree of discrimination than is possessed by certain other ants. I know of one carnivorous species which if given pebbles moistened with the juice of insects, will foolishly carry off the pebbles and store them as provender in the nest. The harvester can make a nicer distinction than this. I mingled with chopped walnuts some pieces of blotting-paper soaked in the walnut juice, in the hope of deceiving the husbandmen as I did the carnivorous ants. But there was no cheating the harvesters. They eagerly sucked up the juice from the blotting-paper, but made no attempt to store the worthless fragments in their nest.

It is very usual to hear from one who has not paid special attention to the habits of these ants an expression of surprise at their extraordinary cleverness. And there is no doubt that when one first observes their wonderful organization, their law and order, their indefatigable industry, the skilful methods by which they overcome all obstacles, and to see in every act the subservience of the will of the individual to the general good of the whole community, one is tempted to exclaim "they are amongst the most intelligent of living beings." But as observations increase, it becomes more and more evident that such a conclusion would be hopelessly at fault, and that behind all this wonderful social organization there lies but the faintest glimmer of an individual intelligence.

I will give a few observations illustrating the poverty of their intelligence. On one occasion I discovered a nest situated just above a large smooth slab of slate lying at an angle of about forty-five degrees. The ants, in order to pass from the ant-field to the nest, had to climb up this slippery slate. The journey was a very difficult one, and an ant scarcely ever succeeded in climbing up the slate without falling down many times and having to recommence the journey again and again. Numbers of ants in this way got lost; many others were unable to reach the nest by nightfall, and probably hid themselves away beneath the stones. The nest rapidly dwindled as it lost its workers, but the remaining ants still persisted in their struggle up the slippery slate. By travelling round the edge of the slate, a not very much longer journey, the ants could have gathered their harvest in safety, or they might have migrated to a more suitable nest. But these expedients never seemed to strike the ants; they persevered in their impossible task until all were destroyed.

On another evening, while exploring a little ravine, I observed a more obvious instance of their lack of intelligence. Harvesters, I have already mentioned, carry the chaff and husks of their seeds out of the nest, and these they carefully pile up into a little refuse heap some eight or ten inches clear of the nest. Now I found a nest-opening on the face of a vertical wall of clay bordering the side of the ravine. The ants were carrying their loads up the perpendicular wall. The nest interested me and I stayed to watch the work, as it was evident that to transport the seeds up to a nest in such a position must entail much more labour than if the nest was situated on the level ground. However, when I noticed the pile of chaff and husks lying on the floor of the ravine below the mouth of the nest, I thought that, after all, the ants stood to gain as much as they lost, for instead of having to make a journey with the refuse chaff to some little distance from the nest, they need only come to the mouth of the nest and from there drop their burdens to the ground. But as I watched, to my surprise I saw an ant emerge from the nest with a fragment of chaff, but, instead of dropping it to the ground, the foolish insect actually climbed for nine inches down the vertical wall, and then lowering its burden against the clay, let it fall down into the ravine. All the other ants engaged in the work of removing refuse conscientiously followed its example. It is an excellent instinct that compels these creatures to carry the fragments of refuse a short distance clear of the nest, but such was their lack of intelligence that, when the nest was situated on the face of a perpendicular wall, they were quite unable to modify that habit though it involved them in much unnecessary labour. Yet in a similarly situated nest further up the ravine their folly became almost ludicrous, for here, not only did they make no use of the position of the nest for dropping refuse to the ground, but they actually carried the fragments vertically up the wall until they reached a horizontal ledge almost a foot above them, and there they carefully deposited each fragment of chaff, which was almost immediately blown away by the wind. I cannot attribute to creatures that so wastefully expend their energy in the performance of such foolish acts as these anything more than the faintest spark of intelligence.

Other ants behave with equal folly when their nest is similarly situated. I have observed little ants of the genus *Tetramorium*, when excavating their nest, carry the loads of earth and fragments of stone down a vertical slab of rock and drop them just as though they were removing the particles to the mound of ejected earth usually situated a short distance from the nest. Had they dropped their loads at the mouth of the nest they would have saved themselves a considerable amount of misspent energy. I suspect that ants have no conception of the different dimensions of space, and that to transport seeds or debris up the vertical or along the horizontal makes to them no sensible difference, and that when the ant carries its little load of earth down the perpendicular rock to the correct distance from its nest and allows it to fall from its jaws, it believes, if it is capable of forming any mental impression at all on the matter, that it is building up the usual pile of debris in the neighbourhood of its nest, and is quite oblivous to the fact that every load it so carefully lays in the correct place falls downward to the ground. Men may wonder at the cleverness of ants, but how often do we find that their acts are the acts of folly?

Such are the activities of the harvesters in their daily life of toil. Guided by a wonderful instinct, they incessantly come and go in strict obedience to the duty of the hour. They display some of the best qualities of a race; a perseverance in industry, an economy in provision, a resolution in defence. They have evolved an organization for the benefit of all in which each submits to the common good. They live in a world of socialism, but know nothing of its laws. Unconscious of their actions, knowing not why they toil, sufficient for the day they labour, for they remember no past, take thought for no morrow; yet are they not happier—if they can feel happiness—than the richest of human beings? For what belongs to one belongs to all. None is rich, none is poor; all enjoy an equal share, none can despise its neighbour's poverty, none envy its neighbour's wealth. Nor, since they all toil in a common field, is there that jealous competition in different spheres which amongst humanity divides class from class to set up barriers of envy and discontent. Having no forethought they feel no cares, having no ambitions they experience no regrets. Their life is one of industry, their lot of endless toil. They strive to earn a livelihood in which each will gain its just share, but oblivious to all those stings and sorrows which darken the mind of man as he looks forward or backward on the troubled road of life.

CHAPTER IV

CARNIVOROUS ANTS

Myrmecocystus setipes—General habits—Division of labour—Food—Sense of smell—Attitude of abdomen—Absence of sympathy—Mode of founding new colony—Intelligence—Folly.

I PASS from the habits of the Himalayan harvesters to consider some other species of ants that occur less frequently in this valley.

On the Indian borderland, at the foot of a gloomy mass known as the Black Mountain, stands a small stone fort, loopholed and barricaded, as a protection against the border tribes. All round are towering mountains; those in the distance are clothed in glistening snow; those near at hand are less rugged and are softened with a covering of pines. A broad valley is enclosed by these encircling hills. It is a green and fertile tract studded with small hamlets and watered with sinuous streams.

Just outside the fort, under the shadow of the Black Mountain, were some nests of that active little ant, *Myrmecocystus setipes*. I never saw this species in any other part of Hazara, though it is extremely common in the plains of the Punjab. How strange that I should find it again far away on the extreme frontier! It is such a very different creature from the harvesters that I will give a short description of its habits and endeavour to contrast the two species.

A MOUNTAIN VIEW IN THE HIMALAYA.

[Face p. 44.]

Myrmecocystus setipes is a sturdy active species much larger and more ferocious than the harvesters. It is dark red in colour, sparsely clothed in a few scattered hairs. Its head is large and strong, furnished with powerful jaws that are armed with curved pointed teeth suited to its predaceous nature. A narrow neck divides the head from an elongated thorax which supports the six dark slender legs and ends behind in a black conspicuous abdomen. A distinct difference in size exists amongst the workers of a single nest. The larger individuals generally reach about half an inch in length, while the smaller ones scarcely exceed three-eighths of an inch; and all gradations in size are found between the two extremes (see Plate, p. 13).

It is a predaceous ant, existing chiefly on other insects, while the harvesters are peaceful husbandmen. The harvesters move slowly, regularly and methodically along definite roads, but this carnivorous ant is extraordinarily active, and runs about in every direction with darting agile motions well suited to its predaceous habits. The smallest workers are exceptionally active, and take great pains to keep the entrance to the nest smooth and clean by continually digging in the earth with their front legs, shovelling up the larger granules and carrying them away in their mandibles.

A community of harvesters contains thousands of individuals, but the number in the nest of *Myrmecocystus* probably does not exceed more than about thirty or forty members. Though possessing fewer workers than the harvesters, the excavation of the nest is by no means a slow process. The ants, by their activity, compensate for their lack of numbers. To see them hurrying from their nest with a load of earth, dashing away to the refuse heap and darting back again with incredible speed, was to think that in their work of excavation they were engaged in a contest against time. One of these ants, which I marked, carried out from the interior of the nest no less than ten loads of earth in six minutes, and I do not think a harvester could undertake anything approaching such rapid work as that. Moreover, in their habits they score over the harvesters, for they not only carry the particles from the nest, but also possess a most valuable habit of kicking back the loose earth from the mouth of the nest in the same way as a dog kicks back the earth when rooting at a burrow. They are diggers as well as carriers, and by the former process they gain a great advantage, for, in each individual journey from the nest, the ant can confine its efforts to a large particle, and all the smaller fragments, which to the harvester would necessitate innumerable journeys, can be swept backward with its feet.

A harvester, when it casts its load of earth upon the refuse heap, has no further interest but to return for another load. The carnivorous ant, on the other hand, is more attentive to the vicinity of its nest; it often spends a little time amongst the refuse, dragging the larger fragments further away and kicking back little clouds of dust as though it was trying to make things neat and tidy, and above all to prevent the earth from falling back again into the nest. In this act they often display a division of labour. They detail three or four of their members whose sole duty it is to pick away the larger pebbles, sweep back the refuse and clear all earth from the aperture of the nest.

Division of labour was a character which I was always delighted to discover in ant life, for the specialization of work and the allotment of different tasks to the individuals of any community is one of the surest manifestations of its mentality and advancement. Just as specialization of function indicates the superiority of the individual being, so does the division of labour determine the progress of the race. In this connection I will give another instance to illustrate this great principle. At sunset a worker might sometimes be observed paying very special attention to the outside of the nest. The other ants have retired to rest, and this ant is clearly engaged in some special individual work. It has been detailed for the particular duty of sealing up the entrance for the night. One evening I watched the little labourer at work. It carried the larger pebbles from the refuse heap and dropped them down the opening of the nest. It dusted back the finer earth with its hind legs so as to fill the crevices between the pebbles and firmly bar the door. How strange it is that the all-important instinct of carrying out the pebbles and sweeping away the debris from the nest should here seem to be reversed, and that the ant should labour to replace the same little stones and the same fragments of earth which, earlier in the day, it had so eagerly cast forth!

Having barred the door, with the exception of a narrow slit sufficiently wide to permit of its own return into the nest, the ant entered and, with particles of earth carried from the interior of the formicary, it sealed the crevice through which it had passed and then rejoined its comrades for the night. Without assistance or interference the solitary worker performed this important duty; the division of labour in the community had reached such a degree of advancement that the specialized toil of one member was to the advantage of the whole nest.

In this instinct, like all others, are occasional mistakes and imperfections. I was surprised at one foolish error made by a busy worker when engaged in the evening duty of sealing the entrance. It carefully stuffed its load, transported with much labour, into a blind hole in the ground, presumably under the impression that it was barring the aperture of its nest.

But the labour of closing the formicary was not a changeless routine as are many instincts in many species. For on a subsequent evening I observed the ants adopting a somewhat different mode of work. Not only one, but a number of workers took part; and instead of dropping the larger pebbles from outside down the mouth of the nest, they performed all their work within the orifice and closed the opening by piling up fragments of earth all of which they carried from the interior of the nest.

As the harvesters cast out the husks of the seeds, so do these carnivorous ants cast out the shells of the insects. At one nest I watched them dragging out shell after shell and piling them up at the distant margin of the excavated earth, and I thought at first that they were wonderful sanitarians for so choosing the furthest limits of their refuse heap for the deposition of their objectionable burdens. But this was certainly untrue, and there could have been no design or choice about their actions, for when I blocked the aperture of their nest with insect shells, the ants dealt with them in the same way as they would treat an obstacle of earth, and deposited the fragments, not on the shelly heap, but just outside the mouth of the nest. I have no doubt that it is a valuable habit for the ants to collect the remains of their carnivorous food all in the same place some distance from the formicary, and to pitch the earth just outside the gate. But it is all unconscious. It illustrates how strange is instinct in its thoughtless action. The ants find the nest blocked with the shells of insects, an unusual discovery. They clear away the obstruction, but they are unable to place the shells on the refuse heap for shells. All their experience tells them that the only material that blocks the gate is earth, and therefore the shells must be treated as such and thrown out on to the earth heap.

Grasshoppers are the chief prey of this ant. But bees, beetles, larvæ of all kinds, terrestrial shells, ants of other species, particles of dung, even their own dead comrades are carried into the nest. Unlike many other carnivorous ants, they do not combine in vast numbers to overwhelm their prey. They are not, like the harvesters, of a tranquil and peace-loving temperament, but are strong, ferocious and determined ants, and are capable of overwhelming so many insects, each by its own individual efforts, that combination is not very essential to the capture of their prey.

Harvesters, like civilized human beings, remove their dead far away from their homes. These carnivorous ants, on the other hand, are degraded cannibals, for they drag their dead back into the nest and store them up as food.

Unlike the harvesters, these carnivorous ants have an indifferent sense of smell. Nothing fills a community of harvesters with a greater feeling of anger or throws it into such violent confusion as a few particles of camphor scattered near the nest. But these ants are quite unaffected by the camphor. After recovering from their slight alarm at the sight of the strange substance, they continue their work of excavation; they make no attempt to remove the camphor; they will even carry into their nests insects soaked in a solution of the substance, and while every harvester will spring backwards when it has arrived within half an inch of a fragment, a carnivorous ant of this species will cross and recross a mound of camphor and apparently derive no more sensation from it than if it were the hillock of earth that was being built up outside the nest. The difference in the sense of smell in the two species is readily shown by drawing the finger across the path of a returning ant between the insect and the nest. On reaching the line made by the finger the harvester is confused and lost, but the other, unaware of any interference, continues on its path.

This ant gains by acuteness of vision what it loses by the poverty of its sense of smell. By sight it recognizes the approach of a stranger and darts immediately into its nest. Within the shelter of the fissured aperture it peers outward with quivering antennæ, watching keenly every movement, and ready to spring backwards at the slightest danger. I mention these details in my contrast of *Myrmecocystus* with the harvesters to indicate how greatly do the habits, instincts and special senses vary in the different species of ants.

The most obvious feature in the appearance of this species is the peculiar manner in which it erects its abdomen when running about. The whole abdomen is extremely mobile, and the slender pedicle, that connects it with the insect's thorax, allows it to move with such extreme freedom as to be either extended horizontally behind or erected vertically in the air at right angles to the remainder of the body. The latter position is the most usual, and gives the ant a terrifying appearance as though it were a dangerous insect armed with a powerful and venomous sting. The ant is really a harmless creature, and I first thought that this attitude was assumed for the purpose of striking terror into its enemies and giving them a false impression of its innocent nature. But this ant has very few enemies, so I suspect that this strange attitude of the abdomen has not a defensive function but is really a balancing agent; for when the ant is struggling with a heavy burden and attempting to drag it over all kinds of obstacles, it is a great advantage to the insect to have a large abdomen projecting out behind as a counterbalance to the weight, and the ant will naturally turn the abdomen up over the thorax when the jaws are empty and the counterbalance not required.

I had read of certain ants treating one another with affection, and I have mentioned an instance of the harvesters rescuing their companions when in difficulties, so I thought that these rapacious workers might, perhaps, behind their cruel nature, possess a little spark of kindness.

I imprisoned one of them by fixing its large abdomen firmly in the earth and allowed the head and thorax to project above the surface. But its fellow-ants showed no compassion, no desire to rescue, not a spark of pity. They attacked their imprisoned comrade as though it was their greatest enemy. One endeavoured to bite off its antennæ, another to tear away its legs, a third seized its narrow neck and used every effort to decapitate it. All struggled with the prisoner to drag it unmercifully from the pit. Nor did the imprisoned ant see any sympathy in this rough treatment, for it attacked every worker that approached, opened wide its jaws, closed with its comrade as with a foe and battled for its life. At length, having failed by force to drag it from its prison, the workers commenced to dig. As they did not dig very intelligently or show any co-operation in their actions, it took them a long time to uproot their companion, now wounded in the struggle. At length, having unearthed it, they certainly bestowed on it no sympathy, but dragged the unfortunate creature for provender into the nest. Some ants may, perhaps, be imbued with a sense of pity, but there is no compassion in these cannibals.

It has frequently been observed that ants possess the peculiar habit of carrying their companions about in their jaws, but it has seldom been possible to detect any purpose in this strange action. I have noticed ants of many different species transferring their comrades from place to place, but they always seemed to lay them down and release them haphazard without gaining any special object. However, one day in a nest of this species which I had under close observation, I did detect a reason for these strange efforts. I noticed that at short intervals one or two workers emerged from the nest each carrying a companion in its jaws. They seemed to behave with more purpose than usual. Each emerged hurriedly; each made off in the same direction; each acted with enthusiasm as though it had an object in view. I followed one of these ants and found that it conveyed its companion to another nest of the same species seventy-two feet distant. The other ants were engaged in the same task. A continual transfer of workers was in progress from nest to nest, and the transferred ants were always carried by their companions. The supported ant lay passive and resistless. It hung back downwards beneath its supporter, with its slender legs entwined round the body and jaws clutching tightly the jaws of its companion.

I have some doubts as to why this transfer of ants should take place from nest to nest and why so strange a mode of transit should be necessary. I do not think that the ants of the one nest were stealing workers from the other nest, for they acted quite openly and were not treated as enemies, nor did the transferred workers make any resistance as they presumably would if they were being carried surreptitiously away. Nor could it have been a case of slaves transporting their masters, for both the carriers and the carried were of the same species. I frequently observed this transference on subsequent occasions and found it to be a general habit of this ant. I suspect that it is a modified migration; a mode of founding a new nest when the old one becomes overpopulated. It is possible, though this is only a conjecture, that, as the season advances and the nest is densely thronged from the development of many workers, it becomes essential for the community to expand and found new colonies elsewhere. One or more workers proceed on a voyage of discovery and thoroughly explore the vicinity of the nest. Having found a crevice suitable for the establishment of a colony, the worker returns to the old nest and lays the foundation of the new home by transferring workers one by one in its jaws until sufficient have been carried off to relieve the congestion in the old nest and lay the foundation of the new colony. This, I think, is one method by which this species increases its geographical range, though the process is undoubtedly a remarkable one. However, after having hundreds of times seen workers transferred from place to place by their companions for no apparent purpose, I was interested to observe at last worker carry worker for the achievement of a definite object.

It is difficult to read the accounts of the habits of ants as observed by our greatest naturalists without feeling some faith in the power of intelligence so often ascribed to these insects. I could see little of such high mental powers in the life of the harvesters, and, in my account of their activities, I have dwelt more on their folly than on their reason. But I look with another eye on this species, for I once carefully observed a wonderful act, which, unless I make a grievous error, I must consider a manifestation of real intelligence.

On a cool dry evening I discovered a nest of this species on the side of a bank bordering a field of Indian corn, and noticed that the earth which the ants were throwing out had accumulated in the form of a steep cone extending base downward from the mouth of the nest. It was like a landslip down the side of a hill, and, whenever an ant emerged with its little load of earth and ran out on to the apex of the cone, the loose sheet of earth crumbled away beneath its little feet and it tumbled down the slippery cone. The position of the ants at each exit from the nest resembled that of a man on the snow-slope of a mountain in imminent danger of losing his foothold and rolling down into the valley.

The next evening, on visiting the nest, I found that the ants were adopting a wonderful and most ingenious method of overcoming their difficulties by making the ground so firm and resisting beneath their feet as to prevent their fall. One energetic worker had been detailed to collect pebbles from the foot of the cone, to carry them up the slope and build a level platform of stones over the apex of the cone just outside the mouth of the nest. As the workers emerged they now no longer moved over the crumbling and slippery earth, but over the firm and secure platform of pebbles.

I watched the ant in this strange, intelligent labour. Down the slope it hurried to search for a suitable pebble. Backwards and forwards amongst the larger fragments, which by their weight had rolled to the very foot of the slope, it rushed about in enthusiastic haste. It was now digging in the ground for suitable fragments, now turning over the pebbles, now testing the weight of the larger stones or attempting to drag those too heavy for its strength. It was never content to take the first pebble that offered, but was continually selecting as though choice was an important factor in the perfection of its work. Back again to the platform it struggled with the chosen pebble; up the slippery cone it toiled, now pushing, now dragging its heavy burden. Ever stumbling, often slipping down the crumbling slope, it laboured on in its persistent toil. So great was its energy and determined its efforts that it seemed to recognize the importance of its task. Hour after hour it laboured on. Repeatedly it returned for pebble after pebble. No other ant ever relieved it; none ever shared its monotonous toil. All alone it struggled to build a platform of pebbles to save its fellow-creatures from misfortune.

The platform consisted of a layer of stones spread over the apex of the cone outside the entrance of the nest. The worker did not cast down its burdens haphazard, but selected a suitable place for the deposit of each load, and often carried its pebble all round the mouth of the nest before it was satisfied in its choice. Though the other workers took no active part in fetching pebbles or building up the platform, yet they rendered a milder form of assistance, for as they emerged from the nest in their work of excavation they occasionally dropped a few fragments of earth between the pebbles of the platform, and this served to cement the mass.

I thought I would help the solitary and laborious worker in its strenuous task, so I added a few pebbles to the platform, but the other ants would have none of this interference, and immediately seized my pebbles in their jaws and hurled them down the slope. I think that they recognized them by the smell of my fingers, for two pebbles which I did not touch but added to the platform on the point of a knife were allowed to remain.

I know the danger of applying a human motive to the behaviour of any insect, yet I could not escape the impression that the building of this platform of pebbles was the most remarkable instance of division of labour in an ant community that I had ever seen and the strongest testimony to their possession of intelligence.

In the mountains of Kashmir I have seen a narrow path crossing a dangerous landslip and a Kashmiri workman building up a rampart of stones to prevent the traveller from losing his foothold and falling down to his destruction. That certainly would be described as an intelligent action on the part of the workman. Nor can I see much difference between the mental attitude of that laborious little ant which spent hour after hour building up a platform of stones to save its fellow-ants from tumbling down the slope and the mental condition of the Kashmiri workman who laboured to build a stony rampart to prevent his fellow-creatures from rolling down into the valley.

This wonderful method of building up pebbles at the mouth of the nest is also undertaken by them under different conditions. I have seen a nest so situated that the earth thrown out by the ants formed a circular hill around the aperture, and the excavated earth tended to fall back into the nest. But the ants overcame the threatened calamity by detailing one of their number to build a rampart of stones around the opening of the nest inside the circular hillock and so prevent the excavated earth from rolling backward into the nest.

All this seems intelligent. It resembles the act of a rational being. But in the midst of this seeming intelligence I must give an example of their utter folly.

I have mentioned that these ants so divide their toil that certain workers are detailed to remain outside the nest for the very important duty of carrying off the pebbles and sweeping away the finer refuse so as to prevent it falling back again into the nest. But I discovered a nest situated on the face of a steep bank three feet above the level ground. The ants were engaged in excavation. Each ant carried out its little load, conveyed it about six inches down the bank and then laid it against the steep side of the bank, from where it, of course, tumbled down to the level ground. That in itself was folly, the same folly as the harvesters, for the ants would have saved themselves much unnecessary labour had they dropped their loads from the aperture of the nest and not carried them six inches down the bank.

But what utter folly. What apparent absence of the first rudiments of intelligence when I looked at the mound of excavated earth three feet below on the level ground. There I saw six busy workers earnestly engaged at work on the mound. Each was hurrying backwards and forwards picking up the pebbles and carrying them away to the edge of the mound, digging and uprooting the larger fragments of earth and sweeping back the finer dust with such energy that one might think it was in imminent danger of tumbling back into the nest. Assuredly the ants did think so, yet the aperture of the nest was three feet above them. So great was their folly and so impulsive was their instinct that they found themselves driven to indulge in the useless labour of clearing away the fragments from a nest into the aperture of which they could not possibly fall.

And thus does folly seem to contradict intelligence and ignorance to clash with reason. Would that we could know what was working in the insect's brain when it built up the valuable platform and when, on the distant rubbish heap, it expended its energies in useless toil. Why is it now intelligent, why now foolish? Why these inconsistencies? For in Nature there are no real contradictions; all moves by unalterable law.

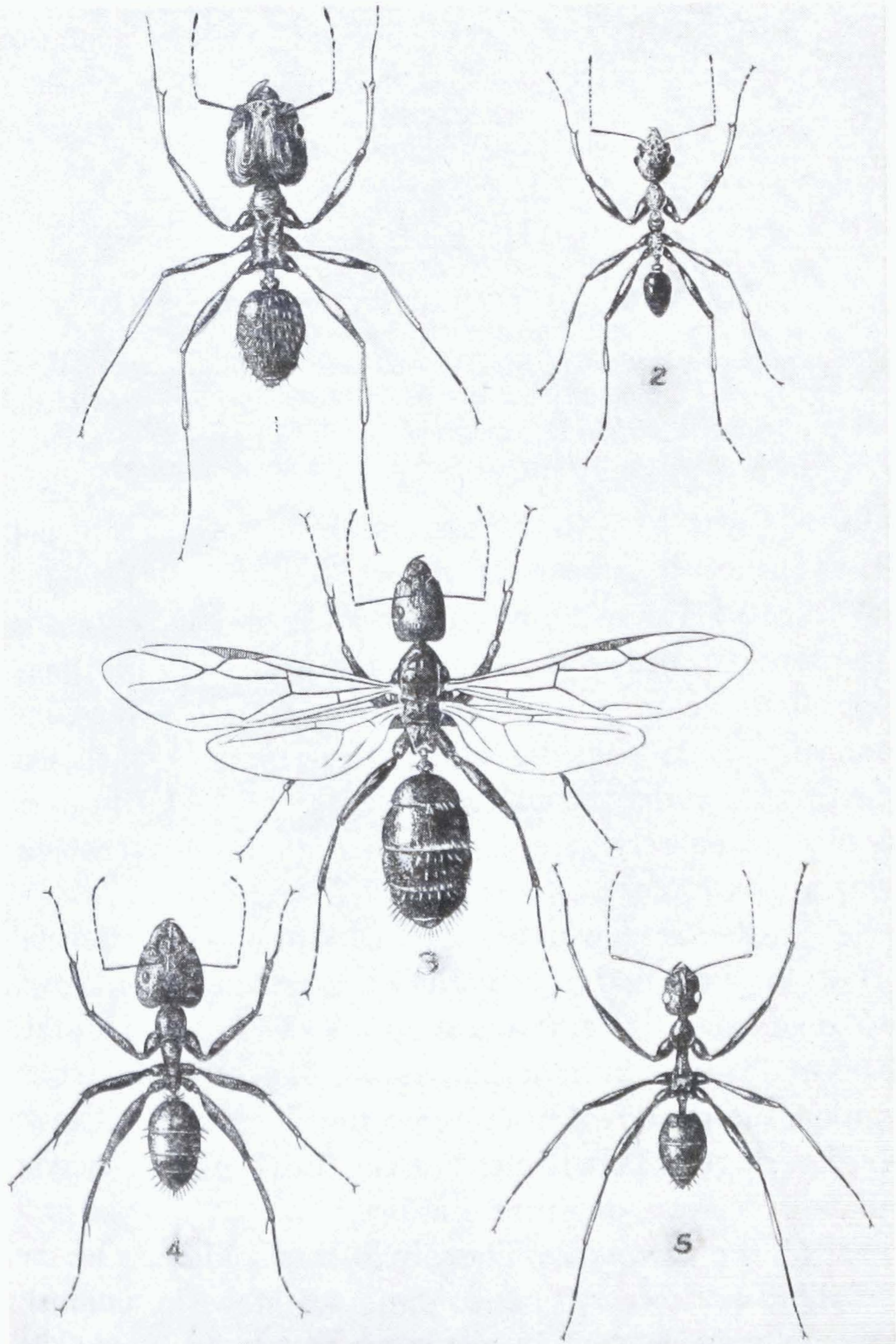
CHAPTER V

COMMUNICATING AND OTHER ANTS

Phidole indica—Mode of attack—Power of communication—Experiments on faculty of communication—Sense of smell—Every individual in nest differs—Division of labour—Attitude of *Cremastogaster*—Migrations of *Acantholepis*—Sexual forms of *Camponotus*.

The power of ants to communicate intelligence one to another has been at different times affirmed and denied. I have shown how feeble is this power in the Indian harvesters, nor does it seem much more highly developed in *Myrmecocystus*. It is therefore instructive to consider another species in which this faculty is perfected to an astonishing degree and on which the existence of the community essentially depends.

A little ant, widely spread through Continental India and ascending to the Hazara valley, is known to science as *Phidole indica*. I will mention this species with some detail, as I have seen no ant in which the power of communication is developed to so high a degree. It is clear to the most casual observer that two very different kinds of workers exist in a nest of the *Phidole*. There are the soldiers and the smaller workers. The soldiers are few in number, strong and massive in their general build, while the smaller workers are slender, more agile, and swarm about the nest in hundreds. Nor do we see any intermediate gradations connecting the two different



COMMON ANTS OF HAZARA.

1 and 2. *Phidole indica.* Soldier and smaller worker.
3 and 4. *Camponotus compressus.* Sexual form and worker.
5. *Acantholepis frauenfeldi.*

[*Face p.* 60.]

classes. They are quite distinct in build, and we shall see that they perform different functions. The soldiers seem to be in about one to five hundred of the smaller workers. Each possesses an enormous square head, large out of all proportion to its slender body, and severed above by a deep median cleft. It is of a dark brown colour with a light red thorax clothed in a few pale hairs. From the thorax a pair of sharp spines projects upwards, and behind is attached a glossy, almost black abdomen. The smaller workers are scarcely one-eighth of an inch in length, not very much shorter than the soldiers, but distinctly less powerful and robust. I do not think the head of a smaller worker can be one-tenth the size of that of a soldier, nor has it the peculiar deep cleft that nearly severs the head of a soldier into two separate lobes; though for some reason, possibly connected with its more highly developed functions, it possesses distinctly longer antennæ.

I will pass immediately to the power of communication in this species, which is remarkably acute. These ants are carnivorous and capture insects and larvæ alive. The workers are so very small that by their individual strength they can effect little. It is only by the combined efforts of the whole community, under the direction of the soldiers, that a capture is made.

As soon as a worker discovers a caterpillar or other suitable material for food, it proceeds to make a careful examination of its prey. It runs all over the caterpillar, exploring it with its sensitive antennæ, shaking it with its jaws and attempting to drag it to the nest. The worker, satisfying itself that the discovery is suitable for storage and finding the removal of it beyond its own weak efforts, hastens off to the nest in great excitement and by the shortest route. It meets another worker on its path; their antennæ meet; the second worker is imbued with the enthusiasm of the first, has received information of the discovery and hastens off to the insect. A third, a fourth, and possibly more workers are similarly informed on the route and all hurry away to lend their assistance. But the excited discoverer hastens on to the nest. Now it has reached the entrance. It enters and is lost to view. In a few seconds a swarm of rushing, bustling and excited ants, led by a number of ferocious soldiers, come dashing headlong from the nest. From the way they are all lying in readiness just within the door and emerge at the same moment in one body as though they were awaiting a call for aid, I have no doubt but that these ants so divide their labour that certain workers are detailed for the duty of discovering food, and others, under the guidance of the soldiers, are under orders to remain in permanent readiness within the door of the nest to hurry out and render assistance when news arrives that a discovery has been made.

The news has come. Out they swarm in a dense throng preceded by the soldiers. Without the slightest hesitation they hurry over the ground, passing and repassing one another in their excited haste. In amongst the stones, round the fallen leaves and stems of grass they retrace the track of the discoverer. They have reached the caterpillar. Round about it they collect in a struggling and ferocious swarm. They cluster over it in hundreds, cling into its head and back, and seize on to its limbs; but it is at the tail of the larva that they make the sternest attack. There they firmly attach themselves with their minute jaws while with their hind legs they cling to every pebble so that the larva in the endeavour to make good its escape drags behind it a little hillock of pebbles. These impede its progress and give the ants time to bring up reinforcements to the attack. On all sides they besiege the larva, which tries in vain by violent contractions to throw off its enemies. The battle grows hot and fierce. The caterpillar in its struggles now gains the mastery, but ants hurrying on in increasing numbers gradually overpower it. Workers, at intervals, retire from the battle and hasten back to the nest at the greatest speed to call out more reinforcements and hurl them into the fight. The caterpillar weakens; it cannot face these repeated additions to the strength of its foes. It is overwhelmed by the force of numbers, soon becomes exhausted, and then lies at the mercy of the ants which, clinging in a body round their powerless victim, drag it slowly to the nest.

I have often watched a contest of this nature in which the prey was almost always vanquished. But the strangest thing I observed in this connection was that, not only did the ants remove their victim larva, but, in addition, the little stones and fragments of grass that had come in close contact with the body of the larva were also dragged deliberately to the nest. I killed a grasshopper and moistened a number of small stones with the juice from its body and then gave them to the ants, and these stones were also removed to the nest. It appears that the ants carry off to their nest the fragments of stone and grass under the impression that they are actually edible substances, though in reality they have been only moistened externally with the animal juices. I was surprised to find that a group of insects possessed of such remarkable instincts should have been so hopelessly misled as to confound animal tissues with stones.

But I must return to their power of communication by virtue of which a single ant can inform the nest of its discovery of prey, can launch the awaiting army to the attack, and can, if necessary, return again and again to call successive reinforcements to its aid. This, I think, is a true communication, a real transfer of information from one ant to the remainder of the body, and as a consequence of which, a distinct series of activities result. Wonderful as is the instinct of communication and essential as it is to the life of the community, yet like every instinct it is imperfect and capable of confusion. I gave a dead insect to a worker. The busy little creature hurried back with the news of its discovery and in a few moments the swarm came rushing to the scene. I then removed the insect, and the ants, finding nothing, returned to the nest. I then placed the insect on the opposite side of the nest. A worker soon discovered it and brought back the news. Again the swarm issued from the nest, but confusion almost at once followed. Many ants hurried along the correct track and found the insect, but others, as though still confused by the memory of their previous exit, hastened to the spot where the insect was first placed and searched for it in vain. On another occasion I have observed the instinct so confused and the swarm so lost in its efforts to find the object to which it was summoned, that the original discoverer, previously marked with a speck of paint, has had again to return to the nest and call out the swarm a second time.

The ants are sufficiently careful not to empty completely their nest when the swarm emerges. The whole strength is not lost in one effort. A reserve swarm is left in readiness within the nest to be called out should information be received of a second discovery while the main swarm is engaged in overcoming the first. Or should the contest be severe, the ants will have reinforcements in readiness to advance and support their fellows. Like the prudent commander of an army, they rarely throw the whole strength of their force at one moment into the struggle, but rather keep a strong reinforcement in reserve to be sent forward should necessity arise.

This, in truth, is a wonderful power of communication, for not only does the worker supply the information that it has discovered something, but it can communicate to its fellow-workers the place where the discovery has been made. The other ants which I have described could never have transferred one to the other such definite communication as this.

The process is worth further investigation, so I describe the following observations and simple experiments to shed some light on the manner in which I believe it works. At first it appeared possible that the returning ant might have caused the excitement in the swarm and urged them into activity by bringing into the nest a tiny fragment of the discovered treasure. But I am certain that this was not so, but that the communication was a real transfer of information. I never could detect the slightest trace of a fragment of the insect in the jaws of the returning ant, and sometimes the discoverer would merely examine the tarsus of the insect before returning to call out the swarm, and from the hard tarsus it could certainly not tear away a fragment. Moreover, I was later able to convince myself that the swarm was not excited by the sight or smell of a particle of the prey, for I found that certain workers in the community were quite unable to communicate, and though they returned again and again with fragments of the discovered insect, they did not in the slightest degree excite the swarm, nor were they able to give any information of their valuable discovery.

In some way or other it is within the power of a single worker, independent of anything it may carry to the nest, to convey information to a swarm of other workers, and to announce to them the valuable fact that "I have discovered food." But how this process of communication works, by what mechanism the one ant transmits its information or the other ant receives it, I find it not only difficult to understand but even to investigate. I will therefore consider in more detail the second link in the process, as I find it more intelligible; namely, the power possessed by the solitary ant of directing the struggling, hurrying swarm straight to the discovered insect.

At first I thought that the ant returning with the news led the swarm from the nest and directed them along the true road; that the discovering ant was the leader and that the swarm followed in its train. It was necessary to mark the discoverer with a speck of paint in order to investigate the matter. This is a difficult operation. The workers are so tiny, so agile and quick in their movements, so excited and easily frightened that the slightest touch fills them with alarm. At last after many days and innumerable unsuccessful attempts, I succeeded in marking three ants without terrifying them out of their senses. I found that the worker returning with the news of the discovery emerged from the nest, not at the head of the issuing throng as though it was acting as a leader, but appeared in the midst of the swarm. Nor was it essential as a guide to the true road which led to the discovery, for many of the ants in the issuing swarm outran it and came first to the treasure. Undoubtedly its presence in the swarm was a great assistance, for many of the ants would rush up to the marked ant, rub their antennæ against it and then hasten off to the insect in the greatest excitement as though they had gained valuable information by contact with the discoverer. But it is certain that the discovering ant, once it has given information, is no longer essential as a guide to the swarm, for I captured one of the marked ants at the moment of its emergence from the nest, and the swarm, in its absence, had no difficulty in finding the insect.

Since the returning ant cannot act solely as a guide and since, indeed, its presence seems to be no longer essential once it has passed its information to the awaiting throng, it was difficult to form any other conclusion but that the issuing ants found their way to the treasure by retracing the scent of the returning ant.

I think that this can be the only explanation, for when the swarm is hurrying to the discovery it certainly does follow back along the track of the discovering ant, but if the finger be drawn across the track so as to disturb the scent, then the swarm of ants will be thrown into confusion. The line drawn by the finger will form a regular barrier over which the ants will cross with difficulty, or at which they will lose their way and return to the nest. Members of the issuing swarm, I have said, repeatedly communicate with the discoverer, and they act thus, I believe, because they are following the scent of the discovering ant and wish to reassure themselves that they are on the right scent by again testing the odour of the ant. For this odour is a guide to the true road.

FIG. 1.—Experiment with Communicating Ant.

But a few simple experiments will confirm the matter. If a dead insect be fixed to the top of a stick standing erect on the ground, and a worker be placed on the insect and then allowed to run down the stick, return to the nest and inform the swarm of its discovery, then the issuing swarm will have no difficulty in finding the insect in this strange position. But if, after the departure of the worker, the vertical stick be replaced by another similar stick, then the swarm will be thrown into confusion at the base of the new stick owing to the scent being there lost.

Now if F (Fig. 1) be the discovered food, N the nest and FN the returning path of the discovering ant, and if, on that path at the point A, the ant be raised from the ground and transferred to B, then the swarm on emerging from N will proceed rapidly to B, but at that point will be thrown into confusion and unable to advance further owing to the gap in the scent between B and A.

Those who believe in the hypothetical sense of direction, supposed to guide ants in their wonderful journeys, might suspect that it was some strange directive power, inexplicable to us, that impelled the swarm along the true road. I do not think that this is the case, for I placed a dead insect on the end of a horizontal stick directed to the west and allowed the worker, after making its discovery, to run back along the stick on its way to the nest. Then, during the absence of the worker, I rotated the stick in a semicircle so that it was directed to the east, but the swarm on reaching the foot of the stick were not confused; they hurried along it without hesitation though its direction had been reversed.

I feel confident that their wonderful power of scent is their true guide. No other explanation seems to fit the facts. I think that the ants within the nest recognize the distinctive odour of the worker that brings the news, and can thus retrace the track which that particular worker has followed. The information which the returning ant communicates to its fellows appears to be this, "I have found food; retrace my scent and you will find it."

When observing the harvesters, I was driven to the conclusion that each individual in the community was capable of distinguishing its own odour from that of every other individual in the nest and that, therefore, each ant must have a distinctive scent. Here we are forced to a similar conclusion, for the swarm must distinguish the specific odour of each returning worker, and if so, then every single worker must have a distinctive scent.

How marvellous are the manifold works of Nature, and what extraordinary conclusions are we forced to form when we endeavour to penetrate the secrets of her work. It is interesting to contemplate a host of hurrying ants, to see them advance in mass to the attack, do battle with the foe and drag it to the nest. It is instructive to witness their strategy, their system, their organization and the union of all for the general good; but few thoughts can be more wonderful, few can fill us with a deeper sense of the complex scheme of Nature than the knowledge that, in a nest, each single one of these thousands of tiny insects is known to every one of its fellow-creatures. Each little worker seems but a moving speck lost in a swarm of insect life, but it is a speck unlike the thousands of other specks; it has its own distinct characteristics, its own individuality; it distinguishes separately each one in the countless multitude and each one distinguishes it.

A shepherd can distinguish each sheep in his fold; man can see differences in all his fellows; but it seems a far more wonderful thought that this swarming, hustling throng of insects should possess the faculty of individual recognition. All these ants must differ; there can be no two quite alike. The thought arises as to how far through living nature may this difference extend. At times we may look into the skies and see birds congregated in tremendous flocks; we may peer into the ocean on vast shoals of fishes; we may survey a desert for hundreds of square miles all green with swarming locusts. Do these all differ, though to us all alike? If analogy is any guide, then surely our reason would lead us to suspect that as man differs from his millions of fellow-men, as every sheep is known to its shepherd, as in the multitude of busy ants all the members are unlike, so this endless difference may extend through every path of organic nature, even through that most amazing profusion of fertility, the dense locust swarm. How wonderful is Nature to mould her creatures all unlike and collect them into groups of great resemblance. That none shall be identical may be as inexorable a law of Nature as that like produces like.

It is only the smaller workers that possess the power of bringing information and calling out the swarm. The soldiers rarely hunt about for prey; their duty is to remain indoors and await the news brought by the smaller workers. Their great strength is their most valuable asset. To the community they are useful, not for discovering food, but for fighting battles, directing the swarm, and dragging insects to the nest.

On two occasions I found a soldier hurrying about outside the nest and gave it a dead insect. Now if this had been an ordinary worker it would have hastened to the nest with the news and the awaiting swarm would have poured out through the gate. But the soldier could not undertake that duty; it remained for ten minutes dragging vainly at the insect and running round about it, but never attempted to call out the swarm. The second time the dead insect was rather bruised, and the soldier tore off a fragment and carried it to the nest. Again and again it returned for another fragment, but always singly. Its excited state and the presence of food in its jaws had no effect on the awaiting throng. It seemed to possess no power of calling out the swarm or of giving information of its valuable discovery.

But the division of labour in this community is brought to a still higher degree of perfection, for not only is the labour distinctly divided between the larger and smaller workers, but also different tasks are assigned to different groups of the smaller workers. I draw this conclusion from the following observation. When a nest has been fully excavated and the duty of the whole community is to collect food, then every ant appears to render aid when the call arrives. But one evening I discovered a nest which was still undergoing excavation. Certain of the ants were carrying out their little loads, while others were running about outside the nest. I gave a dead grasshopper to one of the workers and expected that, on arrival of the news of the discovery, the work of excavation would cease and all the ants would hasten to the spot. But this was not the case. The swarm emerged and attacked the grasshopper, but the workers engaged in excavation took no notice of this rich discovery, but continued their monotonous toil. The swarm dragged the grasshopper to the nest, but the insect was too large to enter the aperture and remained fixed, half in and half outside the nest. Round about the gate was this seething swarm of ravenous workers, all tearing and dragging at the insect in their excited efforts to draw it past the obstacle, but still the workers engaged in excavation took no notice. At every exit each little excavator had to force its way through the greedy throng and sometimes had even to climb over the body of the insect, but it never interfered in the efforts of the swarm. It recognized that the labours of the community had been divided, that it was its office to engage in the humble duty of excavation, while to others alone was assigned the more adventurous work of capture.

In the defence of the home they also divide their labour. To the soldiers is the chief glory of the battle. I have watched nests with stalwart and ferocious soldiers posted at their gates. They stand guard over the entrance, ready at a moment's notice to hurl a reckless attack on an invader. In this species the soldiers are very pugnacious and sometimes exert an autocratic tyranny over the smaller workers; for I have seen them, in the exertion of their authority, crush and mangle in their powerful jaws the workers of their own nest and rend them into fragments.

In their migrations, likewise, we see the same principle in force, each one to its own duty. The main burden of toil falls on the smaller workers. It is they alone that transport the larvæ, and they often carry their companions from nest to nest. The soldiers carry nothing. They are not humble toilers, but are the directors of the transport. They are the aristocracy of ant life. They hurry out of the nest singly and at intervals with a throng of laden ants following in their rear; and as each powerful soldier hastens along the migrating line, it looks like an officer leading and directing his company of men. Nor do the soldiers return again to the old nest. The smaller workers, once they have deposited their larvæ in the new nest, hasten back for a fresh burden, but a returning soldier is never seen. It, no doubt, busies itself with important duties within the new nest, but takes no further part in the migrating line.

And as sometimes happens in human society, the directors of the community, the oft-reviled aristocracy, become neglectful of their great duties and sink into a contemptible idleness; so do the soldier ants, the aristocracy of this insect labour, appear sometimes to neglect their duties, and, instead of taking an active part in the direction of this migrating stream, resign themselves to abject laziness and permit the busy little workers to carry them from nest to nest in their jaws.

I must now pass from these wonderful *Phidole* ants to consider other species. I could never tire of studying them, not in confinement, but on the mountain sides, in the fertile fields or the sheltered glens. I loved to watch them divide their labour, each one to its own task, and to test and retest that remarkable intercourse by which they communicate one with the other.

But because these ants communicate, it must not be presumed that all ants communicate. From the study of a single species of ants the presence of the power of communication has been asserted and denied for this whole tribe of insects. The fact appears to be that one species may possess the power and another not possess it, and it is quite unjustifiable to affirm or deny the presence or absence of any sense from the study of any single species. For do we not here find the absence and presence of the power of communication amongst the different workers of the same species? And what is true for the power of communication is equally true for any other faculty. Harvesters have an acute sense of smell; in other ants it is almost absent. *M. setipes* detects by sight the slightest movement, harvesters have a dim, limited vision, other ants are totally blind.

By communication these ants live; it is the mainspring of their existence. Could they not communicate they could neither capture their prey nor overpower it and drag it to the nest. But is there any real intelligence in this essential act of life? I could never see that there was. The ants were impelled by a power far greater than their own feeble minds; they neither knew what they did nor did they know why they did it.

I have but few remarks to make on the remaining species of ants that occur in this valley. A common genus, *Cremastogaster*, which frequents the trunks of the trees, has the peculiar habit of turning up its heart-shaped abdomen so as to stand out at right angles to the rest of the body. When the ant is running about excitedly, the pointed and projecting abdomen gives the insect a somewhat terrifying appearance, and suggests that it is prepared to sting savagely on the slightest provocation. As in the case of the *Myrmecocystus*, I first considered that the peculiar attitude adopted by this genus possessed the useful function of suggesting to insectivorous enemies that it was a ferocious creature and that they had better abstain from attack. I doubt, however, if this explanation is correct, for I have observed that another species, *Camponotus compressus*, which does not usually adopt this attitude, will, when descending a tree-trunk head foremost, allow its abdomen to fall downwards over its back under the influence of gravity until its position exactly resembles that of a *Cremastogaster* ant. A large abdomen, under such insufficient muscular control as to have its position affected by the stress of gravity during the ascent and descent of the tree-trunk, must to some extent diminish the stability of the insect. And I suspect that a *Cremastogaster* ant, which is continually moving up and down the trunks of the trees, has found it more advantageous to its stability and balance to maintain its abdomen permanently in the position that gravity would fix it during the descent of a tree, rather than drag behind it an unwieldy mass ready to sway about in every direction that might always serve as a threat to its equilibrium. The adoption of this attitude might be expected to produce anatomical changes in the structure of the ant. This seems to be the case, for the narrow pedicle, that in most ants connects the thorax to the middle of the front of the abdomen, is in this genus attached not to the middle but to the upper margin of the abdomen. An attachment of this nature permits the unusual attitude to be more easily adopted.

The migrations of ants often display the plasticity of instinct in the species and the power of the ants to modify their behaviour to meet unusual conditions. One small and agile little ant, *Acantholepis frauenfeldi*, seemed to be continually in a state of migration (see Plate, p. 60). After every shower of rain a stream of workers might be seen hurrying from an old to a new nest, all heavily laden with larvæ. I suppose that the rain, flooding the nest, makes it uninhabitable for the ants, and they are forced to remove to drier quarters. The ants often do not migrate to any great distance;

the new nest may be established six, eight or ten feet away. They do not necessarily migrate in one body all at one time, but those which carry the larvæ to the new nest may continue to return to the old nest again and again to convey another burden.

One day I watched them migrating in a long file and entering the new nest by four small apertures. I sealed up with stones these apertures in order to observe what the ants would do with their precious larvæ. After a short period of great excitement and commotion, the workers carrying larvæ turned away from the closed doors, retraced their steps for a short distance towards the old nest, and then branched off to one side in the direction of a small heap of withered grass. Beneath this grass they deposited their larvæ, in order presumably that they might not become injured by exposure. They then returned to help in the removal of the obstruction. Now as each ant turned away from the barred door to conceal its larvæ, it frequently passed and appeared to communicate with other ants bearing larvæ to the new nest. Yet it never appeared to be able to convey the information to them that the opening of the nest was barred and that the larvæ should be stored beneath the heap of grass. Each ant had to proceed right up to the obstruction and investigate for itself the unusual state of affairs before it could deposit its burden and help in the task of demolition.

On another occasion, during a migration of the same species, I killed a number of the migrants close to the entrance of the nest into which the ants were carrying their larvæ. This filled the ants with intense alarm; there was now no attempt to hide the pupæ until the danger was removed. Migration at once ceased and the larvæ were hurried back to the old nest. A number of ants remained about the aperture searching in all directions for the cause of the calamity. After an hour of fruitless search they must have concluded that all cause for alarm had disappeared, for the ants began to emerge with their larvæ from the old nest and the migration again continued in a steady stream. Thus can the migrants modify their behaviour. If they meet with an obstruction, they conceal their larvæ and break down the opposing barrier; if they imagine danger is at hand, they cease their migration and retire to the deserted nest.

As rain stimulates migration, so also does it awaken the sexual forms which, on emerging from the nest, soon seek union. This takes place under different conditions in different species. In the large *Myrmecocystus setipes* union sometimes occurs on the ground near the mouth of the nest shortly after the males and females escape. It may therefore enjoy no nuptial flight. This is not so with the harvesters, for the males and females of this ant fly away independently, and the probability of union must in this species be more remote, as it will depend on a chance meeting between the opposite sexes at a distance from the nest. The sexual forms of other ants congregate in the air in a regular swarm. The males and females of one of the smaller species of the *Myrmecinæ* collected round me one morning in June as I wandered through the fields. They moved through the air like a cloud of insects, and persisted in alighting on my head and shoulders, after which act union occurred.

The life of the male after it leaves the nest must be extremely short. One evening I observed that a number of the sexual forms of the large black Indian ant, *Camponotus compressus* (see Plate, p. 60), were flying about the lamps, so that it was clear that a nuptial flight had emerged. The following morning I found that the ground was strewn with thousands of their dead bodies, all of which seemed to be males. Such is the flickering life of the sexual male; just a few hours of sunlight or perhaps a single night; just a sufficient time to perform the sexual function for which sole duty alone it lives.

The workers bestow much care and attention on the sexual members of the community. One evening after heavy rain the males and females of the species *Camponotus dolendus* had collected, preparatory to flight, in a swarm on the ground close to the gate of the nest. The workers, chiefly those of the large, strong soldier type, formed a ring of defence around them like a bodyguard of infantry drawn up in battle-order to repel an attack. I disturbed one of the workers, and soon the whole community was thrown into alarm. From the intensity of their excitement it was clear that the soldiers recognized the sanctity of their charge. The males and females, being the peaceful and inoffensive members of the family, hurried away into the security of the nest; but the more stalwart workers, in their position as protectors, scattered savagely in all directions to seek out and come to battle with the foe.

After this alarm had passed, the sexual forms again emerged and wandered away into a tuft of grass a few feet from the nest. As nightfall approached, the workers became restless. It was the hour when the ants ought to have been retiring to rest, yet all the winged forms on which they bestow so much attention lay scattered about in the grass. It was obvious that the sexual forms had no intention of returning home before dark. And this is in itself interesting, for the workers in their daily labour retire each evening to the nest; but the males and females, not taking part in the routine of work, felt no instinctive impulse urging them to retire. When darkness fell they were helpless. They had never been in the habit of returning to the nest before dark; they were therefore quite unable to do so now, and were prepared to remain outside for the night.

But their protectors would have none of this. Though in the sexual forms instinct failed, the workers would meet the needs of the case. They were determined not to leave their precious care exposed, and they soon solved the problem. They formed a line between the tuft of grass and the nest; workers hurried out; each seized a prospective parent in its mandibles, clutching it by the back of the neck, and carried it off to the nest. It was the males alone that required transport. For the females example was enough; they seemed to possess a stronger instinct of self-protection, for they found their own way back to the nest. The males received very bad usage during the process, yet they calmly resigned themselves to their fate. The workers either dragged them roughly by the neck over the stones, or pushed them forward with such vehemence against sticks and slates and tufts of grass that it seemed as though their heads would be severed from their bodies. But they made no resistance. They folded their wings against their sides, curled up their slender legs, passively surrendered their lives to the care of their sterile sisters, and submitted to the hardships of the journey until they were lodged safely in the nest. Thus do the workers guard and cherish the sexual forms on whom the future life of the race depends.

How variable are the habits and instincts of ants, even among members of the same nest. I have endeavoured to tell something of them as seen in the common species of this valley. But it matters not how their labour varies, we always see the same underlying principle of the subordination of each one to the well-being of all. The individual is nothing; the community is supreme. The single ant is lost when separated from the formicary. So organized is the social structure, so dependent is each ant on its fellows, that when it finds itself alone it is helpless. It cannot even live unless it again joins the throng. Its brain, though infinitely complex, exists not for the single ant, but as an integral part of the whole communal mind. Each individual is as a single cell of which the commune is the developed being; each brain is a single atom submerged in the restless spirit of the swarm.

CHAPTER VI

GEOMETRICAL SPIDERS

Home of spider—Species under discussion—Constitution of colonies—Construction of snare—Emission and structure of the first line—Mechanism in construction of radii—Mechanism in hub—Mechanism in temporary spiral—Mechanism in viscid spiral.

THE most ancient beds of the earth's crust involved in the upheaval of the Himalaya mountains are thick masses of primary slates into which the molten granite has intruded. They rise in Hazara into rounded hills with smooth summits and sides crumbling to decay. Little verdure clothes them. A few pines may cluster on their peaks, or thorny bushes collect in their more sheltered glens. Their flanks are hidden in a coarse mountain grass, brown and parched in the dry sultry months of summer, but changing into a pleasant green after every fall of rain. The moisture that freshens their surface likewise hews them to their present shapes. Streams eat into their fissile sides and erode valleys between their rounded backs. Softer and harder strata meet the waters as they cut deeper into the rock, and each changes the nature of their flow. As the consistency of each bed alters or obstructs it, the stream stagnates into a sluggish pool or splashes onward in rivulets and cascades.

These streams are the home of the geometrical spiders. Over the running water, more often over the transparent pools, these skilful architects extend their fragile snares. Suspended on either side from a tuft of grass, a thorny bush or a bare slab of shale, the fine silken webs span tight across the stream. The site is a perfect one for the *Epeira*, for here flies and other tiny insects abound which, as they hover over the water, fall entangled in the well-laid snares.

Two species of the *Epeiridæ* haunt these streams. They belong to distinct genera and differ greatly in appearance. The more common of the two is *Araneus nauticus*, a brown globular little spider from a quarter to half an inch in length. Its narrow flat head sunk low between its limbs is scarcely visible. But on the upper surface can be seen the six black shining eyes, and projecting in front are a pair of sharp-pointed ponderous jaws. Behind the head is the inconspicuous thorax clothed in thick greyish hairs, with the limbs, banded in black and yellow, spreading out on either side. Overhanging the thorax and forming the larger portion of the spider, is the massive heart-shaped abdomen. A thin coat of hair covers the abdomen, while its upper surface is marked with a yellowish cross. The other spider is a species of the *Tetragnatha*, not so common as the *Araneus*, but possessed of very similar habits. It is strikingly different in appearance, with a narrow elongated body, and a small head supporting its massive jaws. A line of minute teeth strengthen the jaws on the inner side, while their distal ends are armed with a long pointed fang. Its legs are unusually long and slender, so that the spider seems ungainly in its motions. It has the peculiar habit of extending its legs backwards and forwards, pressing them close together so as to bring them in line with its body.

Though foreign to the usual habits of spiders, these two species live together in perfect harmony. Most spiders prefer a solitary existence, desiring no companions, devouring every intruder or driving it savagely away. Yet these spiders often follow a gregarious life, interweaving their snares into one wide common sheet. It is not unusual to find half a dozen of these snares all connected by their foundation-lines, and even those of the two species sometimes intermingle. I once found a collection of twenty-one snares all communicating one with the other, and both *Araneus* and *Tetragnatha* were represented in the colony, and they all lived together in complete harmony. Spiders in other countries sometimes unite into similar communes. Darwin tells us that in South America a species of *Epeira* congregates in small colonies so as to encompass large bushes with their united nets. He remarks on the singular fact that this gregarious habit should exist in such bloodthirsty and solitary creatures. Peace exists in these colonies over the streams. The spider from one snare seldom invades that of its neighbour ; should it by mistake cross the frontier, it is immediately made aware of its error and ordered to be off. For the spider in the invaded snare throws the whole structure into a state of rapid vibration, and the intruder, feeling this, instantly turns about and returns to its own territory.

From year to year the numbers of these spiders vary. A dry summer results in a scarcity of insects, and this is a direct cause of the rarity of the spiders. A wet season supplies an abundance of snares. And not only are the spiders affected through the medium of the insects, but so also are the insects that prey on insects. In a dry season there is a marked diminution in the dragon-flies and the robber-flies that hunt insects on the wing. Similarly will the insectivorous birds be reduced in numbers, and each species will affect each other species in the complex web of life.

The mode of construction of the snare is similar in these two species of *Epeira;* yet it is obvious that *Araneus* has a decided preference for suspending its web in the vertical and *Tetragnatha* in the horizontal plane. This wonderful architecture has often been described, yet I here take the liberty of again displaying the method of work in order that the subsequent experiments that I made on the snare may be found the more intelligible.

I isolate an *Araneus* on the tip of a blade of grass standing in a shallow pool. The spider is cut adrift from land; it is marooned and cannot escape. I sit down to see how it will act. The hour of work is at hand, so the spider soon sets about the construction of a snare. A series of successive stages now follows, each stage a definite step in the architecture, a preparation for the succeeding stage. The first essential are some foundation-lines to serve as a framework for the snare. The spider begins. It climbs to the tip of the blade of grass; it elevates its abdomen and from its spinnerets emits a silken filament to the wind. The light filament is wafted to the shore, becomes entangled in another blade of grass, and the first foundation-line is in place. Backwards and forwards runs the spider along its line, adding each time a new filament, doubling, trebling, quadrupling the line until it is strong and sound. The first foundation-line is secure. For the second foundation-line the spider adopts a different procedure. It takes its stand about midway on the first line and suddenly drops down suspended on a filament of silk. Perhaps it finds an attachment. If not, it climbs up again and drops down from another point. At length it meets a blade of grass and anchors its second line. It has now two lines with three attachments to stalks of grass, one at each end of the first line and one at the lower end of the second line. By joining these points together with a filament of silk a triangle is formed of three foundation-lines, the simplest form of framework to support a geometrical snare. The spider reinforces these lines with additional filaments until it is satisfied with the strength of the scaffold. This is the first and elemental stage; the construction of the foundation-lines.

I now come to the second step in the architecture. A triangular framework is in position; or, if suitable connections can be found, a trapezoid figure is more to the spider's choice. Whatever its shape, the spider next proceeds to construct the radii. These are the spokes of a wheel that diverge from a common centre to end at the foundation-lines. The spider constructs them with little trouble. It first runs a line from side to side across the framework. Then, selecting a point on that line which will be the future centre of the snare, it carries a number of lines from that central point to the circumference of the snare. In this way it completes a series of radii, each equidistant from its adjoining radius. Each radius is in accurate position; all diverge equally from the common point. The second stage is mathematically complete.

Now comes the third stage, the construction of a hub. The snare in its present state resembles a wheel. It has a centre, radiating spokes and a rim formed of its foundation-lines. The spokes need some strengthening at the point where they leave the centre; the wheel requires a hub. This the spider proceeds to make. It winds five turns of a slender filament around and close to the central point attaching the filament to every spoke. A hub is thus added to the wheel; the spokes are bound together at their inner ends and the third stage is complete.

The fourth step in the work is the formation of a temporary spiral. This adds a further strength to the snare, holding the radii still more firmly in place. The spider takes four turns round the hub, stepping from radius to radius and attaching the filament every time it passes a spoke. A spiral of four turns, like the hair-spring of a watch, is thus wound about the centre. All the turns are parallel, all accurately placed. The work is perfect and precise. This is the fourth stage in the architecture, the construction of the temporary spiral.

The spider now reaches the fifth and most important step in its work, the formation of the viscid spiral. It proceeds to the outer margin of its snare close to where a radius joins a foundation-line. It now commences to wind another and much longer spiral round and round the snare, commencing at the circumference, working towards the centre and attaching the spiral at every spoke. To pass from radius to radius it uses the temporary spiral as a bridge. Now this viscid spiral is the vital element in the snare. It is continuous in closely parallel lines from the circumference to the very centre, It is covered with a highly viscid fluid, while all the other lines, the radii, the hub, the temporary spiral are non-adherent to the touch. It is that part of the fabric that has the power of capture. The formation of the viscid spiral is a laborious task; it occupies the spider more time than all the rest of the snare. It is a fine and subtle filament, often continuous from end to end. Every line is parallel, and the whole is a wonderful work of

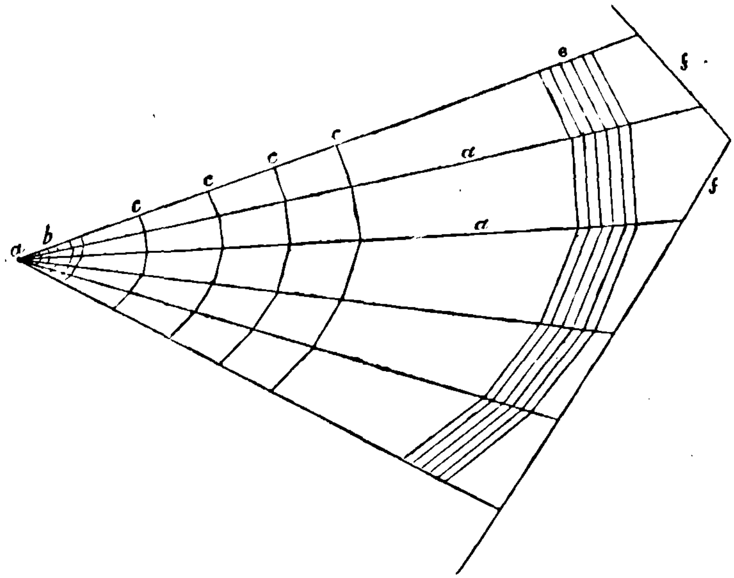


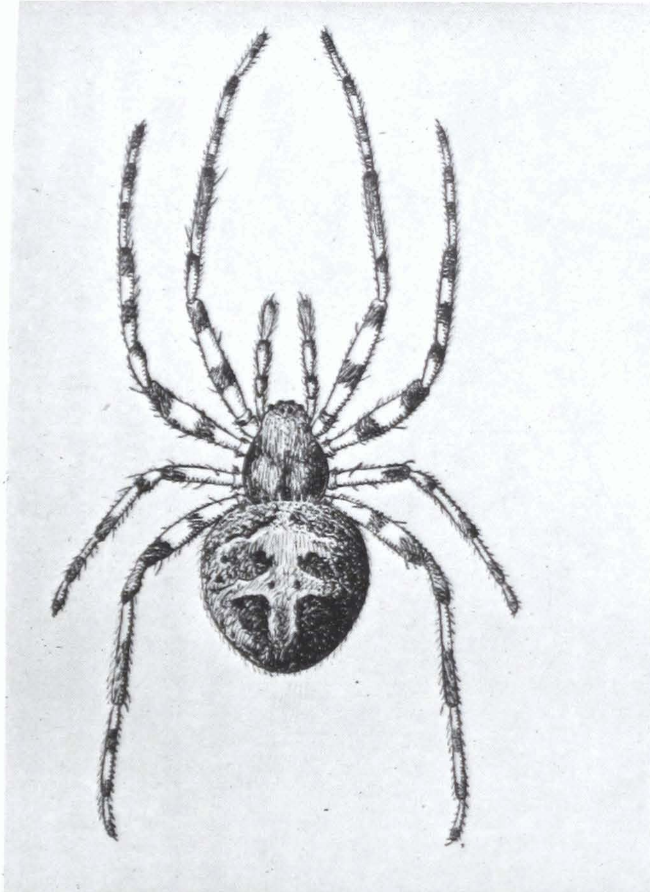
FIG. 2.—Diagram of the parts of a Geometrical Snare.

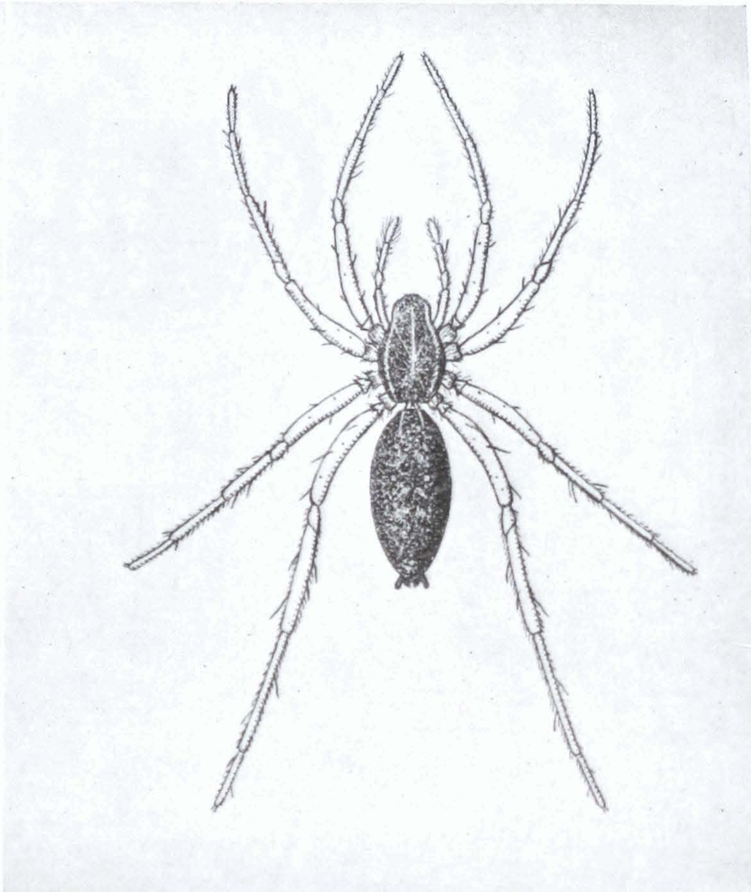
(*a*) Centre.
(*b*) Hub.
(*c*) Temporary spiral.
(*d*) Radius.
(*e*) Viscid spiral.
(*f*) Foundation line.

mathematical beauty and perfection. The spider at length completes its viscid spiral. It anchors the end close to the centre and the snare is finished.

Such is the construction of the geometrical snare, a work of the most marvellous texture. There are five successive stages in its architecture (see Fig. 2).

1. The foundation-lines.
2. The radii.
3. The hub.





SPIDERS OF HAZARA.

The Geometrical Spider
(*Araneus nauticus*)
Magnified four times.

The Sheet-building Spider.
(*Hippasa olivaceæ*)
Magnified four times.

[*Face p.* 88.]

4. The temporary spiral.
5. The viscid spiral.

I have some remarks to make on each step in this work. It is a fabric worthy of our note. The strength of its transparent filaments, the geometrical accuracy of its lines, the subtlety of its device and the unerring certainty of its power cannot but excite our wonder and admiration. To produce such a consummate work needs the skill of a master-hand moved by a geometrical sway. I will endeavour to disclose the nature of this handiwork, to show how all this accuracy is attained. I hope to demonstrate how the spider works; how it measures its equal angles; draws its perfect parallels; secures its equidistant lines; how it achieves all this mathematical accuracy which, woven into its architecture, makes for the beauty, the perfection and the certainty of its snare.

First with respect to the construction of the foundation-lines, the fact of most interest is the ingenious manner in which the spider pays out its filament to the wind. The spider does not act altogether haphazard, allowing the filament to trail away from the spinnerets in search of a chance attachment. It shows some method even in this simple act. It supports the thread with the claws of its second tarsus and tests its every quiver and motion. With the filament curved over the tip of its tarsus, it is really fishing for an attachment, using the most delicate of lines and the most sensitive of fingers. But the filament itself is more worthy of notice. It is specially adapted to its peculiar purpose. Not only is it light and slender, fit to be supported on a gentle breeze, but the spider has in addition given it a special construction by which its buoyancy is still more improved.

In the *Araneus* it is difficult to detect this special peculiarity of the first line. Little more can be seen than the silken thread extending outward from the spinnerets. But there is a large and handsome genus of the geometrical spider known as *Argyope*, about an inch in length, in which more detail can be seen. If we have the chance to watch an *Argyope* in the act of emitting the first filament of its snare, we will see that the tip of the line that it gives to the wind is not a single filament but a complex structure. It is divided into a sheaf of the very finest fibrils, each inconceivably light and delicate. These float freely in the air and serve to support the more compact and single thread that follows them from the spinnerets. Thus the first filament of the snare is a highly specialized thread, a long single line ending in a free cluster of the finest, almost invisible fibrils; a structure beautifully adapted to sail on the wings of the faintest breeze. Even the emission of the first line is worthy of our note. It illustrates the ingenuity of the spider's methods by employing the wind to support its lines, and the exquisite adaptability of its filaments to the varied stages of its work.

I come now to the method by which the spider constructs its radii; a mode of workmanship that has always filled me with wonder at the geometrical powers of this simple creature. It is clear from the beginning that the radii are laid down in no definite order, but in a haphazard manner. Nevertheless they are all equidistant; all diverge from the common centre with the same perfect symmetry as the spokes diverge from the hub of a wheel. We ask ourselves, how is this symmetry attained? By what mechanism does the spider measure with such accuracy the same distance between each pair of radii? Let us watch the spider at work. It has completed the foundation-lines, and is now throwing out its radii. Backwards and forwards from the centre to the circumference we see it hasten. Out along one spoke, back along another spoke, and on each return journey a new radius is secure. For a moment it halts at the centre. Something engages its attention here. It busies itself about the hub. It rotates from side to side. It is examining the radii all round the snare, satisfying itself that in one part they are complete, that in another part they have not yet been spun. We watch with care this examination of the radii. We see that the spider with the tips of its fore legs is feeling and testing the radii just at the point where they leave the hub. We see a pair of legs expand like a mathematical dividers; the tip of one leg rests on one radius, the tip of the other leg on the adjoining radius; and it is clear that the spider is measuring the inter-radial distance by using its legs as a pair of dividers while it remains seated at the hub. The limbs are kept at an even distance and the spider stretches forward to feel all round the snare. Should it feel a radius with the tip of each limb, then it knows that the radii are complete in that segment and are at the correct interval. It then turns to another part of the snare and again feels for the radii. It has now to expand its legs more widely to feel two adjoining radii, and it therefore knows that here the radii are incomplete. Legs expanded the normal width mean radii accurately placed; legs too widely expanded mean that a radius or more is absent. Thus the first step in the adjustment of the radii takes place at the centre of the snare. It is here that the spider learns in what part of the snare the radii are complete, in what parts more are to be laid down. It is by this mechanism that the spider rests finally satisfied that every radius is in place.

So much for the process by which the spider locates those parts of the snare not yet supplied with radii. I pass now to a second mechanism, that by which the spider measures the correct distance between the radii. This takes place not at the centre but at the circumference of the snare. It follows in this way. The spider at the centre has discovered an interval not yet supplied with a radius. Its legs, acting as a pair of dividers, have expanded two radial-widths. It therefore knows that a spoke is here absent and it must needs supply it. Out along the nearest radius it hastens, paying out its filament of silk. It reaches the circumference where the radius joins the frame. Now occurs the interesting part of the mechanism. The spider takes four paces along the foundation-line, then halts, draws tight its filament, secures it to the frame, and a new radius is in place. It is the four paces along the foundation-line that makes the measurement exact. In this the spider never errs. Every radius is secured to the frame four paces from an adjoining radius, thus all the radii are equidistant and perfect symmetry is attained.

It may seem degrading to the exquisite workmanship of the spider to reduce its methods to mathematical terms. To my mind the work appears more wonderful by knowing something of the manner of that work. The spider is not degraded because at the centre it can measure equal angles, at the circumference equal arcs. Would not man act similarly under like conditions? Would it not be a simple method of drawing equidistant radii from the centre of a circle to take equidistant points upon the circumference and then join them to the centre? Would it not be a simple method to measure the angles at the centre to see that no radius had been left out? The spider has adopted human methods; it works on geometrical lines. Its limbs are its dividers and its measuring rule. By their aid the snare assumes those accurate proportions that we never cease to admire. Man can do but little better were he faced with the construction of a similar snare. Each would work on similar principles, the one knowingly, the other instinctively. The spider, like man, is a geometer. Assuredly by being so it is not degraded. Rather must we not wonder at similar methods existing in the highest and the humblest creatures so far distant in the tree of life.

Before leaving the radii I must mention a little detail with regard to their structure, since it is a special adjustment designed to give them additional strength. Each radius is so constructed as to consist of a double line. The method of duplication takes place in this way. The spider during its examination at the hub discovers an interval where no radius has yet been laid down. It immediately hurries out along one of the radii that bounds this interval and of course pays out its filament of silk behind it. It reaches the circumference, takes its four paces along the foundation-line, halts and anchors its filament. In this way a radius of one strand is secured. But this is not sufficient for the spider. The line must be of double strength. The spider sets about it in this way. It climbs back again to the centre of the snare, but this time it makes its journey along the new radius that it has just laid down. It pays out its filament of silk behind it. It reaches the centre, draws tight, anchors and secures its line. In this way the radius is duplicated, and this gives additional strength to the essential framework of the snare.

I pass to the next stage of the architecture. The radii are complete. In the snare I have just examined they are twenty-four in number. The spider now commences the next feature of its work. It winds five turns of a slender filament around and close to the centre, anchoring it at every spoke. Thus it constructs its hub. It does not always complete its radii before commencing the hub. It may lay down a few radii, then take a turn on the hub, then again resume the radii. No doubt the hub helps to secure the radii. But its construction has a greater value; for, as the spider circles five times round the centre testing each radius in succession at every circle, it satisfies itself repeatedly that all its radii are in place. It examines with its dividers the position of each pair of radii, and if they are not in accurate position it proceeds to remedy the defect.

An experiment will make this clear. A snare is under construction. All the radii are in place. The spider is engaged in the winding of its hub. I divide one radius. The spider circles round and reaches the gap made by the lost radius. It is obvious that it is feeling with its leg for the radius, but finds nothing in its place. It recognizes the loss, ceases its work on the hub, runs out a new radius and again resumes the spinning of the hub. The experiment is repeated and more radii are divided. But the spider replaces the lost lines so long as it is engaged on the hub. It is thus clear that the time of hub-formation is the time for testing a previous stage in the construction; the time to examine if every radius is secure.

This process of testing the radii is one of great importance, for the absence of a radius means a loss of symmetry in the web. Thus the spider is most diligent in this stage of its duty. I will mention an experiment to indicate its persistence in this important task.

A snare of twenty-four radii was being reconstructed. The old snare had been battered to fragments; and the spider, having cleared the remnants, was building a new structure in its place. It was laying out its radii. Now as fast as the spider secured a radius, I severed one that it had previously laid down. As the spider worked on one side, I divided on the other side. My destruction kept pace with its construction of the radii. The spider continually found the gap that I had made, a vacant interval where there should have been a radius. But it was equal to the emergency. It ran out a new radius. As fast as the spider discovered the injury it remedied the defect. In all I divided a radius twenty-five times and the spider constructed new ones in their place. Sometimes the same radius was severed three or four times, and each time the structure was replaced. After the twenty-five divisions the spider refused to construct any more radii. The snare had eighteen in position, and the spider, satisfied with this, passed on to the next stage of its work. Such is the persistence of the spider in the application of its radii. In this snare that should have contained twenty-four radii, the spider constructed eighteen together with the twenty-five that I had severed. In all it laid down forty-three instead of the normal twenty-four. From this experiment we rest satisfied as to the mechanism by which the spider tests its radii, and we see the clear determination of the little architect to make every radius secure.

Such are the geometrical means by which the spider constructs its radii. I pass now to consider if similar methods are employed in the other features of its work. The radii and hub are complete and the next step in the architecture is the construction of the temporary spiral. This binds the radii together. It is the scaffolding of the snare.

We again watch the workmanship. We again discover the method of measurement; the mathematical instinct on which the accuracy of the work depends. Round goes the spider from radius to radius constructing the first turn of its temporary spiral. Watch it carefully at one radius. Its fore limb is applied to the hub; its spinnerets touch the radius and a definite length is measured off along the radius; the length being the distance from the tip of the fore leg to the spinnerets. Where the spinnerets meet the radius a line is secured. The spider passes on to the next radius. The same process occurs. The same length is measured off on this radius. The fore limb again finds the hub, the spinnerets again touch the radius a similar distance away. The line is drawn tight between the radii and secured. So continues the spider on to the next radius and completely round the snare. At every radius the same distance is measured; the distance being the full expanse of the spider's body from the tip of its fore leg on the hub to the spinnerets applied to the radius.

The first turn is complete. The spider passes on to the second turn. The same mechanism follows. But the spider measures its distance not from the hub but from the first turn. And as the second turn is measured from the first turn, so also is the third turn measured from the second turn, and the same mechanism continues round the snare until all the turns are complete.

Again we find that the method of construction is a simple geometrical act. The spider is faced with a definite problem and must solve it on mathematical lines. Each turn in the spiral must be parallel, and only by accurate measurement can this parallelism be secured. The spider by its wonderful instinct can meet the problem. It has many organs of measurement at its command. In fashioning its temporary spiral it employs the simplest of all—the measurement of its own length.

The temporary spiral is complete. A solid framework is in position to receive the viscid spiral, the deadly element of the snare. No part of the fabric is more beautiful than this, nor displays its mathematical perfection to so remarkable a degree. The question is, how is all this accuracy attained; how does the spider measure with such precision this most wonderful portion of its architecture?

Again we watch the spider at work. It has sealed the end of its temporary spiral and immediately starts at the first turn of its viscid spiral. Out along a radius it travels with agile movements and unerring skill. It takes three hurried paces, halts, applies its spinnerets to the radius and secures a line. The first turn of the viscid spiral has commenced. Back along a radius it hastens and across the last turn of the temporary spiral that now serves it as a bridge. It reaches the next radius and hurries out along it. We watch carefully, for this is the important point. It moves out along this radius for exactly three paces. It halts, applies its spinnerets, draws tight and secures the line. Back again along the radius, over the next bridge, out along the next radius for three paces, and it again secures the line. And so on for every radius till the first turn of the viscid spiral is complete. Every attachment in this turn is fixed to every radius exactly three paces distant from the last turn of the temporary spiral.

Again do we find that accuracy of measurement is the clue to the spider's work. As the turns of the temporary spiral are measured, each one from the preceding turn, so is the first turn of the viscid spiral measured from the last turn of the temporary spiral. Similar is the principle but different is the method. The interval between each turn of the temporary spiral is short; it can be measured by the body-length. The viscid spiral is laid down at a greater distance; it must be measured by the number of paces, an equal number at every spoke. Thus does the geometrical spider measure and calculate each step in its architecture. How human-like are these simple acts, all the more wonderful because they are simple. For as the spider paces the distance through its snare, so does man often, in his daily life, pace his distance over the ground.

The first turn of the viscid spiral being complete, I come now to the construction of the succeeding turns of that spiral, the perfect parallelism of which makes for the beauty and subtlety of the snare. How is this parallelism secured? How is each filament in the spiral adjusted by the spider at an equal distance from each adjoining filament? We have seen that the second, third, fourth and succeeding turns of the temporary spiral are measured off each from the preceding turn. We have also seen that the first turn of the viscid spiral is measured off from the last turn of the temporary spiral. In fact the distance of each turn is estimated from the turn immediately internal to it. I therefore first thought that the spider in some way measured all the turns of its viscid spiral from the bridge formed by the temporary spiral. I was unable to understand how it could effect this, until at last a simple experiment convinced me that I was mistaken; that the temporary spiral was not the guide to measurement, but that the architect worked on some different plan.

I found a spider spinning. The viscid spiral was being laid down. Between every attachment the spider had to cross over its bridge formed by the temporary spiral. With a sharp pair of scissors I divided the bridge in one segment. The spider took no notice and circled on. In every other segment it pursued its normal course, crossing over the customary bridge. But in the experimental segment the bridge was gone and the spider had to continue inwards until it reached the next turn of the temporary spiral before it could cross over. This did not alter the accuracy of the spider's work. Without any hesitation it made use of the inner bridge, and I was surprised to see that this did not in any way interfere with the parallelism of the viscid spiral which it was laying down. If, as I imagined, the spider measured each turn of the viscid spiral from the last turn of the temporary spiral, then in that segment where the turn was divided the parallelism should have been lost, for the point of measurement was gone. But this was not the case. The threads were as parallel in the experimental segment as in any other segment. We must look to some other mode of measurement to explain the secret of the work.

It is clear that the measurement is not made from within. Perhaps it is made from without. The spider may measure the turn of its viscid spiral from the turn that lies just external to it and which was laid down in its last circuit. We watch the operation with the greatest care. Out along the radius moves the spider until it reaches the point where it will attach its thread. A peculiar motion now occurs and this is the secret of its work. The attachment is not yet made. The whole body of the spider first undergoes a partial rotation; the fore limb is extended forward; the sensitive tip gently touches the filament of the viscid spiral laid down in the previous circuit, and, when this is done, the spinnerets are applied to the radius and the attachment is made. What is the spider doing? Surely it is using its fore limb to measure the correct distance from the previous turn of the spiral at which to make its new attachment.

Just as a human being, when drawing one line parallel to another line, uses the position of the first line to judge with his eye the accuracy of the second line, so does the spider in weaving the beautiful parallel texture of its snare use the position of one turn of its spiral from which to measure with its fore leg the accurate position of the next turn.

Observation of the spider at its work makes us almost confident of the truth of this. But its movements are so agile; the turn of its body, the gentle touch with the fore leg, the rapid application of the spinnerets, follow one another so quickly that it is difficult to be certain of the sequence of events. If the fore leg is indeed the vital organ in the operation, the measuring rule by which one line is laid parallel to the preceding line, then a few careful experiments should confirm the truth of the belief.

If the spider places one turn in position by estimating the distance from the preceding turn, then if I divide the preceding turn, the spider will have lost its point of measurement and parallelism will be destroyed. I choose one segment for the experiment when the spider is working at its viscid spiral. It has just crossed the segment, leaving a filament in its train. I divide the filament. The spider circles on, laying down the spiral to perfection until it again reaches the experimental segment. Arriving at this segment, what happens? The spider as usual stretches forth its leg to feel for the line laid down in its last circle. But the line is gone. The spider finds nothing there. It stretches still further forward and feels the next line, the one laid down in its second last circle. This line it takes to be the true line. From it the measurement is made, and the filament anchored in the wrong place. The diagram (Fig. 3) illustrates what has occurred. Turn first to diagram *a*. Let *w*, *x*, *y*, *z* be four adjoining segments. Let *x* be the experimental segment, and let three turns, 1, 2, 3, of the viscid spiral be complete. I divide the innermost turn in segment *x*. Now turn to diagram *b*. The spider circles on laying down the fourth turn of its spiral all round the snare. At length it reaches the radius

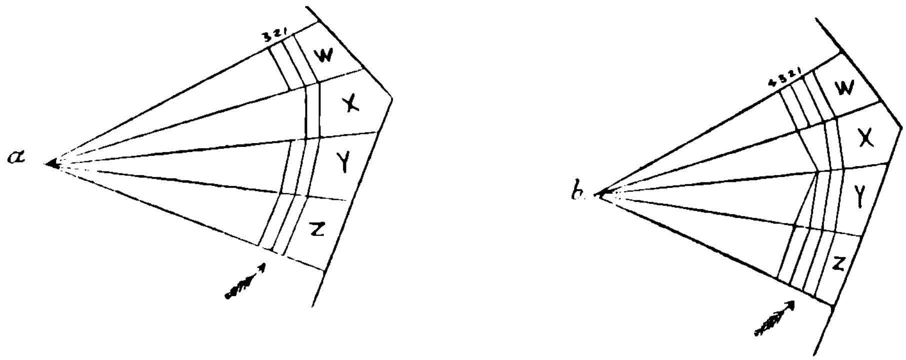


FIG. 3.—Loss of parallelism resulting from division of one turn of viscid spiral in one segment.

(*a*) Viscid spiral divided in segment X.
(*b*) Result of spider's work. Loss of parallelism in both X and Y.

Arrow marks the direction of spider's circle.

between *z* and *y*. Here all is well. It feels in its measurement the turn it has last laid down and the fourth line is parallel across segment *z*. It passes on to the radius between *x* and *y*. It reaches forward to feel line 3. But line 3 is gone, so it must touch line 2. Its measurement is incorrect. The attachment is made in the wrong place, farther out on the radius, and the line drawn across segment *y* is out of parallel. The spider passes on. It reaches the radius between *w* and *x*. Stretching forward, it touches the correct line. It anchors its filament in the right place. But the other end of that filament has found a wrong attachment, therefore the line across segment x is also out of parallel. To sum up, the result of the experiment is this. One turn of the viscid spiral is divided in one segment. Parallelism is lost in both that and the preceding segment. In the one the lines diverge, in the other they converge. The essential fact is that, the point of measurement being removed, then the parallelism is lost.

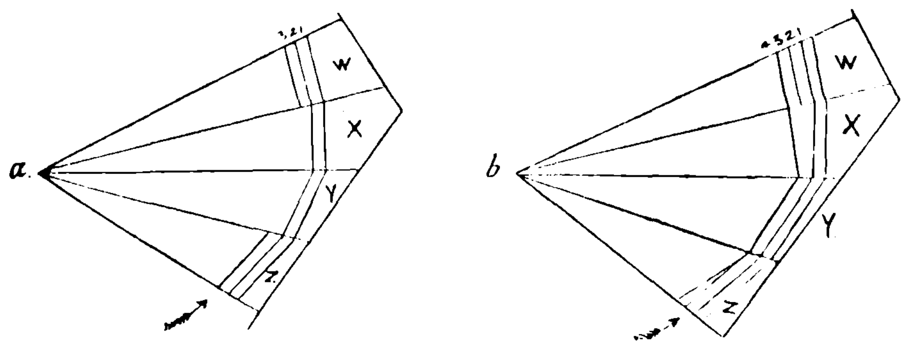


FIG. 4.—Loss of parallelism resulting from division of one turn of viscid spiral in two segments.

(*a*) Viscid spiral divided in segments X and Y.
(*b*) Result of spider's work. Loss of parallelism in both X and Z.

Arrow marks the direction of spider's circle.

I perform a similar experiment, but divide the spiral in two adjoining segments (Fig. 4, *a* and *b*). I will not labour over the details, as these the diagram should explain. Again a similar sequence follows. The spider measures from the wrong lines; the attachments are made in the wrong place, and the perfect parallelism is lost.

Difficulties may prevent the success of these experiments. For when I divide a filament, little tags of the spiral are left attached to the radii. Now the spider in reaching forward to find its point of measurement may touch one of these little tags and, believing it to be the spiral, may anchor its new filament correctly. Moreover, the experiment seldom succeeds when the spider is working at the inner and smaller turns of the spiral. This, I think, is due to the fact that here the spider can move directly across from radius to radius without deviating its course, or can stretch directly to its point of attachment from its bridge on the temporary spiral, so that the previous turn of the viscid spiral is here much less important as a means of measurement than in the earlier and more external part of its construction.

But these difficulties avoided, we reach a clear conclusion. Each turn in the viscid spiral is the essential guide to the accuracy of the next turn. For if the one be divided then the next is incorrect. And from the way the spider feels with its leg at each attachment, there is strong reason to think that the fore leg is the organ on which the accuracy depends. These experiments strengthened my belief that the fore leg was the instrument employed by the spider to draw line parallel to line.

But a third experiment overcame all doubts. I found a snare in which the spider had completed the outermost turn of the viscid spiral. With a fine pair of scissors I succeeded in cutting off the tips of the spider's two fore legs. By this operation I had removed what I believed to be the sensitive organs of measurement, and I was eager to detect whether the spider could continue the construction of the snare after so serious a mutilation, and, above all, if it could still ensure the parallelism of its lines. Immediately after I had nipped off the tip of the limbs, the spider hurried away along the foundation-lines to a place of shelter outside the snare. After a lapse of fifteen minutes the spider again returned, remained motionless for about two minutes at the centre of the snare, and then moved out along a radius to continue the work of construction. It was distinctly evident that the movements of the spider were greatly hampered by the mutilation. It advanced slowly, deliberately and more laboriously than before. There was a complete absence of all skill and agility in its motion. It approached the point where the work had been interrupted and again took up the thread of its labour. Away it started on its spiral round, struggling with difficulty from radius to radius and trying in vain to attach a spiral at equidistant radial points. There was no mistaking the fact that the spider was at a great disadvantage after the loss of its organs of measurement, and that it was quite unable to ensure the parallelism of its lines. It attempted to use its amputated stump, waving it helplessly in the air, but its efforts were in vain. Yet the spider was more adaptable than I thought. Finding itself unable to measure after the loss of its fore limbs, it began now to try and estimate the distance by the use of its hind limbs. In this way a limited degree of compensation took place. It made some attempt at measurement, but with indifferent success. Yet the spider circled on. Laboriously it plodded round and round the snare, continually measuring its distance incorrectly and making the adhesions in the wrong place. Three times it neglected to insert a whole spiral; again and again it made attachment to the spiral instead of to the radius, and sometimes it passed by a radius without making any attachment at all. Yet the spider toiled deliberately on. Smaller and smaller grew the spiral, stranger and stranger grew the irregularities of its structure, yet the spider, in spite of all its difficulties and mutilations, brought the snare to a completion. But it was of a remarkable workmanship. No one who has contemplated the mathematical accuracy of a circular snare could have looked with indifference on its tangled texture. Its radial and parallel beauty was lost; threads in confusion adhered to one another; triangles, quadrilaterals of every shape replaced the perfect symmetry of its parallelograms; spirals crossed other spirals; broad and narrow spaces lay indifferently between the turns; radii were drawn out of shape or were left without attachment; the web was not a visible harmony but a strange intermingling of confusion and disorder.

No experiment convinced me so strongly that the fore limbs were the all-important organs of measurement to ensure the perfect symmetry of the snare.

Such are the geometrical powers of the *Epeira*; wonderful in their origin, simple in their execution, accurate in their result. Measurement and precision are the secrets of the work. On the possession of these powers, and the instinct to employ them, depend the perfection and beauty of the snare. On its body it carries its organs of measurement—the number of its paces, the length of its body, the divergence of its limbs; the very same organs that, in his rough measurements, primitive man might use. Employing those organs with mathematical precision, it weaves that silken texture, every line in harmony making the whole so exquisite in our eyes. Yet underlying the complex structure is a pure and simple mechanism conducted on rigid lines. Let us not think less of the beauty of the architecture because it is built on the strictest measurements, nor less of our wonder at the architect because it is governed by unswerving laws.

CHAPTER VII

FURTHER OBSERVATIONS ON THE GEOMETRICAL SNARE

Ultimate fate of temporary spiral—Reversal of spiral—Reason of reversal of spiral—Example of plasticity of instinct—Spider's power to estimate tension—Delicacy of sense of touch—Industry of *Araneus*—Mode of emission of filament—Economy of spider and destruction of snare—Perfection and imperfection in snare.

In the previous chapter I have endeavoured to make clear the mathematical powers by which I believe the spider works, and I now pass to consider some other features of interest in the geometry of the circular snare.

I must first mention one incident in the workmanship of the spider, since it serves to illustrate how a certain step in the architecture can serve merely as a temporary support until the next step is complete. I refer to the ultimate disappearance of the temporary spiral. If the viscid spiral was brought to a completion while the temporary spiral still remained in place, then the final workmanship would consist of a mixture of two spirals, one of viscid and the other of non-viscid lines. But so clumsy an architecture will not suit the spider. It works on a more perfect plan. Its edifice must contain only a single spiral composed solely of viscid lines. How does it effect this? We watch the spider at its work. In the snare under observation the temporary spiral is complete, and we notice that the spider has just sufficient room to fit in four turns of the viscid spiral between the circumference of the snare and the outer turn of the temporary spiral. What I wish to make clear is this: that after the spider commences on its viscid spiral it will have sufficient space to complete the first four turns, but that the fifth turn will happen to meet the outer turn of the temporary spiral and the two will become intermingled. We watch to see what the spider will do. It completes the first three turns in the ordinary way, of course using the outer turn of the temporary spiral as the bridge to pass across from radius to radius. It comes to the fourth turn. It has sufficient room to insert this. It is the next turn that will coincide with the temporary spiral. What does the spider do? It rises to the emergency. It behaves as though it foresaw its difficulties. It sets about destroying its bridges so as to allow a free space for the fifth turn of its viscid spiral. Each time it completes the fourth turn of the viscid spiral in any segment it at the same moment severs the bridge in that segment. It first crosses the bridge, then divides the line behind it. And this process of division continues until the outer turn of the temporary spiral has been severed all round the snare. The fifth turn of the viscid spiral can then be freely laid down. A similar destruction follows in the case of the inner turns of the temporary spiral. As soon as the spider finds that the next turn of its viscid spiral will get entangled with its bridge it adopts the ingenious method of simply dividing the bridge. Each turn is severed as soon as the viscid spiral reaches it.

Thus does the temporary spiral disappear. It has served its purpose and has served it well. It has served as a measuring line from which to adjust the outermost turn of the viscid spiral, it has bound the radii together until the viscid spiral was in place, it has served as a succession of many bridges to convey the spider from radius to radius. All these functions are now complete; they take no part in the ensnaring of the prey. The temporary spiral is therefore of no further use; its presence any longer would

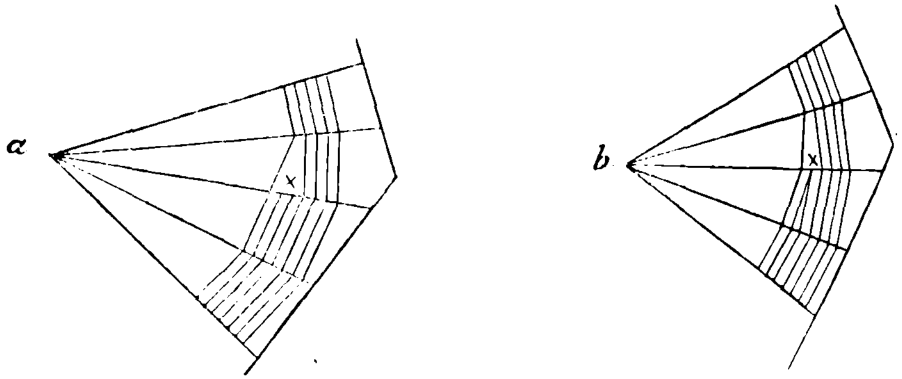


FIG. 5.—Diagram of reversal of spiral.

(*a*) One method.
(*b*) Another method.

The spider has reversed at the point X.

lead to loss of symmetry and to imperfection; it is therefore destroyed and disappears.

I come now to consider another feature in the architecture of the snare. If an *Araneus* be carefully watched while constructing its viscid spiral, it will be noticed that from time to time the spider stops, turns about and commences to circle again round the snare in the opposite direction. It rarely completes its spiral from the first to the last turn by always circling in the same direction. It is working to the right. It suddenly halts, seals off the end of its spiral, turns about, commences a new spiral and starts off on a fresh circle to the left. I shall speak of this change in the mode of operation as "the reversal of the spiral." A reference to Fig. 5 will show two modifications of the way in which this reversal is made.

For a long time I was at a loss to understand why the spider should suddenly, and without apparent cause, interrupt its instinctive circle and start a reverse

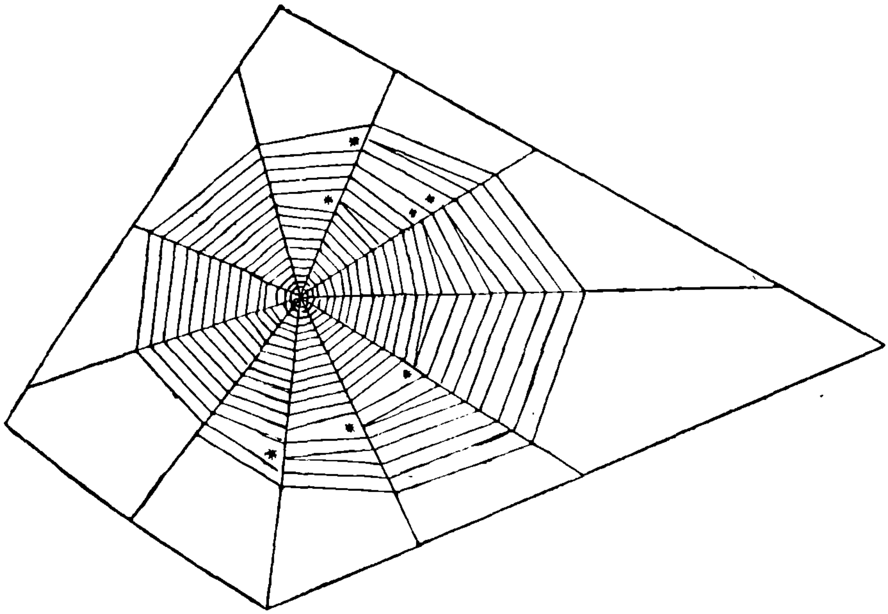


FIG. 6.—Reversal of spiral in an eccentric snare.
Points of reversal marked with an asterisk.
Twelve turns on narrow side, twenty turns on broad side of centre.

spiral in the opposite direction round the snare. It always occurred so unexpectedly and seemed such a very unessential act. It was so complete a change in the undeviating course of instinct, and instinct moves by inexorable laws.

I noted, however, after examining a number of snares, that what I have called the centre was seldom a true mathematical centre. The radii varied in length, and the centre from where they all diverged was frequently very eccentric. Thus the spider, when constructing an eccentric snare, would have to separate the various turns of the viscid spiral more widely on the broad side of the centre and approximate them on the narrow side, or else would have to insert more turns on the former than on the latter side if it wished to produce a harmonious fabric. Now every time the spider turned in its course it inserted, as is clear from the diagram (Fig. 6), an additional filament on that side of the centre, which addition was absent from the opposite side. Can it be that, in order to ensure harmony in its snare, the spider reverses on the broad side and continues an uninterrupted course in its work on the narrow side? Certainly this method would produce symmetry, and in all probability would be a more simple operation for the spider than the attempt to draw parallel lines at different distances, wide apart on the broad side and closer together on the narrow side of the centre.

I discovered a very eccentric snare with the radii just completed. I followed the spider at its work on the viscid spiral. I carefully noted the number of reverses and whether they occurred on the broad or narrow side of the centre. The spider circled round and round the snare and made exactly thirty complete turns from its commencement to its completion. But in addition to the complete turns, the spider reversed fourteen times, and every single one of those reverses added an additional filament to the broad side of the centre and not one to the narrow side. The turns of the spiral on the broad side were not more widely separated than those on the narrow side, but their number was much greater. After the completion of the snare there were forty-four turns on the broad side and only thirty on the narrow side. It was evident that the cause of the reversal of the spiral was the eccentricity of the snare, and that it was the means adopted by the spider to perform the difficult operation of winding spirals round an eccentric point with the least possible loss of parallelism and symmetry.

This reversal of the spiral is to my mind an excellent example of the plasticity of instinct. No two snares can be exactly alike; some are more, others are less eccentric. All must vary somewhat in their construction. In some the number of reversals are few, in others many, possibly in others there may be none required. In some the reversed spiral may be so short as to connect but two radii, in others it may connect ten. In every snare the reverses must vary in number, in order and in length. What a wonderful flexibility of instinct must a spider possess to adapt its work to such changing circumstances and construct in the end a perfect architecture. Every snare the spider weaves must differ in some way from its predecessor and must demand some modification in the plastic instinct which may never before have been called into action. It would not be surprising to see every snare varying in length or breadth or even in the number of the turns of the spiral, for such variations are those of the ordinary course of nature and directed to no vital end. But it is wonderful to think that this variation in the reversal of the spiral is so necessary, so intricate, so universal, and is directed to the ultimate purpose of mathematical perfection in the complexity of the snare. It is indeed strange to witness the mechanical motion of the spider round and round the web and to ponder over the heedless instinct that compels the same eternal round. But still more strange would be the picture of the snare if instinct was so blind as to allow of no reversal and to compel the spider in the same headlong course. The whole fabric would be unsymmetrical, all its perfect beauty would be lost. The astonishment is not in seeing the monotonous routine of instinct, but rather in seeing that instinct so plastic as to enable the spider to achieve this perfect symmetry no matter how great is the eccentricity of its snare.

Is it possible to gain any clue as to what guides the spider in the performance of this essential act? How does the spider know when to reverse and when to pursue an unbroken course? I cannot with complete confidence explain this, but I strongly suspect that it is guided by its fine sense of touch and the power to estimate the tension of its lines. I have observed that a small species of *Epeira*, which constructs its snare in the coniferous forests, seems distinctly to possess the power of discriminating between any alterations of tension that may exist at different parts of the snare. This spider weaves its web at the point of radiation of three foundation-lines. If one of these foundation-lines be gently stretched away from the snare, the spider, while resting at the centre, will immediately recognize the change in tension that has occurred. It will form a correct impression of the direction of the abnormal strain, and will advance to investigate the cause of the disturbance. I am satisfied that the *Epeira* can discriminate between different states of tension, and we should remember how acute is the delicate sense of touch. Watch a spider seated at the centre of its snare. Its sensitive limbs diverge so as to rest on radii coming from all parts of the circumference. It can in this way detect vibrations in all directions, as it is in tactile communication with every area of the snare. It is interesting to see the spider testing the radii at every thrill and feeling their tension when it is doubtful of its capture.

I have thought that the stimulus to produce that wonderful accuracy in the reversal of the spiral might be the differences in tension along the unequal radii of the eccentric snare. For since a spider is able to estimate changes in tension, it is probable that it could also differentiate between the long and short radii of an eccentric snare, which would certainly, if they were wires or strings, give to the human fingers very perceptible differences in sensation. By the difference in tension the spider should discriminate between a radius on the broad side and a radius on the narrow side of the centre. At the moment of attachment of the spiral to a radius the spider probably estimates the length of free radius between the point of attachment and the centre of the snare; and in an eccentric snare all these lengths will vary. The sensation produced by contact with long radii would be of a different nature to that produced by the short radii, and the spider may react to the former stimulus by a reverse. The outer portions of the radii, to which the previous turns of the spiral have already been attached, would not be considered by the spider, as that portion would be damped by the turns of the spiral in the same way as the finger damps off a segment of a violin string.

Thus a spider, during the construction of a circular eccentric snare, may, by its exquisite sense of touch, differentiate between the long and the short radii. It may continue to reverse its spiral so as to attach additional turns to the long radii until sufficient reverses have been made to give the free parts of all the radii an equal length and convey a uniform stimulus to the sense of touch. This speculation is to a great extent surmise. It is supported by the fact that the reversals are more numerous during the earlier turns of the spiral when the inequality of the radii would be more easily felt. In the latter half of the construction the number of the reversals is few or there may be none at all. And this I think is due to the fact that the radii are then less unequal owing to the many reversals already made.

And if this view be true, then how delicate must be the sense of a spider's touch. It must be developed to so high a degree of perfection that the mathematical accuracy of the work will very largely depend on the delicacy of the tactile power to estimate the changes of tension in the lines of different length that radiate from the centre of an eccentric snare.

A geometrical spider engaged in architecture pursues its work with a restless energy. The bees, when seeking nectar from the flowers; the ants, when storing up provision in their nest, are no more tireless in their toil. It moves with hurried pace along every spoke; it measures its lines with almost imperceptible touch; it seals its filament in an instant and then hastens away. All its movements are so agile that at the moment it can have but one object in view, the speedy completion of its snare.

I made some attempt to investigate the industry of the architect; to estimate the amount of work performed and the time taken to complete it. Spanning a deep reflecting pool I found the fragments of a snare. Only the external frame, composed of strong foundation-lines, remained. The more fragile texture in the centre had vanished. It was evening. Soon the *Epeira* would descend to its ruin, for the time of work was drawing near. I thought I would wait for the reconstruction to commence and attempt to estimate the length of line emitted and the distance travelled by the spider during the complete construction of its snare. I waded out into the pool, found the diameter of the framework to measure twenty-two inches, and awaited the commencement of the work.

As the sun sank low in the sky, the *Epeira* felt the call to work. It moved out along the foundation-lines, first to explore the framework, then to extend the radii through the snare. I followed all the movements of the spider from its first attachment to the completion of the web, but I did not take the foundation-lines into my reckoning, as these were a permanent structure laid down many days before. With the exception of these main foundation-lines, I estimated that, from the commencement to the completion of the snare, the spider emitted 122 feet of filament, made 699 attachments and travelled over a distance of 178 feet. Yet the whole was woven into a circular web 22 inches in diameter and occupied the spider only 36 minutes. This seemed to me an excellent instance of untiring industry as displayed by the more humble of organic beings.

It has been a subject of discussion how the silken filament escapes from the spider's spinnerets. Is it drawn out by external traction or is it emitted by the muscular effort of the spider? I am inclined to believe that the spider has no power to shoot forth its own fragile thread. If we look to that large spider, the *Argyope*, we see that the viscid spiral escapes from the spinnerets only with great difficulty. The *Argyope* certainly cannot shoot forth its viscid spiral. A definite traction is necessary to withdraw it. For once this spider arrives at the construction of its viscid spiral, its movements become more laboured; it cannot circle with the rapidity of other geometrical spiders. At each attachment of the viscid spiral it has to grasp the adhesive filament with its tarsus, slowly draw the sticky line from its own spinnerets, sometimes transfer it to the opposite tarsus to gain an additional purchase, and not until it has with no little labour pulled from its own abdomen a sufficient length of line is it able to attach the spiral.

Like the *Argyope*, so I think are the rest of the *Epeiridæ*, unable by their own internal force to thrust out their silken lines. The thread must feel a gentle strain before it can be drawn from the spinning-wheel. I do not know of any time during the emission of the silk when this strain is not clearly present. As the spider circles from spoke to spoke it strains on its last attachment; as it suddenly drops suspended on a filament the strain becomes its own weight; as it gives its first line to the breeze the strain is on the tuft of finest fibrils that catch the moving air; and in the beautiful *Argyope* the strain is often the traction exerted on the line by the spider's own legs. During the emission of the line, therefore, there is always some tension produced by an external strain. Never does a flaccid filament hang loosely from the spinnerets. May not the tension which is ever present be present of necessity?

I have dwelt so long on the method of construction that I will say but little on the destruction of the snare. Yet nothing in the architecture of the spider so surprised me as the manner in which it disappears.

I first observed the process in a true home of the *Epeiridæ*. Where the water falls down over a ledge of rock and splashes in a transparent pool the spiders love to construct their snares. Amidst the noise of the falling waters the smaller flies revel in the cascade. Above the pool they hover and dash at intervals amongst the dancing drops that leap from the quivering pool high into the air. It is strange that they should choose the commotion of the waters. It may be for pure pleasure that they dart through the glittering drops and flash over the tiny foam. Where the flies hover, there the spider will weave its snare. At the very edge of the fall the slender lines extend, and look as though they would be torn to pieces in the spray. But the silken threads are strong, and, as the sparkling drops ascend, each line in the slender fabric is spangled with a row of pearls.

I often visited this pool at sunset to watch the colony at work. The snares were then renewed. After twenty-four hours only the tattered fragments remain; a new snare was spun every evening. One evening on coming to the pool, I happened to look on a tattered snare with the spider resting at the centre. The snare must have done duty for twenty-four hours; it was very much broken, and attached to its meshes were hundreds of tiny insects too minute to attract the attention of the spider at the time of their entanglement. As I contemplated the ruin of the snare, the spider slowly emerged from its position at the centre. It advanced along one of the radii, and it was immediately evident that it was breaking up the snare in its progress. Closer observation revealed the extraordinary fact that it was actually eating up its own snare. As it proceeded outwards the spider swallowed the radius, the lines of the viscid spiral, all the little tags of broken filaments and the innumerable tiny insects that lay entangled in its course. On reaching the outer extremity of the radius, the spider returned to the centre and rested there for about five minutes. It then commenced to destroy and devour a second radius with its viscid attachments and again rested at the centre. This continued until all the radii, the whole of the spiral and the hundreds of little insects had all been devoured. After the destruction of each radius the spider always rested at the centre for some five minutes, presumably for the purpose of emptying its stomach so as to fit it for receiving the next radius. The spider did not devour the foundation-lines of the snare, as it intended to use them for the main framework of the new snare. However, it carefully examined these lines and removed from them any loose filaments or minute insects that happened to remain attached.

What wonderful economy is this to allow nothing to disappear! If in a snare I divide a number of filaments, the spider will often come out and swallow eagerly the little tags of silk wherever it finds them. But in this final act how much more strict is the economy displayed! The construction of the snare expends the spider's substance; but all that remains, the tattered lines, the tiny insects, again return to the architect; even the foundation-lines are searched that nothing goes waste.

I was at first very much surprised to think that a spider's stomach could be so capacious as to contain the complete snare. In this, however, I was much mistaken; for I found that a large, complete snare, eleven inches in diameter, was of such delicate substance and compressible into so small a bulk that when rolled into a ball between the fingers, it formed a compact mass but little larger than an ordinary pin-head. A spider will often swallow entire a fly of much greater dimensions than its own compact snare.

I look on the circular snare of the *Epeira* as almost as beautiful an example of mathematical accuracy in the life of organic beings as the exquisite structure of the honeycomb. But how much more wonderful does it all seem when we picture the web as a potential fabric, first woven into an inimitable harmony to lure to death thousands of living creatures, then, tattered and torn in the tragedy, to be again received into the maw of its voracious host, to be repurified in the strange economy of a spider's structure, to emerge again from the spinning-wheel in fine transparent filaments, to be woven again into the same lovely texture, and to repeat day after day the same eternal drama that fills the mind with such enthusiasm and admiration.

Throughout this chapter I have spoken repeatedly of the perfection of the snare. And this is true in a general sense. But a close observation of nature shows us that in the organic world there is nothing really perfect. Even in the structure of the human eye there is error upon error. So it is with the snare. Exquisite as is its workmanship, it is not in the strictest sense geometrically exact. Careful observation will detect numerous imperfections. The centre is often not a true centre, the radii diverge from an eccentric point; the radii, first thought to be of equal length, are found to be unequal; the angles, though approximating closely, all slightly differ; lines, though in apparent parallel, would many of them soon meet. The vision of the whole is one of delicate perfection; the inspection of the detail reveals minute imperfections. But surely this does not diminish our wonder at the workmanship. It is enlightening to see the apparently accurate built up of countless error. And the errors are trivial. Each, no doubt, has some reason for its existence; though each to our eyes appears a fault, yet they all blend in harmony. So it is all through organic life. Everywhere in nature, both in instinct and in structure, we witness imperfection and error. Even that most wonderful and economical of instincts, the cell-building of the honey-bee, is far from really perfect. I doubt if in the whole world of nature there exists a faultless instinct or a perfect structure. But few structures can better claim perfection than this delicate circular snare.

Such is the construction, such the destruction of a spider's geometrical snare. This is the architecture of the *Araneus*, though I do not speak for the rest of the *Epeiridæ*. Strict and unswerving mechanism is the secret of the work, not only of its accuracy but of its beauty. The power to measure is the guiding instinct that underlies the mechanical routine. The spider is to my mind the more wonderful because it is mechanical, because it works on the strictest plan. With instincts so perfect it fashions its lovely fabric. I know not which to admire in it the more, the geometrical instinct that builds it up, or the economy that tears it down.

CHAPTER VIII

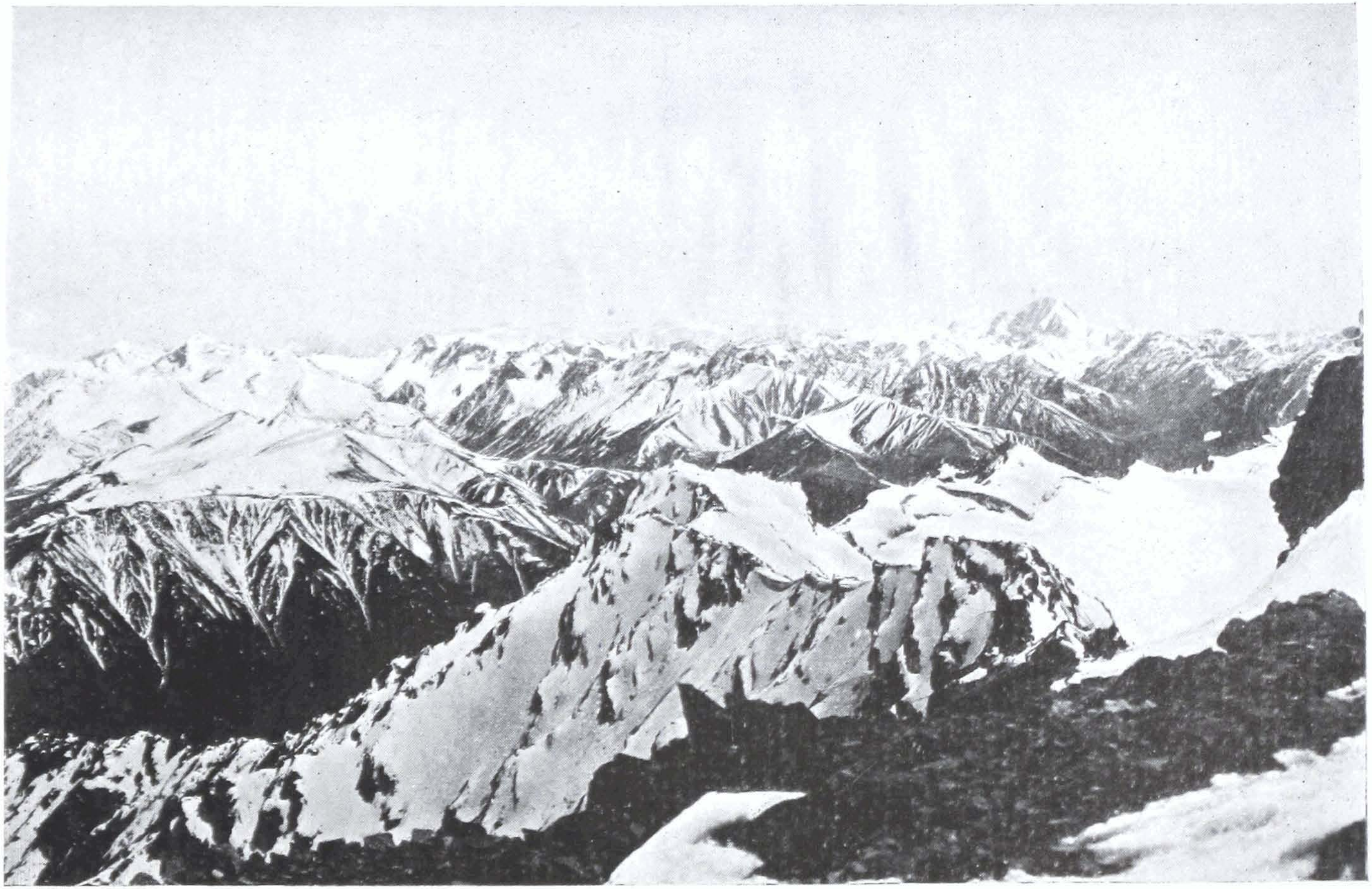
THE INSTINCT OF SPIDERS

Spiders and weather—Force of instinct—Repair of web—Experiments to indicate the unswerving force of instinct—Slavery to instinct—Transference to other snares—Spider not entangled in its own snare—Mode of escape—Protective resemblance—Special senses of spiders.

THE days are dark and dull. Heavy threatening clouds rest on the encircling hills. A black mass of nimbus hangs over half the sky, enshrouding the mountains at its base, and high in the zenith breaking into grey ragged fragments that seem to tell of the fury behind. Low peals of thunder issue forth and lightning flickers through the gloom. The sun is setting, and its rays streaming across the sky penetrate the dark cloud. A bow of intense brilliancy appears through the threatening vapour with every hue defined. Without is a second and fainter arch reflecting in inverse order the clearer colours of the brighter bow. Above they fade into the lowering sky; beneath they shine firm against the higher hills that glow with a dull purple.

There is little need to visit the spiders on such an evening as this. Few will be at work. For the *Araneus* understands the signs of the weather. It will not spin when rain threatens. It knows that the falling drops would annihilate its work.

To find the *Araneus* in full vigour we choose a dry



THE HEART OF THE HIMALAYA.

[Face p. 124.]

September evening as the sun sinks in a clear and settled sky. A few snow-white flocculi of cloud rest lightly on the wooded hills; a gentle haze of dust dims the further peaks, and all the valleys are refulgent with the evening light. When the sun dips behind the enclosing ridge the spiders are most busy at their work. They toil while the hills and clouds change their hue beneath the fast declining light. The green woods turn to a dull purple, the white clouds pass into a faint pink or, tinged with yellow, they assume a golden hue.

On such an evening each spider is busy; all are weaving with a subtle skill. Filaments of inimitable texture are being wafted over the rippling stream; ingenious nets are being spun amidst permanent foundation-lines, and snare is being linked to snare. The intricate sheet of web soon spans the channel in the hill. There is no strife; all work in perfect harmony. By sunset the fabric is woven. Each little architect takes its station at the centre of its web and there awaits the entanglement of its prey. Not till another sunset will work again commence. In the meantime insects innumerable will be captured; the juice will be sucked from their bodies, and the spider will feed in peace and plenty.

I have dwelt so long on the mechanism of construction, that I will now say something of the motive instinct on which all this work depends. At first sight the work of the spider looks like the act of an intelligent being. How exquisite is all its harmony! The precision of science here blends with the beauty of art. Untiring industry, exact method, faultless accuracy, inimitable skill raise this edifice of mathematical beauty. It might be a work of profound wisdom; the product of a calculating mind measuring angles, estimating areas, tracing with skill the geometrical curve, examining tensions, appreciating minute imperfections, halting, reversing, circling backward as perfection may require. Is this premeditated design? Are spirals, parallels, angles, areas, clearly depicted in this creature's mind to make her so cunning and so exact an architect? Does she fashion the beautiful because she loves beauty, the accurate because she loves precision? I cannot think so. I believe the spider lives in total ignorance. She knows naught of her wondrous work. Its beauty and precision are both lost on her. Why or how it is made she cares not. She is as oblivious of her spiral filament as is an ammonite of its spiral shell. What in our ignorance we call instinct, impels her to her task. She must work; she knows not why, she knows not how. The delicacy of her silken threads, the perfection of her workmanship, gratify other minds than hers. Certain acts on the part of the spider will help us to appreciate this.

First of all, can the spider repair its web? If so, then it can claim the gift of intelligence. For to repair an injury the spider must appreciate the nature of the damage, and direct its action to a definite premeditated end. One evening I deliberately injure a snare. I excise a portion of three adjoining radii with six turns of the viscid spiral. The sides of the rent are drawn apart by the elasticity of the web, and a hole remains through which three or four fingers can be passed. The spider, after a momentary alarm, takes no further notice. It patiently awaits its prey.

No attempt at repair is made this evening. I visit the snare the following morning. The spider is still at the centre; a number of insects are strung along the filaments, but the rent still remains. Indeed it is enlarged, for the snare is here weakened and gives way further before the strain. The fact remains that there is no attempt to repair the damage. This a spider cannot do. It cannot seek out the ends of its severed radii and connect them with new filaments; it cannot pick up the points of its damaged spiral and join them with new lines. I do not believe it can even contemplate, far less appreciate, the nature of the ruin. Such an act as this is outside its daily work. It can build up and it can tear down, but to repair a broken filament is beyond its feeble mind.

Once the work of construction is over the sole duty of the spider is to sit at the centre of its snare and await the entanglement of insects. Injury to the architecture is then of no concern to the spider. When evening approaches the fabric will be renewed. The instinct to reconstruct will then impel the architect to work; but till that hour arrives it feels no impulse but to sit and wait.

Let us consider the spider engaged in the construction of its snare. Is it then in the same subjection to its instincts as when it sits patiently waiting for its food? It is fulfilling a complex and difficult duty. It is performing each act with mathematical precision. It is building up a fragile and harmonious texture, and every thread must be in place or the final symmetry will be lost. Through all this delicate workmanship is the spider an intelligent agent or only an unconscious tool? Has it any power to modify the nature or perfection of its fabric, or is it but a slave to an instinctive guide? Can it see anything of the final beauty, or is it ignorant of all its work?

Experiment will show. If I alter a snare so as to place difficulties before the spider, can the spider appreciate what has occurred and, by some simple device, remedy the defect? I find a web partially constructed which the spider is busy bringing to a state of completion. The temporary spiral has been laid down and seven turns of the viscid spiral. The completion of the latter is the earnest duty of the spider. It is moving from spoke to spoke, using the outer turn of the temporary spiral as a bridge by which to cross over. With a sharp pair of scissors I gently divide the bridge between two of the spokes. The spider circles on. It comes round again and meets the broken bridge. It shows some hesitation but does not interrupt its work; it continues inward till it meets the second turn of the temporary spiral and there crosses over. I have destroyed the spider's bridge. It has to pursue a longer journey at each circuit. It is obvious by its hesitation that it feels something to be at fault. The remedy is clear; another filament should be run across and a new bridge formed. It is the simple work of a moment, but the spider will not do it. It prefers to continue its longer round and cross by the inner bridge. I now divide the second turn of the temporary spiral in the same segment. The spider again takes no notice, but crosses over by the third turn. I divide the third turn and the spider crosses by the fourth. I divide the fourth turn and the spider has now to continue to the very centre of the snare before it can cross over. It has to perform fully three times as long a journey and pay out three times as much line to complete the spiral in this segment than in any other segment, yet the spider works mechanically on. The journey, the labour, the confusion of the spider have all been increased. A single filament for a bridge and the work might continue as before, but the spider cannot see this. It made many bridges a few minutes before; it cannot make a single bridge now. The reason is clear; the time for bridge-making was before the commencement of the viscid spiral. In this snare seven turns of the viscid spiral are complete, and therefore the spider cannot build a bridge now.

I continue the experiment. In one segment there are no bridges and the spider must continue to the centre of the snare in order to cross over. I now cut carefully across the centre, so that the spider in order to complete the segment will have to pass the centre and cross over by the temporary spiral of the opposite side. Even this does not move the spider to repair. It continues to perform its long journey over the damaged web, cross at every circle to the bridge on the opposite side in order to complete the spiral in that segment. The snare has by now lost almost all trace of its beautiful regularity; the spokes which bound the divided threads have separated to a hand's breadth, while those on either side have approximated to the width of a finger; that perfect parallelism in the spiral coils is lost; threads adhere to one another; in the narrowed segments they hang down slack; in the wide segments they are tense to breaking point; the radial symmetry has become shapeless; the snare is held in an uneven strain and it no longer has a centre. Yet the spider works mechanically on. How blind is this instinct that impels the spider in this course! A single bridge would improve matters; it could not remedy them now, for the damage is too great. But it is all the same to the spider. To construct a bridge now is far beyond its mental power; it can only circle mechanically on. I was amazed to think that a creature could be compelled by such a blind unswerving instinct to circle round and round the formless web, and driven by so unalterable a mental stimulus to weave such a shapeless and imperfect structure.

I modified the experiment in different ways. I divided the outer bridges in two adjoining segments, but the spider crossed over by the second line of bridges. I divided all the outer bridges in all the segments, and the spider crossed by the second circle of bridges. I have no doubt that if I had removed the second circle, then the spider would have used the third circle; or if I had removed the third circle, then it would have used the fourth circle; but what it never would have done was to construct a new bridge.

But one experiment will include all. I found a snare with twenty-one radii and a temporary spiral of six turns. The spider had commenced the viscid spiral and five turns were complete. I removed the whole of the temporary spiral in every segment. That is, I divided 126 possible bridges, so that the spider had now no bridge left in any segment. It must either build new bridges or continue right into the centre at every passage from radius to radius. It must either go back on its work or face tremendous obstacles. What will the spider do now? Its difficulties are acute. All its bridges are gone. The radii are slack from the loss of the scaffold; they now wave and tremble in the air. If the spider can appreciate anything of the precision of its work, it must do something now.

At first it is alarmed and hurries away to the edge of its snare. I can divide two, three or four turns while the spider continues in its course, but I cannot remove the whole spiral. In twenty minutes the spider returns. It again takes up its work, the continuation of the viscid spiral. It meets with immediate trouble. It can find no bridge; it moves with difficulty along the slackened radii; its confusion is clear. But it makes no attempt to remedy the damage, no effort to lay a new bridge. Into the centre it travels at every segment except where the slack radii fall close together, when it can step across from radius to radius. Great disorder follows in its architecture. The loose radii confuse its sense of tension; the little tags of filament perplex it and it anchors its line in the wrong place. All its attachments are out of order; radii are glued to radii; parallelism is completely lost. Construction continues, but the snare rapidly develops into a hopeless tangle. Yet the spider is satisfied. It still makes no effort to place new bridges between its radii. It cannot go back on its old work; it is bound to its routine. A few turns of a temporary spiral would solve its difficulties, but this the spider is quite unable to effect. It would mean the commencement of the routine at some other point, while there is only one point at which the spider can commence, and that is the point at which the routine was broken. Still the spider labours on. Its difficulties overcome it.

Hesitating and perplexed, it works backwards and forwards from the centre to the circumference in the struggle to lay down its viscid spiral. The slack radii make it continually reverse where there should be no reverse. Aimlessly it gropes with its fore leg, seeking for the spiral to guide its measurements. It either touches nothing or, if it finds a filament, an attachment follows, usually in the wrong place. The difficulties of the spider increase at every turn, and greater confusion follows in its architecture. But it persists in its one duty, the only duty it can then perform, the construction of its viscid spiral. At length it ceases; its duty done. Satisfied that all is well, it seats itself at the centre of the snare surrounded by the hopeless tangle of its lines.

How blind is the instinct that impels a spider in this fruitless course! All the snare needs is a few bridges to stiffen the radii and allow the spider to pass over. But the spider neither sees it nor knows it. It understands nothing of its architecture. Each step must follow the preceding step. Each act has its determined sequence. The spider works unknowingly, driven by the clear, cold logic of events. At the obedience of an unswerving force it struggles in its unconscious duty. Its instinct tells it that when at work on its viscid spiral it must continue till its viscid spiral is complete. This instinct the spider implicitly obeys, though it leads it to confusion.

I will mention a few more experiments to indicate the blind instinct by which the spider is controlled. I found a snare of *Araneus nauticus* in which six turns of the viscid spiral were complete. The spider was busy continuing the work. It was monotonously circling round the snare, crossing from radius to radius and attaching the viscid spiral to each radius in its passage. I divided one radius immediately after the spider had attached to it the spiral. The spider circled on. It again came round to the severed radius. The radius being gone, the spider found before it a segment twice the normal width. It had to cross over two bridges instead of one, extend a line twice the previous length, as it had now to span two segments with the one line. Nevertheless, the spider did not seem confused. It made no attempt to replace the radius, but kept straight on. I then divided a second and adjoining radius so that the spider had to perform three times the journey and bridge a gap three times as wide as was required in the uninjured segments, yet the spider worked on. I divided a third and adjoining radius, subsequently a fourth, but still the spider continued its monotonous circuit. It made no attempt at any repair, but kept blindly to its routine. On severing a fifth radius, the bridge in the temporary spiral over which the spider crossed had not only become six times the normal length, but also so loose and slack that the spider found some difficulty in passing over it. The spider clearly felt something was wrong; it checked its course round and round the snare; it hesitated, ran backwards along the lengthened bridge searching vainly with its legs for the broken radii. A few new spokes would solve its difficulties, nothing else was required, yet the spider could not do it. It made no attempt at any repair, but again continued the circuit. I divided a sixth radius. The bridge was now very slack and the spider very discomfited during the crossing. It was most amusing to see the little creature sweeping its leg through the air seeking for the lost radii. Nevertheless, it still circled on. A seventh radius was divided, so that now almost half the radii in the snare had been severed, and all were adjoining radii. The bridge was now eight times the normal length, and the space across which the viscid thread had to be drawn was eight times the normal width. Nevertheless, the spider struggled on in the same mechanical routine until the division of the seventh radius made its difficulties acute. The bridge was now so slack that the spider could scarcely cross it, and I could almost have put my fist into the vacant space in the snare. The bridge was almost impassable, yet the spider persisted in its blind circuit, adhering rigidly to its routine.

Instinct is the guiding factor of a spider's life ; it is instinct that compels it in the same undeviating course. Introduce difficulties in its circuit, raise increasing barriers to oppose the instinctive progress, build up obstructions to impede the blind routine, and the spider can do nothing to overcome them ; it can only struggle in its course. It can appreciate none of these difficulties ; it can understand none of these obstacles ; all it can do is but circle on.

Another experiment leads us to a similar result, that the spider knows nothing of its work. A snare of the *Araneus* was under construction. Four turns of the viscid spiral were complete. In one segment between two radii I divided the spiral as fast as it was laid down. Thus, with the exception of the four turns that existed before I commenced the experiment, no other filaments were allowed to remain in that segment. The spider circled round and round weaving with accuracy its viscid spiral. Beautiful parallel lines were stretched across every segment except the experimental segment. In this segment was a vacant space, for I there divided the line as fast as the spider laid it. But the spider could not appreciate this, though every time it crossed the segment it found that its measuring line was lost. It worked unheeded. Twenty-eight times it drew a line across the experimental segment and twenty-eight times I severed it. The spider could not recognize that, although it was bridging this segment again and again, yet it was constructing no network. It circled on, ever diminishing the circumference of its spiral as it drew nearer to the centre. Finally it sealed off the end of the spiral and ran away to the centre to wait for entangled insects. The spider was satisfied. Without doubt it believed that it had constructed a perfect snare and was quite oblivious of the fact that one whole segment was almost entirely absent.

That the spider is a slave to its own instinct, that it is able to recommence its work only at the point where the instinctive round is broken, can be still further exemplified. I discovered a snare with the spider busy at its work. Ten turns of the viscid spiral were complete. I divided all the turns of the viscid spiral right round the snare so that only the hub, the radii and the temporary spiral remained attached to the foundation-lines. My interference disturbed the spider and it hurried away to the edge of the snare. I wished to know what it would do on its return. It would find a snare with a hub, radii and temporary spiral, but with no viscid spiral. What will it do? Will it commence to lay down a spiral from the beginning, or will it take up its work where it left off, that is at the eleventh turn? The spider recovered from its alarm and resumed its work. Without hesitation it proceeded to where it had left off. It neglected to replace all the ten turns that I had divided. It commenced its work at the eleventh turn, and thus constructed little more than half a snare. It seemed quite contented with the structure, and I have no doubt would have considered it as excellent a snare as it had ever formed.

That the spider cannot go back on its work still another experiment will show. A snare has just been completed. The viscid spiral has been sealed off and the spider has taken its post at the centre to lie in wait for insects. I divide the whole of the spiral in every segment. The snare now consists of a centre, radii and foundation-lines, but it no longer has a spiral. The force of instinct had just been fulfilled, and I wondered if the spider could start again on its routine and build up a new snare. The spider was unequal to the task. The reflex round was over, and not for twenty-four hours would the spider move to work again. It took up its post amidst the bare diverging radii. I do not believe it even had the power to appreciate that any damage had been done. Till dark I watched it solemnly waiting for insects that were never captured, for the snare no longer had a network.

Fulfil the predestined plan is the doctrine of a spider's life. Not one can look back upon its woven chain nor retrace the slender links of architecture. The work is done; it cannot be done again. The snare has vanished; the naked spokes remain. But to the spider's mind the net is perfect, and relentless instinct is fully satisfied. It cannot for an instant contemplate its handiwork and witness the utter ruin. Reconstruction now is impossible. Another day must pass before the instinctive fire rekindles and the spider feels the call to work.

I recalled in these connections the ingenious and oft-described experiment of P. Huber. He discovered a caterpillar which made "by a succession of processes a very complicated hammock for its metamorphosis; and he found that if he took a caterpillar which had completed its hammock up to, say, the sixth stage of construction, and put it into a hammock completed up only to the third stage, the caterpillar did not seem puzzled, but repeated the fourth, fifth and sixth stages of construction. If, however, a caterpillar was taken out of a hammock made up, for instance, to the third stage, and put into one finished to the ninth stage, so that much of its work was done for it, far from feeling the benefit of this, it was much embarrassed, and even forced to go over the already finished work, starting from the third stage which it had left off before it could complete its hammock." The rhythm of the caterpillar's instinct was so mechanical; the creature was in such abject slavery to its routine, that once the rhythm was broken it could only recommence at the point where the break took place, even though it might greatly benefit by commencing somewhere else.

It is very similar in the case of the rhythm of a spider's instinct. The spider in the snare of ten turns is unable, after all the turns are destroyed, to commence in any other place than at the eleventh turn; the spider in the snare without any temporary spiral continues to struggle on with its work, but is unable to reconstruct a bridge ; and the spider that has come to the end of its instinctive round by the completion of its viscid spiral is unable to commence again. Thus the spider is, like Huber's caterpillar, a slave to its own instinct. In a beautiful mechanical rhythm it toils onward in its daily task ; but break that rhythm and the whole chain of action is disturbed, and the only place at which the spider can again take up the thread of its motion is the place at which the rhythm was broken. As in a machine each movement follows another movement in an unalterable sequence, so do the far more complex motions of a spider's life follow one on the other in a long ceaseless rhythm.

If we learn anything from these experiments, it is how feeble are the mental powers of the *Araneus.* He who studies for the first time the subtle device of a circular snare is full of wonder at the skill of the contrivance. He who watches for the first time the work of construction is amazed at the ingenuity of the architect. But this is a false impression. There is no skill, no ingenuity in the sense that man would use it. There is little credit to the spider ; at least to the workings of its mind. It is ignorant of all it does. It can neither reflect on its past nor take thought for its future. It must act at any moment in accordance as its instinct tells it. It must fulfil each step in its architecture independent of any choice. It knows not why or how it does it, nor can it do aught else. It cannot go back one inch in its construction. The spider is an automaton. It learns little if anything from experience ; all its knowledge is innate. A definite sequence of events must follow and the spider must obey each step in the sequence. To ponder over those events or to alter a single link in the long chain of action is far beyond the simple mind of the *Araneus*.

I pass now to another question. How will geometrical spiders behave when their snares are interchanged? The snare of an *Araneus* is made with such precision; each line is so accurately measured by some portion of the spider's body that I fancy the complete structure is specially adapted to the movements of its owner. If we take a spider from a snare and place it on another snare, we see that the movements of the spider are more difficult in the new snare, and it often injures the fabric in its progress. The intricacies of the new snare are not suited to this spider. Each is best fitted to the product of its own precision.

But a spider will often rest content with a snare other than its own. I interchange two *Aranei*, placing each on the other's web. They are first scared, hasten away to the foundation-lines, but, taking confidence after some twenty minutes, return to the centre. There they wait. They grow restless; they test the radii with their fore limbs, vibrate the snare, make short explorations towards the circumference as though dissatisfied with their homes. Soon confidence increases; they remain passive at the centre and seldom stir from the resting-place unless to seize an entangled prey. They are satisfied with the exchange. Each is probably quite oblivious of the fact that it is not in its own snare.

I make a more marked exchange. I place an *Araneus* in the snare of a *Tetragnatha* and a *Tetragnatha* in that of an *Araneus*. What will happen now? The snares are more dissimilar. One is horizontal, the other vertical. The spiral of the *Araneus* is closely wound, that of the *Tetragnatha* more wide apart. The one is a narrow, the other a wide-meshed net. The spiders themselves equally differ. *Araneus* is a stout, compact, globular little creature with short quivering limbs and hasty in all its motions. *Tetragnatha*, on the other hand, is a narrow elongated spider, with limbs disproportionately long and slender and, in its circles, moves with apparent method and precision. Each has just finished the construction of its snare. I make the interchange. At first there is the usual alarm, but soon the spiders settle in their new abodes. They accept the unnatural conditions and are satisfied.

When I found that the *Araneus* accepted the snare of the *Tetragnatha* and the *Tetragnatha* that of the *Araneus*, I imagined that a geometrical spider had little choice in this matter and was content with any snare. But this proved to be a false opinion.

I interchanged spiders when employed in their architecture. I took a *Tetragnatha* from a snare in which seventeen turns of the viscid spiral were complete and transferred it to a very similar snare of an *Araneus* in which only two turns were complete. I expected the work to continue in the new snare, but in all likelihood with greater difficulty. I was mistaken. After a period of hesitation which lasted for about ten minutes, the spider commenced to explore its new surroundings. It repeatedly shook the web as though it were discovering the direction in which the main foundations lay. It moved all over the network. It examined closely the radii, the temporary spiral, measured all the numerous intervals and made itself thoroughly acquainted with the complexity of the new snare. But it remained unsatisfied. It refused to sit in patience at the centre. It set about to demolish the snare. It moved out along each radius eating up the fabric in its progress. Methodically it worked until it had devoured all. When the snare had been completely destroyed with the exception of the foundation-lines the spider then took up the work of construction. It began to lay a new snare in the foundations of its alien predecessor.

The *Araneus,* which I removed from the snare completed up to two turns, I placed in that of the *Tetragnatha* completed up to seventeen turns. Now this was an advantage to the *Araneus.* The new snare was more complete. Much of the work had been done by the *Tetragnatha* that it had replaced. If the *Araneus* just continued the work and brought the snare to a completion, it would gain much by the expenditure of less silk. But I felt sure that the spider could not do this. It first explored the snare. Then, unsatisfied with the exchange, it behaved like the *Tetragnatha* in the previous experiment ; it ate up the whole snare. All the new radii, all the complete bridges, the seventeen turns of the viscid spiral, just newly spun, were systematically destroyed. In this instance the spider was in a position to gain by the transfer. But it was unable to reap any advantage from the half-completed work. It must commence again from the very beginning.

Similarly have I transferred *Araneus nauticus* while engaged on construction, to another snare of its own species. I have sometimes seen it rest satisfied with the transfer and resume the work, but often it destroyed the snare. I am unable to understand why a spider sometimes accepts and sometimes rejects a new snare. It is not necessarily the snare that looks the most unsuitable and different from its own that the spider will destroy, for an *Araneus* may accept the snare of a *Tetragnatha.* I have a note that points to some other cause. I once removed a spider from its half-constructed snare and, after a lapse of five minutes, replaced it again on its own snare. I saw no reason why this spider should not continue the work of construction, commencing again where it had left off. But it did not act as I had thought. It did not seem to recognize its own property. It first tested and examined the fabric on every side. Then, after a thorough exploration, it gobbled up the whole structure and commenced to weave a new snare. What can we say of a creature that cannot recognize the features of its own work!

The problem as to why a spider does not become entangled in its own snare was solved by the inimitable skill of M. Fabre. The only adhesive portion of the structure is the viscid spiral; none of the other lines have any tenacious power. This is well displayed in spring. At that season clouds of pollen float downward from the pines, filling the air with a fine yellow dust. Innumerable grains fall upon the snare and adhere to its sticky lines. The viscid and non-viscid filaments appear in distinct contrast. The radii, the hub, the temporary spiral, the foundation-lines are all unchanged, but the viscid spiral is transformed into a continuous golden line.

I repeated some of the simple but ingenious experiments of M. Fabre, conceived for the purpose of discovering why the spider did not adhere to its own viscid spiral. I touched the various parts of the snare with a clean glass rod. The radii, the hub, the temporary spiral, the foundation-lines were non-viscid; the viscid spiral alone adhered to the glass rod. I then smeared the rod with a thin layer of oil and found that the viscid spiral adhered more feebly to the rod when smeared with oil than when it was quite dry. I used a spider's leg in place of the glass rod. It did not adhere to the viscid spiral, but after moistening it thoroughly with benzene so as to dissolve away any oily coating, the leg immediately adhered to the viscid spiral. From experiments similar to these M. Fabre has discovered that it is the possession of an oily coating which prevents the geometrical spider from becoming entangled in its own web.

A spider, I think, uses as far as possible the non-viscid radii during its movements in the snare, but this is not due to the fact that it would stick to the spiral, for I covered all the radii of a perfect snare with a thick coat of adhesive gum and the spider was well able to run backwards and forwards along them.

Spiders other than geometrical spiders become entangled in the circular snare. They do not possess the oily coat so essential to the *Epeiridæ*. I took a species of *Hippasa* which constructs a non-viscid platform on which insects become entangled but to which they do not adhere. I placed the *Hippasa* on a circular snare. It was quite as helpless as any fly; it did not attempt to creep over the snare, but was immediately entrapped. Moreover, its surface could not have possessed any fine coating of oil, for its legs adhered to the viscid spiral. Thus it is clear that geometrical spiders are perfectly adapted to move over the glutinous filaments of their webs.

Some facts may be of interest regarding the general habits of these spiders. When suddenly alarmed they behave in different ways. If the alarm is slight and the *Araneus* is at work on its snare, it immediately stops and remains perfectly motionless. If the alarm is greater, it hurries away from the scene of its labour and takes up a position in the centre of the snare from where it can move in any direction to attack the invader. If terrified, the spider deserts its snare, hastens away along a foundation-line and takes its stand beneath a sheltering blade of grass. Often, when two spiders are working in close proximity, the foundation-lines of the two snares may cross one another or may be attached to the same object. Under these conditions the spider of one snare sometimes invades the other snare. The owner of the latter immediately recognizes the invasion, turns in the direction of the intruder, grasps firmly two of the radii and violently shakes the snare. The purpose of this, I think, is to warn the invader that he has crossed over into a hostile country and must immediately return to his own territory.

The *Araneus* sometimes acts differently when alarmed. It lets go the snare and suddenly drops down to fall amongst the underlying foliage. There it remains concealed but not lost. It is still connected with its snare by means of the filament of silk that it has emitted in its fall. In addition to dropping from its snare, the *Araneus* sometimes adopts a more complicated method of escape. It first drops, then, while suspended by its filament, it emits a number of additional filaments which are carried away by the breeze until their free ends find a suitable anchorage.

The spider then climbs away along the new filaments and escapes.

The principle of protective resemblance is evident in the behaviour of these spiders. The *Tetragnatha*, when alarmed, remains perfectly motionless and thrusts forward the front two pairs of limbs, the tips of which diverge slightly from one another. This attitude is, I imagine, of some importance to the spider, for it no longer bears any resemblance to a living creature, but might be easily confused with the flowers of the grasses that on all sides surround the snare, and to which the structure is often attached.

But there is in these hills another geometrical spider, unnamed, but belonging to the genus *Cyclosa*, which adopts a still more perfect method of protective resemblance. It envelops its captured flies in a coat of silk so as to form little pellets which it strings along one of the diameters of the snare, almost always, I think, in the vertical direction. The spider itself very closely resembles one of these silken pellets. It is of a brownish-white colour, and, when it tucks in its legs and remains motionless, it is not easy to tell which is the spider and which the pellet. The general shade of colour varies in different individuals. Some specimens, or it may be species, are distinctly browner than others, and the little pellets which they construct are correspondingly of a darker hue. But in addition to the close resemblance, the spider's position in the snare must be of great value, for it sits at the centre in the direct line of the row of pellets which are strung along the diameter on either side. So perfect is the resemblance that it is almost impossible to detect the presence of the spider unless it is remembered that it always remains at the very centre. I showed the row of pellets to a friend, and told him that one of them was a living spider. I asked him to select it, and offered a wager that he would not be correct in his selection. After a close scrutiny of the snare, he at length selected one of the pellets furthest away from the spider, and was then very surprised to see the central pellet climb out along the snare as soon as I touched it.

I have even thought that the theory of protective resemblance might be applied to the snare itself. A circular snare, when spread over a pool, resembles sometimes a series of circular ripples flowing outward on the water from a central point. Flies are continually alighting on these placid pools, and throw the smooth surface into circular ripples as though a pebble was dropped into the water. I have often been deceived by these ripples into the belief that I had discovered a circular snare, and I expect that an enthusiastic supporter of the theory of protective resemblances would claim this similarity as of great advantage to the spider, by deceiving the sharp eyes of insectivorous birds. But to my mind this would be only a fanciful belief.

The special senses of animals, their potency and even their very existence, have often supplied a wide field for experiment and discussion. I wished to satisfy myself as to the presence and activity of these senses in the geometrical spiders.

I made some experiments to test the sense of taste in spiders. I placed a large fly in a strong solution of quinine and gently laid it on the snare of an *Araneus*. Now, whenever an *Araneus* captured a small insect it was in the habit of devouring it at the site of capture, but, if the insect was large, it used first to bind it in a few coils of silk, and then, carrying it away to the centre, used to eat it at its leisure. On approaching the large fly soaked in quinine, the spider first seized the insect but instantly drew back as though it had discovered something distasteful. It then commenced to coil round the fly a thick mass of silk and to shake the web in the endeavour to cast out the bitter morsel. When the fly was thoroughly concealed in the covering of silk the spider returned to the centre but left the fly behind. It appeared agitated and unhappy; it continually brushed its mouth and jaws with its fore limbs as though to remove something irritating or offensive, and at intervals forcibly vibrated the snare in the hope of dislodging the distasteful insect. On another occasion I soaked a much smaller fly in the quinine solution. The spider behaved in a similar manner, immediately rejecting the insect after first tasting it.

I am confident that in these experiments the cause of the rejection of the insects was the unpleasant flavour of the quinine. This substance has no odour and causes no irritation. The species of fly was one that the spider always eagerly devoured, and the spider did not reject these flies when soaked in other tasteless fluids. Consequently I felt satisfied that the geometrical spiders possess the sense of taste.

Camphor is a useful substance for testing the sense of smell. I placed flies in a solution of camphor and then laid them carefully on the snare. The spider came forward to examine them. It did not appear to notice any sign of an unnatural odour, but immediately swallowed the flies. Camphor is a germicide and injurious to insect life, and I have no doubt that it would be equally harmful to spiders. I have before mentioned how certain ants are instantly driven away by the odour of camphor, but the *Araneus* passed it unobserved. It did not seem to recognize the strange substance, and I doubt whether it possesses any more than a rudimentary sense of smell.

I believe a spider often sees the flies becoming entangled in its snare. It does not work by the power of touch alone. I feel sure that an *Araneus*, which I once observed descend to attach the vertical line of its snare, was able to detect the presence or absence of a suitable anchorage from a point eight inches above the surface of the water. I have seen an *Araneus* rush out along a radius in the endeavour to catch a fly that came dangerously close to, but did not touch the snare. Also I observed a spider drop down from the centre of its web to a distance of about three inches in order to seize a fly passing underneath. In both these cases, however, the stimulus may have affected the sense of hearing rather than that of sight.

Touch, I am sure, is the most accurate and sensitive of all the senses. It is by touch that a spider ensures the shape, the structure, and the symmetry of its snare. Its limbs are rule, compass and dividers with which it weaves its perfect plan of architecture. Moreover, it is ambidextrous, measuring with either limb as it circles to right or left. It is by touch that it discovers the entanglement of its prey. Another spider far away on the external frame is instantly felt and distinguished from a captured insect. Imitate how you will the entanglement of a fly, you cannot deceive the spider's fine sense of touch; it will not hurry out to seize a capture, but violently shake its snare to repel an enemy. How accurate, how discriminating is this sense of touch! A snare extends from bank to bank at the brink of a cascade. As the waters pour over the rocky ledge and splash in the pool beneath, hundreds of little drops leap up and strike against the snare. At every stroke the fabric quivers, but the spider sits unmoved. The slightest touch by a passing fly and it rushes out along the quivering line. But the vibration of the drops of water no more mislead it than do the tremors of the wind. There can be few creatures that possess so fine a tactile sense as the spiders that construct geometrical snares.

> "The spider's touch, how exquisitely fine!
> Feels at each thread, and lives along the line."

I have now concluded my remarks on the geometrical spiders. I find that they are endowed with acute senses in relation to the outer world. They see, hear, taste, and have an exquisite sense of touch. But their minds are an utter blank. They know nothing of their lives. They are oblivious of all their subtle skill. They lack the faintest glimmer of knowledge, the flimsiest conception of the why and wherefore of it all. They can no more reflect upon their past nor retrace their thread of architecture than they can conceive the nature of their toil.

CHAPTER IX

SHEET-BUILDING SPIDERS

Habits of spider and character of snare—Refusal to spin in stormy weather—Mode of capturing prey—Injection of poison—Sense of touch—Function of pedipalps—Force of instinct—Shamming death in spiders and insects—Physical properties of web—Pertinacity of *Artema*.

EVERY nook and cranny in these hills was used as a lurking-place by another common genus of spider that constructs its snare in the form of a non-viscid sheet. This is the genus *Hippasa*, and the species most probably *H. olivacea* of Thorell (see Plate, p. 88).

The sheet of web, continuous with the funnel-shaped tube at the mouth of which the spider waits in hiding for its prey, is so well known as scarcely to need description. The sheet is composed of such an enormous number of tiny threads that at first sight it seems incredible that the spider could lay down so dense a network of single lines. After observing the spider at the construction of its snare, it soon became evident that, unlike the geometrical spider, it worked with a bunch of filaments and not with a single thread. After a series of single foundation-lines had been drawn from point to point so as to form a scaffolding for the snare, the spider commenced to emit a sheaf of filaments and to wander in a haphazard manner backwards and forwards from side to side, attaching the sheaf to suitable points until the fine sheet of webbing was complete to satisfaction. There is no geometrical accuracy in this structure. Nor is there any viscidity in its lines save at the points of attachment of the filaments. Insects are captured by entanglement in the fine meshes and not by adherence to its lines.

Instantly an insect alights on the snare its feet and wings become entangled in the meshes. With a little struggling it can usually break free, but the hungry, evil-looking spider, crouching near the mouth of its retreat, dashes at terrific speed across the snare and seizes its victim before it can escape. It is a most extraordinary fact that a spider can move about so freely on the snare without ever getting its own legs entangled in the meshes. With a magnifying glass it can be easily seen that the spider possesses three little curved claws at the tips of the tarsi, and that at every step these claws hook over a filament of the web. If the tips of the claws be removed with a fine pair of scissors the spider will move over its snare with much greater difficulty, hooking up a thread here and there, though it will not become entangled. It is difficult to understand how the claws never succeed in becoming caught in the meshes and impeding the progress of the spider, yet this never occurs no matter how tattered and broken the snare may be. It is strange to witness a spider darting with such incredible speed over its snare that its movements are almost impossible to follow, and to recognize that at every one of the little steps that go to make each movement, twenty-four tiny curved claws are hooked over various filaments in the web, and that these claws, though apparently just the very implements suitable for entanglement, are raised and lowered and hooked around the filaments with such perfect precision that under no condition whatsoever do they become entangled in the snare.

I was interested one day in observing that the *Hippasa* was actually able to burrow through the substance of its snare. A wasp of the species *Polistes hebræus* had become entangled. The spider dared not attack so formidable an enemy, but slunk away to the edge of the snare. The wasp, in its struggles to get free, dragged the web to pieces and succeeded in confining the spider beneath a fold of its own snare. The spider, nothing daunted, flexed its limbs, deftly separated the filaments of its web, very rapidly burrowed its way up through the body of the snare, and set about the work of reconstruction. Such is the freedom of the *Hippasa* when moving amongst the intricacies of its own lines.

These spiders have learnt the lesson of the uselessness of snare-construction in stormy weather. Heavy downpours of rain, occurring at frequent intervals and sometimes lasting for many days, break upon these hills. At such periods the spiders remain in their little rocky clefts and never attempt to construct a snare, knowing full well that it would be broken to fragments by the next downfall.

The *Hippasa* displays a most remarkable instinctive power in the seizure of its prey. It injects the poison into the one vital spot that will instantly paralyze its victim. One might almost be led to believe that these spiders were acquainted with the minute anatomical structure of insects. It is very essential to the spider that it should know how to render its prey immediately quiescent. It must strike suddenly and with instantaneous effect. For when an insect becomes entangled in a snare and is struggling to escape, it forcibly exerts its legs and wings in the attempt to tear itself away. By the force of these violent efforts it often does escape, and on all occasions injures the snare. The movements of the legs and wings cause the greatest damage, so it is necessary that the spider should quickly subdue these and render its prey helpless. The movements of these parts are under the control of a nervous ganglion situated in the insect's thorax, and the spider acts as though it were well aware of this fact. It behaves as though it understood that the thorax is the vital spot and that into the substance of this part it must strike. On every occasion on which I have observed the spider seize its prey it has struck unhesitatingly straight into the thoracic ganglion, producing an immediate paralysis of the legs and wings. It behaves with a similar skill to the tarantula of M. Fabre, that struck into the one vital point in the whole nervous chain. Wonderful as are the instincts of the geometrical spiders in the weaving of their beautiful snares, no less fascinating are the instincts of this humbler species in the exactness of its knowledge of the vital anatomical point and the perfect precision of its stroke.

I think it is a matter of some doubt among naturalists whether or not the smaller species of spiders actually inject poison into their insect prey. I am inclined to believe that they do. For an insect, after being seized by the *Hippasa*, is paralyzed in an extremely short space of time, far shorter than could result from mere penetration of the thorax. The legs and wings are in an instant struck motionless. If the thorax of an insect be penetrated with a pin or even the interior of the thorax entirely destroyed, the legs and wings are not paralyzed for a long time, possibly for days, yet the destruction of tissue is much greater than that produced by the spider's fangs. The rapid paralysis seems therefore to be due very probably to the injection of a minute quantity of a powerful nervous poison.

The *Hippasa* lurks at the entrance to its tunnel with its subtle snare spread out before it. There would seem to be little doubt that it is waiting and watching for its prey. But this may not be strictly true, for the sense of sight does not appear to be very acute in these spiders. They are directed towards their prey by the help of the vibration of the snare rather than by the power of vision. It is possible to move a fine needle from side to side in front of the spider's head without it showing any sign of being aware of the strange object, but touch one of the filaments ever so gently with the needle and the spider is off at lightning speed. I also noticed in some examples, which I kept captive in a box, that they were able to detect the aerial vibrations caused by buzzing flies, but would be quite oblivious of their presence when the insects crawled close by along the floor of the box. But once a fly touched a filament then the spider became instantly alert and darted towards the capture.

The pedipalps are to the spider what the antennæ are to an insect, or the hands to a human being. They are all-important organs on which the creature's livelihood depends. Neither does the sense of hearing nor that of smell reside in the pedipalps, for the spiders of this species respond to sound vibrations and to the odour of camphor after the pedipalps have been removed. But I believe they possess a most exquisite sense of touch and that by their means the spider is able to detect the finest vibrations of its snare. This might be expected from their anatomical position, for they do not extend forwards like the antennæ of insects, but are bent downwards beneath the spider's body, and not only rest on the snare, but move about on it in a manner resembling limbs. The importance of the pedipalps is shown by the results that follow their amputation. After the pedipalps are removed the *Hippasa* can still construct a snare, but it resembles the architecture of the *Araneus* after the amputation of its fore limb; it is a tangled and a shapeless fabric. The spider, when deprived of its pedipalps, crawls about clumsily; it has lost much of its skill and precision. It continually catches its feet in the filaments of its web, an act which, in the uninjured spider, never occurs, and I have even seen it tear the snare in the endeavour to free its limbs. Without its pedipalps, the *Hippasa* can no longer capture flies. It seems to be quite unable to detect the vibrations that follow on the entanglement of its prey. I doubt if its hearing is affected, for I have noticed it extending its fore limbs towards the sound of a buzzing fly as though it were a man deprived of its eyesight and groping in the dark. I believe it had lost a sense as important to a spider as is sight to a human being; it had lost the sense of touch.

A little incident illustrating the force of instinct in this species rather amused me. The *Hippasa* was waiting for visitors at the entrance to its tube and the shell of a fly, long since emptied of its juices, lay rejected on the snare. An unwelcome visitor in the shape of a stinging wasp came buzzing by and entangled its feet in the spider's snare. Now the *Hippasa*, though armed with fangs and poison, is by no means valiant; though fierce enough with harmless flies, it will not join battle with an angered wasp. However, on feeling the vibration of the snare it darted forward, but, on perceiving the nature of its capture, it halted for an instant and then sprang swiftly back. But the presence of the wasp seemed to have imbued the spider with an impelling instinct of capture, a feeling that, if it could not seize the wasp, it must seize something, for it again darted forward with equal rapidity, not to attack the stinging wasp, but to sink its fangs deeply into the rejected remnants of the fly. It is dangerous to interpret insect emotions in terms of human feeling, but it was difficult not to conclude that the entangled wasp had aroused in the spider that instinct which compels it to rush forth and seize an insect, and that the instinct, being first foiled by the fierce nature of the prey, yet still impelled the spider on until it finally attained its unprofitable fulfilment in the body of the empty fly. The force of instinct is remorseless. It must be satisfied even in a useless end.

We see similar instances of this blundering, misguided instinct all through the animal world. I have already mentioned how the harvesting ants will sometimes during times of famine store up grass and pebbles in the nest, not that this material is of any use to them, but because they feel compelled by instinct to gather something, and there is no grain available for them to collect. Also I have shown how the carnivorous ants, *Myrmecocystus*, will ferociously attack an injured comrade, not because they owe it any hatred, but because they associate the injury with the presence of an enemy and, being unable to find this enemy, they satisfy their instinctive sense of battle by turning on their own kin. So also it is with many of the higher animals. I was once told of a tiny kitten that was reared from birth in a cigar-box. It recognized the safety of its cradle, and when alarmed used to hurry away to hide itself in its little home. At length the kitten grew into a big cat, but it still retained the instinct of its early days. It seemed to believe that its first home was still its sure place of refuge, for whenever it thought itself in danger it used to dash away and squat over the old cigar-box, though now little more than its feet were able to fit inside. Surely this was a mistaken instinct, for the cat could find no safety there.

Similar instances are to be found even amongst the monkeys. I once saw a monkey so annoyed by its owner that it flew into a passion. It was full of resentment, and it hissed and snarled at its master. But just as in the case of the angry spider and the well-armed wasp, so also did a similar behaviour occur in the case of the enraged monkey. It dared not attack its master, but the force of instinct impelled it to attack something, and it fastened its teeth upon a chair. So also it is amongst the most intelligent and social of beasts. In their case this misguided instinct leads them into horrible and cruel acts. For just as the carnivorous ant will rend in pieces the disabled members of its own nest, so also will the sagacious elephant turn on the wounded of its own kin, or will a herd of oxen led by the same blundering instinct ferociously attack an injured comrade until they gore it to death.

I noticed that, after catching these spiders in a glass tube so that all mode of escape was cut off, they used, after running up and down the tube a few times, commence to feign death. I do not suggest that the spider voluntarily placed its body in the posture that it thought it would occupy after it was dead, for I greatly doubt if so lowly a creature could have any mental idea of what that posture would be. But certainly the posture of death was that which the spiders did assume, for I allowed some specimens to die in order to satisfy myself of the fact. The *Hippasa* has instinctively learnt that it must first rely on its great speed to effect its escape, and that, when its retreat is cut off on all sides, its last resort is to lie absolutely motionless and pretend that it is dead.

This is often an excellent mode of escape and not at all uncommon amongst both spiders and insects. A cantharid beetle, with a red prothorax and dark metallic blue wing-covers, often found in the valley, used to sham death in the most perfect manner. When touched, it immediately became motionless, flexed its head, turned its antennæ beneath its body, bent in its legs and appeared quite dead. Another much larger form belonging to the genus *Mylabris* of the same family, with conspicuous wing-covers banded with warning colours of bright yellow, also feigned death and, when alarmed, sometimes remained in that state for over a minute. A very similar species of the same genus, coloured with red bands and usually found at higher altitudes, remained absolutely motionless for two minutes with little yellow drops of acrid fluid exuding from the joints of its tarsi. It is curious that, in addition to flight, this insect has three other modes of defence, by shamming death, by a display of warning colours, and by the secretion of an acrid juice.

Weevils (*Curculionidæ*) are a group of insects that commonly sham death. The characteristic feature of their attitude is the position of the antennæ. Normally the antennæ are angular and project forward very much like those of an ant, but when feigning death they are turned downwards and curved in beneath the flexed head so as to be completely hidden from sight, and this is also their posture when the insect is really dead. But a weevil will not sham death when it would be more advantageous to adopt some other mode of escape. It seems to have some sense of discrimination in the matter; for I placed one near the entrance to a nest of carnivorous ants and, when attacked, it never for a moment attempted to sham death, but rapidly took to its heels.

But the best instance that has come under my notice of the strange practice of feigning death was in the case of the butterfly *Libythea myrrha*. This little butterfly is swift and erratic in its flight; it is protectively coloured on its under surface so as to closely resemble a dried leaf, and in its movements through the air it looks very like a moth. I once observed the common bulbul, *Molpastes leucogenys*, make a sudden attack on this butterfly. The *Libythea* was fluttering across a dusty path when the bulbul dashed swiftly on it. But the insect appeared to be well aware of its danger, for it instantly checked its flight and literally threw itself to the ground. Thus the bird missed its prey and the butterfly looked to all appearances dead. I went to pick it up, thinking that it must be either dead or injured since it did not rest upright, but rather lay on its side like a leaf in the dust. However, it was far from really dead. I had no sooner touched it than it raised itself from the ground, opened wide its wings and flew uninjured away. This seemed a good illustration of the principle of feigning death ; there was no doubt that the *Libythea* was well aware of its danger and saved its life by adopting the simple ruse of hurling itself to the ground, where it lay motionless pretending that it was dead.

I have mentioned these instances to show how general is this instinct both amongst spiders and their prey. Whatever may be its origin, it is a very real and valuable behaviour, and the fact remains that the attitude adopted by the species when feigning death is the same as that assumed when the spider or insect is actually dead.

Before leaving the *Hippasa* I may mention a few physical properties of the webs of spiders that somewhat interested me. The first was the remarkable power possessed by the web of the sheet-building spiders in preventing evaporation in the air beneath it. One species of this tribe of spiders used to construct its sheet amongst the rank grass or over hollows in the sand. During the night a deposit of dew used to form on the under surface of the web, and one would think that the warm sun would quickly evaporate the cluster of dewdrops that hung from the silken snare. But the sun did not seem to have the power, for the drops remained. I did not take much notice of this until I saw the same occur in the broiling heat of the Euphrates valley. There some little spiders used to spin their sheets of web close to the river. In the mornings they were often spangled with dew. Then the sun would rise; its rays would grow intense the moment it appeared; the temperature would slowly creep up to 100° F.; the sands would burn to the touch and the air quiver with shimmering heat, but the glittering drops would still remain suspended from the sheet of silk. Of such protection is this webbing that, even at midday in a broiling sun, I have seen the drops still pendent on the sheet. No doubt this property is of value to the spider in retaining for its use a plentiful supply of moisture.

Another physical property of the spider's snare which adds still further to its own intrinsic beauty is its power of separating the white sunlight into its primary constituent rays. We see this best in the circular snare when it is stretched between a pair of pines high above us in the forest. The snare is suspended in the vertical line, the sun is approaching the zenith, and we look from below at a steep angle into the snare so as to see the sun's rays streaming down through it from above. We look up at it through the dark trees; we can scarcely see it against the clear sky, when suddenly it becomes suffused with a lovely glow and a rich stream of coloured light illuminates its silken lines. Every filament has become a prism; the sun's white light is broken into many parts and the whole circle of the silken fabric gleams with a rainbow light. It is a vision of transient beauty amidst the conifers when all around is the silent forest wrapped in a gloomy shade.

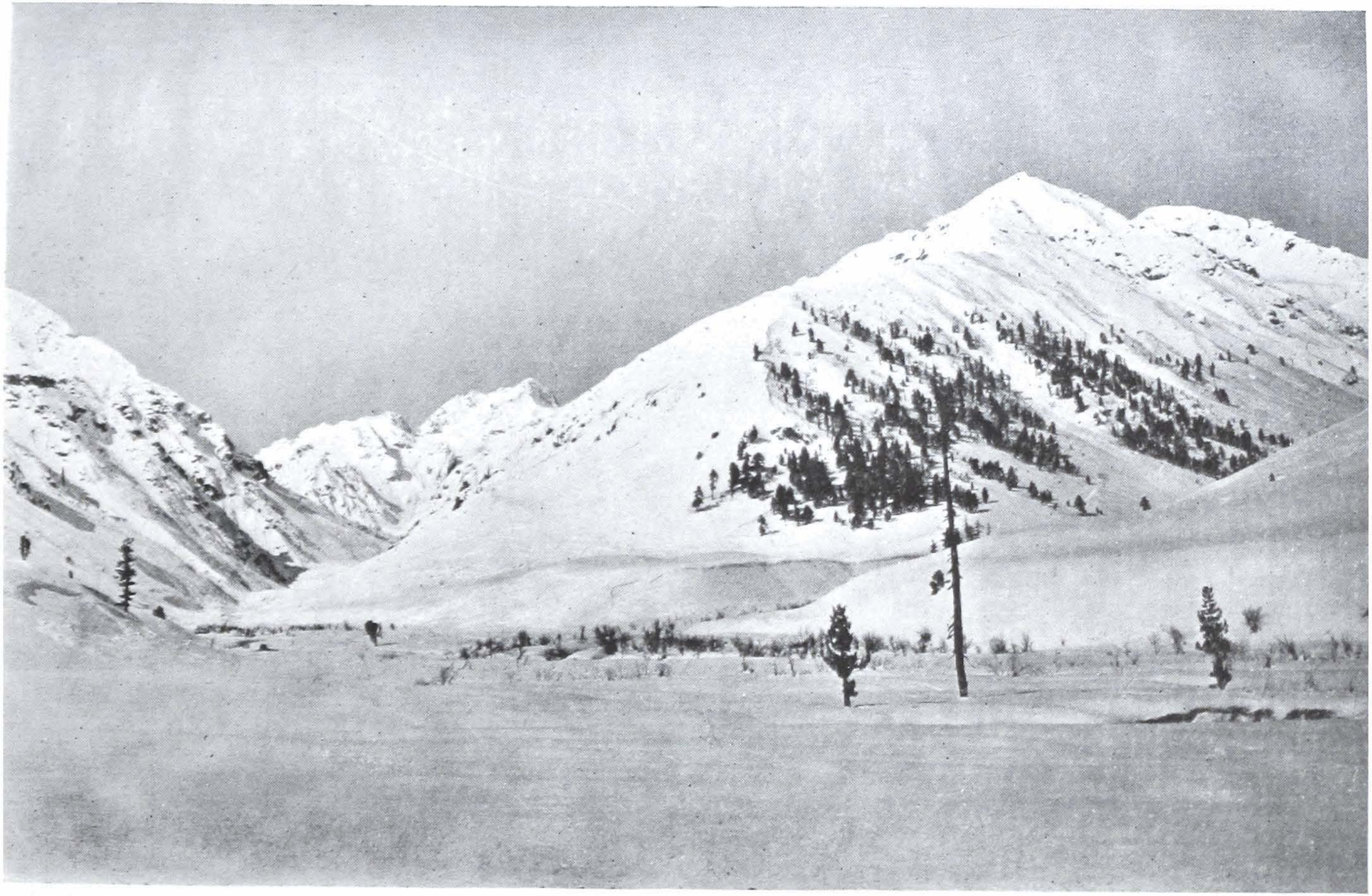
I fear I have wearied my readers with this long account of my observations on spiders. I wish I could give them a little of the pleasure that I obtained in making them. I will conclude with an incident illustrating their strength and pertinacity. Spiders of the genus *Artema* spin a snare in the form of a tangled network of stay-lines supporting below a concave hammock. The spider hangs head downwards from the under surface of the hammock, and, whenever an insect becomes entangled in the stay-lines, it violently vibrates the snare in order to shake the capture down into the hammock. On one occasion I watched a large moth strike against the stay-lines, meet with immediate difficulties and soon tumble down into the quivering snare. The spider instantly seized the moth by the tip of the abdomen, while the struggling insect, in its efforts to escape, broke through the floor of the hammock. The moth was now unsupported by the snare, but was held firmly in the spider's fangs while the latter hung head downwards by its hind claws from a filament of the snare. This genus of spider injects no poison; it has no knowledge of the vital anatomical point; it subdues its victim by its own strength. Now the moth was at least six times as large as the spider and must have been an enormous weight for that little creature to support; moreover the moth, by continual struggles and vibrations of its wings, endeavoured to escape, and it seemed as though at any moment it would break free. Yet the spider continued to cling with its hind claws to the filament and to maintain its fangs fixed in the abdomen of that unsupported struggling moth. It persisted in that attitude, stubbornly refusing to let go its prey, and not till five hours had elapsed did it fall exhausted to the ground. Its strength but not its determination had failed, for its fangs were still buried in its victim. I had long since ceased to be surprised at the wonderful instincts of spiders, but I had never believed that they possessed such brute strength and resolution.

CHAPTER X

OBSERVATIONS ON INSECT LIFE

Mountain dust—Inhabitants of pools—Carnivorous flies—Water-boatmen—Struggle for life—Mentality of fishes—Habits of *Vespa orientalis*—Nest of *Polistes*—Depredations of *Vespa magnifica*—Mimicry in humble-bees—Humble-bees and flowers—Habits of leaf-cutting bees—Instinct of mud-wasp—Instinct of digger-wasps.

TEMPERATURE and season greatly influence the aspect of a country. They are the common agents of physical change. Their action in this valley presents one feature deserving of our notice: the cloud of fine dust that daily fills the sky. In the oppressive days of summer, when for weeks no rain may fall, a dense haze collects over the mountains. It hangs thick over the valleys, and, like a veil, envelops even the highest peaks. The burning cliffs radiate a fierce heat and there is scarce a movement in the breathless air. All objects are obscured as though in a dim mist. The trees are unreal; the hills are ill-defined; they look bleak and uninviting, as though we looked through a moist fog on to a rocky shore. From a summit we obtain no sight of a distant range, and the plains are concealed beneath a shroud of dust. The atmosphere looks polluted, foul and murky, a vision of discomfort. Sickness increases. All vitality is lost when the cloud of heat obscures the sky. This haze is due to the permeation of the atmosphere with a very fine dust carried up by ascending convection currents



THE PEAKS UNDER FRESH SNOW.

[*Face p.* 164.]

generated by the contact of the air with the heated rocks. That these currents rise with great force from the valleys is indicated by the ease with which the plumed seeds are swept aloft from between the cliffs into the open sky, or the way in which a rain-cloud pouring over a ridge is opposed by an ascending stream within the valley and driven upwards as though in wreaths of smoke. The mornings show a clearer sky. The dust has settled in the cool of night. But it is only a temporary lapse; the haze again deepens with the daily heat. Nothing but rain can now purify the air.

At last the clouds collect over the hills; first in silvery wisps increasing each evening into heavy cumuli, and backing away at night, leaving a clear sky. Finally the clouds burst; a sense of relief is felt as the rain pours down in torrents. The sky clears and we see that the haze of dust has been swept to earth. A vast panorama is now exposed; thousands of square miles of mountain are seen in a single view. All that was wrapped in gloom appears through a transparent sky. So clear is the prospect that every object looks magnified as though drawn miles nearer to our vision. Shadows cast by a passing cloud or by a mountain side roll across the clear valleys. Sinuous rivers sparkle in the sunlight; tiny villages or strips of cultivated soil, hiding in some narrow glen, for the first time appear to view; the nearer hills are tinged with blue as if reflecting the azure of the sky, and the snowy peaks climbing above the wooded slopes contend with the whiteness of the clouds.

Thus do the waves of heat, rising from the enclosed valleys and lifting the finest particles of dust, darken the sky and hide the face of Nature. Plains, whole mountain ranges, even the very sun, are blotted from our view. At last the thunder-clouds burst; torrents of rain descend; the veil of dust is swept to ground and a new world is exposed.

Animal life continues to flourish amidst this changing scene. In the streams that rush down the wooded slopes or flow more gently through the rounded hills are many forms, all competing for the right to live. Fresh-water crabs creep lazily through the pools. They did not seem to struggle hard for life, yet even these crabs had their own device by which to seize their prey. One day I observed a fresh-water crab eagerly devouring a dead frog. As I never saw dead frogs floating in these streams, I felt sure that the crabs must capture their prey alive. They were not very active animals and usually remained at the bottom of the pools, so I wondered how they succeeded in catching the sharp and nimble frogs. In another pool the little problem was solved. On first searching the water for any sign of life I detected nothing but a few tadpoles; then, on looking more carefully, I saw the tips of a pair of large claws projecting from beneath a quantity of bright green water-weed. Not a trace of the body was visible; nothing but the pair of limbs widely separated, with the claws partly open, clearly showing that the crab was lying in ambush to seize a passing animal. There were no frogs in this pool, so I removed one from the stream and gently lowered it towards the extended claws. The crab immediately darted from beneath its green hiding-place, clutched the frog in its strong claws and scuttled away beneath the overhanging bank. Thus do the crabs, though the most sluggish creatures in the pool, gain their livelihood by a subtle skill. I suspect it is similar in the depths of the ocean, and that there the crabs and lobsters lie in hiding amongst the sea-weed and the stones to pounce suddenly upon their prey.

Dragon-flies (*Odonata*) and sometimes robber-flies (*Asilidæ*) loved to haunt the streams. The dragon-flies came, not only for prey, but to lay their eggs in the water. One large and beautiful species, with a black and green thorax and banded abdomen, used to alight on the grass and dip its abdomen deep down into the water; while its partner, hovering just above, dashed furiously to attack any strange dragon-fly that dared to invade the sacred precincts. Dragon-flies must be included amongst the few enemies of ants. After a heavy downpour of rain flights of male and female ants belonging to a small yellow species used sometimes to congregate in a cloud and hang in the air near the banks of the streams. The dragon-flies then took a heavy toll of their numbers, darting hither and thither through the swarm like a flock of insectivorous birds amongst a flight of termites.

The *Asilidæ* used to lie in wait for prey usually on a projecting spur of limestone. These flies, as is well known, capture insects on the wing, drive their sharp beaks into the bodies of their victims and suck up the body-juice. In dealing with smaller prey, such as a house-fly or a Syrphid, it simply drives its beak straight into the abdomen of its victim. No more cunning is required. This is sufficient to subdue its capture. But it is different with stronger species. I watched an Asilid that had seized a moth. The robber-fly lay astride the back of its prey, gripping it tenaciously with all its limbs. So firm was its hold that the victim could not possibly escape. The fore tarsi of the fly were hooked round the anterior edge of the front wings of the moth; the median tarsi similarly held the hind wings; the hind tarsi closely grasped the sides of the moth's abdomen, while the beak of the Asilid was driven deep into the thorax a little to the right of the median line. In such a grip a moth is helpless; its wings and abdomen are held as in a vice. It resists, but its struggles are in vain. It rapidly dies as its juices are sucked away. What strikes the mind in a contest of this nature is the skill with which the Asilid controls the wings of its prey and the strength of its grasp from which there is no possible escape. This insect needs no poison to stupefy its captures. Its strength and skill suffice for all its needs. It can overcome so powerful an insect as the cicada, and one so well armed as the humble-bee.

I paid more attention to those very common little water-bugs, the *Notonectidæ*, known popularly as water-boatmen. They were the most numerous element in the society of the pool. I often wondered why the frogs did not attack the boatmen, for it was obvious that they never attempted to seize them, though the boatmen often nibbled at the frog's hind legs. I thought that most probably the boatmen were possessed of an unpleasant taste; yet this was not so, for the frogs eagerly devoured dead boatmen when thrown into the pool. The *Notonectidæ* escape the frogs by their great activity. The frogs recognize their inferior skill and never attempt to attack the boatmen. They have learnt that for these insects they are no match. Thanks to their nimbleness the water-boatmen are secure from attack. The only creature that I have seen successful in capturing them has been the water-scorpion, *Nepa*, and it succeeds by its stealth rather than by skill. It lies in ambush until a boatman comes between its wide-opened anterior legs furnished with strong blades. Then suddenly the blades come sharp together and the boatman is secured.

The *Notonectidæ* are predaceous in their habits. They capture the small insects that tumble into the pool. One peculiarity in their mode of feeding interested me. Anybody, who has carefully watched these water-bugs, must have noticed that at intervals they swim down into the water and maintain themselves absolutely stationary some little distance beneath the surface by very rapid vibrations of their hind limbs, specially modified for the purpose of swimming. I could not understand the significance of this habit until I saw the boatmen dealing with their insect prey. I noticed that, immediately after capturing an insect on the surface, the boatman would descend with its victim and literally hover beneath the water with its struggling capture until the insect was drowned. I therefore conclude that this habit of repeated submergence has been developed by the boatmen to enable them to drown their insect prey.

The boatmen do not confine their attacks to the smallest insects, as their powers of swimming are sufficiently strong for a single insect to drag beneath the water and drown a beetle six or eight times its own size. They are cannibals, not only eating their own dead comrades, but attacking them when wounded or dying. Water-boatmen, when handled, sometimes give a sharp bite. I am sure they inject a small dose of poison, as the numbness remains for twenty-four hours and resembles that of a bee-sting. I suspect that the boatmen, in addition to drowning their prey, possess also the power of injecting poison into the insect, especially if its struggles make it difficult to control.

The manner in which these insects swim on their backs is their most interesting feature. The long hind legs make a most perfect pair of paddles, and the plan on which they work may be easily observed when the boatman is placed in a glass of water. From the posterior margin of the tibia and tarsus there is directed backwards a double fringe of delicate hairs. At each thrust of the limbs these two fringes separate; the hairs spread out so as to form a broad resisting blade through the medium of which the pressure is exerted on the water. As the limb is again brought forward the fringes collapse, and a narrow edge, offering the minimum of resistance, is now presented to the water. We know that in flight the point of the wing of a bird or insect not only moves to and fro but traces in the air a succession of ellipses. I think it is possible to detect a similar motion in the swimming-paddles of the water-boatmen. They not only oscillate but also rotate. It is difficult to follow this in the rapidity of their motion, but, when I placed the insects in a glass of water coloured with methylene blue, I felt certain I could see the particles of pigment being whirled round in a spiral at each rotation of the limbs; but it is difficult to be confident of this observation.

I made a few experiments to test the special senses of the *Notonectidæ*. I think that they appreciate the events in their own little world almost solely through the organs of sight and touch. It is obvious that they possess the power of vision. One has only to look at their large eyes and observe the manner in which they dart under the water at one's approach to a pool to be satisfied that their sense of sight is acute. They do not appear to be fastidious in their taste. I drop some evil-smelling Heteroptera and other nauseous insects into the pool; the boatmen dart out and eagerly devour them. I throw some bitter alkaloids into the water, but the boatmen take no notice. I place some boatmen in a basin of water and let fall close to them a few drops of a solution of quinine; the boatmen remain unaffected; the quinine no more disturbs them than the fall of drops of water. I throw them some insects injected with quinine; the bitter morsels are eagerly devoured. I give to one a fragment of a strychnine tablet; it is seized and carried down beneath the water as though it was an appetizing prey. I cannot, therefore, think that the *Notonectidæ* possess much sense of taste. I doubt if their power of smell is any more acute. They certainly did not behave like ants and spiders and recoil from the presence of camphor, but, rather, dealt with it in the same way as they treated the strychnine. Nor does their sense of hearing enlarge much further their prospect on life, for, if care be taken that the experimenter is not seen by them, he may shout, clap hands or blow shrill whistles without alarming them in the slightest. It is, I believe, through the sense of touch that they "live and move and have their being." The moment the tiniest insect falls on the water the boatman is instantly aware of the surface vibrations and darts like lightning on its prey.

A few experiments will soon make evident this delicate sense of touch. I place some boatmen in a basin of water; they swim about content. I approach one with the point of a fine needle. It takes no notice. I bring the needle so as almost to touch the boatman, but it excites no sense and the boatman hovers on. I lower the point till it touches the water. The boatman is instantly aroused; it springs forward on the needle. The sense of touch through contact with the water stimulates the insect. It would not be so foolish as to dart upon a needle had vision been its guide. But it is easy to make still more certain that it is touch and not sight which guides the boatmen to their prey. I stand a glass tumbler in a basin of water. I pour water into the tumbler until it reaches the same level as the fluid outside. I now place six boatmen in the basin and they swim about content. I throw them some insects; the boatmen dart on them, plunge beneath the surface to drown and devour them. At a distance of six inches they feel the prey touch the water and dash forward to the capture. I now throw some insects into the tumbler. They fall on the water standing at the same level as the water in the basin. The boatmen are swimming outside; the insects fall within the glass. The insects fall close to the boatmen, but the glass intervenes and the boatmen take no notice. I throw an insect into the glass when the boatman is on the water outside not half an inch away, but it remains quite oblivious of anything that has occurred. The glass intercepts the surface vibrations of the water; it cannot affect the boatman's vision. The boatman can well appreciate the direction from which the vibrations come. I approach one with a needle and touch the water with the point. The boatman is aroused but it does not act aimlessly; it first turns about so as to face the point where the needle touches the water before making its unerring stroke. This tactile sense is exquisite. The boatman is not disturbed by vibrations other than surface tremors. It is not misled by the ripples of the wind. I tap the sides and bottom of the basin, but this will not excite the insect. Visible ripples may flow across the basin, but the boatman is not deceived. I will mention a more remarkable instance as a proof of the nicety of this tactile sense. I drop some fragments of cork into the basin, and the boatmen, feeling the vibrations, instantly spring upon them. I allow the same pieces of cork to strike the surface by floating up through the water from below, and the boatman takes no notice. In both cases the surface vibrations spread over the surface of the water. In one the contact is from above, in the other from below, and the boatmen can discriminate between them.

It seems most probable that it is on one of the parts of the insect in contact with the surface of the water that the sensitive organs of touch will be developed. Those parts are the tarsi of the first two pairs of limbs and the tip of the abdomen. Now just at the base of the claws of the intermediate tarsi there is a specialized tuft of delicate hairs, and I have thought that these might have been the highly sensitive organs of touch. These creatures possess, so far as I could see, no trace of antennæ, and are therefore deprived of one organ very essential to insect life. The conjecture of course arises that to a land insect an antenna is a very necessary organ, but for a water insect the hairs on the tips of the tarsi can fulfil the function better since the detection of surface vibrations is so important to its life. When the insects left the land and sought an existence in the water the antennæ underwent degeneration and the sensitive organ was developed elsewhere. Nor is it difficult to picture the organs in an intermediate state, when the antennæ were degenerate and the sensitive hairs only partially developed.

It is not unreasonable to believe that water insects attained their present mode of life in the pools and streams as a consequence of a gradual change from terrestrial to aquatic habits in remote ancestors that once lived upon the land. In this connection it is interesting to observe that these water-boatmen will occasionally scramble out of the pool to take a short walk along the bank, and when they do this, they revert to the normal insect posture; they no longer move upon their backs, but walk about on their legs after the manner of their terrestrial ancestors.

In the society of the streams and pools all the members live in continual conflict. I passed many evenings watching the incessant struggle for life. Not a cloud in the clear sky; not the gentlest breeze; not a sound in the mountains to disturb the tranquil scene. One would think that in these placid pools Nature was happy and at peace. But no. War and destruction reign everywhere in Nature. As I walk along the margin of the pool, insects start up from the dried grass. Locusts tumble into the pool and are swallowed by greedy frogs lying in wait upon the surface. Smaller insects, in their efforts to escape, fall a prey to a shoal of water-bugs and are suffocated in the stream. Others, that escape the water, meet their enemies in the air. The larger kinds may be seized by insectivorous birds ; the robber-flies watch for intermediate forms, and the winged ants or tiny Diptera are pounced on by the dragon-flies that methodically work along the stream. Spiders that spin their snares across the pool live a life of continual carnage. They destroy and they are themselves destroyed. Insectivorous birds may spy them, or a spider may drop too far upon its filamentous thread and fall into the jaws of a ravenous frog, while down below in ambush amongst the green weeds are the patient crabs to whom the frogs themselves are prey. It is a merciless and cruel battle between all the inhabitants of the pool ; there is no rest from the continual warfare, no prospect of peace. To each occupant the little pool is a world and all the world is at war.

A few fish occupied the streams, but I observed nothing of special interest in them. At the entrance to the valley, however, was a sacred tank, thronged with fish, so tame and so dependent on their owners that they must be considered as domesticated creatures. These fish are objects of veneration amongst the Hindu Pandits. They may not be captured, but I feel sure they are the common species of mahseer, *Barbus tor*. The fish grow to a large size and people the tank in such numbers that, were they not artificially fed, only a fraction of them could survive. The Pandits care for them, feed them, protect them from injury, and, in return, derive a small livelihood by displaying to strangers, in the hope of reward, these living objects of their veneration.

The introduction of the fish into the tank and the kind care taken of them by their owners has greatly changed the character of the fish. From a shy creature defying the angler's skill, it is transformed into an animal that regards man as its protector and support. So fearless have they become that, when the priest approaches the wall of the tank, the fish advance to meet him, and either take the food directly from his hand, or dash after the fragments, struggling and leaping in such a seething shoal that the placid water seems to boil within the tank. That a fish can recognize its keeper and advance to meet him, and that it can so change its mode of action as to appear to regard man no longer as an enemy but as a friend, seems to imply some degree of mentality and possibly a dim shadow of consciousness.

It has always seemed to me remarkable how feeble is the manifestation of conscious life in the higher fishes which possess a nervous system of such comparatively advanced structure. The intensity of their emotions is clear. The anger of the males in sexual rivalry or their solicitude in parental love are the outbursts of glowing passions that demand no conscious effort for their fulfilment. But the fact that these creatures can so change their existence under unusual conditions as to hasten towards a being that before would terrify them, and to behave in his presence as though he were not an enemy but a friend, seems to suggest some glimmer of consciousness and perhaps a tiny gleam of reason.

Next to the ants, no insects in the valley interested me more than the various kinds of bees and wasps with their many peculiar instincts. The widespread species, *Vespa orientalis*, that extends into Northern Africa and Southern Europe, was very common in the district. I sometimes watched a continual stream of these wasps, large, brown, ferocious-looking insects with bright yellow bands on their abdomens, passing backwards and forwards. Those passing in the one direction were laden with a rich store of provender, and those in the opposite direction were returning empty for a fresh load. It was a perfect picture of insect industry and labour. I once followed the living stream across the country. At length I found the nest in the wall of a neighbouring village, and from there I traced back for over a mile the line of busy workers and did not even then reach the furthest limits of their toil. Over the granite rocks, across the open plains, high above the village roofs and the waving fields of corn, the stream of insect labour moved in one continuous flow. What sense was guiding them in their unerring road? What force impelled them in the same unswerving line, to chose a course direct, undeviating and headlong to their nest? It may have been the rocks and trees that were the landmarks on their route, but I greatly doubt it. To see a wasp sailing in an unerring flight high over a broad expanse of corn and shaping a course direct for its distant nest, was to feel that some other sense than sight impelled it, for to a wasp a rolling field of corn must be as trackless as a boundless ocean.

Far and wide these wasps had scattered over the country. Wherever filth and refuse had accumulated there were the wasps to be seen searching every corner for a precious burden. Down the village street, exploring every nook and cranny in the foul bazars, boldly entering every shop, busy amongst the mules and camels of our transport and far around over the fertile fields, these industrious insects were engaged from morning to night in a continual search for plunder. Fragments of decomposing meat, decaying remnants of fish or anything of a sugary nature was enveloped in a swarm, torn into pieces by a hundred busy jaws and carried off to the nest. These wasps, at certain times, are the natural scavengers of the country. With the kites, the pariah dogs and the dung-rolling beetles, they help to cleanse the village of its refuse.

At one place they had crowded round a dead pigeon. Nothing was left of the flesh but a few tough fragments on the wings which the wasps were unable to separate from the bases of the quills. They dragged about the feathers and the whole wings in the attempt to bite away the hard fibres, and one of them, unable to detach the flesh and unwilling to desert its provender, sailed away for the nest carrying in its tiny claws a large pinion almost five inches in length. It was amusing to watch the insect struggling in the air laden with this strange burden. The breeze seized the broad vane of the feather; the wasp was wafted about by every wind and sometimes whirled around in circles in the air, yet it still struggled on, and at every interval of calm it renewed its efforts to make direct for the nest. All the changing and eddying breezes, though they turned the wasp about in every direction, could not confuse its guiding sense and turn it from the true road.

I gave the wasps one of their own dead comrades. The cannibals rushed upon it. One seized the body in its claws and endeavoured to rise into the air, but, powerful as are the wings of these insects, they are unable to raise twice the body-weight, so the wasp had to cease its efforts. Then a companion appeared on the scene. One seized the dead comrade by the head, the other by the abdomen; they both drove their strong mandibles into the thorax and soon divided the wasp just in front of the wings. The one grasped the head and made off straightway on its journey; the other struggled with the larger share, rose twice, and again fell beneath the heavy weight, but, rising higher in the third effort, it at last took wing for the nest, to add the body of its dead companion to the food of the growing larvæ.

Vespa orientalis used to construct its nest in the mud walls or roofs of the village houses. Through a narrow aperture the wasps enter into a spacious chamber in which is suspended the papery comb with its rows of hexagonal cells. I noticed that this wasp was in the habit of ventilating its nest by creating a current of air with the rapid vibration of its wings. I observed two wasps stationed at the aperture of the nest fanning with all their strength. It seemed clear that their object was to direct a current of fresh cool air into the interior of the tunnel.

These wasps also post a sentinel at the nest aperture. The sentry is most earnest in its duty. It challenges each new arrival, possibly examines each burden as to its fitness for the store, or identifies each worker before it gives admission in order to prevent the intrusion of a stranger. Sometimes, as though in doubt, it pursues a worker into the interior of the nest. It pays less attention to the departing wasps; it seems to care little whether they leave empty or carry a little load of earth from the interior of the tunnel. As one ant knows every other in the nest, so it may be that this sentinel knows all others in its own community, and is placed there to prevent a stranger from entering the precious store.

Another species of wasp, *Polistes hebræus*, adopted a method similar to that of *Vespa* of vibrating its wings to lower the temperature of its nest. A colony of these wasps had built a large nest in a rose tree close to the verandah of my bungalow. The nest consisted of a circular comb hanging from a central stem and built of a single layer of hexagonal cells, all closed above and with the open ends directed downwards. I noticed that in their efforts to cool their larvæ they acted much like the *Vespa*. The nest was so situated that, throughout almost the whole day, it was shaded from the sun by the surrounding trees; but, in the early morning, the sun, while still low on the horizon, could peep below an overhanging shrub and fall on one margin of the nest. As a consequence the cells at this margin became uncomfortably warm and gave the wasps much trouble in their labours to keep them cool. It was instructive to watch a worker-wasp creeping about over the heated cells, testing each one with its sensitive antennæ. As soon as it discovered a cell which it considered too warm for the contained larva, it would stand over the spot, violently vibrate its wings for a minute or two, and continue to repeat this remarkable process until the draught of air, thus produced, had sufficiently cooled the cell. I never saw workers cooling any part of the comb except that warmed by the early morning sun, nor did they ever find any necessity to do so once the sun had so risen in the heavens as to be no longer able to peep beneath the overhanging verdure. It was by means of the antennæ that the wasp appeared to judge if the cell required cooling, so that I suspect that the antennæ, in addition to other functions, also possess the sense of judging changes in temperature.

This cooling of the cells by fanning is probably a satisfactory process. It is not a customary habit of *Polistes*, as the species seldom hangs its nest in a sunny place. We may perhaps regard it as an early stage in the evolution of that far more complex system by which relays of workers, all fanning in regular order, can ventilate with a fresh current of air the dark hive of the honey-bee.

There is another slight resemblance between the *Polistes* and the honey-bee. *Polistes* loves to suspend its nest from the roofs of dark verandahs or the ceilings of disused rooms, yet it sometimes chooses to build in the shelter of a thick bush, or even on the branch of an exposed tree. The hive-bee also, especially the form known as *Apis dorsata*, has been known to build in the open when no hollow tree is to be found. It probably once possessed the habits of *Polistes*, sometimes building on an exposed branch, but usually seeking a shady place; and when now a European honey-bee constructs its comb in the open air we perhaps see a relic of a more general ancestral habit when it once lived in a tropical clime.

Another conspicuous member of the *Vespidæ* in the Western Himalaya is *Vespa magnifica*, one of the largest and most powerful of the species. The queens, which fly about early in the season, are ferocious-looking insects; they are almost an inch and a half in length, of a dark brown colour, with the base of the antennæ a bright orange, and the whole body covered in a silky golden pile. The point of interest in the life of this wasp is the habit it has of making depredations on the hives of the honey-bees. I observed it attacking the swarm on different occasions. The honey-bees, *Apis indica*, had settled in a hollow tree. The workers were busy entering and leaving the aperture, and there was an appearance of bustle and energy about the hive. Some of the workers were, as usual, creeping lazily about the opening as though they had no special duties to perform. Suddenly a queen of *V. magnifica* appeared in the vicinity of the nest. It hovered about the entrance giving utterance to an angry buzz. The workers feared the intruder; at intervals one of them would dash at it in a vain and timid effort to drive the enemy away. But the *Vespa* came in closer to the hive, and after some hesitation made a sudden swoop on one of the more sluggish workers, which it bore away in its jaws. In four minutes it again returned, seized another worker, and this time I distinctly saw it turn forward its abdomen to plunge its sting into the body of its prey. It then made off to a neighbouring branch, where the victim was devoured. A *Vespa* worker then appeared and joined in the act of plunder. It did not attack with the same gallantry as the queen; it was very unwilling to approach the hive, and only at a favourable moment would it dart in upon its prey.

On another occasion I saw the *Vespa* plundering the compact swarm. The bees had gathered into a seething globular mass. They hung suspended from a branch, a trembling globe replete with danger and quivering with angry life. A few workers were leaving; many more were arriving to join the clustered swarm. A *Vespa magnifica* appeared. It hovered about the black heaving mass, but it feared to come too close. It never dared to extract a worker from the swarm. It awaited its chance a little distance away and occasionally fell upon a vagrant worker as it was about to leave or join the throng. The *Vespa magnifica* is therefore a plundering and rapacious species, and I have no doubt, from the way these wasps systematically remove victim after victim, that they must work great destruction amongst the hives of the Himalayan honey-bees.

Wasps and bees occasionally mimic other insects to which they bear a close resemblance both in structure and habits. Some of the digger-wasps are very similar in appearance to certain ants. Amongst a number of ants belonging to the species *Camponotus compressus* that were seeking for aphides on a rose bush I noticed a little Pompilid wasp running eagerly about. It resembled the ants even to minute points in its anatomical structure; it moved with the same jerky gait; it vibrated its antennæ in a similar manner and systematically searched each leaf just as though it was a *Camponotus* ant.

This close resemblance between insects of different orders has been observed in different parts of the globe. Another instance specially struck me, though it has frequently been noticed before, of the extraordinary similarity in the external appearance of the flies, *Bombylius*, to the humble-bees, *Bombus*.

The common humble-bee in these hills was *Bombus tunicatus*. It used to frequent the wooded slopes at an altitude of 8000 feet, and there it busied itself amongst the flowers that blossom above the undergrowth. Now the coloration of this bee is very distinctive. It displays a black shining head, a thorax hoary white with a black band between the wings, an abdomen with three successive bars of white and black and red. We look to the fly and see an identical coloration: the same black head; the same pubescent thorax with its hoary fur and intermediate band of black; the same abdomen with its bars in the same order, white and black and red. In fact the insects are marked from head to tail with seven transverse bands, and these bands are identical in each. Such superficial resemblance is remarkable. For it is evident not only in the exact shade of coloration, but in the width of each band, and the general scheme of decoration is identical in both. Similarly it is with the shape and build of the insects and the buzzing sounds that they produce. They occupy the same stations and feed on the same flowers. If defence is gained by this resemblance it must be all in favour of the fly. And this would seem in accordance with the principles of mimicry. For the fly is the more defenceless of the two; it exists in much fewer numbers than the bee; it is a more wary and active insect, tending to keep more in the shady undergrowth and less on the open flowers.

Humble-bees are well known to play an important part in the fertilization of many flowers. It was instructive to watch the untiring industry with which they sought the nectar from a pretty little blue blossom, the *Strobilanthus dalhousianus.* In this act they showed a good example of the variability of instinct, how different individuals of the same species will each employ its own method in order to attain a common end. For some of the bees were in the habit of pushing their way into the interior of the funnel-shaped blossoms in order to reach the nectar, while others had learnt to adopt the simpler plan of drilling a hole with their mandibles through the base of the corolla and in this way secured the nectar by a shorter route. Now this variation in the instinct appears to be very fixed in different individuals, each always acting in its own peculiar way; for I once watched a pair of bees belonging to the species *Bombus hæmorrhoidalis* actively engaged upon a profusion of *Strobilanthus,* and of the two, one always gained its end by perforating the corolla, while the other persisted in the more laborious task of pushing its way into the interior of the flowers.

There is another point worth notice in this little observation. I suppose it is reasonable to assume that it was the original habit of the humble-bees to come direct to the mouth of the blossom in the same way as other insects and to reach the nectar by the obvious route. The plan of cutting a hole through the corolla is a new device, a later instinct developed in order to give the bees less trouble, to save more of their valuable time, and perhaps to allow them to secure the nectar from those blossoms which are too narrow to permit their entering within. The behaviour of the bees themselves supplies some evidence to show that this supposition is true. For if one of these perforating bees is watched with a little care, it will be seen that it does not go direct to the place where it intends to perforate, but rather reaches the base of the corolla by an indirect route. It always goes first to the open mouth of the flower, then runs down along the outside of the corolla until it reaches the point where it is accustomed to cut through. Why does it act in this way? Why does not the bee go direct to the base of the corolla? Why does it go first to the mouth of the flower? The procedure seems a useless one, and certainly involves the bee in additional labour and wastes its precious time. I think there is something to be learnt from the act. I believe we see in it a relic of the past, a trace of that older instinct when the bee was accustomed to sip the nectar by entering the interior of the flower. The bee had then of course to go first to the mouth of the blossom, then crawl down the inside of the funnel in order to reach the nectar. But now, although the instinct has partly changed and many bees secure their nectar by cutting through the base of the petals, yet the relic of the older instinct still remains; the bees still persist in going first to the mouth of the blossom and then run down the outside of the funnel, and at length reach the point of perforation by a longer and indirect route.

The act is a kind of fossil instinct; the useless remnant of what is gone. And it is in these relics of forgotten habits as it is in the fragments of now worthless structures, that we can to-day review the past incidents and changes which have influenced the course of organic life.

Another plant visited by the humble-bees with untiring energy is the pretty little yellow balsam, *Impatiens scabrida.* Both the humble-bees, *B. tunicatus* and *B. hæmorrhoidalis*, used freely to fertilize this balsam. The size and form of the bell-shaped flowers are beautifully adjusted to that of the humble-bees. There is just sufficient room for the bee to squeeze itself into the interior of the bell beneath the overhanging anthers, and in so doing it covers the upper surface of its thorax with a coat of viscid pollen. When the flower first opens the pistil is enclosed within the compact bunch of stamens and is thus hidden from view, but later, when the petals begin to shrivel, the stamens fall away so as to expose the mature stigma and bring it in contact with the pollen-stained thorax of every fertilizing bee.

As in the case of the *Strobilanthus*, the bees secure their nectar from this flower also by two methods, either by perforating the corolla or by pushing down into the interior of the bell. It is an advantage to the plant if the bees enter the blossom, since in this way they distribute the pollen and fertilize other flowers. It is an advantage to the bees if they perforate the corolla, as by this means they secure the nectar by an easier and shorter route. But this must be only a temporary gain; in the end they would also be the losers, since they would be deprived of their nectar by fertilizing no flowers.

Thus there is a ceaseless competition between the plant and the insect. The balsam is always striving to adjust its blossoms to the size and shape of the fertilizing bee. If the bell grows too wide, then the bees will be able to enter without touching the anthers; if the bell grows too narrow, then the bees cannot enter at all, and they will then adopt the new plan of perforating the base of the petals. In either case the plant will be the loser, as the bees will fail to fertilize the flowers. The competition is no doubt incessant, and only those plants bearing flowers of suitable size and shape will be able ultimately to survive. Nevertheless, the plant must meet with great success in the struggle, since it is a dominant species, and its beauty is now spread and may be still further spreading over the wooded slopes of the Western Himalaya.

In this plan of perforating the base of the corolla the hive-bee seems to be lacking in the instinct so well performed by the less social humble-bee. It is amusing to watch the hive-bee in its earnest efforts to secure the nectar from some tubular blossom too narrow to permit its entering within. It eagerly examines the outside of the tube; it explores with its antennæ the base of the corolla in the hope of finding a way in. It sometimes meets with a blossom about to fall from the parent stem, and in this way discovers a natural aperture through which it can insert its tongue, or it may happen to alight on a hole previously cut by a humble-bee. It knows well the exact spot where the nectar lies, but what it seems quite unable to do is to cut an aperture for itself. It certainly seemed a little strange that a species endowed with such mental attributes as the hive-bee, in which the social instincts are so highly developed and to which the faculty of intelligence has so often been ascribed, should fail in a simple device that has long since been discovered by a number of the less gifted humble-bees.

Towards the end of May a number of small leaf-cutting bees, belonging to the species *Megachile cephalotes*, determined to construct their nests in my bungalow. They selected the holes that once held the screws for the hinges of an old doorway. I often used to watch them coming during the heat of the day carrying their burdens to the screw-holes and lining their tunnels with a layer of leaves. It was interesting to observe how the bee used to take the edge of the leaf between its jaws and work all round the margin licking it with its long tongue, and covering the edge with a sticky secretion to make it adhere firmly to the underlying leaves. It reminded one of a human being licking the edge of an envelope in order to seal it down over a letter. And the resemblance was more complete, for the bee would often press down the gummed edge with its mandibles and, I think sometimes, with the front of its head, just as a man presses down the edge of the envelope with the fingers in order to make it firmly stick.

The mud-wasps of the genus *Eumenes* are well known in India. They commonly enter houses and construct their mud nests against the walls or furniture of the room, and provision the cells with caterpillars as food for the larvæ. A large species, *E. dimidiatipennis*, used to make a flat nest of smooth clay on the wall of my bedroom. It was composed of mud without the trace of a pebble. One evening I discovered that a species of mud-wasp had constructed its nest beneath an overhanging ledge on the face of a cliff composed of a fine conglomerate. Now a nest of smooth, pale mud lying against the stones of this cliff would be very conspicuous, and I felt sure that the wasp must have understood this. For it had covered the whole surface of its nest with pebbles so that it was very difficult to differentiate the nest from the underlying conglomerate. The rounded stones, with which the wasp had studded its nest, were comparatively large, many over a quarter of an inch in diameter, and it seemed surprising that the insect could carry so substantial a load.

I was delighted when I discovered this little nest of pebbles, for I felt certain that I was looking at a beautiful instance of harmonization, so invisible did the nest become by blending with the conglomerate cliff. I wrote in my journal that "this was one of the prettiest examples that I had seen in the life of insects of a plastic instinct employed to so useful a purpose, for I have no doubt that it was a gain to the species to render its nest invisible through harmony with its surroundings by covering it with a layer of the same little water-worn pebbles that went to build up the conglomerate cliff."

But I was making a grievous error. These nests were not common, and for some weeks I could find no others than those on the conglomerate cliff, until one day I discovered a nest of four cells implanted on a smooth slab of slate. I was surprised, for I had felt almost convinced that the covering of pebbles was an example of a wonderful protective instinct and that a wasp constructed a nest of pebbles only against a pebbly cliff, yet, there before me was a nest studded with brown and white pebbles standing out against a background of purple slate in so prominent a manner that any one might see it. Had the wasp intelligently attempted to construct a conspicuous nest it could scarcely have been more successful. I was disappointed at finding that the pretty example of harmonization was but a myth, but I had received an excellent lesson in the danger of arriving at a conclusion without careful and repeated observations.

I found the little digger-wasp, *Ammophila*,[1] very active at the end of June in the open glades of the forest at an altitude of 8000 feet. It is an insect of wide altitudinal distribution and ascends to at least 11,000 feet. It is a slender black species somewhat under an inch in length, with the sides clothed in a silvery pile and the front two-thirds of the abdomen coloured in a shining red. On a patch of short grass the wasp was incessantly digging, hunting for caterpillars, or feeding on the sweet flowers. It was amusing to watch its untiring industry in the excavation of its tunnels, thrusting out the soil in spouts of sand, sweeping it backwards with its fore legs and dislodging the larger fragments with its mandibles.

The marvellous instincts of these wasps have been displayed in the minute and accurate observations of Fabre. The *Ammophila* captures caterpillars, paralyzes them by a succession of stings into the different segments of the body, crushes their heads between its mandibles and then drags them off to

[1] Mr. Bainbrigge Fletcher, who kindly examined my specimens of this wasp, tells me that an exactly similar specimen from Abbottabad has been returned to Pusa named by Mr. R. E. Turner of the British Museum as *Psammophila tydei*, but that the species is an *Ammophila* according to Bingham's diagnosis of the genus.

a previously prepared tunnel in the ground. After lodging the victim in the blind end of the tunnel, the wasp lays an egg upon it, then seals the entrance, disappears and comes no more to the nest.

I will here mention a few illustrations of the blindness of instinct displayed by this species. The first problem was: How will the wasp behave if, when in search for plunder, it discovers, not a virile prey, but a caterpillar already paralyzed with the head already crushed? Will the wasp despise such prey, or will it recognize that the caterpillar being paralyzed, there is no need to repeat the process, that much of its work has been already done, and that nothing now remains but to drag away the larva and to bury it?

I unearthed a caterpillar from a wasp's nest. It lay motionless, paralyzed from the repeated stings of its captor. On its left side, distant from its head by one-third of its length, was attached the oval whitish egg. I placed the exhumed caterpillar before a wasp that was running about in search of prey. The wasp rushed on it. Never had it found such a morsel as this. Here was a prey that made no struggle to escape, that needed no sting to overpower it. Yet the wasp could not recognize this. It seized the passive larva in its jaws and legs, pierced it eight separate times with its sting, and finally crushed the head between its jaws. All was labour lost. The caterpillar had hours before been paralyzed by a previous wasp; its head macerated by other jaws. But the wasp could not appreciate this. That the caterpillar made no resistance had no influence on the wasp. Struggle or no struggle, the force of instinct must be fulfilled. The caterpillar cannot be removed until sting and jaw have done their work. The paralyzed larva must be again paralyzed, the crushed head must be again crushed before the next step in the instinctive round can follow and the caterpillar can be dragged into the cell.

The closure of the nest supplies a second instance of the utter folly of the insect when, through any interference, the instinctive round is broken. A caterpillar has been carried to the nest, dragged below, an egg has been laid and the wasp is now industriously engaged in sealing up the tunnel. First it spreads a roof over the buried chamber to provide a safe nest for the growing egg. For this it selects what is suitable from the soil around. A bulky pebble or a few flat laminæ of slate serve the purpose and are pushed down into the pit. The wasp follows, moulds them into place by the pressure of her head until the cell is closed. The roof secure, any material serves to block the tunnel. Surrounding debris, dust or sand or pebble, is shuffled indiscriminately down the passage. More is poured in; everything is swept backward into the pit. All it needs is to be pressed tight; the tunnel wall must be a consolidated, not a crumbling structure. Down goes the insect's head, the legs clutch the sides of the tunnel, the wings vibrate, and, with the vertex as a ram and all the strength of the body as a driving force, the loose particles of crumbling earth are compressed into a solid mass. Again the debris is poured in, again the process of consolidation follows. The stoppage of the tunnel is half complete and the wasp rests. It flies off to a neighbouring bank of flowers. It will feed for a minute, then resume its work. For one half the tunnel remains to be filled in.

Now is the time to expose the insect's folly. I open the tunnel, lay bare the cell, extract the caterpillar with the white elliptical egg adherent to one side. I lay the caterpillar right across the entrance of the ruined tunnel that leads to the pillaged cell. The problem is: What will the wasp do when she returns to her labour? She left behind a tunnel, the inner half walled, the outer half not yet complete. She returns to find another picture. Facing her tunnel is the larva and egg, the object of all her toil; within is the ruin of her work; her solid wall is no more; at the end of her tunnel is a broken and an empty cell. Surely she will recognize all this; she will either replace the caterpillar and repair the damage or desert the hopeless ruin.

But no. The wasp returns. She approaches the tunnel as though oblivious of any change. She treads on the caterpillar lying at the entrance; she stands astride of her own egg, but sees nor cares nothing for it. She reaches the mouth of the tunnel. Before her lies desolation and ruin; within is the pillaged cell; but to the wasp all is in good order. She has returned for one object, to seal the outer half of her tunnel. To the fulfilment of that duty she is now so abject a slave that she is impelled to do it whether she wills it or no. So she continues where she left off. She shuffles earth into the ruined tunnel, pours dust into the empty cell, discards the exposed caterpillar, in fact resumes her labour just as if nothing had happened and cell and tunnel were in perfect order.

Futile is such toil, and every sign of its futility lies patent before the wasp. But the wasp sees it not. What should be hidden lies exposed; what should be filled lies empty; what should be a solid mass lies a crumbling ruin; but to the wasp all is well. She has returned to seal the entrance and, ruin or no ruin, seal the entrance she will. Instinct is blind. It has no concern in the why or how it acts. What it does it must do, and it can do naught else. Every link in its chain of action must be forged no matter how worthless the bond.

CHAPTER XI

BUTTERFLIES, MOTHS AND CICADAS

Swallow-tails of Hazara—Sexual display—Protective coloration in butterflies—Butterflies resembling leaves—Protectively-coloured moths—Enemies of butterflies and moths—Instinctive fear of enemies—Rainy season in Hazara—Habits and musical organs of *Cicada.*

I HAVE a few observations to make on the Lepidoptera. The butterflies of the valley were not specially attractive, but many beautiful kinds fluttered through the higher woods. In the open glades were bright-coloured species that love the sunlight. Here different species of *Colias*, *Pieris*, *Vanessa*, *Argynnis* either hasten from flower to flower or collect into quivering groups over the moist patches on the ground. In the shade of the trees are more sombre species, chiefly of *Satyrus* and *Ypthima.* For a few weeks the woods are thronged with species. Every glade is gay with life. Then, as if by magic, all in a few days disappear and new forms take their place.

Swallow-tails of most beautiful colour fly overhead or dart swiftly down the slope. The widespread *Papilio machaon* occasionally appears. Its soft yellow wings are veined and bordered with a dense black, marked above with yellow crescents and adorned beneath with spots of pink and blue. From the hot plains even to the line of permanent snow this butterfly may anywhere be found; but nowhere does its beauty seem more fitted to its life than amongst the subtropical flowers. More striking is *Papilio philoxenus*, a large black species, moving with heavy flight and hovering like a humming-bird before a flower. On its hind wings are bright and crimson bands handsomely displayed as it hangs on the blossoms of the chestnut. A smaller, but equally lovely species, is *P. cloanthus*, a swift and active swallow-tail sweeping hither and thither above the viburnum, showing its delicate green transparent wings surrounded by a jet-black border, like windows in a dark frame. Most beautiful of all is *P. polyctor* with an expanse of over four inches. It is a dark brown colour, covered in scales of golden green; its hind wings stamped with a patch of brilliant blue and a border of pale red crescents beyond a band of velvet black. All this lovely play of colour flashes in a moment before the eye as it hangs fluttering upon a flower. Sometimes these beautiful *polyctors* collect into groups of ten or twelve about some patch of moisture on the ground. There they rest with quivering wings or rise above the pool in short amorous flights, where they dance and hover in the air. A gleam of green and gold and blue flashes from their gaudy wings; new colours shine out at every movement and in every changing light. It is the most beautiful vision of insect beauty to be seen in the Western Himalaya.

Butterflies often display great energy under the influence of sexual excitement. *Junonia orithya* is a very common and beautiful species with brilliant blue wings. While the female is seated on a flower the male circles round her in hovering flight with his wings quivering so violently that he might be a hawk-moth hovering before a flower. At intervals he ceases, sinks down to the female, strokes her with his antennæ and then rises again to recommence his whirling flight in ever swifter circles. The common brimstone butterfly, *Gonepteryx rhamni*, another very conspicuous and attractive species, is equally eager at its courtship. In amorous circles the male hovers round the female and strokes her at intervals with his wings. It may be worth mentioning that both these butterflies, in which the sexual enthusiasm was specially intense, were very conspicuous and brightly coloured; in both the numbers of the males predominated over the females, and in both the male was the more brilliantly coloured of the two.

The subject of protective coloration is perhaps hardly worth discussion, since so many examples of the great principle have been collected in every part of the world. But I feel inclined to mention a few instances which specially attracted me in connection with the Lepidoptera.

A peculiar butterfly, *Nytha parisatis*, one of that large family, the *Nymphalidæ*, was common at 4000 feet. It is a dark brown species with a light bluish margin along the termen of the wings. The under surface is of a paler hue, streaked with white and ornamented with black ocelli. Now this butterfly haunts the hills of slate. It is in the habit of settling on the bare rock, usually in dark crevices or beneath overhanging ledges, where its brown wings harmonize well with the similarly coloured slates. On ascending to 6000 and 7000 feet we meet with two other species possessed of a similar habit, *Satyrus schakra* and *Aulocera brahminus*. These are also dull-coloured butterflies of the same family and they likewise seek protection against the dark rock, but they are not so successful in this as is *Nytha parisatis*.

Many butterflies bear a close resemblance to the leaves of certain trees and no doubt gain protection thereby. A little butterfly known as *Libythea myrrha* was certainly a member of this group. This species has its upper surface of a rich brown colour marked with some blotches and streaks of yellow. But when it alights it rests with its wings tightly closed, and then the appearance of the insect both in shape and colour is very similar to a dried leaf. It is a butterfly of swift and erratic flight and is in the habit of settling on the smaller branches of the trees, where it must often escape observation by virtue of its leaf-like form. Indeed I have little doubt that the possession of protective shape and colour must be of distinct advantage to this species, since it is one of the few butterflies that I have ever seen attacked by insectivorous birds.

My remarks on protective coloration would be very incomplete if I made no mention of that most striking example of leaf butterflies the *Kallima inachus*. This butterfly is almost classical, and was brought into special prominence by the researches of Dr. Wallace in Malay. Even in the dried state when preserved in a museum there can be no mistaking the fact that in this insect the principle of protective coloration has been developed to the most refined degree.

We see it in the shape, the size, the outline of the wings, which is clearly that of the forest foliage; we see it in their dull brown colour which resembles that of the forest leaves; on the wings we see the pair of tails that mark the stem, the pointed tip that marks the apex, the central band that marks the midrib, and the lines that mark the veining of the leaf. At the tips we see the clear white spot that looks like an insect-boring, and beneath is the profuse and varied mottling such as stains the surface of the fungus-covered leaves.

But the *Kallima* must be seen in its natural habitat in order to appreciate the full value of this wonderful protective scheme. We wander through some shady glen where the dense foliage is spread out above and the leaves of the oak are strewn thickly over the ground. Suddenly a brown fluttering object rises up before us. It looks like a withered leaf that has been wafted upward by a gentle breeze. It flutters on. We follow it with the eye. Suddenly a flash of yellow appears and we know it to be a *Kallima*. On it goes in a swift confusing flight. It darts and dances in the air. Then in an instant it seems to turn on itself; it disappears; it has alighted head downward on a bush; its wings have come sharp together and it is transformed into a leaf.

Sometimes in these same haunts we come upon another very similar and equally remarkable form, the *Melanitis*. It resembles the withered leaves as closely as does the *Kallima*. Its flight is equally swift and erratic, but there is no patch of yellow on its wings and it never alights on the bushes, but chooses rather the dead leaves that lie strewn about the ground.

There is no doubt that these two butterflies when seen in their natural habitat make a deep impression on the observant mind. It is not only the close anatomical resemblance between the butterflies and the withered leaves, but the way they cling to their leafy haunts, their swift and zigzag flight, the way they suddenly burst into view and then as if by magic instantaneously disappear, must place the *Kallima* and the *Melanitis* amongst the most perfect examples of protective coloration that can anywhere be seen.

I am not certain if the butterfly *Dophla patala* actually occurs within the limits of Hazara, but I have seen it in the Himalaya a little further to the east. It is a butterfly of some four inches in expanse, of much the same size and shape as the *Kallima*. Its upper surface is of a rich green marked with patches of pale yellow, and its form is such that the colour, shape and outline of the wings closely resemble the mature green leaves that grow on the forest trees. The cilia that border the edge of the wings are marked with spots alternately light and dark, and this has the effect of giving the outline of the wings some resemblance to the crenated margin of a leaf. It might be thought that the yellow patch on the surface of the wings would have served to destroy the protective scheme, but this is not the case, since many of the forest leaves are marked with similar spots of yellow which indicate where the green tissue of the leaf is first passing to decay. The *Dophla* is a butterfly of rapid and irregular flight. It sometimes settles on the ground or on the bark of a tree, in which places it is fairly conspicuous; but its favoured haunts are the smaller branches, where it settles amidst the green leaves. It is there well concealed by its protective colours. It always alights with outstretched wings, as it is the upper surface that is coloured a protective green, and it has also the habit of slightly raising and lowering the tips of its wings so as to give them the appearance of a pair of leaves moved gently by the wind.

It is instructive to contrast the *Dophla* in its resemblance to the green leaf with such a form as the *Melanitis* which resembles the leaves after they are fallen and dry. The *Dophla* is coloured a rich green to blend with the fresh foliage, the *Melanitis* is a dull brown in harmony with the scattered leaves; the *Dophla* alights where it is lost upon the branches, the *Melanitis* seeks concealment on the leaf-strewn ground; the *Dophla* rests with wide-open wings as it is its upper surface that is protectively displayed, the *Melanitis* alights with wings tightly closed for beneath is its protective scheme; the wings of the *Dophla* are even and entire and so are the green healthy leaves, the wings of the *Melanitis* are ragged and torn and such is the scattered foliage in all stages of decay; all the *Dophla* are much alike and such is the harmony in the mature leaves, in the *Melanitis* all differ and so do the littered fragments that lie everywhere beneath the trees; the *Dophla* when it settles displays a pair of wide-open wings and so also is the growing foliage placed in pairs upon the stem, the *Melanitis* brings its wings tightly together so as to appear to have only one and thus blends with the multitude of single leaves that lie scattered broadcast on the ground.

Such is the contrast between the *Dophla* and the *Melanitis* in their hard struggle for life. Each is secure in its own habitat; each is perfectly adapted to the special nature of its own haunts. We can see all this in the dead insect, in its structure, its colour, its size and shape, but we must see each in its accustomed haunts, we must watch each select its own special habitat, each alight in its own peculiar way, before we can appreciate how closely function is interwoven with structure and both with the protective scheme.

More numerous and undoubted examples of protective coloration are to be found in the suborder of moths. The place to seek them is in some shady glen where only a rare shaft of light gleams in between the trees and where no intruder enters to disturb their daylight haunts. They love the silent gloom where the long ferns droop down about the rocks, where the pale grey lichen clings about the trunks and the moss in tufted sprays hangs pendent from the oaks. Here they gather for the day amidst the dark and dripping foliage, where not a sound is heard to break the silence but the shrill noise of the cicada or the rumble of some distant stream. Many different kinds occur, each suitably adapted to the special nature of its own abode. *Gnophus acciptraria* is a dull grey-coloured moth nearly three inches in expanse, mottled with brown and with darker patches near the tips of the wings. This species was frequently seen between 7000 and 8000 feet, where it used to haunt the limestone cliffs and harmonized in a most perfect manner with the mottled colour of the stone. It is an insect of fairly strong flight and moves about after dark, at which time it is often attracted to the glare of an artificial light. In open places it is more uncommon; but in a dark glen, where the trees drip with moisture and the bosses of limestone project through the decaying soil, this species will almost certainly be found. It seldom alights anywhere except on a grey block of limestone, usually in some dim recess where it clings head downwards with outstretched wings pressed closely against the rock, and so carefully concealed that it can be detected only by the sharpest eye. It is an excellent example of a protectively coloured species that blends with a grey weathered stone.

In marked contradistinction to the *Gnophus* is another nocturnal moth, *Boarmia admissaria*, a smaller species about two inches in expanse, with brown wings streaked at intervals with bands of black. This moth would gain no protection on the light-coloured limestone, so it resorts to the trunks of the trees. It spends the day attached to the bark of the pine, cherry, sycamore, silver fir and other forest trees. Its pattern of coloration bears the very closest resemblance to the bark on which it rests, and makes it a difficult insect to discover until it flies out into the air.

These two moths, the *Gnophus* and the *Boarmia*, cannot but arouse interest in the principles of protective coloration, so perfectly adapted is each to the nature of its haunts, the one to the cliffs, the other to the trees, and each keeps so exclusively to its own respective habitat.

Another little point of interest was that the different species of *Boarmia* did not necessarily seek protection in the same haunts. For instance, *Boarmia granitaria* was a smaller and greyish-coloured species, and it used to rest by day not upon the trees but on the slabs of limestone, with which it harmonized very well. Like the other species, it flies by night and often comes about a lamp. The colouring of its under surface is a little conspicuous, but this is of no disadvantage since it rests with wings outstretched and pressed firmly against the stone.

Another of these protectively-coloured moths was *Gnophus variegata*, a much smaller and lighter-coloured species mottled with a yellowish or pinkish tinge which harmonized fairly well with the hue of the mountain limestone. Its colours did not blend quite so accurately as was seen in some of the other species, unless it happened to alight on a specially suitable patch of stone. And we should remember that this limestone is marked with many streaks and patches, tinted with numerous shades of colour, clothed with different kinds of fungi, all of which so vary its surface as to fit it for the concealment of a number of distinct and varied species.

Anonychia rostrifera was another very common species. It was a pretty little grey moth with a brown angulated pattern on the upper surface of the wings. It took refuge on the dark shales and I seldom saw it on the limestone. It does not harmonize so well as some of the previous species, and it seemed to prefer a somewhat lower altitude of 6000 to 7000 feet. There was also another little moth that sought the limestone, the name of which I did not determine. It was of a uniform grey colour and harmonized exceptionally well with the weathered areas of the stone. This species seemed to rely even more than the others on its close resemblance to its environment, for I found that it was less liable to take alarm and less inclined to leave its shelter than any of the previous species.

Abraxas sylvata was still another of the Hazara moths that possessed the habit of alighting on the crags of limestone. It is a white insect, with its fragile wings studded over with patches and spots of grey. This species harmonized fairly well with the stones, though any one seeing the insect in a museum would scarcely have thought so. Harmony must be its main protection, but I was interested to observe that one which I took in a net remained perfectly motionless and shammed death. It has thus recourse to another method of eluding its enemies, and this is the only instance, with the exception of that widespread moth *Deiopia pulchella*, that has come to my notice of the strange practice of shamming death amongst this large division of the Lepidoptera.

I have mentioned fourteen species of the butterflies and moths which frequent this valley, all of which would seem to be preserved because they resemble those structures on which they are accustomed to alight. Some seek protection amongst the leaves, others on the shales, others on the limestones, still others on the trunks of the forest trees, and the colour of each is beautifully adapted to the nature of its resort. I have been asked if these moths deliberately select the objects on which they alight with the conscious intention of seeking concealment. But this cannot be for a moment admitted. The moths have through generations gradually adapted themselves to those habitats where they would naturally find the greatest security. Those which tended to roam into other areas would soon be destroyed, and only the individuals which kept to those places that they resembled would ultimately survive. The *Gnophus* alights on the limestone, but it knows not why. On most occasions it closely resembles the rock on which it rests, but the moth does not understand this; indeed I have watched it settle on a patch of dark shale and on an iron-stained slab of limestone where it was really conspicuous, but at the same time perfectly content.

It knew nothing of its colours and was quite satisfied when it settled on a stone. Similarly have I seen a *Boarmia* alight on a portion of a tree where the inner wood had been exposed by the woodcutters ; but the moth did not appreciate the fact that its dark wings were highly conspicuous against the white and splintered wood; its instinct was to alight on wood; it had satisfied that instinct and seemed contented with its choice. These moths know nothing of their wonderful protective scheme. Instinct tells one that it must spread itself against a stone, another that it must seek the trunk of a tree, but as to why it should do so it knows no more than why it unfolds itself from a grub.

Protective coloration is developed to a much higher degree in moths than in butterflies ; and the reason of this is very obvious to any one who has taken much notice of their habits. Butterflies are seldom attacked by birds, while moths form a tasty morsel. If moths moved about by day in the same way as butterflies we should see them being continually devoured by a host of insectivorous enemies. It is only when they are occasionally disturbed that birds have an opportunity of darting on them in the air, and we seldom see those occasions when they are sought out and captured on the bark of the trees. I have records of warblers, robins, chats, flycatchers and woodpeckers from time to time devouring moths, and I have no doubt that they are far more persistently preyed on than the conspicuous but nauseous butterflies.

Butterflies have few enemies, probably in consequence of their being distasteful to insectivorous animals. During seven years' observation in the East I have witnessed an attack of birds on butterflies only in the case of three species. I have seen the large bee-eater, *Merops persicus*, hawk systematically and with destructive effect amongst numbers of the painted lady. I have already mentioned an attack made by a bulbul on a *Libythea*, but this butterfly is protectively coloured and looks very like a moth. The third instance was on the part of the paradise flycatcher, though this bird did not seem to be very eager, since it failed to secure its prey. I have no doubt about the fact that only on rare occasions do butterflies fall a victim to birds. Nevertheless, they show an instinctive fear of the few species that attack them. The *Libythea* hurls itself to the ground and there shams death; the painted ladies are thrown into wild confusion before the assault of a flock of bee-eaters. When the bird dashes on the butterfly, the latter recognizes its danger and swerves to one side. It then darts to the ground in a zigzag course, while the bird falls on it and often misses it again and again. I have seen four bee-eaters in succession fail to capture a butterfly that was fully aware of its danger.

Any one who has seen birds hiding in the trees or scattering away for shelter in the undergrowth when a hawk appears in the vicinity; any one who has watched worms emerge from the earth before the advance of a hidden mole, will feel satisfied that animals have an instinctive fear of their enemies. This is a fact in nature. It might have been thought an obvious truth that could be seen in operation on every side throughout the endless battle of life. But instances are not so very common. I think most creatures meet their end oblivious of the dangers that confront them.

It is not unusual in India to see young chickens hurry away for shelter at the sound of the angry caw of a crow. Doves will most savagely attack crows; drongos will throw themselves ferociously on kites when they approach unpleasantly close to the nests. I will mention some less general instances. On a large shallow lake I watched flocks of coots dash hurriedly from the shore into the water whenever a marsh harrier came sailing overhead. The appearance of the harrier filled them with intense alarm; they all broke into wild commotion, made headlong for the water, which resounded with the splashing and the flapping of their wings. They fully understood that the harrier could swoop on them while on the land, but that they were in safety on the water. I have seen fishes in a river dash from the shallows into the deeper parts whenever a pied kingfisher happened to hover above them. In the rainy season the frogs of this valley were in the habit of congregating along the banks of the streams close to the brink of the water. Whenever a kingfisher or a heron would fly gently down the stream, then all the frogs used to spring headlong into the water and dive down into the mud. Nothing filled these frogs with such alarm as the sight of an approaching heron.

Thus many creatures recognize their enemies and understand the dangers that they run; but to others the end is swift and sudden and they know not how it comes.

In the months of July and August the shrill noise of the *Cicada* rings loudly through the forest. The rainy season has then set in and vegetable life on every side springs into luxuriant growth. Fresh green grass covers every wooded slope; on the alpine pastures flowers of most vivid hue appear; every bank is carpeted with soft moss and from every nook the varied ferns hang down their graceful fronds. Thick clouds collect about the dripping trees and spread over hill and valley in their strange inconstant shapes. It is often a remarkable sight to look down from a mountain ridge on to the fleecy clouds that congregate below. We watch a thick mass of cumulus as it surges up the valley. It strikes against an opposing ridge and, like a sea breaking on the rocks, it pours down over the mountain side. Here the ascending currents of hot air oppose it; they drive it again to the higher elevations; they roll it back upon the ridge. The visible vapour again pours down. Conflict follows upon conflict; the broken cumuli form and reform, scatter again over the sky, separate into ragged fragments of thin dissipating wisps. In varied forms they float about the valley, now thickening, now condensing, and always in a state of evanescent change. Sometimes they obscure the hillside in a thin veil of translucent mist; at other times they envelop it in a dense white mass that hides every feature from our view. Then, again, they may burst like a tempest on the cliffs or ascend through the air in a pillar of vapour like the smoke from a forest fire.

At such a time as this the *Cicada* is heard on every side. Its shrill vibrating note resounds through the moist woods. At times all is silent; then a single sound rings out from a point high up upon a tree; a second soon adds to the music; a host of others then join the chorus, until the whole forest trembles with the noise.

The cicadas belong to the Homoptera, a suborder of the bugs. The species common in the Hazara district was *Oncotympana obnubila.* Farther to the east in the Kangra valley was a second species of very similar appearance, *Platylomia brevis.* It was the latter species that I more carefully examined, but the following account of the musical apparatus is, I think, applicable to both. These cicadas are stoutly built insects about two inches in length. They are of a dark brown colour with a number of green markings, and support on either side a pair of beautiful transparent wings. The cicadas spend the day clinging motionless to the trunks of the trees. Their colours are a distinct advantage to them in this habitat, since they blend so closely with the bark that the insects are with difficulty seen. On sunny days they become a little restless, and in the open glades may be seen to take swift sallies into the air. They are widely distributed in altitude and may be heard at all elevations, from the low-lying valleys up to a height of 10,000 feet. An occasional insect may be heard at any hour of the day, but it is at sunset or when the sky is darkened with impending rain that the woods vibrate most loudly with their shrill importunate cry.

I will pass immediately to the musical organs of the cicada, and, since I have not been able to understand clearly the mechanism of the instrument from the descriptions that I have seen in works of natural history, I will here describe in a little detail how it seems to me that the music is produced.

I must first enter on a few simple anatomical facts. I will mention five structures, each of which is in some way related to the production of the sound.

A simple inspection of the under surface of a cicada will reveal the presence of a pair of flat plates, each about three-quarters of an inch in length, that cover the anterior half of the under surface of the abdomen. These plates are known as the opercula. They are in reality prolongations backward of the hind segment of the thorax; they lie one on either side of the middle line and are separated from the abdomen by a deep narrow fissure. Hidden away within the base of either operculum and stretched tightly across a hole in the side of the first abdominal segment is a tense white mem-

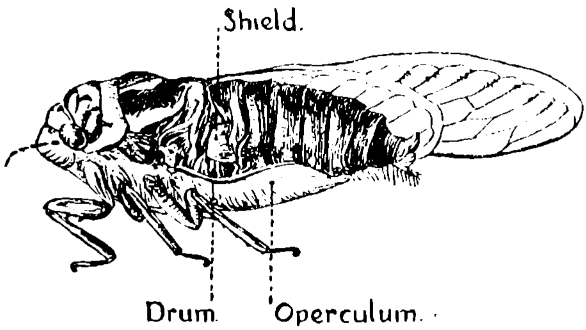


FIG. 7.—Cicada (*Platylomia brevis*).
Wings on near side removed to show position of musical organs.

brane, a structure of great importance in the production of the sound. This is the tympanum or drum. In appearance it reminds one somewhat of the organ with a similar name in the structure of the human ear. Immediately above and overhanging the drum is a curved plate that projects down from the first abdominal segment. This is obviously designed to protect the drum, and may be called the shield. These organs can be seen by a simple inspection (Fig. 7). The remaining two can be in a moment exposed. If with scissors a small window is made in the under surface of the abdomen of the cicada, it will be seen that the greater part of the abdomen is nothing but a large air cavity and that all the essential organs are compressed into a narrow band above. This air cavity may be called the abdominal sac. We look forward into this vacant sac. In front we see a pair of stout white rectangular muscles that meet below in the middle line and diverge as they ascend to be finally attached to the posterior margin of the drum.

These are the five organs to which I wish to direct attention: (1) the opercula, (2) the drum, (3) the shields, (4) the air-sacs, and (5) the muscles.

In order to understand the mechanism of these different organs it is necessary to examine the cicada while in the act of emitting its sound. I find the insect at sunset singing on the trees. When captured, it immediately ceases, but I squeeze its thorax and it again gives forth its note. With a pair of sharp scissors I snip off the opercula; the sound continues; the opercula therefore are not essential to the production of the noise. I amputate the shields. The music still continues; so we reach a similar conclusion here. I decapitate the insect. Even then the sound may reappear; the mechanism is therefore reflex; it is not in necessary subjection to the brain. I seek another specimen. It is playing loudly on a tree. Its abdomen is seen to distend and collapse in accordance with the increase and diminution of the pitch. While the note is low the body is more flaccid, but with a rising pitch the abdomen swells into a tense transparent globe. It would seem as though the abdominal sac was therefore an essential organ for the production of the sound. Let us see. I catch the insect and make a little window into its abdomen so as to open freely into the sac. There can be no air pressure now. The air will escape through the artificial hole. Yet the sound continues. The air pressure within the sac is therefore not the essential cause.

The only organs now left for investigation are the muscle and the drum.

It is simple to experiment on these. I remove both drums and the insect remains permanently silent. I divide both muscles; the result is the same. The cicada cannot utter another note. I take the divided muscle in a forceps and gently pull it and vibrate it. Even these clumsy efforts may generate a faint note. The conclusion is clear. The muscles throw the drums into vibration, and the vibrating drums originate the note.

The matter must be considered a little further. A simple membrane thrown into vibration by a muscle could not produce this powerful sound unless there was something particular about its structure. Let us consider it in a little detail. The drum is a somewhat pear-shaped membrane about five-sixteenths of an inch in its longest and three-sixteenths of an inch in its shortest diameters. It has a pearly white appearance and is crossed by a series of brown parallel bands. Its mechanism is, I think, more easily understood if the drum is considered as consisting of two parts. First, there is the part of the drum which bears the ridges. It comprises the anterior half of the organ. The membrane is here soft and delicate. It is crossed transversely by five chitinous bars. The first of these bars is undeveloped and imperfect; the second is more complete; the remaining three are firm and strong and each is thickened in the centre so as to form a stout oval knob. Such is the ridged area of the drum.

The second part is the area which bears the tooth. It comprises the posterior half of the organ. It is composed of a hard elongated plate prolonged above into a distinct tooth that fits into a recess immediately beneath the knob on the last bar. The diagram (Fig. 8) ought to make clear the relationship of these two essential parts, the thickened ridges and the tooth.

Now for the attachment of the muscle. When this is traced to its termination it is seen to end in a smooth

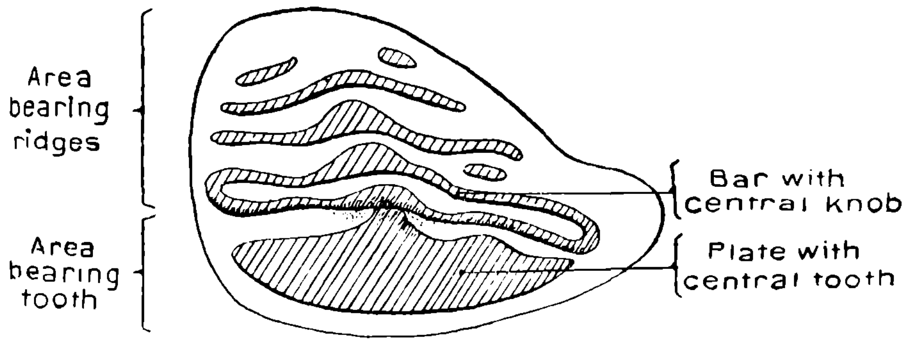


FIG. 8.—Drum of Cicada.

plate. A flat tendon then connects this plate to the posterior margin of that portion of the drum which bears the pointed tooth (Fig. 9). The muscle therefore acts upon the drum and at each contraction pulls upon the tooth. A rapid succession of muscular contractions thus throws the tooth into a quick vibration. At each movement the tooth strikes against the thickened bar and a single sound is thus produced. Backwards and forwards moves the tooth. The bar is thrown into a quick vibration and this originates the noise.

There are left the other parts, the abdominal cavity, the operculum, the shield.

The function of the abdominal sac is to control the volume of the note. The cavity is in direct communication with the inner surface of each drum. When the tension of the enclosed air increases then an additional pressure is thrown upon the membrane; the bars are more tightly stretched, and therefore, as in the case of a violin string, they give rise to a more powerful note.

The function of the opercula is obscure. They lie so close upon the abdomen that they force the sound

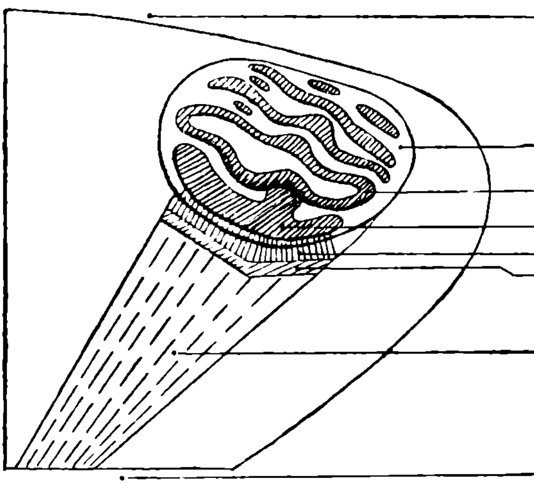


FIG. 9.—Diagram to show essential parts of musical organ of Cicada.

to issue through a narrow slit, and this probably increases the intensity of the note. It may also be possible that the opercula serve to direct the sound in a special direction suitable to the purpose of the insect. Nevertheless, these suggestions do not seem to me sufficient to explain the function of such large and conspicuous organs as the opercula.

The shields are merely what their name implies: they simply protect the fragile drums.

Such is the musical organ of the cicada, a perfect mechanism of delicacy and power. It has no parallel in the insect world; its sound has no equal but that of a steam whistle. Its component parts are those of a musical instrument. The pale membrane is the supporting structure; the bars are the vibrating strings; the muscle is the motive power and the tooth is the pointed finger that sounds the long refrain. The whole mechanism is a wonderful example of beauty, simplicity, and strength. It is the most perfect and exquisite contrivance of its kind that I have ever been privileged to see.

CHAPTER XII

GLOW-WORMS, TERMITES AND SHELLS

Habits and luminosity of glow-worms—Their contests with snails—Flight and destruction of termites—Instincts associated with their distribution and preservation—Shedding of wings—Habits of ant-lions—Notes on the dispersal of shells.

An insect common in the hills is the glow-worm, *Lampyris*. They usually frequent the low-lying marshy portions of the valley, but I have found them glowing actively in the cold nights at an altitude of 8000 feet. The female, as is well known, looks like a large conspicuous larva, while the male is small, active and winged. The glow-worms here reached a length of two and a half inches and shone with a very brilliant light. The banks of the irrigation channels, the edges of the rice fields, or the moist ground beneath a garden hedge were the spots where they were most likely to be found. The *Lampyris* lies quiet by day, motionless and showing no light. In the evening it grows restless; its lamp begins to burn and it crawls off in search of prey. In addition to its legs, its power of propulsion is greatly aided by the last abdominal segment. This is sometimes used as a lever to push forward the body. It may also act as a hook to support the glow-worm when climbing. From the extremity of this segment the *Lampyris* can protrude a tuft of slender filaments each terminating in a delicate sucker. These suckers are a further aid to progression, since by means of them the glow-worm can obtain a very firm hold. The insects also use these suckers for the purpose of cleaning their bodies. They feed on snails, and the mucus of the prey often smothers their bodies in slime. The glow-worms remove this by flexing their bodies and turning forward the tip of the abdomen so as to be able to brush away the mucus with their tuft of suckers.

The large females shine with a very brilliant light. On the under surface of the eighth abdominal segment are two smooth white patches, oval in shape, one on either side of the segment. At night these patches emit a beautiful green light, of a penetrating nature, and resembling in colour the brilliant phosphorescence of the ocean. The light is fixed and steady; it does not pulsate in the same rhythmical manner as in the firefly. The glow-worm shows a continuous gleam: the firefly is a twinkling star. Owing to the luminous patches being directed downwards, the lights are largely hidden from above. The portion of the ground on which the rays fall is a transverse patch, since the light spreads out on either side of the abdomen. One large female illuminated an area of newspaper one inch in length with sufficient intensity to enable me to read the print. None of the rays extend to the head of the insect, so that the light can be of no assistance in the finding of food. Nor can it be thought that a light, so concealed beneath the abdomen that most of its rays are hidden, could be of much use for one insect to attract another. I do not think a glow-worm is capable even of perceiving a light. At all events, one, which I kept apart for twenty-four hours, did not seem to take any notice of a brilliantly glowing female which I held close to it. Indeed, they seem to be almost destitute of any special sense. I have seen them pass and repass within half an inch of their prey quite oblivious of its presence, and then, after running accidentally against it, commence their fierce attack. Glow-worms are active throughout the whole night, not continuously, but at intervals. An hour before dawn I have seen them shining in the damp fields, and some, which I kept in a box, were brilliantly phosphorescent when the first rays of light were appearing in the sky.

The glow-worm is provident of its light. By day it is usually extinguished; at night its intensity seems to depend on different causes. It is not the dark that stimulates luminosity, for I watched glow-worms kept in a dark box throughout the day and they showed not the trace of a glow. There seems to be a relation between general bodily activity and luminosity. An energetic glow-worm is usually the most brilliant. By day the insects are motionless, but I once saw one of a group distinctly active in the daylight and it showed a clear glow. Mechanical stimulation induces luminosity. If a glow-worm is stroked on the dorsal surface it often displays its light. I severed one transversely a short distance behind the head and the phosphorescence continued for two minutes after decapitation, but the muscular contractions of the limbs and abdomen still remained and were quite active one and a quarter hours later. The light of the glow-worm does not burst suddenly into full flare as in the case of the firefly. It appears gradually and comes slowly to a maximum. Its disappearance is even more gradual, fading imperceptibly away. Fireflies are replete with energy; glow-worms stolid but inert; so it is with their luminary organs; the one pulsates with active flashes, the other burns with a steady glow. The two luminous areas usually shine together, each with the same intensity. This, however, is not essential. I once watched a glow-worm in which the patch on the right side was glowing, while that on the left showed not a trace of light. A faint gleam soon began to appear in the non-luminous area which, gradually increasing, at length equalled the brilliancy of the right. Thus it would seem that the nervous stimulus which controls the light may have either a unilateral or bilateral action.

Moisture has a powerful influence in exciting luminosity. Glow-worms are most active and usually congregate in damp places. After a shower of rain or when a heavy dew covers the ground their phosphorescence is more intense. I kept some glow-worms away from moisture for twenty-four hours. I then touched the luminous areas with a drop of water on a fine brush and the luminosity increased. Even by day, when the insects are inactive, the lights will often shine under the stimulus of a drop of water, and within a minute of coming in contact with the moisture, they often glow with the same brilliancy as at night. If the insect is then placed on a piece of blotting-paper to remove the moisture, the luminosity will disappear. Of seven glow-worms that I kept in a tin box, I noticed that only two were feebly shining on a clear dry evening. I allowed some water to drop gently amongst them so as to resemble the falling of rain, and as each glow-worm felt a drop of the fluid, it immediately became more active, began to show its light, until in a short time all were glowing brightly and creeping in every direction over the floor of the box. Also when I placed a box of glow-worms in a shower of rain many of them became phosphorescent even before sundown. It is not essential to moisten the luminary organs, for a drop of moisture on the head of the insect produces a similar effect. The fluid has therefore a reflex action. The moisture increases the muscular activity of the glow-worm, so that it might be thought to excite luminosity in the same way as gently stroking the insect's back. But this is not so. Irritating the glow-worm by blowing at it or stroking it never produces the same intensity of glow as does the presence of a drop of moisture. Contact with moisture has a special power in developing the luminosity of these insects. It is not alone water that excites the light. A drop of spirit has a similar effect, and none shine more vividly than those which are enveloped in the moist and viscid mucus thrust over them by snails. Moisture of any kind is the chief stimulus to luminous activity.

At night it is not the influence of darkness that calls forth the light, but rather the profuse dew that covers all the ground. The insects which I kept in absolute darkness by day showed no light. Nor is it the case that the advent of darkness coincides with the appearance of the glow-worm's light. Luminosity does not appear until an hour or more after sundown, when the earth has sufficiently cooled to permit the deposit of a layer of dew. In all likelihood the luminous activity of the glow-worm is under a rhythmical sway, appearing by night and disappearing by day through the regular pulsations of an internal nervous mechanism. But this mechanism is dependent in part on external stimuli of which one of the chief is moisture and one of the least important is the absence of light.

Phosphorescent animals in general live in close association with moisture. The luminous inhabitants of the sea exemplify this. Not only many of the species that live at great depths, but the little globular *Noctiluca* that stain the surface of the ocean with patches of rusty red, are brilliantly phosphorescent. The glow of the *Noctiluca* resembles that of the *Lampyris*, the light being a similar shade of green. It is specially attractive on a summer night in the Persian Gulf. The surface of the ocean gleams with light. Each little ripple is an evanescent glowing gem, one amongst millions in the quivering sea. From the bows of a ship two curling waves diverge, displaying first their gleaming crests, and then, spreading into a sheet of foam, they shine like burnished silver. Porpoises roll in rivers of light, and flying-fish, in glistening streaks, flash through the dark sky. The phosphorescence of animals is as beautiful as its origin and object is unknown.

Glow-worms have long been known to feed on snails. I witnessed the attack of a large glow-worm on its prey. The snail was crawling over the ground, and the *Lampyris*, coming up behind it, climbed on to the shell and remained seated on the summit while the snail moved onwards. The glow-worm then gradually altered its seat on the snail's back; it methodically worked itself into a position suitable for attack until its head projected forward over the anterior edge of the shell. The beetle was now firmly fixed. By means of its hind suckers it had a secure hold on the shell, and its head overhung the soft body of the snail in readiness to strike. Suddenly, and with much greater rapidity than might be expected from so sluggish an insect, the *Lampyris* plunged its head beneath the front margin of the shell. Immediately the snail withdrew its head into the shelter, but the retreat was too late. The glow-worm's mandibles were already fixed. The snail struggled. Large drops of viscid mucus oozed out from beneath its shell, but this did not affect the glow-worm. The snail squirmed from side to side, now rolled its body to the right, now to the left in the struggle to throw off its enemy. Its efforts were of no avail. Deeper and deeper sunk the head of the *Lampyris* into the soft tissues of its prey. The victim was doomed. There was no escape from such an attack as this. The snail writhed in agony; every muscle was convulsed; the whole body swayed in violent contortions; the thick fleshy foot was twisted into a rigid corkscrew, then untwisted, then again rescrewed, then curled up in the vain effort to sweep its enemy off the shell. Every gland poured out its mucus until enemy and victim were both enveloped in the same slime. But the glow-worm still clung on, persisting in its fierce attack. Its mandibles were now deeply buried. It seemed to be striking at the very vitals of its prey. Its luminous powers shared its muscular efforts, for it glowed with an intense light. Its hold on the shell was firm. Its suckers had a secure grip. No bodily contortion could unseat it. And its place on the very summit of the shell was so well chosen that, no matter how the snail twisted itself to the right or to the left, it could never crush its adversary between its shell and the ground.

After about ten minutes the snail had clearly given up the struggle. Its efforts slowly died away. In eight minutes more it was quiescent, and the glow-worm withdrew its head, now covered in a dense mass of snail-flesh and slime. It then commenced to clean away the mucus from its head and limbs, and this being complete, it again returned to its victim. Slowly it mounted to its previous seat on the shell, and burying its head in the under surface of the snail's foot, it began to devour the dying flesh. The brilliant light now subsided to its normal glow, as though to mark the end of this little tragedy of nature. Hour after hour the *Lampyris* clung to its vanquished prey, and not till fourteen hours had elapsed did it cease to feed on the flesh which by then was decomposed and putrid.

Who would think that these pretty glow-worms would join in so intense a battle? The face of Nature may deceive us, we see so much apparent peace. The birds, the butterflies, the fishes of the sea, all the brilliant tints and joyous notes seem to bear witness to a life of happiness and concord. Yet how false is such a picture. All is war and carnage; greed and cruelty are the ruthless weapons with which Nature fights, and every living creature must be a victor or a victim in the battle. Would that we could believe that the little glow-worms, apparently so innocent and gentle, were beautiful merely to be beautiful, and glittered with a bright green starlight merely to illuminate the world around. But they play a sterner part. They occupy a rough place in life's struggle. They wage a cruel and relentless war.

I pass now to another of these contests in which life is pitted against life. The termites, or white ants, were not very common at the altitude of this valley, but they were sufficient to indicate how great is the destruction of certain species at some special moment of their lives. At the time of the emergence of the sexual forms of the termites another drama is opened to our view.

A seething mass of insect life swarms about the aperture of the nest. The workers have broken through the galleries; they have excavated apertures in the sides of their tunnels through which the winged forms can easily emerge. Out they come in a dense throng. They squeeze themselves through the newly opened doors; others follow in thousands; a few push their way back into the tunnels, but the main body, after crawling for a few minutes about the opening, scramble up the stems of the bushes or the blades of grass and then take wing into the air. The soldiers and the ordinary workers remain busy about the apertures. They are filled with activity and energy. They seem to realize the importance of the event. The soldiers resent the slightest intrusion or interference. They are ferocious to a degree. If touched, they make an immediate attack. They drive their sharp curved fangs into the skin and exude a milky irritating juice.

Let us follow the winged forms into the air. Their journey is a short one. The sharp eye of an insectivorous bird soon detects them and they are instantly devoured. Other termites rapidly follow, but their enemies have found them out. Birds great and small come flocking to the scene; little chats and bulbuls vie with hawks and pariah kites in the work of carnage. All nature appears set on their destruction. Round about the nest the crows and mynas congregate in hundreds, devouring the living morsels as they emerge into the light. Those that succeed in escaping into the air are seized by drongos, shrikes or bulbuls that dart out from every tree. Swifts and swallows meet them at higher altitudes, and kestrels swoop down on them from above.

I sat down beside a nest and watched the ants emerge to take wing upon their fatal voyage. Thousands of hungry birds were cackling and chattering in an angry tumult or were darting and swooping through the air. I carefully noted the fate of fifty consecutive termites as they embarked into the sky, but not one of them succeeded in travelling thirty feet before it was devoured. On all sides could be heard the incessant snapping of beaks and the rustling of feathers. I could not see a single insect escape. Not only were the insectivorous birds devouring them, but the house-crows and jungle-crows were snapping them on the wing, pariah kites, both with feet and beak, were seizing them in the air, and at one moment no less than six kestrels were hovering over them or swooping on them from above. A filthy scavenger-vulture was swallowing them greedily from off the ground, and those which I protected at the mouth of the nest were being attacked by a host of carnivorous ants, to be dragged again beneath the soil. Nor is the emergence of the termites a mere event of the passing hour. Its memory still lasts, for two days later the jungle-crows were still congregated around the nest as though in anticipation of a further feast.

I know of no other living creature that has such an array of enemies or that loses such thousands that one may live. At this one nest I counted sixteen different species of birds all joining in the common feast. On the shrubs around were sparrows, shrikes, buntings, mynas, drongos, bush-chats and three species of bulbuls. Higher in the sky were swallows and swifts, and the larger birds were represented by house-crows, jungle-crows, kites, kestrels and vultures. I would never have thought that buntings would have forsaken the seeds of the fields or scavenger-vultures their foul refuse to feed on insects, and on another occasion I have seen both owls and seagulls capturing them in the air. When the termites emerge all flock to the feast; the old accustomed food is forgotten; all aid in the work of destruction.

I do not believe that in the broad daylight a single inhabitant of this nest would ever have escaped its enemies. It was the darkness of night that saved them. They then face bats, reptiles and other insectivorous foes, but the shrieking multitude of the day, gorged to repletion, has slunk away to roost. The termites have now a chance of life. In the fading light of the evening I saw numbers of them hovering over the grass in my garden after their enemies had retired for the night. They had escaped in safety from the nest, were descending to the earth after their precarious flight, and alighting, were casting off their now useless wings.

There are a few points worth notice in this sexual flight of the termites. It is interesting to observe in connection with the preservation of the species that the flight from the nest usually occurs a few hours before sunset. In this valley the termites were not numerous. I saw only four flights in the one season, yet all these flights took place an hour or two before dark. I have never seen a flight at any other time. So long as the daylight lasts the termites undergo a merciless destruction ; but as the darkness increases, many of them escape to found new colonies elsewhere. If the complete flight of all termites was to take place in the full daylight, the species would, I believe, in a few years become extinct.

Another fact which must be of some importance to the survival of the swarm is that the termites in their nuptial flight ascend to comparatively great heights. They soon pass beyond human vision ; but, from the way the swifts and kites can be seen hawking after them in the air, it is clear that many must reach an altitude of at least a thousand feet. This instinct which impels the termites to considerable elevations must be a distinct aid to the survival of the species. In the first place, the insects are liable to meet with high aerial currents which will waft them over long distances and in this way increase their area of distribution. But a greater advantage must rest in the fact that those individuals which reach a considerable height will leave behind them a host of enemies, and will therefore be the more likely to survive. No doubt they meet swallows, swifts, kestrels, kites, at all elevations, but they have escaped the far greater multitude of insectivorous creatures that would decimate them near the ground.

Towards the termination of the flight the termites seem to undergo a natural exhaustion. They descend vertically from the higher elevations as though they had no longer sufficient strength to propel them further through the air. They fall upon the grass and bushes, then climb out upon the twigs, the leaves, the stones, where they begin forcibly to vibrate their wings.

Another point to be noted in the nuptial flight is the fact that the termites seem to possess a definite sense of direction. Indeed, from the way they are often seen to move all in the same course, it might almost be said that their flight was in a sense a migration of the swarm. The insects, when they first escape from the nest, seem somewhat confused. They are lost amidst the entanglement of trees and jungle and they flutter aimlessly about. But their instinct is to ascend. Soon they clear the trees, and then it is obvious that all the termites are pursuing the same predestined course. They are free from obstruction in the clear air, and then all move in the same direction and in one uniform flow. It is difficult not to believe that all are guided by some special sense to move in a common line.

It has often struck me as a remarkable fact that many colonies of termites scattered over a wide area will often give forth their sexual forms all at the same time. I recall the first flight of the season. Many nests, perhaps thirty or forty in number, distributed over an area of about five square miles and through a zone of altitude of 600 feet, were all in eruption at the very selfsame hour. There was no connection between these nests, yet all burst into activity as though it was a single swarm. What force is it that can so influence these termites as to cause a number of widely separated nests to send forth their sexual forms at the same moment of the same day?

There seemed to be nothing peculiar in the conditions of the atmosphere. Clouds hung about the hills, and there was a sensation of impending rain. But this is scarcely sufficient to account for such a uniform effect. Whatever may be the original cause of the phenomenon, I think there can be little doubt that it is of real value to the propagation of the species. No one has shown with greater force than Darwin how dangerous are the effects of close interbreeding and how marked is the improvement in both vigour and fertility that follows on the union of different strains. This, I think, must be the object that Nature has in view. It secures the special benefits of fertilization that follow on the union between different nests. For this reason all emerge at the same time and intermingle in one common stream. We can seldom understand how Nature works; we can only wonder at the results that she attains.

The shedding of the wings is an extraordinary phenomenon. It takes place so suddenly, all four wings at the same moment, that it looks as if it were a premeditated and voluntary act on the part of the insect. I do not think that this is the case, for if the insect is decapitated and the brain thus removed, the wings will still fall off. Nor is the flight through the air or the vigorous vibration and flapping of the wings which the insect makes after alighting in any way necessary, for I find that, if an insect is captured before flight and confined beneath a watch-glass where it can scarcely move, the wings will still come away. The act is hastened by any sudden stimulus. Decapitation, puncturing the thorax, even mere handling of the insect, may cause the wings to be cast off.

After the wings have fallen the insects then hide themselves beneath the stones or make their way into the crevices in the ground. They commence to dig but make only slow progress. By the following morning many are still so near the surface that they are unearthed by the hungry crows. I do not know at what moment sexual union actually occurs. Any one who has watched a flight of termites will have noticed how, after the wings have fallen, the insects do not wander indiscriminately about, but rather separate themselves into distinct pairs. The ground is often covered with these segregated couples, yet actual union is never seen. I am inclined to think that the object of the termites in separating into sexual pairs is not, as might at first be imagined, to secure immediate union. It is rather a device to make certain that each new nest which is established should contain a productive pair. The loss of life amongst the termites is so severe that certain special provisions must be made to help the survival of the race. This is one of these provisions: that whenever the time of union comes, the sexes may be found distributed through the ground in suitable sexual pairs.

I pass to another neuropterous insect. Loose sandy patches, often on the summit of a low, rounded hill, might be found occupied by a colony of Myrmeleonid larvæ. These ant-lions are well known, especially the pits that they excavate in the sand to capture their prey. The hilly country was unsuited to their work, and I never saw them above 5000 feet.

The larvæ are very small, not more than one-quarter of an inch in length. Each possesses a stout oval abdomen and a small head furnished with strong curved jaws. The larva lives at the bottom of a conical pit, and whenever there existed a smooth sandy area suitable for the construction of the pits, there a number of the larvæ would congregate together in little communities of ten to twenty individuals, though each pit never contained more than one larva. The pits are from half to one inch in depth. A casual glance into the pit reveals nothing, but after careful observation with the eye close to the mouth of the pit, a pair of tiny jaws can be detected projecting like pin-points from the sand. The whole body of the larva is concealed; only the tips of the open jaws appear in the pit. Small insects, especially ants, are continually falling into these pits. When crawling leisurely over the surface they usually appreciate their danger when on the brink of the precipice; but if in the slightest degree alarmed, they stumble over the edge, fall into the trap, and are seized in a pair of powerful jaws. The ant struggles to escape; it tries to scramble up the sloping side of the abyss while the ant-lion firmly clings to it below. It strives to drag itself from this grasp, but only tears down the soft crumbling sand which engulfs it still more firmly in the pit. Should it break away from the cruel jaws, the ant-lion throws up in the air little spouts of sand, and these in their fall sweep the victim back. At length it is drawn deeper into the snare by the traction of those powerful jaws, and is buried in the debris that it has pulled down upon its own head. Thus engulfed, escape is no longer possible; the ant-lion at leisure devours the juices of the insect's body, casts the empty shell out of the pit and lies in wait for a fresh victim.

Ant-lions are cannibals. I took a larva from one pit and placed it in another pit. The owner resented the intrusion and treated the stranger with the same severity that it metes out to any other insect.

I observed on more than one occasion that, after an ant had succeeded in escaping from the pit, it moved about with the greatest circumspection, studying every step for fear it might fall into a similar trap. The ant had apparently benefited by its rough experience; its mind had proved susceptible to a simple education which is the most certain test of animal intelligence.

The mode of construction of the pit is ingenious. The larva commences by crawling backwards and using the point of its abdomen as a shovel, by means of which it digs its way under the surface of the sand. After disappearing from view it moves round so as to make a circular furrow beneath the soil. This circle is the aperture of the pit. From within the circle it then commences to cast out the sand and thus deepen the depression. The sides slope gradually downwards to the bottom of the pit where the ant-lion lies buried. After the trap is fully constructed, little particles of sand are continually falling down the crumbling sides, but are immediately thrown out by the occupant. As well as I could observe, the larva fixes its stout abdomen in the sand, and, using this as a point of fixation, it jerks the head and jaws suddenly upwards and pitches out at each thrust a little cloud of sand.

The strength of the creature must be prodigious in proportion to its bulk. I have seen it hurling clear out of the bottom of the pit small pebbles ten to twenty times its own weight. It works very intermittently, a long pause being made after a few violent exertions. This must be a necessary division of rest and labour in a creature that employs such sudden and impetuous efforts. Should a stone, which is beyond the strength of the larva to remove, tumble into the pit, it burrows a little to one side until clear of the obstruction, then commences to hurl up sand, and thus constructs a fresh dwelling-place by shifting laterally the bottom of the pit.

On a still day the ant-lion patiently waits in the floor of its funnel till the unwary ant tumbles in. But in windy weather the larva leads a more strenuous life. The force of the wind continually levels the surface of the sand; every depression in the ground is to some degree lessened and the pit of the ant-lion tends to be filled in. Grains of sand pour down the sides of the pit; it would soon be flush with the surface did not the ant-lion make every effort to contest the downpour. It hurls out the sand as fast as it rolls in; in circles it revolves round and round the bottom of its cone, pitching out the sand that would engulf it. Every day of wind is for this larva a day of continuous toil.

Though ant-lions are almost always seen waiting in the bottom of their pits, yet they sometimes wander about on the surface of the sand. A number seem to move about at the same time, leaving in their tracks lines of sinuous furrows as though a crowd of tiny snakes had been creeping through the dust.

I will now mention a few observations on the freshwater shells of the valley. The dispersal of shells is a subject which has excited the interest of our greatest naturalists, and many interesting methods have been discovered by means of which the various species increase their geographical range.

In this district man, by his mode of cultivation, seems to be the most important agent in effecting the dispersal of shells both of the land and the fresh water. On the broad fields in the beds of the valleys and on the narrow tiers of terraces rising up the slopes of the mountains the cultivator sows his crops of rice. Rice fields need an abundance of water; in fact the crop, in order to thrive, must stand in a watery swamp. To effect this the cultivator diverts the water from the mountain streams and carries it in channels over the land. From the main channel smaller water-courses conduct the fluid to the cultivated area, and still smaller channels connect field with field. Thus vast expanses of land are fed with the water from one stream, and, by means of channels, all the fields of that large area are in intercommunication one with the other. Each field is swarming with molluscs, chiefly *Limnæa*, *Planorbis* and bivalves, and, as the water flows from field to field, many of the smaller shells must be swept along with it. The molluscs also crawl on to twigs or adhere to the under surface of floating leaves, and are thus drifted along the channels from field to field. I think numbers must be floated away on leaves, for I collected many from a clump of herbage that had temporarily obstructed one of the channels.

No living agent is so powerful as man in influencing the course of organic nature. Here the husbandmen sow large areas of their land with rice, and to nourish it they conduct the water from the streams, lead it by intricate channels into innumerable smaller water-courses. The land-shells that cover that area will be moved onward by the advancing flow, and the water-shells that occupy the mountain streams will be spread over the now swampy land.

I will mention one other observation in connection with the dispersal of shells. Just below the summit of one of the forest-clad hills that confine the valley, and at an altitude of 8800 feet, I found a shallow muddy pool not more than twenty yards in width. A few other similar pools lay close by. The little patches of stagnant water were completely isolated on this mountain top which was bounded by deep valleys on either side. Now this pool was teeming with bivalve molluscs. I never saw so many bivalves together in any pool. But I could not find a single univalve.

The questions arise : How came this mountain pool to be stocked with shells, and why are there no univalves? I see no other way by which shells could have been carried to a pool at such a height except in the way suggested by Darwin, namely by clinging to the feet of water-birds and being thus transferred from pool to pool. It might be thought that water-birds would never visit a mountain summit, but I was told by the Rev. Mr. Lawrence, who had observed the birds on this hill for many years, that he had records of a teal and a green sandpiper alighting on these pools.

How are we to explain the presence of bivalves alone? Is it not possible that bivalves with their power of grasping objects between their shells would be more likely to cling firmly to the toes or feathers of birds and therefore be carried more securely than univalves? Birds have frequently been shot with cockles clinging to their bills. Bivalves have been found with their shells firmly closed on the legs or antennæ of water-beetles, or grasping the limbs of water-scorpions or the larvæ of dragon-flies and other inhabitants of fresh-water pools. There would seem to be little doubt that the habit which bivalves possess of lying with their shells apart and closing tightly on objects introduced between them would make them more liable to transportation than univalves, and give them a greater opportunity of being the first arrivals at a newly formed and distant pool. This appeared to me the probable explanation of why this isolated pool should have been stocked only with bivalves.

All creatures are dependent one on the other in the well-balanced scheme of life. One species is essential to another for food, to another for shelter, to another for the rearing of its young. Destroy any one species, and some other will surely suffer Even the life of the molluscs is interwoven with that of the higher animals in that they use the migration of the birds and the agricultural devices of man as an unconscious mode of transport to scatter them over the surface of the earth.

CHAPTER XIII

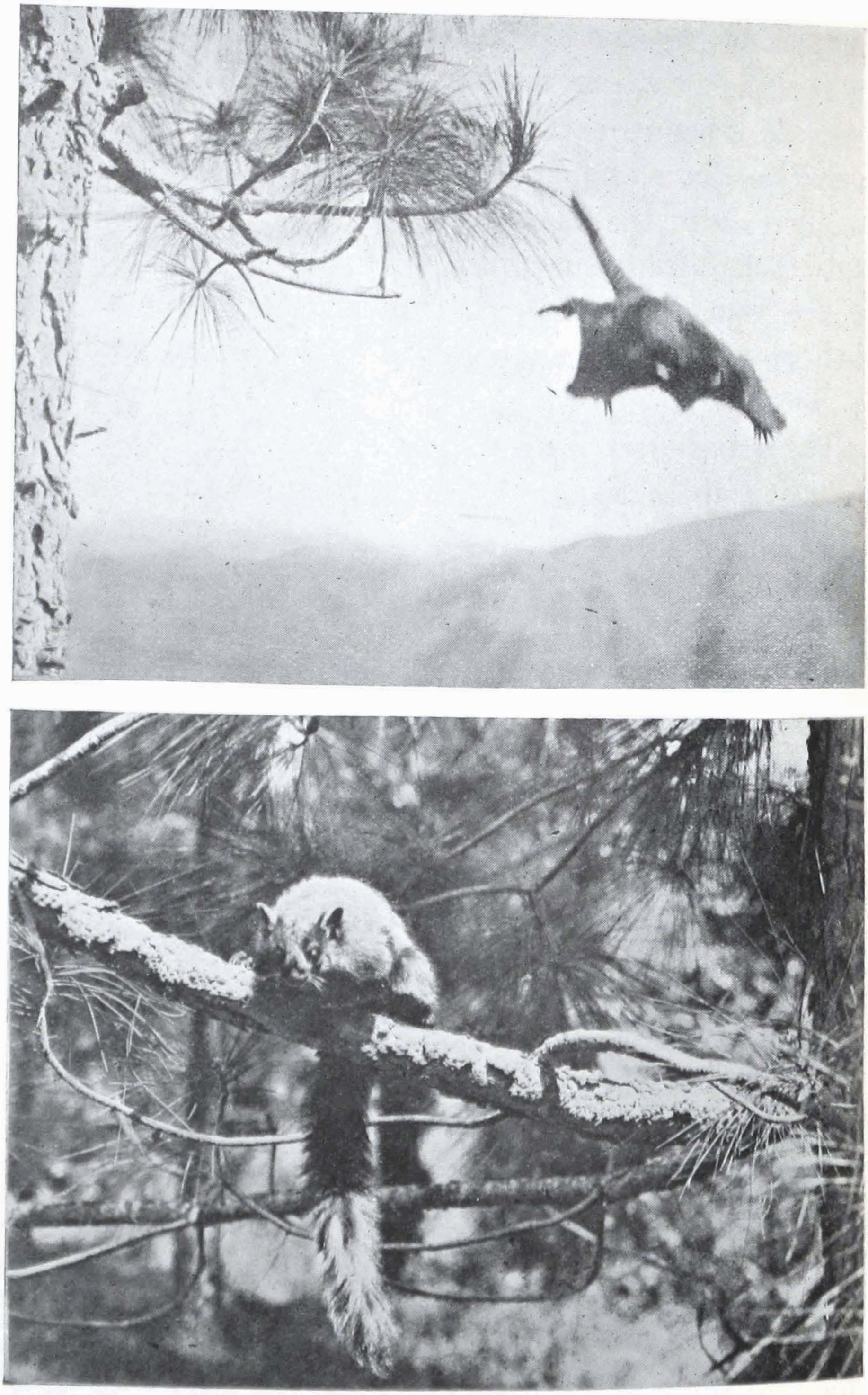
OBSERVATIONS ON MAMMALS

Comparative scarcity of mammals—Observations on flying squirrel—Habits and instincts of Himalayan monkeys—Emotional expression in the leopard—Contentment—Fear—Anger—Distress—Eagerness—Attention—Affection.

The mammals that frequent this valley attract but little attention, and I have few remarks to make upon them. In the forest their scarcity is remarkable. For days we may wander over the pine-clad hills yet only on rare occasions are any mammals seen. A troop of monkeys in the trees, a fox or a civet sneaking through the jungle, a marten disappearing behind a rock or a flying squirrel at dusk gliding from tree to tree, are amongst the few species we may hope to meet. At intervals the report is spread of a bear or leopard in the woods, but these larger mammals are seldom seen.

It is not in the thickest jungles but in the barren valleys of the Western Himalaya that we find the largest animals. The markhor and the ibex frequent the main Himalayan axis or the bleak ranges of the Karakoram and the Hindu-Kush; the great sheep of Marco Polo is confined to the treeless plateau of the Pamir. So it is when we look more widely over the globe. I have never seen the larger mammals collected in such multitudes as on the grassy lands of East Africa. At one time I saw hartbeest, wildebeest, zebras, gazelles, ostriches, antelopes and giraffes all spread over an almost treeless plain. The whole landscape was literally covered with herds of these magnificent creatures. Yet here, in all this luxuriance of Himalayan vegetation, we see scarcely a single mammal. How true is the remark of Darwin that "among the mammalia there exists no close relation between the bulk of the species and the quantity of the vegetation in the countries which they inhabit."

I will mention a few observations on some of the more common species. For many months I kept in my possession a Himalayan flying squirrel, *Petaurista inornatus*, and never have I seen a tamer or a more engaging pet. It showed not the slightest fear of man, but took an unbounded pleasure in scrambling over his body and playing with his hands and face. It looked on man as a playmate rather than as a foe. The contrast between the tameness and wildness of undomesticated animals when brought into a state of captivity is a very curious subject and one difficult of explanation. The celebrated Sir J. Sebright states that the wild rabbit and the wild duck are the most untameable creatures he knows. So powerful is their instinctive sense of wildness that, even when taken from the nest, they defy all attempts to make them gentle and familiar. How different is the flying squirrel which, when captured in the adult state, soon becomes intimate and tame. Few creatures are more persecuted by man than the wild duck and the wild rabbit, few so seldom as these flying squirrels. I suspect that, in the case of the duck and rabbit, persecution by man has generated a sense of wildness from the fear of man,



The Flying-Squirrel (*Petaurista inornata*).

[*Face p.* 241.]

and that this sense has become so fixed an instinct as to be transmitted to the offspring and to have developed in them the same instinctive fear though they themselves have endured no persecution. If any man could persist in the domestication of ducks or rabbits commencing from the wild stock, I have no doubt that he would eventually rear offspring as tame as the rabbits of the rabbit-hutch or the ducks of the poultry-yard.

The tail of the flying squirrel is worth attention. It is long, thick and bushy. Its functions are two in number; the one is its use as a warm covering to surround the head and body during sleep, the other is its employment as an agent to secure the animal's balance in the trees.

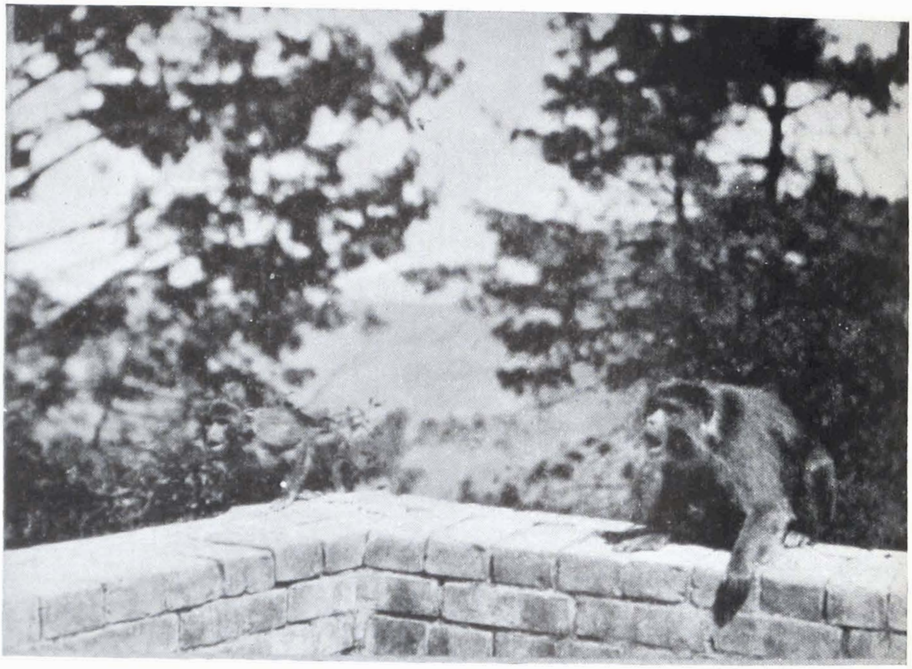
I used to amuse myself by placing the squirrel on a smooth bar to see how the tail was exerted to maintain the creature's balance. The squirrel sits clutching the bar. Its claws cannot penetrate the surface, so that it must use all its powers of balance to keep its equilibrium. The tail hangs vertically down behind; it is rigid, definitely held in that position for a special purpose. I draw the animal's head forward and up goes the tail to increase the counterpoise behind. I pull the hind quarters backward and the tail is swept forward beneath the bar and equilibrium is restored. I push the squirrel to the left and the tail is inclined to the right; I push it to the right and the tail turns to the left. Any movement of the animal in one direction is met with a counterbalance of the tail in the opposite direction, and a uniform equilibrium is thus attained.

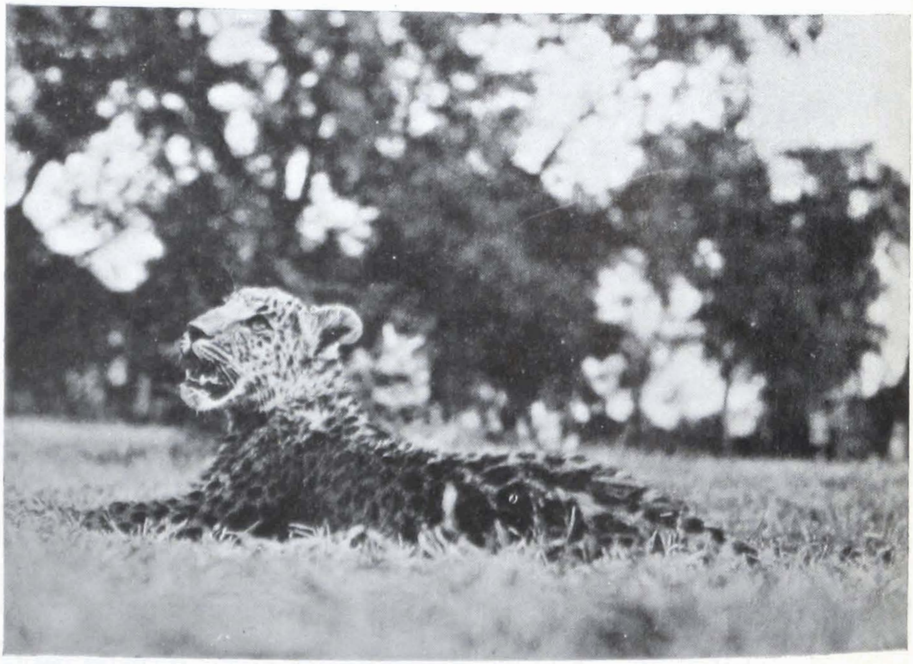
This function of the tail is illustrated in another method. I place the organ out of action by fixing the tip of the tail to the back of the squirrel's neck. I again place it on the smooth bar. It makes vain attempts to keep its balance; the tail struggles with its bonds in the endeavour to break free, and the squirrel may end by tumbling completely over, clinging with flexed claws to the under surface of the bar. Thus the main function of the tail is as an organ of equilibrium. It is a pliant wand gradually developed to its present length to enable its owner to keep its balance while it leaps and clambers through the trees.

On occasions the flying squirrel completely inverts the normal position of its body and hangs back downwards from the under surface of a branch. The tail, under such conditions, becomes curled round the branch from which the animal is suspended, and its position cannot but suggest to the mind that it actually is employed as an organ of support. Indeed it would only require a slight increase in the muscular tension in order to become so. Now in this striking attitude we may possibly detect one of the evolutionary gradations in the development of the prehensile tail, a trace of a gradual passage from an organ of equilibrium to an organ of prehension, from an organ which in the flying squirrel maintains a balance in the tree to one which, as in the American monkeys, actually grasps the branch in order to sustain the body.

When the flying squirrel glides through the air its tail is held rigid and trailed out behind. It has been considered on these occasions to act as a kind of a rudder by which the animal can guide its movements and actually change direction when in the air. This can scarcely be the case. I have never seen the gliding motion take place in any direction but that of a straight line except in the sudden elevation at the termination of the "flight." Moreover, it is improbable that Nature would have provided the animal with a steering gear in the form of a cylindrical bushy tail. I think rather that it acts as an organ of balance, for of what value could the similar long bushy tail be to steer the common squirrel which never "flies"? Just as the tail of a bird cannot act as a rudder because it is compressed in the wrong direction, so also it is unlikely that the tail of the flying squirrel will possess a steering function as it is not compressed at all. I have mentioned that, when the animal is seated on a bar, an excess of weight in the anterior portion of the body is counter-balanced by an elevation of the tail which increases the leverage of the posterior portion of the body. A somewhat similar mechanism takes place in the air. The squirrel when gliding is in an oblique position; the anterior portion of its body is depressed. It will therefore tend to topple over forwards unless it has a sufficient counterpoise behind. To give it this counterpoise the tail is held rigid and trailed; it acts as an organ of balance to maintain a steady flight.

The mammal most commonly seen about the woods was the Bengal monkey, *Simia rhesus*. It is the same species that inhabits the plains, but at these altitudes it has developed into a more robust animal and has put on a thicker and warmer coat. This monkey is of a plain brown colour with a rusty tinge about the lower portion of its back. A red face and a pair of red callosities behind are the only bright marks upon its body. It stands about two feet in height, and its tail is about half that length. It congregates in troops, thirty or more of both sexes and of all ages living together in the same pack. They haunt the forest, where they climb heavily amongst the trees, descend to the grassy glades, or pillage the cultivated tracts about the villages. They pass the day incessantly scratching and picking at one another, turning up the stones and leaves in search of seeds, joining in noisy squabbles, or exploring one another's fur in the quest of imaginary fleas. The adults are the more sedate; they often stretch themselves in the sun while the little ones toss about the ground or gambol amongst the conifers and oaks. They are quarrelsome and pugnacious, are everlastingly hissing, biting and cuffing at one another so that the whole family seems as though it had some interminable dispute. It is an insolent and intrusive creature. It plunders fields, enters human habitations and even presses down into the crowded bazars of Simla. It sets up a show of audacity towards an intruder; it assumes a threatening attitude, it growls, shakes itself, pretends to spring; but it is all a sham and a pretence, it makes off before a real danger. At night they roost upon the trees, but by day they seem to feel more secure upon the ground, and when alarmed they will often come leaping to earth as though they feared to be isolated amidst the foliage. It is an intelligent and crafty creature. It is the monkey that is commonly carried by showmen throughout India. It is also clever in its native haunts, and I knew of an instance where a whole troop of these





The Bengal Monkey (*Simia rhesus*).
Emotional expression in the Leopard. (1) Contentment.

[*Face p.* 245.]

monkeys used regularly to utilize a long pendant branch as though it were a rope to swing themselves across a wide canal. Their food seems to be exclusively of a vegetable nature. They are continually munching the young shoots, leaves, buds and flowers of the trees, pulling at the roots, turning up the stones for seeds, or robbing the grain from the husbandman's field. The sexes come together in September, but there is no disintegration of the herd; in March the young are born, a single offspring at each birth. At first the young is carried in the mother's arms; later it clings into her hairy coat, and either hangs suspended from her belly or rides astride upon her back. They have different notes and intonations in accordance with the emotions and excitements of the time. The usual cry is a plaintive wailing note. It is answered by the other members of the herd; it is the note of alarm that spreads the news whenever danger is near. The sound of a quarrel is placed in a higher pitch. A shrill vibrating hiss is the voice of anger and fight, while a hoarse growl is the note of defiance towards an intruder. The largest males are powerful beasts. They are heavy and massive, with stout muscular arms, bright red faces and thick hairy coats. They often lead and direct the movements of the herd. They permit of no interference. They exert authority, maintain discipline, intervene in quarrels, chastise offenders, settle family disputes. The herd is obedient to their rule, and strife for a time fades away beneath their sway.

I observed a few interesting facts connected with their instincts. I once had a female of this species which had no offspring of her own. One day she happened to find a pair of young kittens only a few days old. She immediately took this unnatural offspring under her charge; she nursed them with the greatest care and would allow no one to take them from her. It illustrated how easily the maternal instinct becomes vitiated when it cannot fulfil its normal course. Another incident seemed to show how quickly an instinct acquired by the parents may become innate in the young. These monkeys dread the sight of a gun. They have learnt to know its power, and are terrified if they see a weapon pointed at them. But a very young monkey was on one occasion chained in my garden. It could never have seen a gun, and certainly could scarcely have learnt what the power of a firearm meant. Yet the very first time that I raised a gun towards this little animal it burst into the greatest frenzy and alarm and commenced to hiss and leap upon its chain. It showed little fear of a stick even though threatened with a beating, yet if the stick was directed towards it in the attitude of a gun then all its passions were again aroused. Are we to conclude that this little creature was born with the dread of a gun as one of the innate instincts of its nature? It had no experience of firearms in its own short life, and unless it was taught these dangers at a very tender age by some of the older members of the herd, it must have inherited from its parents that instinctive dread which they had learnt by experience throughout the preceding generations.

When herds of these monkeys are observed from below feeding on a mountain side, it is not unusual to see stones come hurtling down the cliff as though they were missiles thrown at the intruder. For a long time I doubted the statement of the hillmen that the monkeys actually did employ stones as weapons to drive away an enemy; I thought that the stones must be simply dislodged by chance. But I have no doubt that the hillmen were correct. For at last I saw one of these monkeys deliberately tilt up a large stone and roll it towards me down the slope. This I take to be the most rudimentary manifestation of the more elaborate instinct that employs weapons as a mode of protection or offence. It is the first trace of that higher judgment possessed by other monkeys of selecting stones of suitable size and shape to use as weapons against their foes, or of the skill with which the female orangutan breaks off branches and spiny fruits from the trees to hurl them to the ground in a shower of missiles.

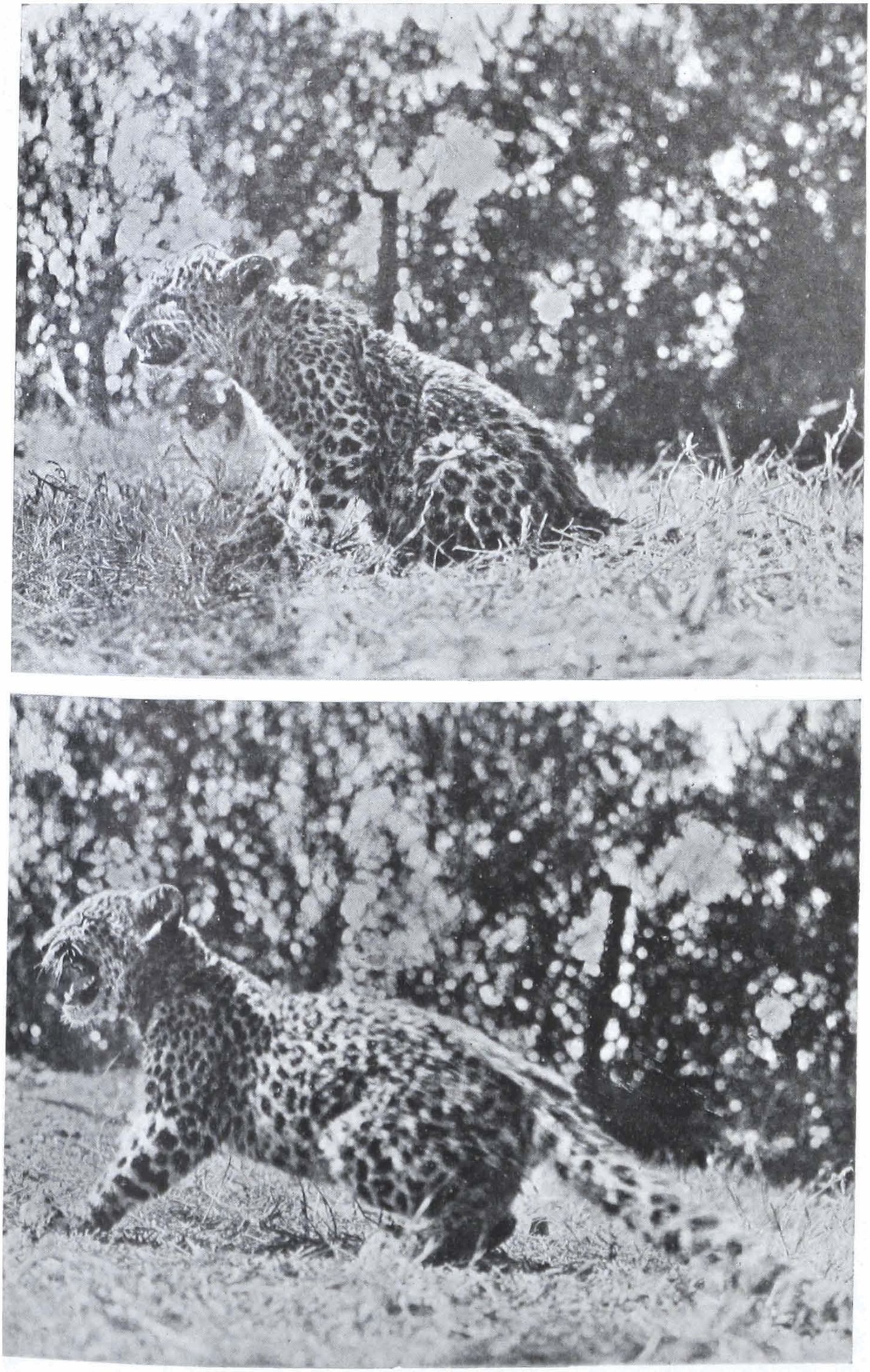
The only other monkey that I observed in the district was the langur, *Presbytis schistaceus*. I saw very little of it. It keeps to higher altitudes than the Bengal monkey, usually remaining above 6000 feet, and I have seen it near the tree limit at 11,000 feet traversing the fields of snow. It is a handsome animal of a slate colour above, yellowish beneath, and carries a long, slightly tufted tail. Its black face is very conspicuous, since it is encircled in a white fringe. It stands two and a half feet in height, while its tail is about three feet in length. The langur seems more arboreal than the *Simia*. Large troops composed of both adults and young leap about the trees and make a great noise as they crash heavily through the forest. It feeds on grain, fruit, leaves and buds. It loves the nectar of flowers, especially that of the rhododendron. Indeed, it is a strange contrast to see the black face of the langur with its white encircling fringe holding in its mouth a bunch of crimson rhododendron. It appears to be less quarrelsome than the *Simia*, though in winter, when the langur is driven down to lower altitudes, pitched battles are said to occur between the two species.

The leopard, *Felis pardus*, was distinctly uncommon in the district. I once kept a cub of this species, which was captured on the hillside, and took some little trouble in noting the changes in its actions and expressions under the influence of different emotions. I will attempt to indicate these various changes, which may seem more evident with the help of the illustrations.[1]

(1) Contentment

In the contented and restful state when, after a satisfying meal, the animal lies partly curled upon the ground and the body and mind are calm and quiet, or when the mental faculties are in complete abeyance during sleep, there is no rigidity of the trunk or limbs, no twitching of muscles or changes in facial expression; the whole animal is limp and supple, its voluntary musculature is in a condition of physiological rest in complete unison with the calm

[1] My observations on the emotional expression of the leopard and my notes on the flying-squirrel have previously appeared in the *Journal* of the Bombay Natural History Society. My photographs of these two animals and also that of the Indian robin and the nest of the paradise fly-catcher have likewise been published in the same journal. I am indebted to the Honorary Secretary of that society for his kind permission to reproduce them here.



EMOTIONAL EXPRESSION IN THE LEOPARD.

2 (upper) Fear. 3. (lower) Anger.

[*Face p.* 248.]

and inactivity of its mind. Occasionally, while coiled in this contented state, the sight of some passing object may excite the interest of the animal. It raises its head, opens wide its eyes and looks steadfastly towards the object producing this mild excitement; the lower jaw drops and the mouth opens but not in anger; the whole countenance alters and the blank expressionless facies which characterized the animal in its state of pure contentment is changed instantaneously to one of interested intelligence.

(2) Fear

Fear in a wild animal must be frequently associated with anger, and perhaps preceded occasionally by astonishment, though the latter would be difficult, if not impossible, to detect. It does seem possible, however, to obtain the expression of fear distinct from that of anger, if the object causing the fear is so powerful as to overawe the animal to such a degree as to prevent it from displaying its anger.

A leopard, when enduring the emotion of fear produced in this manner, acts in a very distinctive way. It lowers its body into a crouching posture and throws its ears well back. These movements have an object. They tend to lessen the apparent bulk of the animal; and as many of the lower creatures in such conditions of danger, as would create the sensation of fear in the higher ones, do diminish markedly the volume of their bodies and by such diminution obtain definite protection, it is probable that these movements are instinctive tendencies inherited throughout a long ancestry, but which now display little, if any, serviceable manifestation.

The head during fear is often turned in the opposite direction to that from which the danger is expected to arrive. The eyes are partially closed, and tightly so if the fear amounts to terror. The nostrils are pinched so as to give the face a characteristic expression. These acts also have a purpose. It is a natural instinct in the higher animals to turn away the face if any special injury is directed towards it, and to close the eyes either partially or completely and contract the nasal orifices in order to give protection to the delicate organs contained within, and in the leopard this instinct seems to be so highly developed and so easily called into action as to occur in general states of fear, even when the danger is not specially directed to the sensitive organs of sight and smell. The limbs and tail are held stiff and the body loses its great muscular laxity. The corners of the mouth are raised, the upper jaw elevated, the lower jaw depressed, the mouth is partially opened and the canine teeth displayed. The general facial expression is one of fierceness, and when a wild carnivorous animal is in fear or terror it must undoubtedly be fierce.

The domestic cat when terrified has been described as arching its back and erecting the hair over the whole body, especially on the tail, and as raising the basal portion of the tail upright and bending the terminal extremity to one side. I have never noticed this attitude in the leopard, nor by experiment have I been able to obtain anything resembling it; and it is possible that, owing to the great strength of the animal, it would not, in its native haunts, experience fear to any great extent, and would therefore not have the emotion so highly developed and exhibited in a manner exactly similar to that seen in the weaker and domesticated creatures of its kind.

(3) Anger, Rage

Anger and rage, so frequently associated with fear, are expressed in a very similar manner. The body again crouches and, if the animal is savage, may be lowered completely to the ground. The trunk and limbs are rigid, the claws thrust out and the tail usually stiff, though it may be curled from side to side. These actions have a purpose; they are the characteristics of an animal about to struggle for its prey. The crouching and rigidity maintain every muscle tense and ready instantaneously for the spring. The claws are projected for the fatal blow. Possibly no cause excites the anger of a carnivorous animal so intensely and so frequently as the prospect of a coming battle, and consequently those characteristics, which are of direct service to an enraged animal about to fight, have become so engrained into its nature as to be instinctively associated with its anger under all conditions, even when there is no suggestion of a fight. The rigidity of the tail is due to the muscles of that organ acting in harmonious contraction with those of the rest of the body, and the occasional curling motion may be an involuntary liberation of that great excess of muscular energy which must be effervescing through its bodily system.

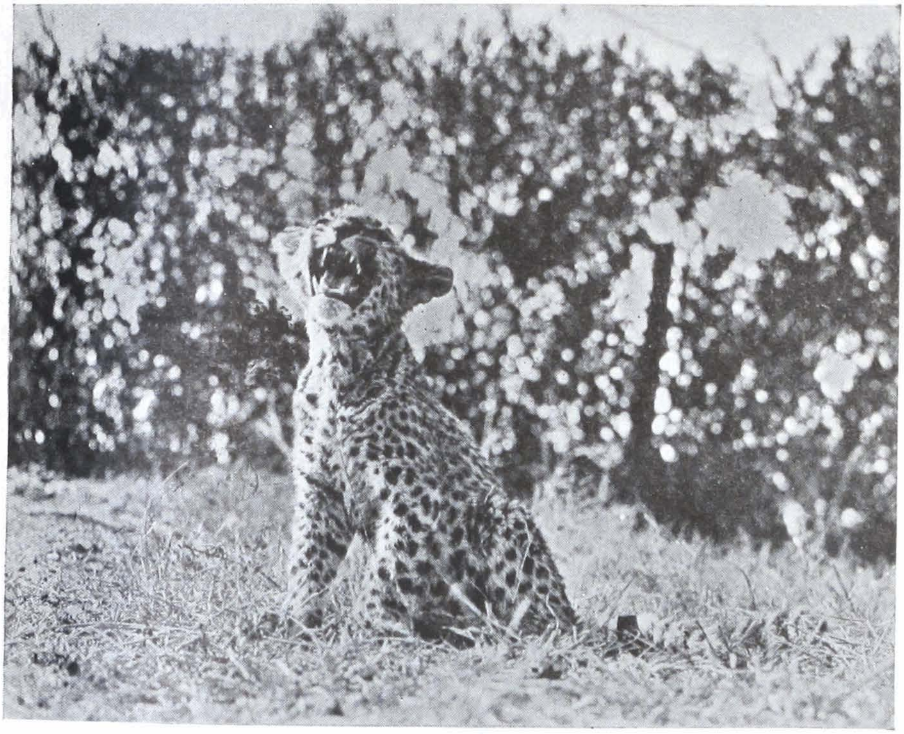
The angles of the mouth are elevated, the nostrils drawn together, but the whole face appears less contracted and pinched than when the animal is expressing true fear. The canine teeth are displayed in an open mouth and, when the anger amounts to rage, the whole row of teeth becomes clearly seen. The face is directed towards the object which excites the anger, and the animal hisses or emits a deep guttural snarl. These marked changes of facial expression and utterance of sound also serve their purpose; they give to the animal a fierce and savage appearance, and are therefore of service to it by causing it to strike terror into the mind of the creature against which its anger is directed. I have never seen the hair erected during a state of rage, nor could I be certain that distinct hair movements ever occurred or were definitely associated with any emotion.

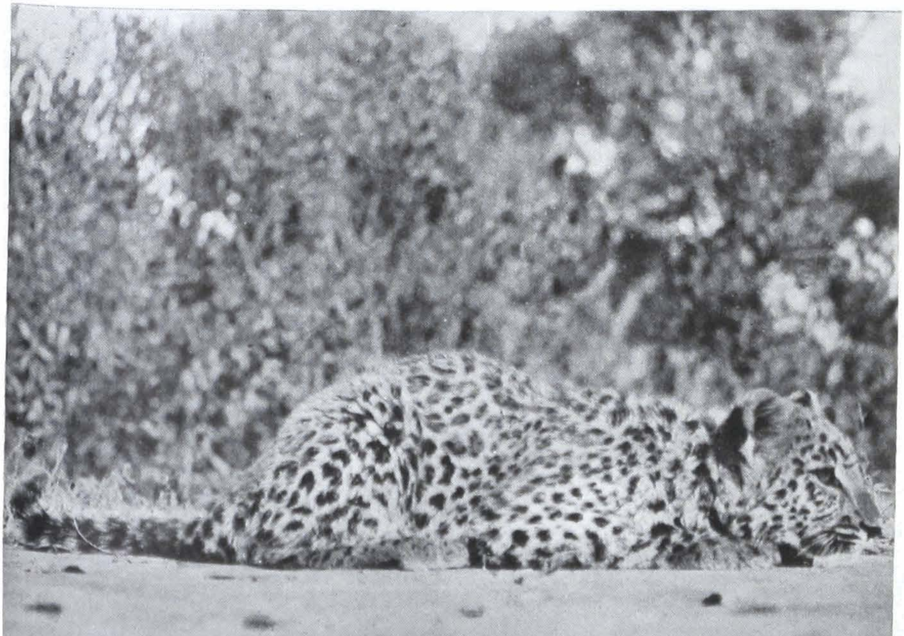
When the animal is enduring displeasure, but not amounting to anger, the above expressions are made manifest to a slight degree; but when the anger amounts to rage or savagery they are pronounced in a more exaggerated manner.

Although on analysis the emotions of fear and anger seem to be very similarly expressed, yet a comparison of the illustrations immediately shows that in the former the animal appears cowed into submission and ready to retreat rather than advance towards its enemy, while in the latter he appears to be full of anger and spoiling for the fight.

(4) Distress

Pain, though a most powerful sensation, can scarcely be considered an emotion. Its presence, however, gives rise to forcible emotionary outbursts so tangibly associated with those of fear and rage as to be incapable of separate recognition. An animal in pain must be in distress, and this certainly is an emotion. It must also be terrified or enraged, and it is therefore not possible to describe any series of characteristics solely





EMOTIONAL EXPRESSION IN THE LEOPARD

4. (upper) Distress. 5. (lower) Eagerness.

[*Face p.* 252.]

distinctive of a pained or distressed animal. A leopard in pain resembles almost identically a leopard in a state of anger, but the face displays a distressful appearance, and it is difficult to determine what individual muscles are brought into play in the production of it. The mouth is sometimes widely opened, and the body may conform to almost any attitude.

(5) Eagerness

When the leopard feels intensely eager, as when it is stealthily creeping towards its prey or crouching low with the intention of springing on it, the attitude and expression again become characteristic. It crouches down so as to lower its body completely to the ground. The hind limbs are flexed beneath the trunk ready to be instantaneously extended when the animal springs. The fore limbs are stretched forwards, and the head, which is lowered on to them, is so fixed that the jaws rest on the dorsal surface of the feet, and the chin is firmly pressed on the ground between them. The object of these movements is clear when it is remembered that in the wild state eagerness is excited by the presence of the animal's prey. By the depression of the head and the shrinking of the body the apparent bulk of the animal is diminished and this gives him a greater opportunity of reaching his prey. The tail is curled, the ears are tilted forwards and the aural aperture enlarged to catch the slightest sound. The eyes are fixed and staring to note the gentlest movement. The mouth is tightly shut so that the teeth are completely covered. There is no twitching of the muscles or alterations in the countenance. The hair is occasionally erected but not often. No vocal sounds are emitted. The nostrils are slightly dilated and the whole body is absolutely motionless and in a state of rigid muscular tension, while the face expresses that earnest determination which at times must be so necessary for the successful accomplishment of the animal's desires.

Intense eagerness is also expressed when the animal is in motion, as when it is endeavouring to discover the whereabouts of its food or is creeping with stealth towards another animal. The general attitude is precisely similar to that of an animal about to spring, but the head and body are lowered less completely to the ground, and the animal moves forward with extreme quietness. When the sense of smell is brought into action in association with this movement, the nostrils are dilated, the nose depressed to the ground, and the animal sniffs with vigour as it moves silently and rapidly from place to place.

(6) Attention

When the leopard distinguishes in the distance an object the nature of which it does not clearly recognize, or hears a sound which it does not understand, the attitude which I have designated as "attention" is immediately assumed.

In the attitude of attention the trunk is raised so that the body is supported sometimes on the two front limbs and sometimes on all four. By this movement the animal's range of vision is greatly increased. The ears are directed forwards and the eyes widely opened. The mouth may be partially open or closed. The head is usually craned a little forward and occasionally moved from side to side as though it was endeavouring to obtain a further explanation as to the cause of the excitement. There is no puckering of the features, no tightening of the angle of the mouth or exposure of the teeth. The hair over the shoulders may be slightly ruffled, but not markedly erected. The intent expression of countenance, produced mainly by the fixed and staring expression of the eyes, can scarcely be mistaken.

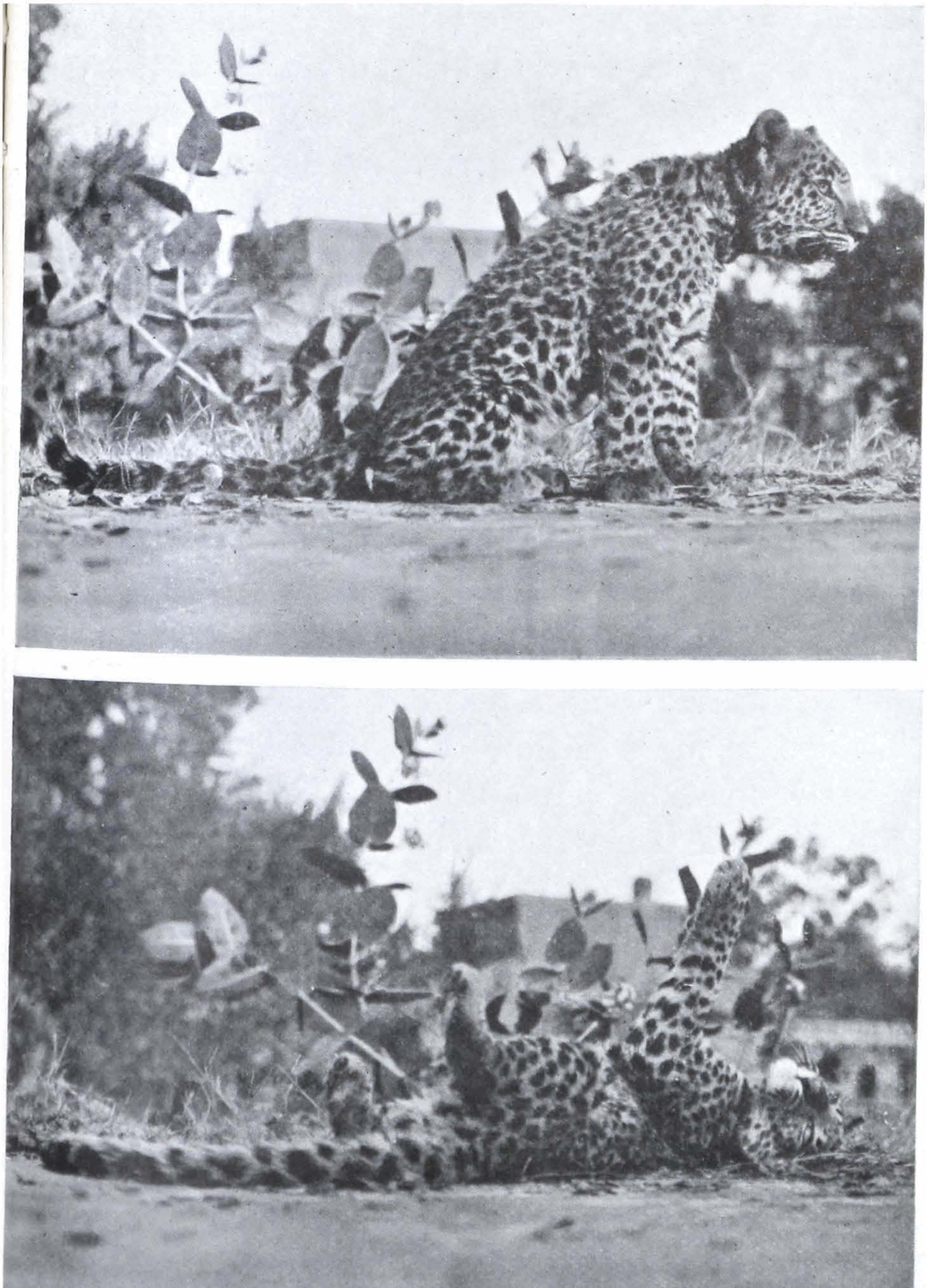
(7) Affection

The emotions of affection and love are diametrically opposed to those of anger and hatred, and are associated with external expressions equally distinct in their antithesis.

When the leopard is affectionate, the body is always limp and supple and the face calm and placid. There is no pricking of the ears or pinching of the nostrils. The teeth may be exposed by a uniform opening of the whole mouth, but never by a raising of its angle or by a wrinkling of the upper lip or associated with any muscular tension which might suggest a snarl. The eyes are dilated and express docility. The claws are sheathed. In this happy temperament the leopard resembles the domestic cat in its desire to lick or rub its head and trunk against the object towards which it is displaying its affection, and to pat or pound it gently with the soft pads of its extended feet. This latter peculiar habit is most probably in origin the same as that pounding which young kittens may be seen to perform on the teats of their mother when they are suckling, and at that time they are no doubt affectionate. I have observed a bull terrier puppy continue to pound the ground in a similar manner while it was suckling.

When we contrast the expression of the emotions of affection and anger it is clearly evident that they are in direct opposition to each other. Compare the supple trunk, the elevated ears, the dilated eyes, the sheathed claws and the happy countenance of affection with the rigid body, the depressed ears, the half-closed eyes, the projecting claws and the fierce and pinched expression of anger. All these characteristics associated with anger are, to a greater or less extent, of some service to the animal if it be considered that its anger is directed towards some other animal which it is about to attack; and in its native haunts there can be no other cause which so frequently and acutely excites its anger. But on the other hand it does not seem possible to detect any serviceable asset in the opposed expressions associated with affection. They can only be explained on the Principle of Antithesis as advanced by Darwin, which states that any action or series of actions which have for long periods of time been directly associated with any sensation or emotion will be immediately suppressed under emotions of a directly opposing nature, and that an antagonistic set of muscles will be brought into play so as to produce an opposite action or series of actions, though they may be of no use.

During play the animal may assume almost any posture. It may roll on its back on the ground and wave its paws in the air and with sheathed claws endeavour to grasp the object with which it is playing. It may spring towards its playmate and leap upon him. It may seize him between its teeth, but will never injure him or express in its attitude or countenance any desire to do so. In its play it often



EMOTIONAL EXPRESSION IN THE LEOPARD.

6. (upper) Attention. 7. (lower) Affection.

[*Face p.* 256.]

simulates the sterner acts of life. It loves to mimic the movements of an animal about to dart upon its prey. It crouches low, it hides itself in every depression in the ground, it advances with a slow and stealthy gait; then comes the flashing eye, the sudden rush, the final spring, the roll and tumble with its playmate, and the round of the game is over. It is all but simple fun and frolic, the exuberant play of youth. Yet in it we see a mirror of its future life and a reflection of the countless cruelties and battles in the past history of its race.

CHAPTER XIV

ORNITHOLOGICAL OBSERVATIONS

General migration of birds—Distribution and habits of bulbuls—Plasticity of instinct—Paradise flycatchers—The black drongo—Habits of the purple sunbird—Nesting instinct of the whistling-thrush, the barbet, and the Kashmir martin—Troops of insectivorous birds—Tumbling of birds—Soaring flight of birds.

I PASS now to some ornithological observations. The migrating season greatly enriched the bird life of the valley. Early in September the stream of migrant birds flows down the mountain flanks, along the valleys and southward over the Peninsula of India. Flocks of wagtails, pied and grey, collect in every stream; drongos congregate in the green trees; quail in thousands infest the cornfields; snipe and duck flow into the marshes. The whole bird life is changing; a new avifauna of winter is replacing that of summer. Many birds with the paradise flycatchers, the black-headed mynas and the magpie robins leave the mountains to winter in the cooler plains. Others like the woodcock, jackdaw and whistling thrush descend from the higher elevations to seek the shelter of the lower hills. Still others, like the snipe and duck, pass the summer in Europe or Northern Asia and now sweep across the Himalayan ranges on their distant journey to the Indian plains.

When bird life was more stationary there were some attractive species to be seen in the valley. Three species of bulbuls were very common. Of these, two belonged to the genus *Molpastes*, and appeared very conspicuous from the bright colours of the under tail coverts. In the Punjab red-vented bulbul these feathers are a brilliant scarlet and in the white-cheeked bulbul a bright sulphur yellow. They both remained in the valley for the whole year and nested there during the summer. The third species, known as the Himalayan black bulbul, belonging to the genus *Hypsipetes*, has a forked tail and is a sprightly and active bird though of plainer plumage. During the summer it deserts the valley and ascends into the cooler forests. The cheerful notes of the bulbuls are amongst the most pleasant sounds, and never were they heard to greater advantage than when the birds were robbing the fruit trees. They devour quantities of seeds and fruits and are a pest to the gardener.

I observed a striking case of the variability of avian instinct in the case of the red-vented bulbul, *Molpastes intermedius*. This little bird occupied the whole district. It was of a dull unassuming colour save for its conspicuous patch of red. The food of this species consists largely of fruit that it finds on the ground. But in the securing of its food it often adopts the methods of other species of birds. I have seen this bulbul hammering and chopping hard berries against the branch of a tree in a manner resembling that of a nuthatch. It hammered with such force that the sound of the blows could be heard fifty feet away. I have seen it climbing skilfully and exploring the trunks of the pine trees as though it was a woodpecker, and often capturing insects on the wing with all the enthusiasm of a flycatcher. Few instincts can be more important than those connected with the procuring of the daily food, so that it is interesting to see those instincts so variable in their action. I have at different times observed mynas, creepers, sparrows, kites, owls, crows and gulls all chasing insects through the air, hoopoes and titmice climbing like woodpeckers up the tree-trunks; but I had never before seen a species with instincts so variable as to resemble the peculiar instincts of three distinct families of birds.

This plasticity of instinct in birds is common. Even the ubiquitous house sparrow once provided me with an interesting display. I watched it first acting like a creeper in clinging to a tree-trunk and scrambling about in search of insects. Then it would change its methods. It would flutter out a little from the trunk, vibrate rapidly its wings so as to frighten the dull-coloured moths and other insects from the crevices in the bark. Then it would dart on them like a fly-catcher as they flew out into the air. In nature all instincts vary, and the closer we observe the habits of animals the easier it is to understand how one species might in time lose completely its natural instincts and adopt those of another species.

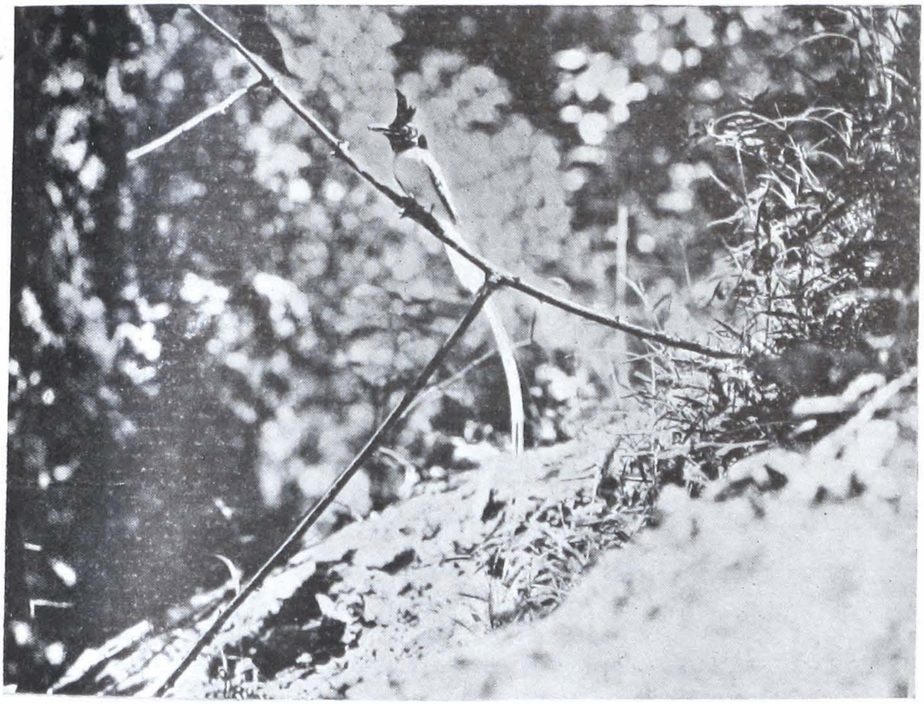
Another act in the mode of feeding of the bulbul somewhat surprised me. The birds used to congregate in winter on the branches of the Persian lilac, *Melia azedarach*, to feed on its nutritious berries. The birds usually pick these berries to pieces; sometimes, as I have mentioned, they will hammer them to fragments like a nuthatch, and, even at times, swallow them whole. Now these berries are from one and a half to two inches in circumference, an enormous bulk for these little birds to swallow. Yet the bulbuls after strenuous efforts succeed in getting the whole berry down along the gullet. The circumference of the bulbul's empty gullet is only half an inch and the circumference of the whole neck one and one-eighth inches, so it is clear that this bulbul is in the habit of swallowing objects not only three times the dimensions of its own gullet but even wider than its own neck. It is, of course, the highly distensible nature of the soft parts that permits the passage of such large mouthfuls. Anything that passes the gape can with ease continue down the gullet. And the bulbuls seem to be unable to judge how big a morsel they are able to tackle. They sometimes struggle with berries which they are quite unable to get down, and I once saw a record of a young red-vented bulbul that had died in the attempt to swallow a mouthful nearly as big as itself.

The paradise flycatcher, *Terpsiphone paradisi*, was the most beautiful of the summer migrants to the southern slopes of the Himalaya. This bird extends northward to Kashmir, and I have seen it at an altitude of 8000 feet. The female is an inconspicuously coloured bird with a bluish head and pale ashy breast. For two years the male resembles the female in coloration; after the second autumn moult a partial change occurs, but it is not until the third season that the male adopts its characteristic and striking plumage. The whole body becomes white, and the head, surmounted by a large crest, is a glistening bluish black; dark streaks appear upon the back, but it is the central feathers of the tail that attract the most attention. The median pair are prolonged into beautiful, pure white, flowing ribbons as much as a foot and a quarter in length, while the body of the bird is little more than four inches. When the bird is in flight the long streaming feathers trail out behind, and, as it flits from tree to tree in the dark Himalayan forests, it seems like a bright flash of sunlight gleaming through the dismal pines.

From the spotless white of its plumage I have heard Europeans call it in error the dhobi-bird, or, from the flowing tail, they sometimes speak of it as the ribbon-bird, while its ghostly appearance has named it the phantom-bird.

The nest of this species is a neat cup-shaped structure of grass and moss. It is usually supported on the fork of a tree, but, on one occasion, I saw a nest actually suspended by its margin to two thin branches which grew downwards from above. The position of a bird's nest, whether it be a supported or a suspended structure, is the result of a very definite instinct and is highly characteristic of the different groups of birds which build their nests according to these two types. I was therefore interested to find a species that was able to adapt itself to either of these methods and whose nest-building instinct was so variable as to allow it either to support its nest on the branch below or to suspend it from a branch above in accordance with the facilities that offered at the site where it wished to build. The nest is very small in proportion to the size of the female bird, and, when she is hatching, the tail, rump and the ends of the wings project out behind.

The young of this species, before leaving the nest, thoroughly stretch their wings and practise the lesson of wing-flapping to a sufficient extent to render their



The Indian Paradise Flycatcher (*Terpsiphone paradisi*) and nest.

[*Face p.* 262.]

first flight free from danger. The lesson takes place at the edge of the nest; here each nestling in succession carefully balances its unstable body and at intervals for about ten minutes stretches out its wings and vigorously beats the air with them before launching out on its first short flight.

The paradise flycatcher of course lives on insects which it captures on the wing. It is not always very dexterous in its efforts, for I once observed the bird make six successive and unsuccessful attacks on a large butterfly and in the end failed in its efforts. A more skilful bird in this respect is the black drongo, *Dicrurus ater*. It is a very common visitor to the lower Himalaya. It is in the habit of perching on prominent branches of trees, and feeds on flies and other insects which it captures on the wing. Its power of vision must be extremely acute, for I have seen it on a dull day detect an insect in the air fully a hundred yards distant and fly off from its place of vantage to a successful capture. I could myself have scarcely detected the insect at one-tenth of the distance. Though the drongo usually captures its prey by the rapidity of its flight and its skilful turns in the air, yet I have observed it on windy days adopt a simpler but no less efficacious method, for instead of darting after the insect it merely faced the wind, hovered in the air and allowed the breeze to sweep the insect into its mouth.

The sharp vision of the drongo calls to mind the same power in other species. The tern, for example, when hovering in the air, detects the smallest fish in the silt-laden river. The vulture, when distant beyond human vision, notes the descent of its fellows on the carrion. The gannet, when high in the heavens, spies its victim in the rough ocean. The birds of prey have most remarkable powers of sight. It is astonishing to see how a lammergeyer can detect a bone lying upon a stony waste, or a kestrel can single out a protectively-coloured locust in a field from a perch perhaps a hundred yards away. Yet this is nothing compared with the vision of insectivorous creatures that haunt the night. It is almost incredible to observe the skill with which bats and nightjars dart upon their prey at dusk. Long after the sun has set, when to man's eyes everything is wrapped in darkness, these nocturnal creatures swoop upon the smallest insects and display in the night a sense of the acutest vision.

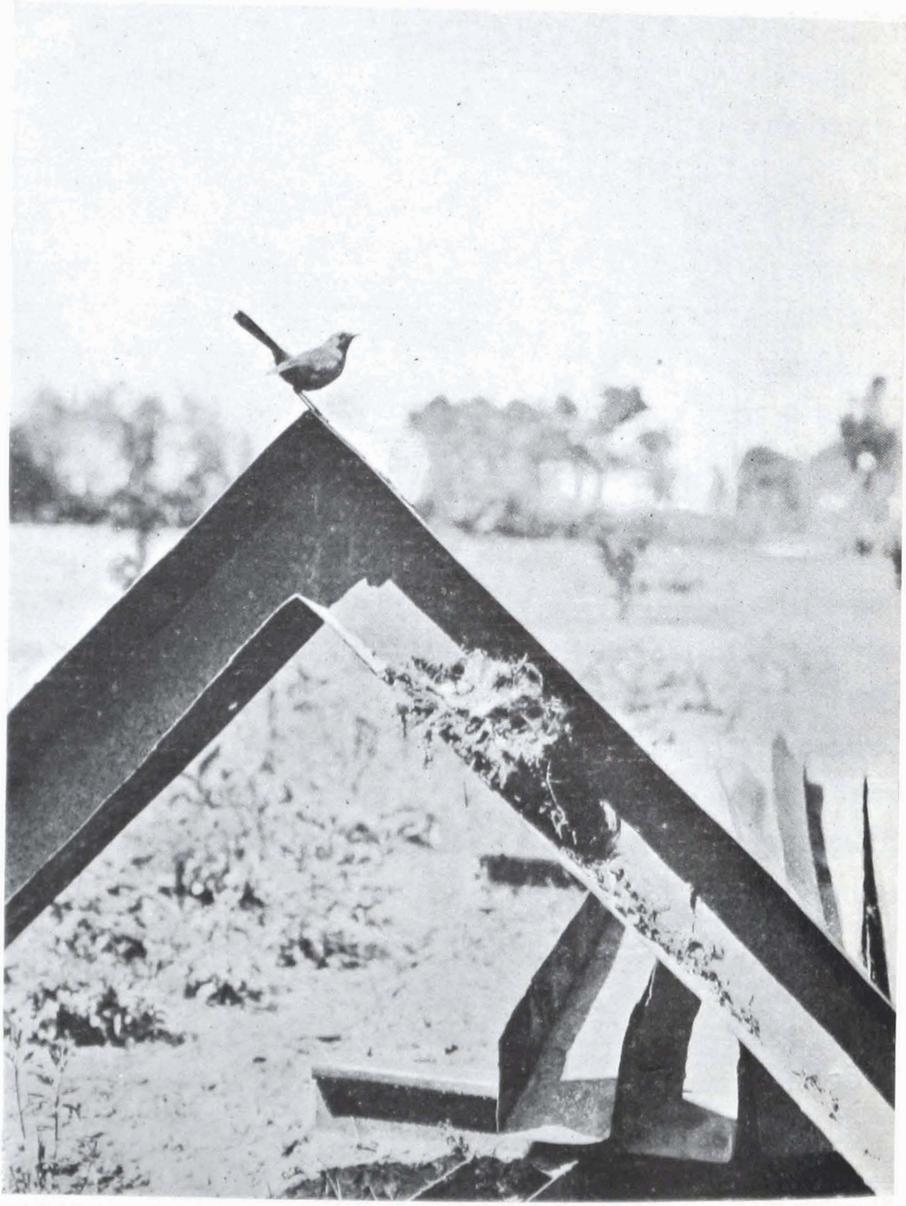
A pretty summer visitor to this valley is the purple sunbird, *Arachnectra asiatica.* Every morning this gay little bird, glistening in the sun with varying hues of metallic purple, used to seek the nectar from the scarlet bignonia that climbed about the sides of my verandah. As it flitted from flower to flower, sucking up the sweet honey with its long tubular tongue, it seemed like a huge insect fertilizing every bloom and called to mind the activities of the humming-bird. As the sunbird passed from flower to flower it never pushed its beak and head into the expanded mouth of the tubular blossom in order to reach the nectar at the bottom of the tube, but it always plunged its beak through the petals near their junction with the stem, and thus reached the nectar by a shorter route. I do not think there was any anatomical difficulty to prevent the sunbird seeking the nectar in the more obvious manner, by pushing its head into the mouth of the blossom, for I found that, in a dead specimen, the tongue could by this route easily reach the nectar. The difficulty seems to lie in the fact that the sunbird is unable to hover in front of a flower in the manner characteristic of a humming-bird, but has rather to cling to the flower stems before it can seek its food. From the stem of the bignonia it would be quite unable to reach the mouth of the flower, and has therefore to penetrate the petals with its beak. I have no doubt that the sunbird is an active agent in fertilizing certain flowers, but from its method of penetrating the blossoms of the bignonia it can play no part in the fertilization of that plant. The bird, however, gains one advantage by this mode of feeding, as it is able to remove the nectar from the unexpanded blossoms and thus steal a march on the insects which compete with it for the precious honey but which can enter only the expanded flower.

I will here mention a few observations on nesting habits that bear on the mentality of birds.

The Himalayan whistling-thrush, *Myiophoneus temmincki*, looks at first sight like an English blackbird, though it is in reality more closely related to the laughing-thrushes and the babblers. It haunts the moist glens, gorges and ravines, and is always to be seen about the torrential mountain streams. It often displays a remarkable foresight in selecting the site for its nest. It is in the habit of choosing a place close to a torrent and of lodging its nest on the side of the gorge immediately above the stream. It does not place its nest high up on the cliff; it rather looks for protection in a more ingenious way. It seeks out a part of the torrent where there is a waterfall or a deep pool and places its nest on a ledge of rock only a few feet above. In such a spot the nest is safe. The pools are deep, the falls turbulent, and the nest, though close at hand, is usually inaccessible. The bird seems to show a clear foresight in this act; it must understand that it can rest secure above these waterfalls and pools.

I have not seen the blue-throated barbet, *Cyanops asiatica*, actually in this valley, though it is very common a little further to the east. These birds construct their nests like woodpeckers by boring a tunnel into the trunk of a tree. One year a pair of barbets had made their tunnel in the usual way. The following season the birds returned to the same tree, but, instead of utilizing the tunnel of the previous year, they went to the labour of digging out a new tunnel six inches immediately above. The third season they again returned; but, as before, they refused to make any use of the previous excavations; they rather hammered away at a new tunnel eighteen inches higher up on the tree. This appeared a great waste of valuable labour; it seemed as though the birds were in such bondage to their instincts that they were compelled to construct a new tunnel each season even though a suitable one lay ready at hand only a few inches away. This may not be a just conclusion, but there must be some strong reason why the birds should refuse to make use of their old excavations and should rather go to the labour of digging out a fresh tunnel into the heart of a solid tree.

Beneath the eaves of the forest bungalows, at altitudes from 6000 to 8000 feet, the Kashmir martins, *Chelidon kashmiriensis*, used to build their nests. The architectural instinct of these birds is very plastic.



The Brown-backed Indian Robin (*Thamnobia cambaiensis*) and nest.
[*Face p.* 267.]

Should the nest adhere to the side of a wall, then the bird supplies it with a dome of mud, but if it is situated in the angle between the wall and the roof, no dome is required since the bird utilizes the roof for a dome. The latter position is therefore more economical for the bird and is thus more frequently chosen. An underlying support for the nest was also adopted, for occasionally the martin used to squeeze its nest in between the rafters and the roof and support its nest on the underlying wooden rafter. This latter change of instinct was less fixed, and I have no doubt was more recently acquired, as I have noticed that some nests, though constructed in a suitable place for deriving support from the rafter, yet were separated by a space of about one inch from the rafter and were completely closed in by mud below. Every instinct, like every structure, is plastic. Given sufficient time, it will mould itself to new ends.

A very characteristic feature of the bird life of the Himalaya is the congregation of insectivorous birds that traverse the forest in a compact troop. Often the woods seem quite deserted and not a sound is to be heard. Suddenly a hustling throng of little birds appears. All is then activity and bustle. The trees swarm with feathered life. Creepers, different species of tits and warblers arrive and flit in company from tree to tree; chats, flycatchers, an occasional nuthatch, perhaps a family of shrike-tits or laughing-thrushes, a fire-crest or a troop of minivets also join in the common throng. A few seed-eating birds like the rose-finches or the cinnamon sparrows sometimes appear, but the main body is composed of insectivorous species. Some hang upon the smaller branches, others search the boughs or climb about the trunks of the trees; there are some which make sallies into the air, others which busy themselves in the undergrowth, others which cling to the cliffs or hunt about the leaf-strewn ground. Every nook is thoroughly explored; the troop then passes on and the woods are again deserted of life.

These troops are to be seen at all altitudes up to 10,000 or 11,000 feet near the furthest limits of the trees. In the summer season they are thin and impoverished since many of the birds separate to fulfil the duties of the nest. Some of the more familiar species then absent themselves from the troop. In early spring they are strengthened by many visitors from the Peninsula. Drongos, magpie robins, different species of flycatchers then arrive to join in the common throng. The birds utter a continual twitter which serves to keep the troop intact; often the notes are very faint, perhaps beyond the range of the human ear to detect. When alarmed, as when a gun is fired, they often have the habit of sitting motionless in the trees. It seems for the moment that they have gone; but soon they reappear and the woods again teem with life.

This habit of different species collecting into gregarious flocks makes for the benefit of all. The insects driven by the tits from the branches are captured by the warblers, chats or flycatchers in the air, or, alighting on the trunks, fall a prey to the creepers; others disturbed by the creepers escape to meet a host of enemies. It is on a small scale the same advantage that Bates and Belt describe in the great flocks of hunting birds that traverse the forests of Nicaragua and Brazil. Here bird associates with bird to increase its insect food. More commonly do we see birds, for the same purpose, in company with other animals. We see starlings, drongos, egrets living in the closest friendship with cattle to secure the insects flushed from the pasture. Buffalo-birds and rhinoceros-birds attend their hosts for the ticks on their bodies. Ant-thrushes accompany the 'foraging ants of America. Similarly have I seen clouds of swallows following the ranks of an army to capture the myriads of insects driven into the air by the advancing troops.

The flight of birds has often attracted the attention of observers. One day I was watching a pair of ravens, *Corvus corax*, chasing one another in the air as though they were indulging in a game of sport. The pursuer would hurry forward as if trying to catch and quarrel with its playmate, but on reaching it, instead of making an attack, it would deliberately roll itself to one side and turn one or more somersaults in the air. Then recovering itself, it would continue the chase only to repeat the same gymnastics. It gave the impression that the ravens were enjoying a game of bird life. This tumbling in the air is a singular habit. Rooks are often seen to indulge in it as they wend their way home to roost; a single bird will at times fall out of the flock and take a few tumbles in the air. In the case of the birds of prey, the habit of tumbling is often associated with courtship. Kites, *Milvus govinda*, at the nesting season, will often roll about in partial revolutions, though I never saw one take a complete turn. That most magnificent bird, the lammergeyer or bearded vulture, *Gypaëtus barbatus*, indulges in a similar performance. It is a splendid sight to see a pair of these huge birds in amorous courtship, tossing, rolling, turning themselves, displaying to the very full their complete conquest of the air. I once saw a pair of Pallas's fishing eagles, *Haliaëtus leucoryphus*, engaged in somewhat similar evolutions. One of the pair, a splendid bird, I suppose the male, used to ascend to a considerable height while the female sailed along slowly near the ground. All of a sudden the male would swoop down upon his partner through a depth of four or five hundred feet. In a few moments he reached her. Then the female would escape his blandishments by gently rolling over to one side so as to make a complete lateral somersault in the air. Then again the male would ascend, and the two great birds would continue to repeat the same strange nuptial play. This habit of turning in the air is also followed by that well-known bird, the scavenger-vulture, *Neophron percnopterus*. Though this bird is strong upon the wing, yet it allows itself sometimes to be persecuted by crows. I have watched the crow darting on the vulture from above, but the great bird seemed unable to defend itself; it merely endeavoured to escape its attacker by rolling itself over in a somersault through the air. Certainly this habit of tumbling is a strange performance. With some birds it is probably a matter of play, with others a manifestation of sexual enjoyment, with others a mode of escape from an enemy. I have mentioned these cases that have come under my notice since they may suggest a method by which tumbler pigeons might have developed their peculiar habits.

The circling flight of the larger birds of prey is more open to investigation. It is indeed a remarkable sight to see the eagles, kites and vultures sailing round the crags and buttresses without the slightest motion of their wings. The birds are so massive, of such vast expanse, that the sight of them gliding with perfect ease through the air and, without the quiver of a pinion, sweeping round the shoulder of a mountain or in repeated circles rising higher into the heavens, makes one wonder if the force that sustains them is not indeed as marvellous as that which has raised the mountains about which they soar.

From a rocky buttress I have often watched their graceful circles, sometimes for hours at a time. As they sailed close around the mountain side I could distinguish every feather, and if there was the slightest quiver of the wing I would certainly have detected it. But there was not a trace of any movement. The birds were accustomed to circle hour after hour, now ascending, now descending, floating about in the air with outstretched motionless wings, full of such unrestrained activity and with such apparent absence of all effort that, in their conquest of the air, they seemed to put the laws of nature at defiance.

The Himalayan griffon, *Gyps himalayensis*, displayed this power of sailing through the air perhaps more fully than any other bird; but I was accustomed to watch the kites, *Milvus govinda*, more carefully, and I think the following observations are distinctly applicable to their mode of flight.

It is clear at the first glance that the kites usually move in circles. For some reason this seems to be essential to a sailing flight. Each circle is therefore worthy of study, and as we watch more carefully we soon learn that there are significant facts to be seen in every circle and certain conditions on which their sailing flight depends.

It is soon clear that a circle is not a true circle, but that the kite in sailing round and round traces a succession of pear-shaped figures. These figures for convenience' sake may be called circles. Now the presence of wind appears to be essential to successful circling with increase in height, so it is possible to divide the circle into segments; one, the windward segment or that portion traced by the bird when moving against the wind, and the other, the leeward segment or that followed by the bird when moving with the wind. Having divided the circle into these two segments, we observe the behaviour of the bird in each of the segments, and from this gain a clue as to the mechanism by which it is sustained. It is understood that the kite is circling, that it is gaining height at every circle, that at one side of the circle it is moving to windward or heading the wind, and that on the other side it is moving to leeward or coming down the wind.

Thus dividing the circle into a windward and a leeward segment, we are able to detect four salient facts. Firstly, we note that the bird on the leeward side makes a much longer sweep than it does on the windward side. It travels over a longer distance. To windward the bird seems cramped for space; it turns more sharply, while to leeward it circles in a free and easy sweep. In the windward segment it is tracing the sharp apex of the pear, while to leeward it follows a broad open course.

Secondly, we note that on the windward side of the circle the kite moves at a diminished speed. Away to leeward it sails free and unrestrained, but as it comes round to the wind its pace lessens, it seems almost to struggle like a ship beating against the element. Slower and slower grows its pace, greater and greater is its contest with the wind, until at length its speed is exhausted and the bird swerves to leeward and sails gaily before the wind.

Thirdly, we note that there is a change in the attitude of the bird in the two different segments. On the windward side the bird inclines its body. To leeward it appears naturally horizontal; but as it comes round with its head to the wind, its whole body inclines so that the head is raised, the tail lowered, and the under surface of the body and wings rest in a steep incline upon the wind like the sails of a ship beating close-hauled against the breeze.

Fourthly, we note, and this perhaps is the most important observation of all, that the bird ascends on the windward side and descends on the leeward side. It is dependent solely on the windward segment to increase the height of its circles; it can do nothing to leeward. It is contesting against the stress of gravity; to windward it gains, to leeward it loses in the contest, but the gain being greater than the loss it moves higher in the air.

These four facts supply us with definite information. It is just this: that a kite can ascend in ever-rising circles without the slightest motion of its wings, and that every time the bird comes to the windward side of the circle it shortens the length of its course, it lessens its speed, it inclines its body obliquely to the wind, it ascends into the air; and every time it falls away to leeward, it lengthens its course, increases its speed, rests horizontally on its pinions and descends slightly to the earth. Thus the windward motions are the reverse of the leeward motions. The bird's objective is increase in altitude. To windward it gains, to leeward it loses its object, but in a moderate breeze the gain up wind is greater than the loss down wind, and the difference between the two is the measure of the bird's success.

But why this extraordinary contrast? Why free gliding to leeward? why restraint against the wind? Why is there a lessened speed, an inclined body, and an ascent on one side of the circle and the reverse on the other side? I believe that the contrast is due to the fact that to leeward the object of the bird is to develop speed, and to windward to convert the energy of that speed into a fresh gain in height. Everything to leeward favours the bird in its accumulation of speed. Its longer and wider sweep, its horizontal attitude, its gradual descent and the fair breeze streaming through its feathers all combine to give it fresh momentum and a new store of energy for the windward rise.

Nor does it appear difficult to undertand the mechanism by which an opposing wind produces an increase in the altitude of a bird already possessing momentum, or, in other words, the method by which the kinetic energy of the leeward speed is converted into the potential energy of the windward height. For each time the kite comes round to the wind it faces a greater obstruction to its forward flight; but as it raises the fore end of its body and depresses the hind end so as to offer an inclined surface to the wind, then the effect of the wind acting against this inclined surface will be not only to check the onward motion of the bird, but also to raise it in the air. The mechanism seems much the same as that by which a child's kite is enabled to rise when an additional momentum is given to it by running onward with the line. The bird develops its fresh store of momentum by sweeping round to leeward and then coming up to windward; the child develops its momentum in the kite by pulling rapidly on the line. But as the bird is lifted upward by the wind, so at the same time does its rate of motion rapidly diminish and at length becomes so slow that the bird can no longer face the wind. Its momentum is exhausted and the kite can in this circle gain no more in height, for without momentum it can do nothing. It must turn away to leeward, develop a new store of energy in its wheel and come up again to windward with increasing speed. It has renewed its store of momentum; it again presents its inclined wings and body to the opposing breeze and repeats the windward rise.

If the kite can ascend only when circling to windward, it follows that, in the absence of wind, the bird is unable to circle with gain in height. It can certainly sweep round in circles on the calmest day, and may even use its momentum to make a short temporary rise; but without wind, it is quite unable to make a permanent addition to its altitude in each successive circle, and must of necessity flap its wings if it wishes to rise higher into the sky. A bird circling in the absence of wind is all the time sinking; at the end of each circle it is a little nearer the ground than at the end of the preceding circle, and as it sinks lower and lower it will have to abandon its passive circling and take to the more energetic motion of flapping its wings. It is very different in the presence of wind. As soon as the gentlest breeze appears the bird becomes less helpless; on the windward side of the circle it begins to rise slightly, but if the breeze is only a gentle waft of air, the rise up wind is not sufficient to counteract the fall down wind, and the consequence is that the bird will still continue to descend but less rapidly than if there was no wind at all. The breeze grows into a sensible current and, as it strengthens, the gain in height increases to the windward; the bird's ascent up wind has now equalled its descent down wind and the kite can with motionless wings maintain itself aloft. Still the wind grows stronger; the leaves now rustle on the trees and the air is felt streaming round the mountain side. The kite has now gained mastery over the element; no longer are its movements deliberate and restrained, no longer does it struggle to hold itself aloft; it rises high to windward as it circles free and full of life. From the invisible air it has grasped the power to raise it from the ground. Higher and higher, but with never a quiver of the wing, it rises towards the snowy peaks, and the strengthening wind renews and still renews its height as it faces the current on every circle. It displays its complete conquest of the air. The valleys, the belts of conifers, the glaciers and the snows pass in succession before its proud ascent. Now it has risen above the glittering peaks and feels the breeze free and unconfined. Round and round it circles sailing with complete ease. Now rising, now sinking, it no longer depends upon its own efforts, but it takes its power from the wind of heaven and, full of confidence in its victory, it sails higher and higher above the broken ranges, a tiny speck in the firmamental blue.

The rise up wind is easy to observe even in a gentle breeze. I have frequently been able to determine the direction of the wind at altitudes far above me by watching the gain to windward in every circle, and to predict the point from where the wind would blow when it was not yet perceptible on the ground. These predictions used to bring conviction that wind was all essential to a bird if by circling alone it was to gain in height. When, in the early morning, there often was no wind, the kites refused to soar; but on the appearance of the first breeze, they felt the energy that was to raise them, and in numbers they rose aloft circling freely in the strengthening breeze. When the wind is streaming in the heavens, the gorges are often sheltered from its force and the birds are unable to rise in circles until they clear the confines of the gorge. While sheltered between the rocky walls, they move by an alternate flapping and gliding flight, rising when they flap and sinking when they glide; but as soon as they overtop the gorge and feel the flowing wind in their pinions all flapping ceases, for the wind now supplies them with the force that in the shelter demanded the energy of their wings, and they rise higher into the heavens by free circling flight.

How often has it been asked, "Why do birds, with outstretched, motionless wings, circle for hours aloft in the sky?" I believe they circle, not because they enjoy circling, but because, if they are to remain aloft without continual muscular effort, then they must circle. A kite or vulture has to soar far above the mountains and, with piercing eye, scan every valley for its carrion. For hours daily it must maintain itself aloft, and it has learned to do so with the minimum of effort. By no other motion but that of circling can it take from the wind at every quarter, for the wind to windward gives it height and to leeward gives it speed, and this leeward speed is again converted into windward height.

I do not pretend that this explains the whole mechanism by which the birds of prey sail with such freedom through the air. But I see no necessity to postulate ascending air-currents or to seek for a solution in hypothetical forces. The streaming winds, whose power we see on every side, is to me a sufficient cause to explain the rising circles of a bird.

The grandeur of the Himalaya is vivified and ennobled by the vultures proudly sailing above its peaks. Their great strength and the majesty of their circles is in harmony with the rugged scene, and as in passive silence they rise and fall, displaying their conquest of the hidden powers of Nature, they call to mind those other invisible forces that shape the peaks and hew the gorges and govern the rise and fall of ranges.

CHAPTER XV

GEOLOGICAL SKETCH

General features of Hazara—Central granite—Palæozoic slates—Infra-Triassic series—Triassic limestones—Jurassic and Cretaceous—Eocene Nummulitics—Vegetation of Tertiaries—Summary of geological changes—Movements of sand in a mountain stream.

ANY one who studies the rocks of Hazara must feel a debt of gratitude to Mr. C. S. Middlemiss of the Indian Geological Survey, to whose labours the geology of the Himalaya, and especially of this district, owes so much.

I will attempt a very brief sketch of the geological structure of the country, and try to indicate the various changes which the hills have undergone through the long lapse of time.

A vast thickness of sedimentary rocks, upheaved and rendered in part crystalline, is the main feature in the geological structure of the district. It has been involved in that extensive crustal movement by which the whole length of the Himalaya has been uplifted so recently as Tertiary times. This disturbance has thrown Hazara into a series of mountain folds. From north-east to south-west these folds sweep across the district; their summits are riven into peaks and domes of which the highest are clothed in perpetual snow; their flanks support broad spurs and buttresses, and in their valleys lie the cold silent glaciers. In the extreme north alone, where this narrow strip of land has invaded the Himalayan axis, are the mountains built on so large a scale. To the south the country is less broken. The mountains have diminished into rugged hills; the snows are replaced by dark coniferous forests and the silent glaciers by torrents and cascades.

To best view the structure of this district we strike a course directly across it. If we start from the north-west and travel in a south-easterly direction over the mountains, the upheaved edges of the strata rise in a succession of rocky zones before us. At first we stand upon the crystalline core of the mountains. This is the central mass of gneissose granite which some time in the Eocene period was forced upward in a molten state and, intruding itself within the overlying sediments, raised up the Himalaya. It is chiefly a biotite granite sparkling with little flakes of black mica, but in some places we find dark masses of hornblende or beautiful crystals of tourmaline. The Himalayan granite covers a wide area. It extends into the centre of all the main ranges throughout the whole length of the Himalaya and upwards into its loftiest peaks. To the north of this district we may trace it to the mountain passes that lead across the frontier. From the passes we may see the granite rising into the distant peaks and sinking into the deep ravines. We see glaciers furrowing its sides and its broken ridges clothed in snow and ice. It is an amazing spectacle; this igneous outburst, divested of all its covering of sediments, torn and shattered by the hand of time and raised into thousands of nameless mountains, range upon range, as far as the human eye can reach. The mind cannot for a moment grasp the force of that upheaval, and is equally baffled at the slow destructive work of ages. No intrusion of the earth's crust bears any comparison to that of the Himalayan granite. It extends from east to west of the Himalaya as the backbone, not of one, but of a succession of parallel ranges through the heart of the continent; it rises to a higher level than any other portion of the globe; it stands as an impregnable barrier across the fertile plains of India.

This intrusion is the backbone of Hazara. Let us follow it to the south-east. As we approach the sediments the scene grows tamer. The mountains sink into more rounded hills; the snows and glaciers disappear. The hills dwindle into what in comparison to the great peaks seem as little hillocks, and on their summits we detect the granite weathered into rounded blocks as though they were transported boulders. These massive blocks into which the granite is worn are conspicuous for miles around. Some stand like natural pillars on the summit of a peak and are consecrated by the inhabitants as a place of worship. Through countless years these boulders must have attracted the attention of race after race of peoples, for on three of the most massive ones, the Buddhist king Asoka has inscribed the principles of piety, tolerance and charity which he demanded all his subjects to follow. It is remarkable to picture this powerful king preaching these noble tenets to his people, to think of him engraving on blocks of granite, almost three hundred years before the birth of Christ, that "self-control, therefore, is meritorious,—to wit, hearkening to the law of others and hearkening willingly."

We follow the central granite still further to the south-east and it gradually disappears. It is lost beneath the second zone, the zone of Palæozoic slates. This is a formation of great thickness and covers a wide area of Hazara. As we first meet it at its place of contact with the granite, we find the strata almost vertically upheaved and the slates converted into crystalline schists in which may sometimes be found beautiful flakes of mica. These schists are very fissile. So brittle are they in places that the ants can drive their tunnels and extend the ramifications of their galleries between their crumbling laminæ. Their weathering is sometimes distinctive, for some of the hills disintegrate into a soft white powder, giving them the appearance of cliffs of chalk. There is thus considerable metamorphosis in the lowest of the sedimentary beds, the consequence, I suppose, of their proximity to the central granite when it was intruded in the molten state.

We soon leave the crystalline schists and travel onward over the upturned beds of slate. They are extremely fissile, breaking away beneath our feet. Here and there we find little bands of sandstone and conglomerate each telling its story of the more troubled waters in which it was laid down, or subordinate layers of limestone indicating the still depths of a deeper sea. But these are only unimportant breaks in the dull monotonous slates. We smash them with a hammer, but not a fossil can be found. We wonder what their age can be. No organic remains give any assistance, so we look to what lies above and below them. Younger than the underlying granite, they are overlaid unconformably by thousands of feet of limestone which are themselves covered by Triassic sediments.

Vastly older than the Trias they must be, but how much older we cannot tell. It is impossible to ascribe their age with greater accuracy than to say that they are Palæozoic.

Across the Himalaya, far away to the north, on the Pamir plateau I have seen similar unfossiliferous slates metamorphosed and upheaved by the same Himalayan granite. They were the highest sediments I had ever seen, and I suspect that they were stratigraphically the same slates that here exist on the opposite side of the mountain ranges.

The accumulations of slate give characteristic features to the landscape. Elongated parallel hills range across the country. Their rounded backs are bare of verdure save for a few scattered pines that struggle hard for life, and a coarse mountain grass parched and yellow until freshened by the summer rains. Many happy days have I spent in their solitary glens watching the spiders spin their snares over the brooks or the insects playing over the placid pools.

We scramble on over the hills and reach the next geological zone, the Infra-Trias series. Should fortune favour, and we find the line of contact between the slates and the superimposed beds, we will see a broad band of conglomerate resting unconformably on the upturned ends of the fissile slates. In the conglomerate are flattened and waterworn fragments of those same slates, indicating that from the denudation of the slates the conglomerate was partly formed. The sea deepens ; the conglomerate is replaced by purple sandstone and later the sandstone by an immense thickness of limestone. Massive and imposing hills are built up of this formation. To the south they display steep, almost precipitous, cliffs, while to the north they sink towards the valleys in a more gentle slope. Many shades of purple, rose and yellow fade imperceptibly one into the other, giving a variety of colour to the stone. There is no sign of any organic remains. Not an organism can be found in these dense limestone strata. All are crystallized and crushed out of recognition in the terrific force of the upheaval.

We wander on in the same direction; we cross over faults in the limestone cliffs and soon become aware of the fact that the rock has assumed a pale blue tint. Almost imperceptibly we have climbed over to the next zone, the Triassic limestones. In broken and detached masses they rest upon the older series and cling to the flanks of the forest-clad hills. We search them as we pass on. Here and there are yellow patches in the solid mass or indistinct blotches like the marks of organic beings. Now we come upon a volcanic outburst; it is a dark red breccia, and we can detect the innumerable volcanic fragments that compose it and ponder over the molten lava that overflowed the ancient mountains. Further on we find the limestone heavy and black with iron, and still further on we may see the natives hewing its substance for building-stones. Again we search for organic remains, but nothing is to be found in the broken rock except little fragments of Megalodon and splinters of other fossil shells that obstinately refuse to separate from the stone. Yet we value these broken fragments; they are the first we have found in our long journey from the central granite over the unfossiliferous deposits of vast ages; they give us an inkling of the geological period in which this bulk of limestone was deposited, and place still further back in the depths of unrecorded time the age of the greater masses that lie beneath.

We pass on. We climb the flanks of the hills to reach the next zone, the bands of Jurassic and Cretaceous rocks with their rich store of fossils. Wedged in between the Trias and the thick Tertiary formation we come upon these strata. They lie in narrow bands stretching from north-east to south-west across the district. Softer in structure, more easily denuded by the heat, the cold and the torrential rains, they present a distinct contrast to the more compact masses that lie above and below them. They seldom stand out in bold relief. They form no crag or buttress on the hillside. More often are they hidden rocks. Accumulations of soil, broken fragments of stone and the less resisting products of erosion may conceal them; they may mark the lines of glens and valleys that have carved them, or the course of a narrow mountain path. Moisture lodges in their substance, and, as it trickles through the fissile shales, they crumble the more easily to decay.

Though these Jurassic bands are narrow, but a few hundred feet in thickness and insignificant compared with the enclosing limestones, yet they are composed of many and different layers. Beneath, resting directly on the Trias, are black and fragile shales easily split asunder. On every face of the severed rock we see the lines and rusty blotches that mark the impress of organic beings. We continue the search and more perfect specimens appear, belemnites often in fragments, a complete *Pecten* or *Inoceramus* with radial or concentric sculpture still perfectly displayed.

Passing from the moist and fruitful shale, we come upon a dark sandstone weathering to a brown hue, and dense beds of a compact limestone studded with countless shells. The stone is thick with these remains. On the weathered surface they appear in mild relief with lines shaded in pink and blue that decorate the rock with innumerable broken curves. More beds of a yellow shale and a narrow ferrugineous band with spherical granules of iron surmount the shelly limestone.

Leaving the Jurassic, we come upon the Cretaceous. This is a narrow strip of rock some ten feet in thickness. It is an orange-coloured sandstone showing here and there an ammonite which, in our efforts to extract, falls to fragments in our hands.

Now we reach the great Tertiary formation that covers so vast an area of Hazara and ascends into its forest-clad hills. This is the Nummulitic series of limestones, sandstones and shales. The lowest beds are barren of remains, but the higher strata are studded with many nummulites. Other shells appear on the weathered surface. Small but nearly perfect specimens of *Pecten* are visible on the shale and the imprints of Echinoids in the grey limestone. The nummulites swarm through the rock; in one square inch of surface I counted 120 of these little foraminifers. Small and indistinct in the limestone, they led a more vigorous life during the deposition of the shales. There we find the same crowds of nummulites, but larger, more robust and perfect specimens, displaying after all these ages the original beauty of their fragile structure, the delicacy of the fine septa and the symmetry of the embracing whorls.

These thick Eocene beds rise to the summit of the wooded hills. Viewed from a distance they seem to ascend like giant steps from the foot-hills to the higher mountains. Sometimes they are moulded into rounded domes, but more often are abruptly carved into narrow ridges that fall in a steep incline to the valley or end in a bare precipitous cliff. The slopes of the hills sink down into deep ravines. A small stream, rarely a torrent, trickles over the valley bed. Other valleys have not a trace of water. It is easy to understand how these valleys are increased in width when we see the debris pouring down their slopes, loosened by the heat and cold, dislodged by the percolation of water or split asunder by the roots of the trees. But it is more difficult to appreciate the slow process by which the valleys have been deepened ; how these small streams, often only a trickle of water or flowing after rain for a few days in the year, can have dug a thousand feet into the ravines. For so slow an agent to produce so great an effect we seem to require an almost illimitable time.

We are liable to form an inaccurate conclusion as to the activity of the erosion of these Tertiary rocks when we view the valleys in the dry months of the year. Then we see so little sign of the wear and tear of the rock surface that we think the hills can never change. But after the first heavy rains following a period of drought another scene appears. From every gully in the limestone cliffs piles of debris and large angulated stones shoot down into the valley. Often they obstruct the roads and take the workmen days to clear away the ruin. Months of slow erosion are made manifest in a single day. I have sometimes imagined that the rush of stones pouring down one of these steep ravines had more effect in grinding into the solid rock than had the waters that dislodged them.

Magnificent trees clothe these limestone hills. The conifers first appear at an altitude of about 5000 feet. They commence as weak and stunted trees scattered thinly over the slope, then rapidly increasing in strength and numbers they become the finest in the forest. It is marvellous to see the way these pines and firs cling to the limestone cliffs, entwining their roots around the spurs or striking down into the crevices of the rocks. They struggle hard to exist in so barren a soil, and, in places, the withered trunks tell how many have failed in the contest. Evergreen and deciduous trees both add their beauty to the Eocene rocks. The pines and firs are mingled with the chestnut, ilex, cherry and sycamore. On opposite sides of the same valley we see a marked contrast in the vegetation. For on the northern slopes of the hills the silver fir, *Abies webbiana*, grows in full luxuriance, while the southern slopes it abandons to the blue pine, *Pinus excelsa.* Standing in the valley, we see the decided contrast. On the one side are the thick, dark, gloomy pines, on the other the equally dark, but taller and more stately firs, while intermingled with both are the lighter tints of the deciduous trees softening the general hue of the vegetation with varied shades of green. And as we look up the pine-clad cliffs to the summit of the hill, we see a row of silver firs, that thrive on the opposite side of the slope, raising their tall straight trunks above the ridge and standing firm against the clear sky like a line of sentinels upon the mountain. Such is the rich verdure that clothes the Tertiary rocks of the district.

Now that we have followed the rocky zones from the central core of the Himalaya to the deposits of Eocene times, let us glance for a moment at the story they tell of the past history of this portion of the earth.

We must cast our mind back in thought to Palæozoic times when a broad sea covered all Central Asia and washed the northern shores of what is now the Peninsula of India. A shore is a line of weakness in the earth's crust liable to be raised into mountain folds, and it was along the southern shores of that Central Asian sea, where the waves lapped the northern coast of India, that the Himalayan ranges were built up. Few deposits are so little known as the sediments of that ancient sea. When Thibet is opened to scientific exploration more will be learnt of these deposits, for the hills of that plateau are largely built up of its sediments and are charged with the remains of living creatures that once moved upon its bed. But our ignorance is not complete, for here, over Hazara, there flowed a little inlet of that sea, a narrow arm extending southward, eating its way into the northern shores of India and depositing those piles of sediment over which we have just passed.

Let us walk over the ground again. The slates indicate the shallow waters of the Central Asian sea, lying near to the ancient coast-line, depositing layer upon layer of mud, and no doubt swarming with animal life though all trace has disappeared. Here and there the subordinate bands of limestone and conglomerate tell how that ocean bed now deepened, now grew more shallow, just like the unstable oceans of to-day. But for immense periods of time that sea must have stood almost unchanged while it deposited the nearly uniform beds of slate. Gradually the crust begins to rise; the Central Asian sea grows more shallow as it recedes northward; its bed at length appears above the waters and the slates become a land surface. Now we see in the upturned ends of those slates, denuded by the rains and rivers and unconformably overlain by other sediments, a trace of that ancient land.

For an unknown time it is worn and denuded by the usual agents that carve the earth. But at last the upheaval ceases; again the land subsides; the waters of the Central Asian sea roll back over the sinking shores and Hazara again becomes an ocean. The waters at first are shallow and troubled and are filled with pebbles from the subsiding shores. Slowly the sea deepens, more and more of the earth is submerged, the pebbles are replaced by a finer sand, the sand is followed by a chalky deposit and a deep ocean covers the whole surface. Millions of tiny creatures live in its depths and with their dead bodies build the thick beds of limestone. Throughout the Trias, and for a vast period before the Trias, Hazara lay beneath the sea. Volcanic outbursts then shook the crust and lava flowed over the ocean bed.

The sea again grows shallow and the waters again recede towards the north. Shales of the Jurassic and the Cretaceous are now depositing in the muddy waters; ammonites, belemnites and other molluscs flourish beneath the surface and fill the silt with their remains. The ocean bed oscillates, now shallow, now deep, at one time accumulating sand, at another building up beds of chalk. At length it rises above the receding waters and again appears above the surface. For an unknown period it stands exposed, worn by subaërial action into all the varied shapes that mark the form of the land.

Again it subsides. A third time the waters return and the Cretaceous land sinks deeper beneath their flow. Shales and limestones are again formed in the depths, while the bed of the sea swarms with countless nummulites. In the chalky deposit they are small and not so numerous, but when the sea grows more shallow and the darker silt settles in its bed, then the nummulites flourish and with their own dead bodies build up the thickness of the future stone. It is the Eocene period, and the main bulk of the limestone hills is being slowly laid down.

Then comes the great upheaval, the period of mountain-building. The Central Asian sea again recedes. The molten granite lying dormant beneath the sediments wells upward into the overlying beds. It intrudes into the slates, crushing and crystallizing them and forcing upwards into crustal folds all those vast deposits. Slowly, perhaps a few inches a year, they rise upwards through the sea, and for the last time Hazara emerges from the ocean. The rain denudes them, rivulets erode them, and, as they rise higher into the heavens, the snows and glaciers mould them into rugged ranges. Sediments are swept away from their summits, and in the great peaks the intrusive granite is laid bare. Upheaving, fracturing and shaking the earth's crust, the Himalaya has slowly risen from the sea, and from the gentle earthquakes that almost monthly shake Hazara, it seems as though the upheaval was still in progress and that the mighty mountains were not yet at rest.

Such are the changes that this valley has known through the long period of its history. It has been involved in some of the greatest movements that have raised or lowered the surface of the globe. These movements still continue and the valley still passes through the same ceaseless change. Erosion and sedimentation work unceasingly on every side. Rivers wind through the broader valleys, depositing sand from the higher ranges and spreading abroad a fertile soil. Weatherworn terraces of alluvium indicate the level of old river beds and provide the cultivator with fields of luxuriant harvest. Other rivers erode narrow gorges through which they rush in echoing roar. Rivulets, sparkling beneath the clumps of pines, wear their own little channels into the granite hills; streams wash the pebbles down the gentler slopes, and waterfalls eat into the rocky ledges to fall splashing into the torrent below. Glaciers erode the higher mountains, and the massive boulders in the lower valleys indicate the vast extent of country once clothed in a sheet of ice.

Heat and cold, rain and river, frost and ice are at work on every side eroding, levelling and sweeping down the mountains. The valleys that are filling and the gorges that are deepening both foretell the same destiny; they predict the building of a plateau of erosion, the lowering of the mountains to the level land.

I will conclude with a little geological observation that somewhat interested me, namely, the movement that took place in the sand on the bed of a rapid stream.

I have before mentioned an old fort that stood near the Black Mountain. A gentle stream flowed past the grim old fort. Its waters were shallow and remarkably clear. Its bed was composed of sand and pebbles all in continual motion, and from the bank it was easy to follow the changes that occurred as all the grains of sand were swept onward in their long journey to the sea.

Grain after grain the little crystals rolled along as though they were all racing for the ocean. But there was some method, some system in their roll. The smallest fragments were swept off the bed of the stream to be dashed about in the gentle eddies, but the larger fragments offered a more stubborn resistance. The current would seize one of these larger granules, hurry it onward, turn it over and over amongst its fellows so as to smooth off its sharp edges and projections. It is swept on, but soon meets an obstacle in its path, and there fixing itself, it defies the stream. Smaller granules are piled up against it, and an ever-increasing resistance is offered to the waters. The mass grows larger, it can now no longer withstand the onset of the current, it is torn up and swept onward to recommence the endless roll. The white crystals of quartz and felspar have a poor chance in their contest with the stream; wherever they turn, however they roll, the water can seize the little bulky crystal and ever roll it on. It is the sparkling grains of mica, though light and fragile, that fight with the most effect against the current, for they glide in between the larger pebbles and offer their sharp edges to the stream. So does each grain of sand, some slowly, some swiftly, roll along the river bed.

Not only were all the little sand-grains rolling, but the bed of the stream itself was rolling. As the sand-dunes of the desert roll in waves before the wind, so was the sandy bed of the stream rolling in waves before the waters. Parallel folds of sand, regular dunes in miniature, crossed the bed of the stream. Facing up the stream each fold presented a gradual and shelving slope, while facing down the stream the slope was steep and perpendicular. It is just the same as in the desert dune. When the stream flowed slowly on, layer after layer of sand was rolled up the gentle slope until it reached the summit of the fold, when it poured down over the perpendicular fall. Here, sheltered from the current by the rising summit of the fold the sand-grains come to rest, but layer after layer pours down upon them, each layer covering the preceding one. The trough in front of the fold thus rises higher and higher as the sand pours down from above, until at length what was once a calm recess has risen to be the summit of a new fold. And thus the folds move onwards by the downpouring sand always building up a new summit in the recess in front of the existing summit. They move by the same mechanism as that which sweeps the dunes across the desert. Each sand-grain is first a part of the gentle slope, then of the summit of the fold, then of the perpendicular fall, then lying motionless for a time in the calm recess, it is engulfed beneath the down-pouring sand until, as the wave moves onward, it is again exposed, again rolled on by the untiring stream, to again build up fold upon fold, and to repeat hundreds of times a day this same eternal roll till at length it will rest in peace beneath the ocean.

It was instructive to watch the motion of these waves of sand. The summits could be seen creeping insidiously onward, pouring down the smothering sand and engulfing every obstacle in their relentless path. They were a real miniature of the sand-dunes of the desert ever rolling onward and burying beneath their debris the cities of men. I calculated the rate of movement of one of these folds and estimated that in every twenty-four hours it advanced down stream one-sixteenth of a mile; and though one glance at the moving sand shows that the change varies in rapidity in different parts of the stream, yet it is perhaps a fair estimate to say that in sixteen days every mile of the bed of this gentle stream has been rolled another mile nearer to the sea.

And as grain rolls upon grain and layer rolls upon layer to build up a fold of sand, so also does fold roll upon fold. Smaller folds roll up the gentle slopes of greater folds and greater folds roll down on smaller folds. As the curling crests of ocean billows pour down their foam to overwhelm the smaller waves before them, so do the larger waves of sand pour down their foam of granules on the wavelets that precede them.

Thus grain upon grain, layer upon layer, fold upon fold is rolling, but the revolution will not end here. At length on the bed of the ocean the sand-grains come to rest. Vast deposits, thousands of feet in thickness, are built up beneath the sea. After a long lapse of time the strata are consolidated, upheaved, exposed to the erosion of new rivers which again roll down their sand. The last stratum to be deposited will be the first to be denuded, and the fragments of each older stratum will be laid down on the fragments of the younger ones. Old deposits will be piled on new deposits, and thus through countless centuries stratum will be rolled on stratum.

And so from the minute sand-grain to the mighty strata inorganic nature is revolving. The little crystal in the brook, the pebble in the stream, the boulder in the torrent, layer upon layer of sand, fold upon fold, stratum upon stratum, all are rolling onward in one endless revolution.

This concludes my record of observations in the Himalayan valley of Hazara. I trust I have not cumbered it with too much detail, and yet hope I have been able to add something to the substance of scientific fact. The reader may not appreciate how much patience is needed before Nature will disclose the methods of her work. He who would pry into her secrets must face failure after failure, and be prepared for many hours of waiting before he will achieve some slight success. It is the record of those patient hours that I have gathered into the foregoing pages. I will be satisfied if the account of them should give to others some slight degree of that pleasure and satisfaction which the observation of them has given to me.

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