Chapter XII

The Rain Forest

I first encountered the rain forest when, fresh out of college, I went to Honduras to work for the United Fruit Company. I was supposed to be studying the diseases of bananas, and I spent my work days faithfully counting fungus spots or writing company memoranda, or watching the black bees that nipped the margins of the banana fingers in the course of their curious sap-collecting operations. But on holidays I headed for the forest. Our experimental station was located in a valley back from the port of Tela, where the vegetation had been preserved to protect the town water supply. The rainfall was about two hundred inches a year, which meant that the hills at the head of the valley were covered with a magnificent forest where a young naturalist could find all sorts of interesting things.

I wasn't able to carry out any systematic studies on this holiday schedule and presently I was transferred to the highlands of Guatemala for quite different sorts of work in a very different environment. After that came a stretch of years in the Intemperate environment of Cambridge, Massachusetts, which was broken by a few tantalizing vacation excursions into the tropics; then a four-year period chasing mosquitoes in the Mediterranean region. The memory of that Honduras experience, however, remained undimmed and I kept up the hope of finding some practical way to get back to the tropical forest to carry out systematic studies. This hope was finally fulfilled when the Rockefeller Foundation suggested that I take up mosquito studies in connection with the problem of jungle yellow fever.

A friend, who had visited the yellow fever laboratory at Villavicencio in eastern Colombia, described it to me and made it sound ideal. It had all of the proper and necessary laboratory equipment, and yet was located across the Andes on the margin of the great forest of interior South America: one of the most interesting parts of the world to the naturalist, and yet one of the least known because of the difficulties of travel and residence, and the unavailability of scientific equipment. These difficulties had been overcome because of the need of getting information about yellow fever. As far as I can see, the only nice thing about disease is that people get stirred up about it, so that they are willing to let scientists spend money in the hope of getting practical results. The scientists get the practical results often enough to justify the practice, and at the same time they get a chance to add to the sum of human knowledge—an activity that in itself seems to have little appeal.

The Villavicencio laboratory turned out really to be ideal. We lived there for eight years, and during all of those years we knew that we were having the time of our lives; that we would never again find conditions so nearly perfect for a naturalist and a naturalist's wife. My wife wrote a book about it, which she called East of the Andes and West of Nowhere, so I won't repeat the story.

This experience, then, is the basis for the present chapter. It means that I am writing primarily about the equatorial American forest. The general characteristics of the African and Indonesian forests, however, are similar, though of course the plants and animals that play corresponding roles would be of different kinds.

This experience also means that my study of the forest was oriented around the problem of explaining the epidemiology of
forest yellow fever. This turned out, however, to be an excellent guide through the maze of forest interrelationships. We eventually came to the conclusion that in our region the disease was maintained by epidemics among certain kinds of monkeys, and transmitted by a curious mosquito of a bright, metallic blue color, known by its scientific name of "Haemagogus." To understand this mosquito-monkey transmission, we had to study the habits of the mosquitoes and of the monkeys, and we soon found that we were led into all sorts of explorations of the forest environment, which I shall try to describe here.

The tropical rain forest is most commonly called "jungle," but I have never liked the word. It brings to mind snakes dripping from trees, panthers crouched in underbrush, centipedes crawling into boots. Explorers are always hacking their way through the "jungle"—but the ground, in the rain forest, is fairly open because the dense crowns of the big trees cut out so much light that few low-growing plants can survive.

There are all kinds of forests in the tropics and it is easy enough to find places that match the most fantastic Hollywood ideas. Some forests are so thick that it is almost impossible to get through them—second growth in a clearing made five or six years before, thickets of spiny bamboo, areas of swamp that have been taken over by low-growing trees. But the typical rain forest, the great untouched forest of interior South America, is not like this. It is majestic rather than tangled; cathedral-like, with its dim light, narrowing vistas, great buttressed trunks and pervading silence.

I have seen many more snakes, poisonous or otherwise, in Florida than in South America. They are in the forest, all right, but they mostly stay pretty well hidden. I'd be scared to death if I ever encountered a jaguar in the forest, but I never have, though I have come across fresh-looking tracks often enough.

I cannot deny that there are insect pests. I am pretty much immune, which often led me to be thoughtless with visitors. My last visiting scientist was a victim of that. He showed an interest in my forests, and I dragged him all over the place without remembering to give him insect repellent (some of the repellents worked out by the army are good). He turned out to be very susceptible to red bugs—a tiny mite that anyone who has hunted in Florida knows well. He got covered with them, and the sores made him look as though someone had skinned him alive. After a week in bed, I shipped him off to the Gorgas Hospital in Panama. Apparently he had a very unusual sort of an allergic reaction to these mites, previously unknown to the annals of
tropical medicine. This didn't comfort him any, though, and he refused to listen to further propaganda on my part.

As for diseases, very few are associated with the tropical forest. Most human diseases must pass directly from man to man, and they need a good supply of people for maintenance. The problem of disease in the tropics is a problem of villages, towns and cities, fostered more by poverty than by climate.

Yellow fever is an exception, because in the interior of South America it is a disease of monkeys as well as men, so that it might be caught in a remote and uninhabited forest. But the threat of yellow fever is gone for civilized man because of the efficient vaccine. There is no more danger from yellow fever today than there is from smallpox.

The scourge of the tropics is malaria, and most explorers have spent their days and weeks in shivering misery with the disease. The attacks may come on in camp far out in the forest, but I am sure the explorers got their malaria when they spent the night in a village on the way. The malaria mosquito does not fly very far, rarely more than a mile or so, and to transmit malaria it must, a week or so previously, have bitten someone infected with the parasite of the disease. The parasites that cause malaria in man can infect no other animal, so it remains a disease of villages and thickly settled farming regions.

But this is getting away from the subject of the rain forest. The "rain" part of the name is important. The nature of vegetation in the lowland tropics is controlled primarily by the amount and distribution of rainfall. A high rainfall, fairly evenly distributed through the twelve months, results in the most complex vegetation type, the rain forest. This means at least 150 inches of rain a year and usually 200 or more inches. For comparison, the precipitation in the eastern United States varies between 40 and 50 inches a year, being less than 40 over most of the central states. Tropical rainfalls are approached only in the Olympic Mountains of Washington, where the Wynoochee Oxbow station records 146 inches a year, the highest rainfall in the United States.

These sixteen or so annual feet of water fall in definite showers, "shower" in the sense of "shower bath." All-day, drizzling rains are uncommon. At first it bothered me to get soaked by one of these abrupt rains. But I found that the discomfort came mostly from the soggy clothes, and I eventually hit upon the scheme of taking all of my clothes off, carrying them in a waterproof bag during a rain. After the first cold shock, the bath was tolerable, and when the rain stopped the skin would dry off remarkably quickly and the clothes, scanty but required by local custom, could be put back on, dry. Waterproof coats, we found, were impossible because the clothes underneath would get soaked with sweat, if not by rain.

We started out, in our forest studies, by concentrating on the Haemagogus mosquitoes, because scientists in both Brazil and Colombia had suspected for some time that this might be the forest vector of yellow fever. At about the time of my arrival in Colombia, one of the yellow fever scientists, Dr. Jorge Boshell, discovered that these Haemagogus were most common in a forest when a tree had just been cut down. This seemed queer until he had the idea of climbing a tree before it was cut. It then turned out that the mosquitoes were always common in the tree-tops. It thus became clear that our first problem was to find out what was going on up in the tops of the trees in the forest.

We tried all sorts of methods of getting up into the trees. Climbing irons like those used by telephone linesmen and lumberjacks were among the first experiments. The climbing irons would have been fine if there had been no ants in the forest, but there must be about as many ants in one acre of tropical forest as in the whole United States. Some of them have stings that make our North American wasps seem sissies. I cannot brag about the Villavicencio snakes, but I'll back the ants against all comers.
It is rather awkward to come across a nest of these insects fifty feet up in a tree, with only climbing irons as support. You simply can’t take your pants off and at the same time leave the belt fastened around the tree, and it becomes a matter of deciding between sudden death from the fifty-foot drop and slow torture with both ants and pants in place.

Actually, I never got as high as fifty feet with climbing irons, though some of my hardy colleagues have done much better. I preferred to pick a likely spot and have the laboratory carpenter make a ladder. He became expert at making twelve-foot lengths which he put in place up a trunk in no time at all. He learned how to build elegant platforms, from which the forest world could be viewed in peace and comfort. There you could take off your pants whenever necessary, remove and squash the ants, and resume contemplation—only slightly disturbed by a few itches, stings and burns.

I spent many happy hours in these forests, sometimes just sitting, sometimes trying to puzzle out the complex relations among the forest inhabitants, and sometimes about my proper business of making observations or collecting specimens. There is ample material for meditation. The rain forest and the coral reef must represent the maximum development of life on this planet, in that more different kinds of organisms and a larger number of individuals are packed into a given amount of space than in any other sort of situation. Both habitats provide the naturalist with inexhaustible material for study.

There are, as a matter of fact, many analogies between tropical forests and tropical seas. In both, the naturalist is always conscious of the thud dimension, height or depth. We walk at the bottom of the forest and float on the top of the sea, and to explore this thud dimension we have to use a deal of ingenuity in climbing or diving. But in both, the conditions of life gradually change from the bottom to the top in ways that are curiously parallel, resulting in a zoning by depth. The zoning depends on the same basic factor in both cases—light. The light that strikes the surface of the sea diminishes rapidly with depth, so that the ocean floor is a region of perpetual darkness. Similarly, the light is cut by the dense foliage of the tropical forest. The forest floor region is not eternally dark, but the light is dim enough to exercise a selective influence on the kind of plants that can grow there.

The basic industry of photosynthesis is thus largely restricted to the canopy zone of the forest or to the surface region of the sea, and the organisms that live below depend in the long run on materials that drop down from above. The surface of the sea is inhabited by incredible millions of microscopic animals and plants, and there is a sort of constant rain of corpses of these organisms into the depths below, to serve as food supply for the bottom dwellers. Similarly, the inhabitants of the floor zone of the rain forest.
the forest depend on the constant supply of dead leaves, of fallen fruits, flowers, branches and trunks, or on materials found in the soil.

The zoning of life in the sea is possible because of the density of water, which enables organisms to keep at whatever depth they prefer. Most organisms have just about the same density as sea water, so that swimming and floating are easy. Floating in the air, though, is a different thing, achieved only by very tiny organisms or by special arrangements like those of certain spiders that drift with long strands of silk. Flying, in contrast with swimming, is much harder work, so that no animal is able to live its whole life flying the way marine animals may live, always swimming or drifting with the current. The zoning in the forest depends on the trees, which form its basic structure, and getting to the top is a matter of climbing.

Tree growth itself is an adaptation for getting up in the air. It might be called "giantism." A tropical forest is composed of hundreds of different kinds of trees, many of them members of families that in the temperate zone include only shrubs or herbaceous plants. Thus bamboo is a grass that has become giant to get its share of forest light.

Other plants have developed the vine habit, using the giants as support to get to the top of the forest. Some of these vines become monstrous things, with thick, woody trunks—the lianas. The foliage at the top of the forest is made up of vine leaves as much as tree leaves, and it may be hard to tell which flowers and fruits belong to vines, and which to trees.

Perhaps the most interesting plant method of getting to the top of the forest is the epiphytic habit, which was discussed in the previous chapter.

Plants, then, get to the top of the forest through giantism, climbing, or the epiphytic habit. Animals have to get there by climbing or flying, and climbing adaptations are consequently common in the forest fauna. Many mammals, for instance, have developed a prehensile tail, a tail that can be twisted around a branch and used for holding on, or even as a sort of fifth leg in swinging through the trees.

In South America there are several forest opossums with prehensile tails. There is an arboreal porcupine—a rodent—with a prehensile tail. The kiijau, a carniverous related to the raccoon, has such a tail, as do certain anteaters, which belong to a very distinct order of mammals, the edentates. In some of the monkeys the tail has developed into a really marvellous organ, with the underside of the skin formed into sensitive palmar tissue. The tail of a spider monkey, for instance, is just as useful as its hands: and in investigating some object or other, a spider monkey seems not to feel satisfied until it has tested the thing with both its hands and its tail.

Now the curious thing is that this prehensile tail business is practically limited to South America. Only one mammal in all of the world outside of South America has such a tail—one of the Australian marsupials. If you see a monkey hanging by his tail, you can be sure that he is from tropical America, not from Africa or the Orient.

Mammals aren't the only animals with striking modifications for life in the forest. The Old World relatives of the domestic chicken are mostly ground buds, but in South America they have taken to the trees. There is a host of kinds of tree frogs, with highly developed sucker arrangements on their feet for sticking to branches and leaves. There are incredibly long and slim snakes, that look just like bits of the vines which they spend their lives.

I think that the frequency of prehensile tails and other arboreal adaptations in tropical American animals reflects the ancientness of the tropical American forest. These great forests must have continued without interruption through long stretches of geological time, so that the most diverse animals and plants were slowly able to develop all sorts of complex ways of living together...
to form the forest habitat. Forests have of course existed for long times in other parts of the world, but not such vast forests, or for so long without interruptions by dry epochs in which the forest was replaced by grass.

When we found that the Haemagogus mosquitoes were predominantly "arboreal," despite their apparent freedom to fly at any level in the forest, we wanted to find out what sort of conditions led them to stay in the treetops. The first step was to find out how the climate differed at different heights in the forest, since it might be some climatic factor like temperature, humidity or light that kept the mosquitoes flying near the ground. For this purpose, we established a series of stations at different heights in the trees where we could leave instruments for recording temperature, humidity and evaporation rate. We also kept records of temperature, humidity, light intensity and height above ground for all of our mosquito catches, so that the kind and number of mosquitoes caught could be related to these environmental factors.

It turned out that the forest climate was zoned. That is, conditions differed in a regular way from the ground to the top of the forest. The differences are most easily realized if we consider the extremes. In the open air, just above the forest canopy, there is no protection from sun and wind. Changes may be abrupt, the air warming rapidly when the sun rises in the morning and cooling rapidly after it sets. The temperature may drop several degrees in a few minutes with the onset of a rainstorm, and may vary considerably between cloudy and sunny periods.

Near the ground, in what I like to call the "forest floor zone," conditions are very different. The mass of foliage of the forest serves as an insulating agent, giving an effect comparable with that of a cork-lined room. It is a long time after the sun comes up in the morning before any change in air temperature occurs in this part of the forest, and the change then is very slow. The drop with nightfall is equally slow. Thus the air during most of the day is much cooler than the air in the open above the forest, while during the night it is warmer.

There is a comparable difference in humidity. It is always damp within the forest, and the air near the ground is saturated with moisture all day long. In the open, the air may become quite dry during the day, though it is usually saturated everywhere at night in the wet tropics. During the day, then, humidity in the forest is highest near the ground, and the air gradually becomes drier climbing toward the canopy; at night this humidity difference disappears. The temperature, during the day, is lowest near the forest floor, the air becoming warmer higher up; while at night this change may be reversed. Mixing of the air is limited because the dense foliage cuts out wind, and slows up all air currents. There is, of course, a similar change in light, from the bright sun above the forest to the dense shade near the ground. Here the change is similar at night, since the light is always brightest above the forest.

We never did arrive at a clear-cut explanation of the factors that kept the Haemagogus mosquitoes high in the forest. I thought that probably humidity was important, since they showed a tendency to avoid very moist air like that near the forest floor. Light also may have been important; and some of our laboratory experiments indicated that there may have been some sort of a visual factor. At least the mosquitoes in a large cage would stay near the top of the cage, even when humidity, temperature and light were the same at the top and bottom.

The forest studies turned out to be most important in connection with our laboratory studies with yellow fever virus. To keep our Haemagogus alive for transmission experiments, we found that we had to keep them in a fairly dry cabinet, provided with a fan to produce air currents. To get the virus established in the mosquitoes, we had to expose them to relatively high temperatures for a while each day. All of these things—low humidity, presence of air movement, periodic high temperature—were
There is still no way of traveling long distances through the forest except by water. As a result, the country away from the major rivers is almost unknown, probably the least known part of the earth outside of the polar regions.

From the earliest days naturalists have commented on the wealth of different kinds of plants and animals found in the forests. No catalogue has ever been made of all of the organisms in any South American forest, so it is impossible to give exact statistics. Scientists have been visiting the patch of rain forest on Barro Colorado Island in the Panama Canal Zone for many years now, and 'the forest there is probably more completely known than any other. Yet every visitor finds new things.

We found about 150 different kinds of mosquitoes within a radius of five miles of the Villavicencio laboratory — more kinds than have been found in all of the United States. Yet mosquitoes were not especially noticeable. During the war, we made experiments at the request of the army with many different chemicals, trying to find something that would give mosquito protection under tropical conditions. Parallel experiments were being conducted in the New Jersey salt marshes, and the army sent me the results of the New Jersey experiments, asking me to try to use the same methods as far as possible. I found, however, that this was impossible. They were getting sixty mosquito bites a minute in New Jersey, and the best we could do in our tropical forest was sixty bites an hour. We had ten times as many different kinds of mosquitoes in a particular experiment as they had in New Jersey, but they had sixty times as many individual mosquitoes!

To understand this tremendous diversity of kinds of plants and animals, it is necessary to think in terms of what the naturalist calls "niches." The tropical forest is full of niches, and life in each particular niche is carried on more or less independently. Take the matter of zonation. The organisms high in the forest...
canopy, those low in the canopy, those that live on the ground and those that live under the ground, all carry on pretty much independently of each other. And each of these major zones is full of nooks and crannies each occupied by its special kinds of animals and plants.

The mosquitoes again furnish a useful example. The larvae of all mosquitoes live in water, and my favorite method of looking for new species was to go out into the forest and try to think of some new place where water might accumulate. If I found a new sort of place with water, I almost invariably found some new kind of mosquito larva living there. Obvious places were rotten holes in trees, and the water collected by the air plants, or bromeliads. Less obvious was the water that collected in the internodes of bamboo where a bird or beetle had made a hole in the stem; the water that collected in certain kinds of large upright flowers; the thin film of water at the base of the leaves of many banana-like plants. Nothing like as many different kinds of places holding water could be found in any temperate forest.

The air plants, or bromeliads, are a good example of a "niche." I have mentioned these several times in connection with the epiphytic habit, because most of them are epiphytes, though a few, like the pineapple, grow on the ground. The bromeliads mostly have long, narrow leaves that grow from a common center, where the bases of the leaves form a sort of watertight vessel which the botanists call a "tank." A lot of water may accumulate in a large plant—sometimes several quarts. Dead leaves, twigs and other bits of forest debris accumulate in the plant along with the water, making a rich infusion that serves as a source of food for the plant. The water of the tank, in turn, becomes "home" to a whole special fauna and flora: bacteria, fungi, microscopic animals, worms, snails, insect larvae of many kinds (including mosquitoes) and the tadpoles of certain kinds of tree frogs. The whole thing is like a tiny pond perched on the branch of a tree high in the forest.

Thus the forest as a whole, with its niches and niches within niches, becomes a sort of multiplication table of possibilities for different kinds of life. The abundance of food and water, the even distribution of sunlight, make the growth of many kinds of trees possible. The diversity of trees offers opportunity to a diversity of hangers-on. Each of these in turn has its parasites or symbionts, or provides new kinds of food or shelter for ever more kinds of organisms. The niches and the animals and plants able to use them thus multiply to dizzy figures.

Much has been written about the "struggle for existence" in the tropical forest. It is easy to believe this when you see a tree smothered with vines, when you see how every leaf and every fruit has been eaten by something, when you think of all of the animals busily hunting each other in search of their daily meals. But there is also something wrong with the idea of this struggle. If the struggle is so keen, how does it come that so many different kinds of things have managed to survive? Many of the animals and plants of the South American forests are clearly very ancient types, types that have died out everywhere else in the world, though we know they were once more widely spread because of the fossil record.

Apparently conditions in the forest are so favorable that almost anything can survive, and almost everything does. Individuals may have a hard time, but some of them seem always to manage to leave offspring; and no one kind of animal or plant is able to get the upper hand of all of the rest, and thus dominate the landscape.

Even man has not succeeded in dominating the South American forests, though he has made great roads on their margins. The conservatism of the forest seems to affect the humans, too. The Motilone Indians of Colombia are still as hostile and as unconquered as when they faced the first conquistadores, and the same is true of some of the Brazilian tribes. The forest Indians have probably never been really numerous, probably never
achieved any very high level of culture. Yet they have managed to resist the impact of Western civilization more completely than any other people. It is as though they were affected by the inertia of the forest, the same forest character that protects ancient animal types long after they have become extinct in other parts of the world.

The Mayas of Central America seem to be the only people who have responded to the challenge of the forest, who have conquered the forest and built up a civilization from its elements. But their history is so lost in the nebulous past that we cannot be sure how they did this, or whether their civilization really had its genesis in the forest, or moved there from some other sort of environment.

It is surprising how little this forest has to offer civilized man. There are valuable timber trees, but they are difficult to exploit because the valuable trees are scattered and lost among the host of sorts for which man has no particular use. There are fruits and fibers and medicinal plants, but again the kinds that man wants are almost hopelessly diluted in the mass of forest vegetation.

The soil seems tremendously rich to support this great forest, yet attempts to bring it under cultivation have not been outstandingly successful. The whole forest is a delicate balance, and if it is cleared, the thin accumulation of topsoil may be washed away with the rains of next year. Or the growth of weeds may be so fast and so dense that the crop is smothered. Local peoples everywhere have the custom of cutting forest, burning it, getting a crop or two before the weeds get out of control, and then abandoning the spot to the processes of nature. After five or ten or fifty years, it may be ready to cut and burn again. To keep the soil under control seems beyond their power, or their ambition.

To what extent the forest could be brought under control, could be used for human settlement, is a matter of much debate among the experts. The job surely will not be easy, else it would have been finished long ago. Probably it will require detailed scientific study, the adoption of special methods that will enable man to compete with and to control the natural processes that govern the development of the forest itself.

This could be a very interesting study, but I rather hope it fails. Civilized man has got completely used to lording it over the landscape, turning everything into neat orchards and fields, or dismal wastes of cutover second growth. It is a humbling experience, and surely a healthy one, to enter a landscape that man has not been able to alter, to dominate, to twist to his own purposes. Man in the rain forest is just another rather simple animal, walking quietly and apprehensively, scared at the snapping of a branch, not sure where he will find his next meal. He gains a new perspective in this complex world which he has not yet been able even to catalogue, let alone control. It is not a hostile world, but it is very indifferent to human needs and human purposes.